2017 26th IEEE International Symposium on
Robot and Human Interactive Communication (RO-MAN)
Lisbon, Portugal, Aug 28 - Sept 1, 2017.

Huggable: Impact of Embodiment on Promoting Verbal and Physical Engagement for Young Pediatric Inpatients

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Abstract— **Children and their parents may undergo challenging experiences when admitted for in-patient care at pediatric hospitals. While most pediatric hospitals make an effort to provide socio-emotional support for patients and their families during care, such as with child life services, gaps still exist between professional resource supply and patient demand. There is an opportunity to apply interactive companion-like technologies as a way to augment and extend professional care teams. To explore the opportunity of social robots to augment child life services, we performed a randomized clinical trial at a local pediatric hospital to investigate how three different companion-like interventions (a plush toy, a virtual character on a screen, and a social robot) affected child-patients physical activity and social engagement – both linked to positive patient outcomes. We recorded video of patients, families and a certified child life specialist with each intervention to gather behavioral data. Our results suggest that children are the most physically and verbally engaged when interacting with the physically co-present social robot over time than the other two interventions. A post-study interview with child life specialists reveals their perspective on potential opportunities for social robots (and other companion-like interventions) to assist them with providing education, diversion, and companionship in the pediatric inpatient care context.**

I. INTRODUCTION

Often times, children have stress and feel anxious when hospitalized and admitted to in-patient care. Child-patients may undergo intrusive medical devices attached to their bodies or experience uncomfortable medical procedures. They have a number of unfamiliar care professionals visiting their hospital room to provide medical services. Parents may not always be present to keep their child company during their hospital stay. This creates a challenging and stressful emotional experience for the child-patients that can negatively impact recovery rates, reduce cooperation and reduce adherence to protocols.

It can also present challenges for the clinical staff. Efficiency of patient throughput and quality of care are better when patients are cooperative participants in medical protocols and procedures. Hence, stress, anxiety and negative emotional experiences during a hospital stay not only adversely impacts child-patients and their caregivers quality of experience, care, and overall satisfaction with the hospital, but they can also negatively impact the hospital as a professional institution with respect to its efficiency, cost management and customer care.

In order to reduce in-patient anxiety and to promote positive affect for children and their families for procedures and clinical care, most pediatric hospitals in the U.S and in Canada have Child Life programs. Certified child life specialists (CCLS) engage and support child-patients and their families to create a less intimidating and more comfortable health care experience by applying developmental interventions and therapeutic play [7]. CCLS use activities like blowing bubbles, playing games and video games, watching movies, or listening to music in order to distract children from anxiety or pain, to foster joyful play, to promote positive emotion, and to promote physical activity associated with improved recovery rates [3, 5, 9, 11, 17, 18].

However, there often exists a persistent gap between the supply and demand for CCLS support for pediatric inpatients and their families. Not every child can have continuous access to these services. In addition, child life specialists do not currently have a way of continuously monitoring the emotional state of every child in-patient.

To address these issues, we developed a social pediatric companion robot that can be deployed by child life services to extend their reach and augment CCLS by playfully interacting with children for therapeutic outcomes [13], estimating emotional and affective states, and working with child life specialists and families to enhance patients experience and medical outcomes.

We performed a randomized clinical trial at Boston Children's Hospital to explore the application of these new child-friendly and companion-like interactive technologies to augment CCLS. Our between-subjects study compares the effect of either a plush toy (current standard practice), a virtual character on an Android tablet, or a social robot. In each condition, a certified child life specialist used one of the interventions in a playful and therapeutic interaction to provide their services in an effort to mitigate child-patients' anxiety and stress, promote physical activity, foster positive affect, and patient engagement [12].

Developing interactive technologies for pediatric inpatient care is a challenging task because the technology-based intervention needs to engage a diverse population of children: different ages, medical conditions, physical/emotional states, etc. Thus, a goal of our study is to understand how these patient factors and the different attributes of each intervention impact a variety of measures that are associated with promoting improved socio-emotional wellbeing and medical outcomes of child in-patients.

*This work was supported by Boston Children's Hospital

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The contributions of this paper are as follows. We present a study that is the first to investigate the application of companion-like interactive technologies as part of CCLS and in-patient care. We present results focusing on the impact of each intervention on social engagement between the patient, the child life specialist and co-present families, as well as overall physical activity – both are associated with positive patient outcomes. The new knowledge produced by this study provides an important foundation to guide the ongoing development of effective pediatric-companion technologies for hospitalized children and their families.

II. Related Work

Social robots have been actively developed to help diverse demographic groups including children, the elderly, and those with disabilities in the health care domain [2, 6, 14, 20, 21]. For example, Beran et al. investigated the efficacy of a small humanoid robot, MEDi, in providing distraction from pain for young children receiving a vaccination procedure. Their work focused on relieving short-term pain and anxiety for relatively healthy children. The robotic baby seal Paro is widely used to mitigate the symptoms of dementia and Alzheimer's disease in nursing homes residents. The robot was found to reduce stress and to increase the social and emotional engagement among the elders and their caregivers. The ALIZ-E (Adaptive Strategies for Sustainable Long-Term Social Interaction) project showed how social robots can motivate and persuade diabetic children to maintain a healthier lifestyle, and emotionally and socially engage and connect with children to increase self-efficacy and self-confidence. Prior work has also shown that physical social contact improves positive affect over virtual embodiments [7].

However, there has been not much work done on how social robots could assist children in the context of child life services and in an in-patient care context. Furthermore, prior work has not compared different companion-like interventions across a diversity of patients to inform how to match patient needs with interactive affordances in concert with how a child life service professional uses each to provide care. Our study is designed to systematically investigate these opportunities. In this paper, we are particularly interested understanding the impact of each intervention on patient-family-clinical staff social engagement, patient physical activity, and overall interactions.

III. Method

A. Research Questions

What opportunities are there for companion-like technologies to assist CCLS? A social robot pediatric companion (*Robot* condition) is physically embodied, co-present, and capable of socially interacting with children in a physical and social manner. A virtual character on a tablet (*Avatar* condition) can animate and verbally interact with children in very similar way to the robot, but lacks physical form and presence. A plush toy (*Plush* condition) is physically embodied, and is soft and pillow like to hold, but does not convey autonomy and lacks social interactivity unless puppeteer-ed by a person. Fig. 1 shows each intervention in the form of a teddy bear, an accepted cross-cultural form of comfort and playfulness for children.

We designed a between-subjects study to broadly investigate a number of questions and opportunities for companion-like technologies to augment CCLS. For instance, what is the impact of different embodiments of a companion-like intervention for patients? How might child life specialists, patients, and families engage with these interventions differently? Might the affordances of a specific type of intervention foster not only patient socio-emotional engagement, but also of the co-present family members? How do more socially interactive technologies that convey autonomy and "states of mind" compare to a passive plush that is used like a puppet in pretend-play to engage child-patients?

B. Hypotheses

We predict that the social and physical characteristics of the robot will yield higher engagement from children than the other two conditions. Specifically, we hypothesize that children will show higher verbal utterance production as a measure of social engagement, an overall longer interaction time as a measure of general engagement, and greater physical activity. In addition, we hypothesize that co-present family members (who observe the child life specialist interacting with their child with each intervention) will be more likely to participate in the interaction in the *Robot* condition. Furthermore, we predict that CCLS staff will have a positive impression of using social robots to augment their pediatric inpatient care services at the end of the study.

- **H1**: Children will interact longer in order of *Robot* > *Avatar* > *Plush*.
- **H2**: The number of verbal utterances produced by children will be in order of *Robot* > *Avatar* > *Plush*.
- **H3**: The number of verbal utterances produced by all interaction participants will be in order of *Robot* > *Avatar* > *Plush*.
- **H4**: *Robot* will produce more physical movement for children over time during the interaction than *Avatar* and *Plush*.

C. Participants

We recruited 54 pediatric in-patients aged 3-10 (33 male and 21 female, age M = 6.09, SD = 2.33) staying at Boston Children's Hospital for at least 48 hours. Out of the 54 patients, 20 children were in the In-patient Surgical Unit, 1 in the Medical Surgical Intensive Care Unit (MSICU), 24 in the Hematology/Oncology Unit and 9 in the Bone Marrow Transplant Unit. Demographically, parents of 36 children reported White, 3 reported Asian, 3 reported Black, 5 reported Hispanic, 1 reported Native American, 4 reported Biracial, and 1 reported Other. All except 2 participants were typically developing children.

D. Companion-Like Interventions

Fig. 1 shows the three interventions used in our study. All three were introduced as Huggable to the participant.

Fig. 1. Three interventions were used in our study: the plush Huggable, the virtual Huggable avatar, and the Huggable robot (from left to right).

The virtual Huggable ran on an Android tablet. The robot Huggable uses an android smart phone as its primary computational unit and uses the screen as digitally animated eyes. Both the virtual and robot Huggable are designed with the same degrees of freedom and the same animations. Both are teleoperated using the same interface by a remote CCLS stationed outside the patient's room. For both, The CCLS teleoperator could trigger various facial expressions and body actions, talk through the Huggable in a more child-like pitch-shifted voice. The remote CCLS operator could see and hear the participant and his/her surroundings via a camera feed. Another CCLS was in the patient's room using each intervention to engage the patient.

IV. Procedure

Our between-subjects design had three conditions (*Robot* × *Avatar* × *Plush*). To counter-balance across the three experimental conditions, we applied block random assignment with participants age and gender as nuisance factors. We assigned children between the ages of 3-5 years to the *Young* block, and children between the ages of 6-10 to the *Old* block. Participants were then grouped into one of four blocks: Age $\{$*Young* vs. *Old*$\}$ × Gender $\{$*Male* vs. *Female*$\}$. Within each of the four blocks, children were randomly assigned to interact with one of the three interventions.

All study procedures were undertaken in participants bed spaces. We set up the experiment equipment (intervention and video camera) appropriately to accommodate each participants bed space. For infection control, all the equipment, including the Huggable robots fur, was wiped down or washed between every study session.

After a thirty-minute observation period, a CCLS brought and introduced the intervention to the participant. The intervention was put on a mobile bedside table and placed next to the participants bed for the interaction (Fig. 2). Each participant was asked to freely interact and play with the intervention as long as he or she liked. The CCLS leveraged the intervention as she would normally do as her standard care for patients, and loosely guided the interaction for safe and proper usage of the intervention. For the *Robot* and the *Avatar* conditions, the virtual and the robotic Huggable were teleoperated by an additional CCLS outside the patient bed space. The virtual and the robotic Huggable engaged participants by conversing about their likes/dislikes, singing nursery rhymes, and playing an I Spy game. The plush was "puppeteer-ed" by the CCLS as in standard practice. When the interaction ended, an additional 30 minute observation period was performed. The pre- and post-interactions were video recorded without audio, and the participants interactions with the intervention were video recorded with audio (lasting about 30 minutes on average). During the interaction and observation phases of our study sessions, we asked the patients, their family, and other medical staff to act as they typically would in an effort to test the effect of each intervention in a natural setting to explore how each might fit in the pediatric in-patient care routine.

At the end of the study, we asked the CCLS who were involved in the study sessions (three in total), to fill out a paper questionnaire about their views on interactive companion-like interventions in their pediatric care routine. Questions included how they viewed companion-like technologies (robot, avatar or plush) as impacting the hospital in-patient experience for children, how patients might benefit from interaction with these interventions, how CCLS might benefit from using these interventions, how the interactive technologies (once more autonomous) might benefit patients and CCLS, and if there are benefits the technological versions could offer patients and CCLS that are not possible by other means.

V. Data Analysis

We analyzed videos recorded during the intervention session from 48 patients to extract child patients verbal and physical behavioral data. Video recordings of six participants were lost due to technical issues.

The videos were transcribed to analyze interaction participants verbal utterances and physical movement of the patient. A professional HIPAA-compliant vendor transcribed the audio clips processed from video footage. Three interaction audio clips were excluded from transcription due to their poor audio quality and were excluded from the transcription data analysis. The transcription data identified each speaker into one of the four categories: *Patient*, *Huggable*, *Moderator* and *Other*. *Patient* indicates the child study participant, *Huggable* indicates the Huggable intervention, *Moderator* indicates the CCLS assisting the interaction by the patient bedside, and *Other* indicates family members who were in the room.

Childrens physical movement during the interaction was annotated on a continuous scale between 0 [no movement] to 1 [active body movement] using a joystick device. The annotator watched the recorded video footage in real time and moved the joystick up/down to indicate the level of childrens physical movement for each video frame. We segmented each childs interaction into three time intervals (beginning/middle/end of intervention) and calculated the mean level of physical movement for each section. Seventeen children were too fatigued to interact physically and showed very low level of physical movement throughout all three sections (below 0.08). These participants were excluded from the physical activity analysis.

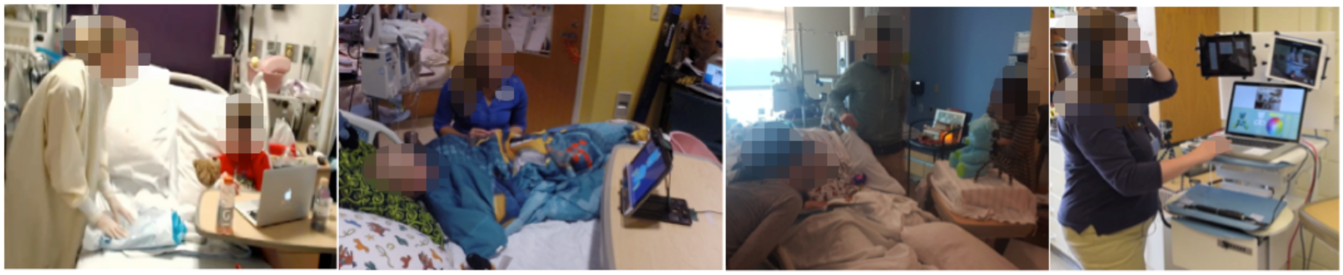

Fig. 2. Children interact with a plush Huggable, a virtual Huggable on an Android tablet device or a robotic Huggable in their patient bed space. For the virtual and the robotic Huggable, a remote operator controls the Huggables behavior (from left to right).

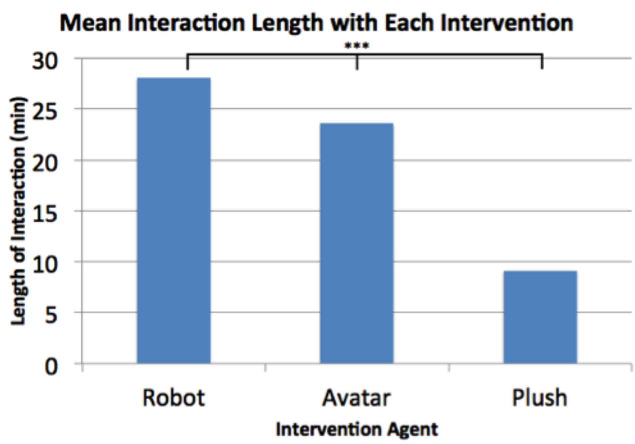

Fig. 3. The length of childrens interaction showed a statistically significant increase over the three experimental conditions (*Robot* > *Avatar* > *Plush*).

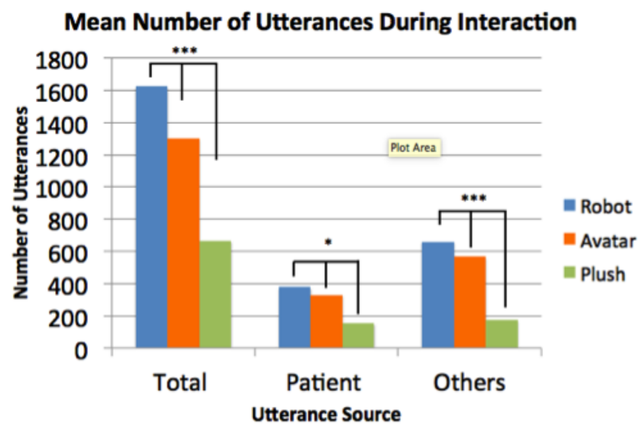

Fig. 4. The number of utterances produced in total, by the patient and by others (co-present family members who were not directly engaged by the intervention) showed statistically significant trends of increase over the three experimental conditions (*Robot* > *Avatar* > *Plush*).

VI. RESULTS

A generalized linear model [15] was applied to predict various measurements of engagement (interaction duration, total utterances, patients utterances, intervention agents utterances, interaction moderators utterances and family member utterances based on the type of intervention offered to the patient. The predictor variable was contrast coded [4] as ordered values [-1 0 1], *Robot*, *Avatar* and *Plush* respectively.

A. Interaction Length

A contrast coded generalized linear regression model showed a statistically significant trend of increase found in the length of childrens interaction with the given intervention across the three experimental conditions (*Robot* > *Avatar* > *Plush*) based on the regression model, $F(1, 46) = 18.2$, $p < 0.001$. A one-way ANOVA also showed a statistical difference in interaction lengths across the three conditions, $F(2, 45) = 9.911$, $p < 0.001$. Fig. 3 shows the mean lengths of childrens interactions with each intervention agent.

B. Verbal Utterances

A contrast coded generalized linear regression model showed a statistically significant trend of increase in the total number of utterances made across the three experimental condition (*Robot* > *Avatar* > *Plush*) based on the generalized linear regression model, $F(1, 43) = 11.7$, $p = 0.001$. There were statistically significant trends of increase in the utterances produced by the child patient across the three agents (*Robot* > *Avatar* > *Plush*), $F(1, 43) = 6.35$, $p = 0.016$. In addition, the number of utterances produced by the patients family members showed a statistically significant trend of increase across the conditions (*Robot* > *Avatar* > *Plush*), $F(1, 43) = 11.7$, $p = 0.001$.

A one-way ANOVA was conducted to compare the effect of experimental condition on the verbal utterances produced by all participants, by patient only and by patients family members. We found statistically significant effects of experimental condition on the number of total utterances, $F(2, 42) = 5.75$, $p = 0.006$; the number of utterances made by the child patient, $F(2, 41) = 3.3$, $p = 0.047$; and the number of utterances made by the patients family members, $F(2, 41) = 6.03$, $p = 0.005$.

We analyzed our data to determine if the CCLS staff and Huggable intervention utterances were consistent across all three conditions. This is important to show that the behavior of the co-present or remote CCLS staff did not bias patient or family behavior. Our analysis shows that the number of utterances produced by the Huggable agent failed to show a statistically significant trend of increase, $F(1, 43) = 1.33$, $p = 0.257$. In the *Plush* condition, we considered the CCLSs utterances as the Huggables utterances when the

CCLS "puppeteer-ed" the plush. The number of utterances produced by the CCLS by the patient bedside also did not show any statistically significant trend of increase, $F(1, 43) = 3.42$, $p = 0.071$. Fig. 4 shows the mean number of utterances produced by all members of the interaction participants (Total), by patient only (Patient) and by family members who were not directly invited for the interaction (Others). Hence, differences between patient and family behavior can be attributed to the intervention and not on differences in CCLS behavior across conditions.

C. Physical Movement

For *Robot* condition, the mean levels of childrens physical movement increased over time: 0.070 (SD 0.057), 0.095 (SD 0.047) and 0.237 (SD 0.155) for the beginning, middle and end of the interaction, respectively. For *Avatar* condition, the mean levels of childrens physical movement were relatively stable: 0.147 (SD 0.210), 0.181 (SD 0.149) and 0.193 (SD 0.140). For *Plush* condition, the mean levels of childrens physical movement were also relatively stable: 0.165 (SD 0.158), 0.160 (SD 0.170) and 0.177 (SD 0.101).

A two-way Repeated-Measures ANOVA was conducted to compare the effect of experimental condition and time on the levels of childrens physical movement at the start, middle and end of the session. We found a statistically significant effect of time on childrens physical movement throughout the interaction, $F(2, 54) = 6.122$, $p = 0.004$. We also found a statistically significant condition-time interaction, $F(4, 54) = 2.951$, $p = 0.028$. Fig. 5 shows the mean levels of physical movement children produced during each stage of the interaction with each intervention agent.

A one-way ANOVA showed that the level of childrens physical movement with *Robot* at the beginning/middle/end differed significantly at $F(2, 30) = 9.049$, $p < 0.001$. A post hoc Tukeys test for pairwise comparison showed that the level of childrens physical movement at the beginning and at the end also differed significantly at $p = 0.001$. Childrens physical movement also showed a statistically significant difference between at the middle and at the end of the interaction at $p = 0.006$.

D. Post-study CCLS Questionnaire

We reviewed the questionnaire responses of the three CCLS on their views and perspectives on social robots in pediatric care settings after their participation in the study. Interestingly, CCLS did not see a critical difference between the robotic and the virtual Huggable in their effect on childrens engagement, whereas there is a significant difference in the video analysis of the interaction.

Nonetheless, they noted that the robot and the tablet caught their [childrens] attention and kept it for longer periods of time [than the plush toy] especially for children with a little more energy overall but who are fatigued and stressed at being in the hospital. However, they viewed the plush Huggable to be more appropriate and effective for children who are extremely fatigued and do not have enough energy for social interaction.

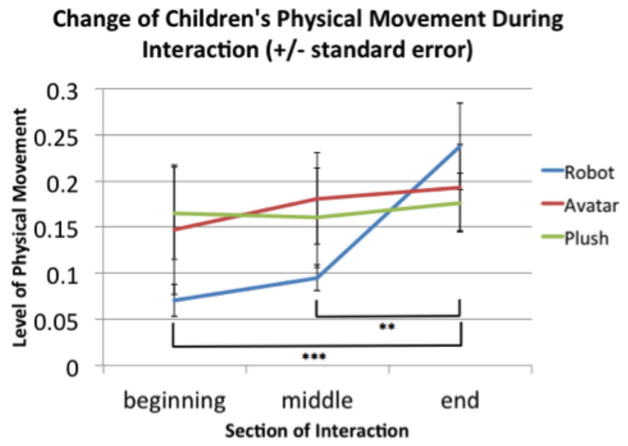

Fig. 5. There was a significant effect of time on the level of childrens physical movement during the interaction. The interaction between time and the experimental condition also had a statistically significant effect on childrens physical movement.

Regarding opportunities for social robots, specifically, in a pediatric inpatient care context – the three CCLSs projected extending their care using the Huggable robot in three ways: education, diversion, and companionship. They saw the Huggable robot potentially being part of perioperative care and supporting children throughout the clinical operation experience. They reported seeing the benefits of a social robot in a pediatric hospital as part of the patient care team and could be used for medical play, procedure preparation, and distraction from stress and discomfort across a variety of tasks and settings.

VII. Discussion

This study investigated how a social robot, a virtual character, and a plush toy could engage young pediatric in-patients in a hospital setting in cooperation with CCLS. Our engagement analysis found evidence that children interacted longer and talked more when given a social robot than when given a virtual character or a plush toy. In addition, we found that family members, who were co-present but not directly engaged in the interaction with an intervention, were more likely to participate in the interaction. They produced higher verbal utterances when a robot was present than the other two interventions. This finding is noteworthy because it suggests that a physically co-present social robot may significantly impact a pediatric patients socio-emotional engagement and wellbeing, as well as their overall hospital experience – in a positive and potentially higher impact way than a virtual counterpart.

These engagement findings support the potential of social robots (and other companion-like technologies) in the context of pediatric in-patient care. Far beyond distraction as reported in prior work [2], pediatric companion robots could be applied to patient education and preparation for an upcoming procedure. By supporting playful interactions, social robots could be used for medical play both in conjunction with CCLS and potentially at other times, too. The companionship aspect of social robots could also be leveraged to not only distract patients from stress and discomfort, but potentially alleviate feelings of loneliness when children don't have others with them in the hospital room. A social robot could also support a physical tele-presence function, connecting the child patient to remote friends and family.

The analysis of childrens physical movement during the interaction suggests that a social robot can potentially promote young patients to engage in higher physical activity *over time* during the interaction. A virtual character and a plush toy tended to maintain a consistent level of physical activity, but did not have effect on increasing their physical movement any further. This opens another opportunity for social robots in pediatric care context because perioperative movement and physical therapy can play an important role in patients recovery and health outcomes.

The CCLS perspective is important, and they did report perceived value in incorporating interactive companion-like technologies as part of their service. The overall level of physical fatigue of a patient is an important factor in their decision as to which type of intervention to use with a particular patient. Whereas they recognize more interactive technologies as being more engaging and flexible in their potential applications, they also require more effort on the part of the patient. At times, patients are too ill or too fatigued, favoring CCLS to choose a plush toy.

VIII. Conclusion & Future Work

This study is the first to systematically compare companion-like interventions for pediatric care in concert with child life services. We found that over time, a social robot promotes physical and verbal engagement from young patients and co-present family more effectively than a virtual character and a plush toy. We also report on perceived opportunities of companion-like interventions to augment CLS – and patient factors that bias CCLS to choose one intervention over another. Both suggest that social robots could potentially play a significant role in improving young patients hospital experience, helping to entertain and educate, as well as to help reduce feelings of isolation through providing various types of playful social interactions.

We continue to further analyze our data to evaluate impact on childrens emotional state, perception of pain, and mitigation of stress and anxiety – as a function of patient factors such as initial affect, age group, medical condition and gender. This will provide additional insights as to how different companion-like interventions can provide value to different groups of pediatric patients.

The knowledge and insights from our ongoing analyses shall also inform the further development of our robot pediatric companion toward greater autonomy and patient personalization to support support professional care teams, patients, and their families.

Acknowledgement

We would like to thank all of our study participants, their family and hospital staff at Boston Childrens Hospital who participated in and supported this study. The certified child life specialists Suzanna Graca, Brianna O'Connell and Laurel Anderson operated the virtual and the robotic Huggable. Duncan Smith-Freedman, Katherine Jamieson, Nicole Stenquist, Honey Goodenough and Katie Fitzpatrick from SimPeds program assisted with the study procedure. Ognjen Rudovic provided the video annotation software and instruction for this paper.

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