Child-Robot Interaction Studies: From Lessons Learned to Guidelines

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ABSTRACT

This project is about the creation of a set of guidelines for Child-Robot Interaction (CRI) studies in cognitive therapeutic settings. We collected past experiences and lessons learned from previous relevant studies - relating to Traumatic Brain Injury (TBI) and Autism Spectrum Disorder (ASD) – and transformed them into general guidelines. The main idea is to 1) motivate the scientific community to collect empirical quantitative data to further develop guidelines for child-robot interaction studies; 2) to give support and facilitate the adoption process to those practitioners implementing similar robot rehabilitation programs; 3) to ultimately help build safer and more effective personalized and engaging educational settings for children in their neurodevelopmental process.

Keywords

Child-Robot Interaction; Guidelines; Autism Spectrum Disorder, Traumatic Brain Injury, Robot Therapy.

1. INTRODUCTION

To be effective, a therapeutic setting should address the predominant core characteristics of the disorder, and be individualized to meet the needs of each participant [1]. Robots have been found to be remarkable at this regard, either in physical – i.e. exoskeleton – or in cognitive rehabilitation therapies [2]. Robots can adapt easily to each individual's needs, they are predictive and repetitive, and also very engaging [3-4]. Building robots also encourages social and cooperative skills, which are very beneficial for children with neurodevelopmental disorders [5-6].

Some common metrics for human-robot interaction studies were released time ago [7]. Yet, there are no practical guidelines for therapists on how to implement robotic therapies. This article is a first step towards filling this gap. We present some guidelines for child-robot interaction (CRI) studies, especially for cognitive therapeutic settings.

Using lessons learned from our projects regarding the use of robots for children with Autism Spectrum Disorder (ASD) [8-9] and Traumatic Brain Injury (TBI) [3,10] as background information, we introduce practical guidelines to give support to those practitioners implementing similar rehabilitation programs. This could facilitate the adoption process of these therapies so that children benefit from personalized and engaging educational settings.

In turn, if scientists and therapist share their experiences and lessons learned to the community, quantitative data could be collected – which is still lacking [11]. Collecting enough empirical data from all of us could help draft common guidelines to promote safer, richer and more effective therapies, and push the authorities towards the inclusion of robotic therapies within the legislative framework.

2. BACKGROUND INFORMATION: THE PROJECTS

This article is based on different studies, some of them refer to the use of LEGO® robotics with children under the ASD, and the rest of the studies refer to use of a social robotic platform for children that suffered TBI.

2.1 Studies related to children with ASD

Children and adolescents with autistic spectrum disorder (ASD) have persistent deficits in social communication and social interaction across multiple contexts [9]. Helping these children to manage simultaneous sensory inputs and peer-mediated approaches through social play interventions has been proven to be effective [10]. Because engagement drives learning [11], the therapy should be configured in a way that children are motivated and engaged. LEGO® robotics creates a context where social and problem-solving skills meet, and this motivates a lot of people. That is why there are studies that show that the creation of such a context is exceedingly positive for children with neurodevelopmental disorders [13-15], including children with ASD [16-17].

Our studies concerning children with ASD were based on these grounds. We created a context were children with ASD could participate in robot-based activities: in some, the children had to create a LEGO® robot and program it to move [4,15]; in other studies the robots had to program a mobile robot to complete a circuit on a game board [18]. We used LEGO® robotics to foster and facilitate social skills, but also as a social robot that interacted with the children. The project aimed at eliciting social behavior

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among children, and between the children and the therapists. The researchers assessed all the behaviors and analyzed the effectiveness of the therapy. They used that knowledge to improve the design of robot-based interventions for future applications.

2.2 Studies related to children with TBI

There is substantial evidence to support cognitive rehabilitation for people with TBI [15]. Under normal conditions, people with TBI maintain all the cognitive functions they have acquired and consolidated before the injury. During and after the injury, TBI sufferers, however, have a close encounter with the development and the acquisition new cognitive functions [19]. Acquiring and develop new cognitive functions is of great importance in young populations.

Robotic technology offers the possibility to adapt to the children's learning rhythm, and offers multiple and different activities that have been found effective and engaging in TBI populations [20]. Moreover, the robot can monitor the children on and off therapy, working as a sort of extension of the therapist. Because of all the benefits robots bring about, we decided to use a social robot with children that suffered TBI in several projects [21-22]. The project included a social robot that children could bring home to do some exercises. The aim of the studies was to compare a rehabilitation program that included a personal robot as a therapist, and a control group with children with moderate or severe brain injury that did not include such a robot. The idea was to evaluate the effectiveness of a robot neuropsychological rehabilitation treatment.

3. GUIDELINES

This section includes lessons learned from different events we experienced. All the events and examples involve the institutions with whom we collaborated, the therapists of those institutions, the roboticists and the children. Some examples will illustrate better the event and will serve as tips for the design of future robot therapies – either for research purposes or for the sake of the therapy itself. The tips relate to patient recruitment, analysis of data, privacy, and to the ending of the therapy.

3.1 Guidelines for the Institution

During the studies with children with ASD and TBI we worked at Hospital Sant Joan de Déu located in Barcelona, Spain. It is a teaching hospital specialized in the fields of pediatrics, gynecology and obstetrics. The institution plays a major role on accepting the development of new therapies: they choose every year in what they will invest their money.

Due to the fact that the hospital has their own methods and their own tools that are already working with efficiency, it is important to provide them with information of the therapies that include scientific and empirical evidence of their benefits and a cost-effective relation for budgetary purposes. A live demonstration could be adequate. Once accepted, the hospital needs to prepare the facilities according to the therapy, including physical premises and network [23].

3.2 Guidelines for Caregivers

Caregivers might have also their own *modus operandi*. It can happen that they consider the new therapy burdensome – because they lack program skills – or because they are reluctant to change – they believe that traditional methods work better.

Nurses are used to work with machines that monitor the vital signs of the patients and other types of data. However, the introduction of a social robot that performs similar activities provokes an adverse feeling: feeling of replacement. It seems that this fear is related to the attribution of agency to the robot. Because of that, there is the need to explain clear that the robot is a tool for the therapist and that roboticists work for the best interest of the child. Educating the staff on these matters with ex-ante transdisciplinary training is very important. Involving other departments in the information sessions can be very beneficial to promote institutional cohesion and encourage interdisciplinary thinking.

Recruiting children for the studies is very hard, either because it is difficult to find homogenous groups, or because the children – or normally the parents – are unwilling to participate in the case. Some of our projects had television (for the Catalan region) and newspaper covers (nationwide) to promote the study and make public the call for participation. In other cases, the same hospital provided the children for the study. For homogenous groups, a neuropsychological assessment needs to be carried out. The difficulty concerning recruitment forces the projects to be flexible enough to be carried out independently of the size of the group. Researchers might have to be satisfied with the sample they have as, in any case, they are also contributing to the progress of science.

The activities with the robot should be done according to the goal to be achieved, e.g. emotion recognition, training collaborative skills or material sharing. They can also be adapted to children's wishes: children may want to play in a session "UNO", the American card game, and thus the robot should be programmed to be able to play the game with the children. This highly motivates them and the engagement is normally a complete success. The activities with the robot should allow different play styles, including parallel, or collaborative (non-numerus clausus), and they

can be ecological, i.e. real-life situations. The activities are not limited to the robot, but to the robot system meaning that everything can be used in the therapy: the user-interface, the sensors, etc.

Attention should be drawn to emotional bonds created between the child and the robot, especially if children can bring the robot home. In the light of a strong attachment, the therapists and the roboticists can consider whether children can have the robot some more days and ask the parents to return it once the child is less interested – because the activities are always the same, for instance. For this reason, activities should be time limited.

Communication between the members should be regularly and should include an updated report on the progress of the therapy. To avoid misunderstandings within interdisciplinary teams, it is important to make the effort to adapt to the level of expertise of those involved in the project, in terms of vocabulary and ways of thinking. In the case of misunderstanding, or doubt, the word of the therapist in the best interest of the child will prime over the one of the engineer's team.

It is useful to monitor when, how often, how long, and how good the child is performing the activities, among other information. Beyond the effectiveness of the therapy, the evaluation concerns children's progress in terms of happiness, social relations and cognitive function recovery. The application of both direct inquiry and observational techniques is a useful approach to describe and understand children-robot interaction. Data analysis might take time, so researchers will have to plan their time accordingly. It is advised to streamline the process when possible. The process is always iterative: it can always be improved. Evaluate success of the therapy, identify problems and establish recommendations. If possible, apply the recommendations and re-design the robot and the therapy associated to it and start again the therapy.

The institution might have privacy-related requirements and need to be followed, i.e. use of a private wi-fi to download information, a private cloud, or not having the possibility to analyze the information out of the research center (only in the hospital). In any case, the project needs to be compliant with the legislation of data protection. In Europe, the national laws determine the requirements of the processing of personal data until the 679/2016 General Data Protection Regulation will enter in force in 2018.

A talk with parents and children at the end of each session improves program's effectiveness not only by reinforcing the skills with the training at home but also enhancing the therapeutic alliance, what presumably would have a positive effect on therapy adherence and clinical outcomes. Project should include a post-monitoring control. Moreover, the creation of a low-cost robot could encourage parents to buy it and the children could continue doing therapy. In such a case, an AI could be of help to update the exercises. A report on the progress of the child over time could be sent to the therapist and these data could be help for quantitative analysis. This could be a return-of-investment plan for the hospital.

3.3 Guidelines for the Roboticists

One of the common misunderstandings that exist between technical and social science communities is the perception of difficulty of own tasks. Programming a robot might be very easy for an engineer but might not be that intuitive for caregivers. The use of easy to use robotics platforms and a specialized training can be of help to ensure efficiency of the therapy. The programming, and the interaction should be represented by familiar and simple concepts.

In fact, most of the therapists wonder which is the best robot to conduct such therapies. Even roboticists do not agree with what are the characteristics that a robot should possess so that the goals of the therapy are met. After doing a literature review, and because our experience, we found out that a robot should be, *grosso modo*, mobile, robust, safe, clear, easy to use, easy to program, versatile, cost-effective, and adaptive:

- The robot should move and enhance freedom of movement to create meaningful and sustained interaction with children; it should be robust, especially if the robot will be brought at home; and it should be safe, i.e. without sharp areas, or little pieces.

- The robot should provide constant and clear feedback of the status of the system to avoid the sudden stop of the activity. The robot should be easy to program and manipulate for the children using it because making the robot behavior dependent on the children action involves the motivation of the child. Moreover, the robot should be versatile (hardware and software scalability and modularity) and easily tailored to specific interaction requirements according to user characteristics (e.g. age, interests, capabilities) and specific contexts (e.g. play games, therapeutic objectives). The robot in fact should adapt to the user profile in terms of realization time, difficulty and engagement.

- The robot should provide communication skills such as contingent visual or auditory feedback when the children complete successfully a task to enrich the interaction.

- Within additional features, the incorporation of artificial intelligence to the robot can improve the interaction but it is not a condition sine qua non. Cloud connectivity enables the combination of human intervention with artificial intelligent multi-agent to bias the robot companion behavior which fosters a better engagement.

- Personalization of the robot can improve the interaction with the child because it accelerates the process of engagement. Personalization may include adapting the activities to the children's likes/dislikes, e.g. a TV-show. As an example, the robot can be adapted with Bob Sponge images for young children or with Modern Family activities for teenagers.

3.4 Guidelines for the Children

The last point highlighted leads to the most important part, those guidelines that are good for the children. At the very end, what matters the most is that the children are happy and they learn. If they are with ASD, the most important is that they learn how to communicate, how to understand emotions, etc. And if they are with TBI, it is important that they work on acquiring those functions damaged by the injury.

The therapy needs to be user-centered. The more adaptive to the child needs the therapy is, the more effective the therapy will be. The child shall receive also training sessions on how to use the robot. The more familiar the child is with the robot, the more improvement in treatment can be enhanced.

4. CONCLUSIONS

This paper encourages the development of guidelines for CRI studies. Children are a vulnerable part of the society, and deserve greater protection, especially those with neurodevelopmental disorders. Because of that, we persuade the community to share all their experiences and lessons learned in CRI studies. The main idea is to collect enough quantitative data to build all together guidelines that can ensure that all the safeguards are met to protect children.

We invite all the researchers working on CRI projects to reflect on what procedures they follow, what problems they encounter and how they solve them and present them to the community in a guideline format. This will enrich the scientific community and will facilitate the introduction of robotics in their therapies. This organized know-how will largely benefit the efficiency in therapies for cognitive rehabilitation and thus, help the children, who are (and should be) the focus of all this.

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Annex I – Guidelines for Child-Robot Interaction Studies in Cognitive Therapeutic Settings

Good for…	Title	Event	Lesson Learned	Guideline
G.I.	Institution Acceptance	The insitution has their own methods and their own tools that are already working with efficiency.	The lack of experience in the new tools might impede the inclsuion of them for the new therapy.	The institution needs clear information on the scope of these therapies and the benefits of it.
				The information may include scientific evidence of the benefits of the therapy.
				The information may include a cost-effective relation for budgetary purposes.
G.I.	Facilities	It can be that the facilities to conduct the therapies such a therapy need to be adequate.	The physical facilities play an important role on the development of the therapy	The facilities to conduct such a therapy need to be adequate.
				The room size and arrangement of materials in terms of organization and accessibility are important
			Together with the phsyical facilities, the network is important.	The network of the setting needs to be reliable.
G.T.	Staff Acceptance	Therapists are used to their own modus operandi. They already their own methodology and their own reliable treatments.	The lack of experience when introducing new technologies, as it could be robotics, might impede the inclusion of them.	All the staff that is going to be part of the research needs to receive clear information of the therapy.
				The information will focus on the capabilities of the robot and the potential it has. Special empathy will be given to those having sentiments relating to the fear of replacement - emphasizing that robots are tools that help therapists, not substitute therapists.
				The information sessions can include presentation but also live demonstrations.
				Information sessions can be open to other staff of the hospital, so that other departments see the progress of the hospital
				In order to fulfill the clinical objectives, the therapist should be acquainted to both the technology and the games related to it. An ex ante training could be of help.
G.T.	Prior the therapy	During the projects the lack of participation is common.	It is very difficult to recruit children.	Use all the possible means to recruit the children. This may include public announcement or personal visits to hospital
				The project needs to be flexible enough to be carried out either with a lot of children or with few participants
				Learn to be satisfied with the sample you have. You are contributing to the progress in any case.
			It is very difficult to recruit children because groups need to be homogenous	Neuropsychological assessment prior to the treatment can help have a control assessment at the end of the treatment to determine the generalization of learning acquired.
				A pre-test based on standardized test and direct observation can be carried out to assess the participants' pre-intervention social skills acting as the base line of the dependent variable

G.T.	During the Therapy	It can happen that the re-use of past/traditional activities do not work with the robot therapy.	Sometimes the activities are well designed but they do not lead to any effect to the child's condition. Activities should match children conditions	The activities with the robot should be done according to the goal to be achieved, e.g. emotion recognition, training collaborative skills or material sharing.
				The activities with the robot should allow different play styles, including solitary, parallel, competitive or collaborative (non-numerus clausus).
			Sometimes the activities do not reflect real situations	The activities can be ecological activities, i.e. real-life situations
			Sometimes the therapist finds the robot a bit limitative.	The activities are not limited to the robot, but to the robot syste meaning that everything can be used in the therapy: the user-interface, the sensors, etc.
		There are a lot of emotions involved in the therapy.	The children develop affection and emotional bonds towards the robot	The interaction with the robot should be time limited to avoid strong affective bonds.
				If the therapy include the possibility to bring the robot home, the parents should monitor the time spent with the robot
		It can happen that there is a lack of communication between those involved in the therapy: the engineers' team and the neuropsychologists.	There is a mismatch between the robot capabilities and the expectations of the therapists.	The information of the project shall be realistic and concrete from the beginning of the project.
				Communication between the members should be regularly and should include an updated report on the progress of the therapy.
				It is important to make the effort to adapt to the level of expertise of those involved in the project, in terms of vocabulary and ways of thinking.
				In the case of misunderstanding, or doubt, the word of the therapist in the best interest of the child will prime over the one of the engineer's team.
G.T.	Analysis	There are a lot of things to analyse, and sometimes it is difficult to manage the information.	Researchers need to focus on what is important to analyze and what is not.	It is useful to monitor when, how often, how long, and how good the child is performing the activities.
			Sessions recordings allow further analysis and can improve therapies	Coding schemes can help carry out the analysis of the videotaped sequence.
			The presence of the cameras causes distraction to the children.	Cameras should be hidden from direct sight.
		In social sciences is very difficult to evaluate performances in children. When you only use quantitative data (from questionnaires) or qualitative data (from taking notes), you can draw false conclusions.	We have to be very aware in the analysis, trying to combine quantitative and qualitative data to be more consistent.	It is useful to monitor when, how often, how long, and how good the child is performing the activities.
				The application of both direct inquiry and observational techniques is a useful approach to describe and understand children-robot interaction.
				As the analysis might take time, it is important to plan the time to do it.
				Whenever possible, streamline the process.
G.T.	Post therapy	There are things that go wrong.	The process is iterative and can always be improved. Specific cases might require specific solutions that might not be applicable at a more general level.	Evaluate success of the therapy, identify problems and establish recommendations.
				Apply the recommendations and re-design the robot and the therapy associated to it and start again.
		During the sessions children can have both a very good or a bad behavior. In the case of good behavior, the children might share the robot and help others while they are building the robot.	The parents need to be in the loop with the program. It is important to explain the goals of the activity, give remarks on children performance and achievements, and propose homework activities before next session.	A talk with parents and children at the end of each session improves program's effectiveness not only by reinforcing the skills with the training at home but also enhancing the therapeutic alliance, what presumably would have a positive effect on therapy adherence and clinical outcomes.
		Once the project finishes, the therapy with the children ends. A report is done to see whether there has been an improvement.	Although being a very beneficial therapy, if there is no continuation or there is no post monitoring control, the benefit is temporary.	The project should include a post monitoring control
				If the project included a low-cost robot, the parents could buy the robot and the children could continue doing therapy.
				In the above case, an AI could be of help to update the exercises. A report on the progress of the child over time could be sent to the therapist. These data could be help for quantitative analysis.

G.T.	Data Protection	During the projects there is an incredible amount of personal data, including behavioral data, to process.	Behavioral data is sensitive data according to European regulations on data protection. There is the need to pay close attention to the privacy laws because they are very strict and they might be different in different countries.	The project needs to be compliant with the legislation of data protection. In Europe, the national laws determine the requirements of the processing of personal data until the 679/2016 General Data Protection Regulation will enter in force in 2018.
				The modules should be accesible by the therapist with a password.
				A private cloud is recommended.
				The institution might have privacy-related requirements and need to be followed, i.e. use of a private wi-fi to download information or not having the possibility to analyze the information in the research center (only in the hospital).
G.R.	Engineer-dependence	The therapy is engineer-dependent.	If the therapy is engineer-dependent, there is a need of technical person during the session, therefore robotics is not transparent as mobile phone is regarding its difficulty.	Use robotics platforms easy enough for everybody.
				Training courses in order to teach how to use the robot if it is not enough intuitive might be very helpful.
G.R.	Robot Characte-ristics	It is not very clear how should be the robot or what should the robot do in order to be an effective tool in the therapy	Robots at home cannot be controlled by engineers, so it should be robust all the time.	The robustness and the effectiveness of the robotic platform are important in the design, especially if the robot will be brought at home.
			Robots may include little pieces to be swallowed and that could endanger the safety of the child.	The robot should be safe and shall not include sharp areas, or include little pieces.
			Sometimes the robot stopped suddenly due to programming failures.	The robot should provide constant and clear feedback of the status of the system
			Sometimes the robot is too dificult for the children - or even the therapists - to understand	The programming, and the interaction should be represented by familiar and simple concepts
				The robot should be easy to use.
				The robot should be easy to program and manipulate because making the robot behavior dependent on the children action involves the motivation of the child.
			Sometimes robots are not easy adapted to the activities or to the users.	The robot should be versatile (hardware and software scalability and modulatrity) and available can be easily tailored to specific interaction requirements according to user characteristics (e.g. age, interests, capabilities) and specific contexts (e.g. play games, therapeutic objectives)
			Sometimes the robot is very expensive so that there are not enough robots to conduct the therapy	The robot should be cost-effective
			Standard activities might not work the same for every child.	The robot should adapt to the user profile in terms of realization time, difficulty and engagement.
			Long-term treatment demands a high motivation and commitment from parents and children to diminish drop-put during the therapy.	The robot should provide communication skills such as contignent visual or auditory feedback when the children complete successfully a task to enrich the interaction
				The incorporation of artificial intelligence to the robot can improve the interaction but it is not a conditio sine qua non.
				Cloud connectivity enables the combination of human intervention with artificial intelligent multi-agent to bias the Robot Companion behavior. This fosters a better engagement
				Personalization of the robot can improve the interaction with the child because it accelerate the process of engagement
G.C.	User-Centered	Work done by the therpaists and the engineers needs to be aligned.	Everything we do is for the benefit of the children and on their best interest. What matters the most is that the children are happy, learn and improve.	The therapy needs to be user-centered. The more adaptative to the child needs the therapy is, the more effective the therapy will be.
				The child shall receive also training sessions on how to use the robot. The more familiar the children is with the robot, the more the social skills can be enhanced.