From training to robot behavior: Towards custom scenarios for robotics in training programs for ASD

J.C.C. Gillesen\(^1\), E.I. Barakova\(^1\), B.E.B.M. Huskens\(^2\), L.M.G. Feijs\(^1\)

\(^1\) Department of Industrial Design
Eindhoven University of Technology
Eindhoven, Netherlands
j.c.gillesen@tue.nl

\(^2\) Research and Development
Dr. Leo Kannerhuis
Doorkwerth, Netherlands
b.huskens@leokannerhuis.nl

Abstract - Successful results have been booked with using robotics in therapy interventions for autism spectrum disorders (ASD). However, to make the best use of robots, the behavior of the robot needs to be tailored to the learning objectives and personal characteristics of each unique individual with ASD. Currently training practices include adaptation of the training programs to the condition of each individual client, based on the particular learning goals or the mood of the client. To include robots in such training will imply that the trainers are enabled to control a robot through an intuitive interface.

For this purpose we use a visual programming environment called TiViPE as an interface between robot and trainer, where scenarios for specific learning objectives can easily be put together as if they were graphical LEGO-like building blocks. This programming platform is linked to the NAO robot from Aldebaran Robotics. A process flow for converting trainers’ scenarios was developed to make sure the gist of the original scenarios was kept intact. We give an example of how a scenario is processed, and implemented into the clinical setting, and how detailed parts of a scenario can be developed.

Keywords – behavioral training in autism, use of robots for therapy, Pivotal response training scenarios, robotics, TiViPE

I. INTRODUCTION

Autism Spectrum Disorder (ASD) is a range of pervasive developmental disorders characterized by a triad of impairments in social interaction, communication and stereotyped patterns of behaviors, interests and activities. [1]. The heterogeneity of the spectrum accords for uniqueness in abilities and disabilities in each individual on the spectrum. This means that needs for therapy intervention are not equal per individual, and may even be contradictory. We would like to address this problem by creating an environment for training that first makes it possible to easily change and adapt the training to the individual case, and second, to give an affordance for different training practices to be readily available and reused.

We like to mention that in our studies we focus on younger people with autism in cooperation with a clinic. Therefore, we use the terms children with autism and clients together interchangeably.

It has been established that using technology can be beneficial in training children with ASD [2]. There has been an increase in technological application in therapy interventions for ASD like computer games [3], tangibles [4-6], video-based instruction [5,7,8], virtual reality [9] and with robots [10-12].

We focus on the combination of movement based social interaction with simple verbal commands which is appropriate for training school aged children. Robots were chosen as the most versatile technological medium. While interaction with a real person can be complex and intimidating for a child with ASD both in verbal and non-verbal behavior, interaction with a robot companion is simpler, more consistent and predictable. This creates a safer and more pleasant atmosphere for an autistic child. Furthermore, the complexity of the robot behavior can be controlled, and adapted for the individual autistic clients. Based on these arguments we assume that it is easy to connect to children with ASD through a robot-actor.

Moreover, Pierno et al. [13] have shown that robotic movement elicits visuomotor priming in children with autism. Robins et al. [14] showed an experiment where a robot actor provoked more proactive social contact than a human.

There are several studies that have established the use of robots in behavioral training of children with autism. A doll-like robot called Robota [15] and a child-like robot called Kaspar [16] have been used to promote imitation skills in low-functioning children with autism. Kozima et al. [17] designed Keepon, a small snowman-like robot with simple abstract movements and used it to elicit joint attention between children with autism and the robot. Barakova and Chonnaparamutt [18] simulated autistic and typical grasping behaviors to be used in robot mediated training. Turn taking and imitation have been trained by a multi-agent system of robotic agents with abstract shape by Brok and Barakova [5] and general social skills training through games with robot agents is discussed in [4].

In several of the mentioned studies [5,14,16,17] autistic children opened up to the trainers, by including them in their interactions with the robot by showing enthusiasm or mimicking the behaviors they practiced with the robot.
Although promising, including the robots in behavioral training practices is difficult because there are no established ways for robots to be used by non technically proficient users, such as therapists. In addition, the busy schedules and the established practices of the therapists would be yet another hurdle. To make this hurdle smaller, we try to include the robot interventions within established training methods.

The existing training practices for ASD address specific skills or behaviors like language and communication skills, problem solving skills, daily living skills or train socially adaptive behaviors, like in speech therapy and sensory integration therapy [19,20]. We have focused on Applied Behavioral Analysis (ABA), which stimulates desirable actions by children through structural positive reinforcement [21].

Pivotal Response Training (PRT) in particular, as part of ABA, focuses on developing crucial areas that are important for many other skills, such as motivation, self-management or initiating behavior [22,23]. Also, as in many ABA programs, clients with ASD are structurally prompted to perform an action if there is no direct response. With prompting, a child is given extra guidance in a specific way to what he or she should do. (For instance, in a situation where a client needs to ask a question, the trainer can ask: “What can you ask me right now?”)

Using a robotic agent to perform different scenarios with a trainer and a child is not a natural circumstance, as is required for PRT. However, we do find these techniques from ABA, and the prompts used in PRT to be a promising course to follow, since they need to be delivered in a consistent and structural manner, which is especially suitable to be done with a robot.

This paper is organized as follows. Section II describes the use of scenarios in training programs and in engineering. It also describes the relevance for our project and how this influenced our scenarios. Section III describes the design of our platform, and how we can convert the scenarios into components that can be used with the robot. The implementation of such a scenario is shown in Section IV. Section V describes the relevance and the perspectives of this work.

II. SCENARIOS

In our approach, the term scenario does not refer to a storyboard-like structure, but to an example story which has a certain purpose related to a learning objective. For example: A scenario where the client imitates different movements of the robot, will be a short exercise where the child is trained in imitation tasks, which is an important skill for particularly young children with autism [24].

Scenarios are already used commonly in autism therapy to explain (complex) social situations. A typical scenario takes the client through different steps and explains in detail the logistics of a task. To formalize the way these scenarios are created, techniques such as social stories [25] were developed, that resulted in an increase in responsiveness [25] and a reduction of disruptive behaviors [26].

In engineering, charting systems such as flowcharts are commonly used, like in Unified Modeling Language (UML), which is often used in software engineering or computer science [27]. They are used to visualize complex systems, or the flow of control and/or data. In ABA the use of flow charts is also common, for example to improve question asking [28].

In cooperation with experts of Dr. Leo Kannerhuis, a centre for autism treatment and research in the Netherlands, scenarios were developed. Since the clients of Dr. Leo Kannerhuis are high functioning, more complex scenarios targeting socialization and communication skills like self-initiation, question asking and problem solving were developed.

During the last four decades techniques and teaching approaches derived from Applied Behavior Analyses (ABA) have been the focus of extensive research for teaching new skills to individuals with ASD [29,30]. Pivotal Response Treatment (PRT) [22] is a promising intervention using principles of ABA. The scenarios developed in this project focus for the larger part on pivotal areas defined by Koegel & Koegel (2006).

III. PLATFORM DESIGN

We are developing a platform that combines 1) the application of robotics in training programs for ASD and 2) scenario building, which is used both in robotics and therapy for ASD. Our aim with this platform is to create a way for trainers to quickly set up scenarios for the robot.

We cannot expect the trainers to have programming experience. Since they are on a tight work schedule, they also don’t have the time to learn or do heavy programming in setting up training scenarios with a robot.

To make it feasible for trainers to use robotics in their training programs, we use a visual programming environment to put together these scenarios using building blocks. The created scenarios are sent to the robot, and performed with the robot and the client. Our complete system consists of the following parts:

1. A robot that is suitable to use in training for ASD, and connects to the programming environment.
2. A visual programming environment where a scenario can be put together with a network of components.
3. Scenarios for people with ASD that have certain learning objectives.

In this paper, we will focus on the components and scenarios. The robot and visual programming tool will be shortly described.

We are using the commercially available humanoid robot called NAO from Aldebaran robotics (Fig. 1). It is a 50cm tall, having 25 mechanical degrees of
freedom walking robot, and has digital cameras, speakers and microphones, different touch sensors and wireless communication capabilities. Using these sensors it can engage in interactive behavior through movement, speech, different LEDs in the face and body, and touch.

Our work does not include building a better robot, so we decided to use this commercially available robot. Yet we do not want this specific choice to be fixed forever. Instead, we design the platform in such a way that different robots can be fitted to it in the future, as this field is still rapidly progressing, and more robots will become available in the future.

We are using a visual programming environment called TiViPE to set up the scenarios for the robot. TiViPE uses a box-wire approach. [31] The boxes, which represent behavioral components with different level of complexity, can be connected to other components, creating a network. Properties of a component can also be modified. Furthermore, networks of components can be merged into new components which enables users to build complex, interactive and intelligent behaviors. By providing the therapists with a powerful set of components they can quickly setup a scenario by connecting different components into a network.

To have an initial set of meaningful components for trainers to create these networks, we started with developing scenarios according to ABA guidelines. By translating how these scenarios can function with a robot as training counterpart to the client, we will discover which robot behavioral components are used more often. These components will be deployed as distinctive blocks that can be reused in other scenarios.

Translating the scenarios for training into TiViPE networks for controlling the robot will require different levels of abstraction. We created a process flow (Fig. 2) to formalize how we can go through these different steps, and make sure the learning goals are still in the final scenario performed by the robot.

The process flow displays the two different disciplines involved in our study (trainers and clients at the top and robot expertise at the bottom). It also shows two routes: one top-down which takes apart a scenario into separate components, and one bottom-up that combines the components into networks that represent that scenario. At present, the role of scenario builder is a joint effort between designers and therapists (authors Gillesen and Huskens). In the near future, it will be done by trainers in the clinic. We will describe the different steps of the process flow below.

At the beginning of the process flow we find the individual learning objectives of the clients. These learning objectives are based on the individual training programs that are designed in the clinic by the trainers, based on the age, level and characteristics of the individual client. Learning objectives will determine the purpose of the stories to be developed. Since learning objectives can be broadly defined, there can be different story purposes for the same learning goal.

These story purposes can again be embedded in different storylines. By varying the structure or context of a story, different storylines can be used for the same story purpose. We assume that using different storylines and story purposes targeting the same learning objectives will be helpful for the client, since he or she needs to apply the same strategies in different contexts. Our ultimate goal would be to see these strategies generalized to everyday contexts. In order to achieve generalized behavior change it is important to incorporate stimulus generalization and response generalization into the training [32].

A storyline can be made more visible using a storyboard, which is a visual representation in pictures of the scenario. It can help to look at the story from a different angle, or makes it easier to communicate a story using the visualizations. We found that this step can be arbitrary; in some cases it made more sense to immediately sketch out a storyline in a flowchart form. Part of such a flowchart is shown in Fig. 3. In the flowchart, the different parts of the storyline are separated and structured into a network of boxes. This already looks like the box-wire programming environment.
For each of these boxes we can start defining what the robot should do, both in sensing and in acting. We call single behaviors the *actions* of the robot. In other cases, behaviors are too complex to grasp in one action; it requires a network of different actions. We can call the networks within one of the flowchart boxes *programs*. Programs thus are small networks of actions. In Fig. 3, names of actions and programs (collected actions) are also visible. Within the actions we can define the behaviors the robot needs to perform, and program this into a component that we can use, re-use and adapt. Because of the heterogeneity of the autism spectrum it is necessary to take into account that individuals with ASD will respond differently to feedback expressed by the robot. Furthermore, certain types of feedback can cause unwanted responses from the client (e.g. anxiety, aggression or indifference). To take these into account, we need to have adjustable parameters within most of our components.

Here are two examples of components that we use, equivalent to an action and program respectively:

- **HeadNod component**: This is a component that makes the robot nod using the motors in the neck.

- **TalkNod component**: This component consists of a network of three other components. 1) It makes the robot talk using a text-to-speech engine. 2) It uses light feedback to show that it is talking. Since it doesn’t have moving lips, we used light feedback in the eyes to show robot activity and attract attention. 3) It shows some non-verbal behavior. This can be a HeadNod component we described earlier. The parameters of these three parts can be altered, making this a very versatile component to use in different scenarios. Fig. 4 shows the component TalkNod, and the network of components behind it.

As the set of available components grows, more and different scenarios can emerge. A starting set of components will be provided to the trainers, but they can also construct components themselves. Components can be made or fine-tuned using a simple string language within the graphical blocks which control the different actuators of the robot [33], or can be constructed by merging a small network of existing components into a new component, like in the TalkNod example.

Table 1 shows our current set of scenarios, including the learning objectives and the derived storyline of different scenarios. This is the starting point for converting the scenarios according to the process flow. We will describe one of these scenarios in the next section.

**IV. IMPLEMENTATION**

In table 1, nine scenarios are shown. We will discuss scenario #9. This scenario does not only allow the clients to train in introducing themselves, but also introduces the robot to the clients. The first impression of the robot can influence the attitude the clients will have towards the robot. Therefore we chose to introduce the robot in the same role as we see it should be used, as a playful emotional mediator. To spread the word about the robot in the clinic, a competition will be held for the name of the robot. In the scenario, the robot first asks the name of the client, which is an opportunity to introduce him or herself. The robot then becomes sad, which would trigger the client to respond. At this point we use the prompts we described earlier to help if the client does not respond within a given time. Once the client responds, the robot explains he is sad because he doesn’t have a name yet. The client is then given the opportunity to enter a name for the competition.

The scenario has several instances where the robot has to say something to the client. For this we can use the TalkNod component, to make the robot ask “What is your name?” We do this by adding a TalkNod component to our network, and changing the text parameter. We may also want to change the length of the light feedback or select one of different non-verbal behaviors. Since it is addressing the client here, a nod will be appropriate. Later on in the scenario, we may use another TalkNod component to make the robot say “I am sad because I don’t have a name”. Here we could change the non-verbal behavior to looking away, and moving one hand to the chest to indicate he’s talking about himself.

Other components that would be featured in this scenario would include a component that would recognize certain key words as a correct response from the client. There are also components that display emotional behavior from the robot, in this case sadness. We display sadness in different stages with non-verbal behavior, such as lowering its head, shaking slowly...
TABLE 1 SCENARIO DESCRIPTIONS

<table>
<thead>
<tr>
<th>#</th>
<th>Learning objectives</th>
<th>Description of robot behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Imitation</td>
<td>Robot displays arm movements that have to be imitated by the child.</td>
</tr>
<tr>
<td>2</td>
<td>Imitation; joined attention; Turn taking</td>
<td>Same as #1, except with the added dimension of turn taking.</td>
</tr>
<tr>
<td>3</td>
<td>Asking for help</td>
<td>Robot asks for help on a task and clients needs to ask if the offered help is useful.</td>
</tr>
<tr>
<td>4</td>
<td>Self initiation</td>
<td>Robot states it can do a cool move (e.g. a dance). Client is then provoked to inquire about the move.</td>
</tr>
<tr>
<td>5</td>
<td>Problem solving</td>
<td>Robot asks help from the client. Client offers solutions and asks if this is the right solution.</td>
</tr>
<tr>
<td>6</td>
<td>Asking questions; self-management</td>
<td>Robot engages in a simple dialog with the client about different topics. Client takes leading role in what to talk about.</td>
</tr>
<tr>
<td>7</td>
<td>Sharing; turn taking</td>
<td>Client and robot play a game where blocks have to be colored using a magic wand. Players need to share the wand, using proper turn taking.</td>
</tr>
<tr>
<td>8</td>
<td>Evaluation of a movement</td>
<td>Robot wants to learn to wave like the client. Client needs to coach the robot to learn this move.</td>
</tr>
<tr>
<td>9</td>
<td>Introducing yourself; introducing the robot</td>
<td>Robot greets client and asks for his/her name. Robot then becomes sad, and client is provoked to inquire what is wrong. Robot states it doesn’t have a name yet and offers to think of a name.</td>
</tr>
</tbody>
</table>

From left to right, light behavior in the eyes resembling tears, and sounds of sobbing and crying, as shown in Fig. 5. These stages of displaying emotion are all small networks of these different behaviors.

Part of a network in TiViPE is shown in Fig.6, where two boxes show the networks behind two of the components. All these components together form a network in TiViPE that when executed would perform the scenario described in Table 1. Furthermore, it is possible to make additions to feedback, movement behaviors, or sentences, given the characteristics and level of the client.

V. DISCUSSION

The clear need of a technological platform that gives the flexibility to allow trainers to set up scenarios tailored to individual clients was featured in this paper. Our experiences showed the complexity of this process. Translating the therapies to robot mediated scenarios is not a single step process. It requires identifying a training system that would allow the existing scenarios as well as the scenarios that would be developed in the future to follow the same theoretical principles and approaches.

For this purpose we have taken inspiration from Pivotal Response Training, which is seen as one of the promising interventions in the therapeutic practices. However, a robot cannot perform PRT - since it is not naturalistic. So instead, we use techniques from Applied Behavior Analyses (ABA) together with principles of PRT, for developing our scenarios.

Before the robot can be used in the clinics, we attempt to offer both the clients and the trainer a stable platform. For the clients, the robot needs to behave naturally and be technically stable. For the trainers, we need a platform that is easy to use and offers them the components that they require, and the possibility to extend that set of components if they wish to do so, so they can create new scenarios.

At the moment, we have developed a set of scenarios, and distilled our starter set of components. We are currently building the components that we need for this set. This includes both the actions of the robot, and the components that sense the actions of the client. We are also doing short design iterations on the platform to improve the stability and test it thoroughly before moving it into the clinic. By performing this study on scenario design first we have made it possible to perform these design iterations, which in turn enables us to perform stable experiments in the clinic, which is planned for the later stages of our project.
The benefit of this platform is that the trainers can create custom scenarios for clients on different learning objectives. It also allows them to make these scenarios on a complexity level that is desired for a specific client. With the current scenarios we have distilled a set of components from which new scenarios can be developed by the trainers. However, they should not be limited to a fixed set of components. They need a way to create new components to make the scenarios that they require. Our approach to handle this in our ongoing research is by creating an online community of participating trainers and people from the clinic, and computer programmers and robotics experts. From the clinic’s perspective scenarios and ideas for scenarios will be developed. The technical people then know what components they need to develop to make the platform even more useful for trainers. In the online community ideas can be exchanged and discussed, and scenarios or components can be exchanged or contributed to. This collaboration of different disciplines through an online community website will power the development of our platform.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the support of the Innovation-Oriented Research Programme ‘Integral Product Creation and Realization (IOP IPCR)’ of the Netherlands Ministry of Economic Affairs, Agriculture and Innovation.

REFERENCES


