Embodied Robotic Visualization of Autistic Child Behaviors with Varying Severities*

Kim Baraka[1], Francisco S. Melo[2], and Manuela Veloso[3]

***Abstract*— The goal of this work is to enable interactions with a humanoid robot that can be customized to to exhibit different behaviors typically observed in children with Autism Spectrum Disorders (ASD) of different severities. In a first step, we design robot behaviors as responses to three different stimuli, inspired by activities used in the context of ASD diagnosis, based on the Autism Diagnosis Observation Schedule (ADOS-2). A total 16 robot behaviors were designed and implemented on a NAO robot according to different autism severities along 4 selected ADOS-2 features. In a second step, we integrate those behaviors in a customizable autonomous agent with which humans can interact through predefined stimuli. Robot customization is enabled through the specification of a feature vector modeling the behavioral responses of the robot, resulting in 256 unique customizations. This work paves the way towards potentially novel ways of training ASD therapists, as well as interactive solutions for educating people about ASD in its different forms.**

I. INTRODUCTION

Diagnostic tools for Autism Spectrum Disorders (ASD) provide us with a behavioral model of individuals with ASD. They do so by linking a taxonomy of typically observed behaviors to values of characterizing features. In this paper, we exploit the standardized aspect of the Autism Diagnosis Observation Schedule (ADOS-2) [1] to design behaviors on a NAO humanoid robot exhibiting behavioral patterns typically observed in children with ASD of varying severities. Our behaviors are compliant with the descriptions and specifications found in ADOS-2. The designed behavior database captures different severities along the scale of values of 4 selected ADOS-2 features. We integrated these behaviors as part of an autonomous agent capable of detecting interaction parameters, such as stimulus type and location, and respond according to the customization of its feature values.

There has been some work on personalizing robot behaviors according to some specified features or parameters to account for human differences [2]. In the context of ASD, while some work has been done on real-time motion imitation of children with ASD [3], to the best of our knowledge, enabling robot to exhibit characteristic ASD behaviors along severity scales based on standardized measure tools has never been achieved before. In a previous work, we aimed at simulating ASD behaviors from high-level child descriptors [4]; in this work, we focus on visualizing, in an embodied way, selected behaviors associated with the ADOS-2 model for possible integration with our simulator.

We foresee a few possible applications for this work. First, it can be used as a building block for a system that trains therapists to administer the ADOS-2, as current training heavily relies on videos and theoretical material, ignoring the important interactive component. Second, it can enable people to learn about ASD by interacting with differently customized robots. Third, it can be used in the context of imitation/demonstration tasks for ASD therapy.

II. APPROACH

We designed 16 parametrized behaviors on a NAO robot and integrated them in an autonomous agent architecture that can be customized according to the different feature values and that automatically detects the interaction parameters.

A. Designing ASD behaviors for a humanoid robot

We consider 4 **features** out of the 29 present in the ADOS-2, as listed in column 2 of Table I. These features were selected according to what was possible on our robotic platform, as well as behavior variety. The different feature values correspond to **severities** (0 to 3). The features characterize the behavioral responses of the robot to three **stimulus families** consisting of stimuli with the same purpose, namely: calling attention by calling the name (N), calling attention towards an object (JA), and asking for snack preference (S). The actual stimuli in each family correspond to the 'presses' used in ADOS-2, and are omitted here for brevity. A **behavior** consists of an animation of the robot's joints as well as possibly speech. These behaviors can also be modulated by environmental parameters (e.g. 3D point to direct gaze or pointing). Table I presents a summary of our designed behaviors, according to the descriptions found in Module 2 of the ADOS-2, suitable for individuals with phrase speech (regardless of age). In the presence of more than one relevant feature for a stimulus family (e.g., S), behaviors are **blended**, meaning they are run simultaneously.

B. Integration into autonomous agent architecture

The designed behaviors were integrated as part of an autonomous agent capable of having continuous interaction with (a) human(s) according to the predefined stimuli it recognizes. Most importantly, the agent can be customized by specifying an arbitrary severity for each feature. The architecture of the autonomous agent, including a perception

*This research was partially supported by the CMU/Portugal CMUP-ERI/HCI/0051/2013 grant and national funds through Fundação para a Ciência e a Tecnologia (FCT) with reference UID/CEC/50021/2013.

[1]Kim Baraka is with the Robotics Institute, Carnegie Mellon University, Pittsburgh PA, USA, INESC-ID and Instituto Superior Técnico, Universidade de Lisboa, Portugal. kbaraka@andrew.cmu.edu

[2]Francisco S. Melo is with INESC-ID and Instituto Superior Técnico, Universidade de Lisboa, Portugal. fmelo@inesc-id.pt

[2]Manuela Veloso is with the Machine Learning Department, Carnegie Mellon University, Pittsburgh PA, USA. mmv@cs.cmu.edu

TABLE I

SUMMARY OF THE DESIGNED BEHAVIORS ACCORDING TO FEATURE SEVERITIES

Stimulus family	Relevant feature(s)	Responses			
		Severity 0	Severity 1	Severity 2	Severity 3
Calling name (N)	‘Response to name’	Looks at human within second name calling attempt with coordinated utterance ‘Yes?’ (rN0)	Same as rN0 but only responds to ‘familiar’ human while ignoring ‘non-familiar’ one (rN1)	Looks in general direction (without eye contact or utterances) of ‘familiar’ human only while ignoring ‘non-familiar’ one (rN2)	Only responds to touch on head by exhibiting succession of random gaze shifts; ignores all other stimuli in N (rN3)
Calling for Joint Attention (JA)	‘Response to Joint Attention’	Immediately looks at object, then human, then back at object (rJA0)	Ignores first stimulus; looks at object only at second stimulus “Look at THAT!” (rJA1)	Ignores first two stimuli; only looks at object when activated and emitting sound (rJA2)	Same as rJA2 but with slight gaze shift towards object without actually looking at object (rJA3)
Asking for snack preference (S)	‘Overall level of non-echoed speech’	Says: “I like this snack of all the snacks in the world.”	Says: “This one.”	Says: “This.”	Echoes: “Snack... Snack... Snack... Like... Like...”
	‘Pointing’	Clearly points at one of the snacks with coordinated eye gaze (rS0)	Clearly points at one of the snacks with slight gaze shift not in direction of pointing (rS1)	Looks at one of the snack but without pointing (rS2)	Slightly shifts gaze downwards with no pointing (rS3)

module with speech recognition, touch recognition, and sound localization to modulate the parametrized behaviors, is summarized in Fig. 1. We implemented this architecture using the NAOqi Python API through the Choregraphe suite.

C. *Work in progress: Robot behavior evaluation*

We have devised an evaluation method for our robot behaviors through a video-based survey showing short videos of the designed interaction with the different feature severities. The survey includes snapshots of the corresponding ADOS-2 manual for trained experts to code the severity on each feature based on their observation. We are currently in the process of gathering this data from 3 trained therapists.

III. CONCLUSIONS

We designed 16 behaviors for a humanoid robot, according to the categorization in the manual of the ADOS-2 diagnostic tool according to different severities along 4 selected features. We integrated those behaviors in an autonomous agent running on the robot, hence enabling flexible and continuous interactions with humans. Interactive robots exhibiting typical ASD behaviors with different severities open the door to a number of exciting applications to train, treat or educate a wide range of individuals dealing with ASD.

ACKNOWLEDGMENTS

We thank Jocelyn Huang and Patrick Lin for their collaboration in the development of the robot behaviors, as well as Marta Couto and Patrícia Alves-Oliveira for their help.

REFERENCES

[1] C. Lord, M. Rutter, P. C. Dilavore, S. Risi, K. Gotham, and S. L. Bishop, *Autism diagnostic observation schedule, second edition*. Western Psychological Services, Torrance CA, 2012.

[2] S. Rossi, F. Ferland, and A. Tapus, “User profiling and behavioral adaptation for hri: A survey,” *Pattern Recognition Letters*, 2017.

[3] A. Tapus, A. Peca, A. Aly, C. Pop, L. Jisa, S. Pintea, A. S. Rusu, and D. O. David, “Children with autism social engagement in interaction with nao, an imitative robot: A series of single case experiments,” *Interaction studies*, vol. 13, no. 3, pp. 315–347, 2012.

[4] K. Baraka, F. S. Melo, and M. Veloso, “Simulating behaviors of children with autism spectrum disorders through reversal of the autism diagnosis process,” in *Proceedings of the 2017 Portuguese Conference on Artificial Intelligence*, Springer, 2017 (to appear).

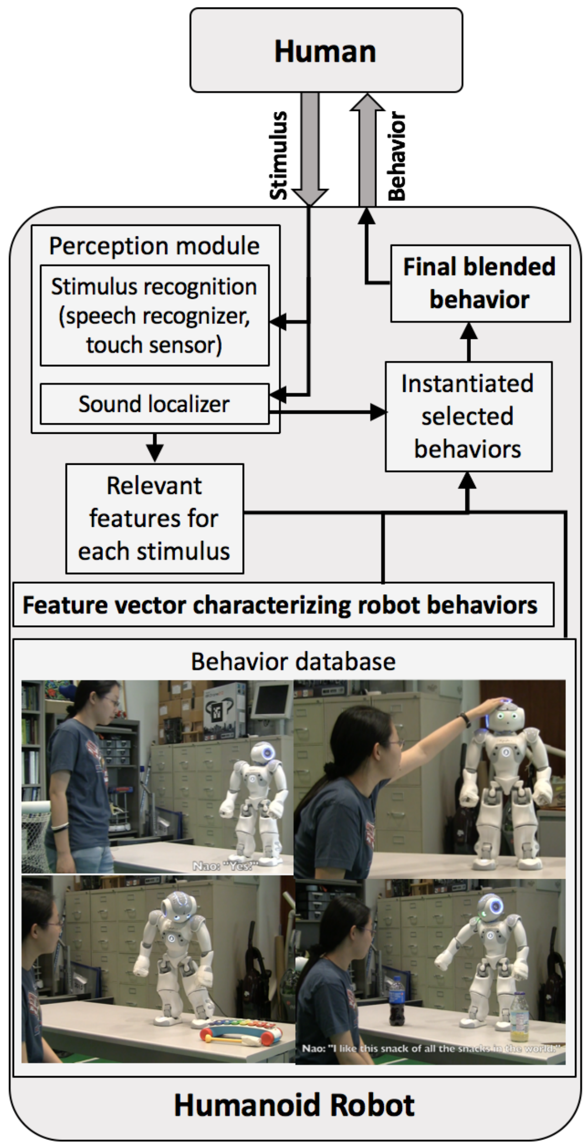

Fig. 1. Architecture of our customizable autonomous ‘autistic’ agent; stimuli are recognized and trigger different behaviors according to the customizable feature vector characterizing the robot.