A Socially Mediating Robot to Assist Non-verbal Children in an Inclusive Daycare Context

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***Abstract*—Non-verbal children are often provided with non-verbal communication cards (NVCCs) to share their needs. However, in busy spaces that prioritize verbal communication, for example, a daycare, this may place them at a disadvantage in comparison with verbal peers. In this work, we introduce the concept of a Socially Mediating Robot (SMR), acting as a communicational intermediary that verbalizes NVCC input. Thereby, we want to explore whether non-verbal children can be empowered by giving them an additional way of expressing themselves in a dynamic, buzzing environment. In an exploratory interview study with six participants professionally working with children, we then provide first insights on the feasibility of our concept from the perspective of caregiving staff. Thereby, we lay the groundwork for evaluating the concept in an ongoing field study in an inclusive daycare context.**

***Index Terms*—Inclusion, Empowerment, Children, Socially Assistive Robot, Disability, Concept**

I. Introduction and Background

An estimate of 97 million people worldwide have complex communication needs (CCN) [1] and typically leverage non-verbal communication strategies. Thus, in a world that heavily relies on verbal expression, non-verbal people with CCN often face access barriers, limiting "their ability to express needs and wants, exchange information, develop social relationships, and establish their identities" [1, p .667], and risking social isolation from peers [2]. Augmentative and Alternative Communication (AAC) strategies can help non-verbal individuals express themselves and engage with their surroundings more effectively [3]. AAC can range from approaches like non-verbal communication cards (NVCC, displayed in Fig. 2) that are "simple to make and easy to obtain" [4, p. 403] to technological solutions like verbalization through apps on a tablet computer. With a multitude of different approaches available, Williams et al. [5] argue that research should focus on giving people with CCN access to redundant strategies that are tailored towards them and their context. Light and Drager [6], in turn, summarize previous research and argue that to especially appeal to children with CCN, AAC strategies should, among others, have the option to give interesting audio-visual feedback, incorporate movable parts, and be able to be characterized as a companion.

Embodying these features, Socially Assistive Robots' (SARs) and their ability of engaging users in social interaction [7] could be leveraged to create novel and effective AAC strategies for non-verbal children with complex communication needs. Previous work has established SARs as beneficial tools to engage children, e.g. when teaching geometric thinking in kindergarten [8], teaching math in school [9], or supporting language training [10]. In the context of disability, SARs are also being integrated as a therapeutic medium to support one-to-one movement therapy [11] or one-to-one speech therapy [12]–[14]. In such settings Robins et al. [15] found that "a robot can serve as a 'social mediator', an object and focus of attention and joint attention" [15, p.188].

While therapeutic application of SARs of course is very relevant, there also is a research opportunity to explore to which extent they can be leveraged to support children's self-determination and independence in daily life, e.g., at daycare, kindergarten, or school. Building on Zimmerman's empowerment theory [16], we want to explore whether non-verbal children want to engage with SARs that serve as intermediaries, relaying their needs expressed through their preferred mode of AAC and engaging in communication on their behalf. Specifically, we propose a Socially Mediating Robot (SMR) which can offer a stable hub for communication in the dynamic, ever changing environment of a daycare facility, hence empowering children to express themselves, and communicating their needs and wishes to peers and caregivers.

In this work, we present a first step in a broader project that explores the potential of SMRs for non-verbal children through real-world lab research i.e., research that is directly embedded in the field and jointly develops new technologies with society. Here, we focus on the exploration of SMRs

for non-verbal children together with carers to appraise the suitability of the concept through a prototype SMR that translates input by NVCC into speech (see Section II-A) with the goal of acting as a bridge between non-verbal children and their peers/caregivers. Leveraging the prototype, we present an exploratory interview study with six participants who professionally work with children. In a two-part interview, participants tested the concept and provided first feedback on (1) card-based interaction between user (child) and robot leading to verbalization, and (2) their opinion regarding possible additional modes of communicating e.g. in form of a text-based application displaying and logging recognized intentions. Thereby, we contribute first insight into the potential of the concept, which was regarded as a potentially useful tool for child autonomy and step towards direct communication between child and caregiver, and lay the foundation for an upcoming field study in which non-verbal children will be given opportunity to engage with the SMR in an inclusive daycare. In the following, we will start by laying out the SMR concept. We will then introduce our exploratory interview study and end by presenting and discussing its results.

II. Concept

The SMR should support the child in their expression and communication by acting as a bridge to others.

A. Socially Mediating Robot

The mediation process between child and caregiver/peer includes three parties: Child, robot, and caregiver/peer. It can, therefore, be divided into three parts (seen in Fig. 1), (1) the child expressing their intention through an AAC strategy, (2) the robot detecting the child's intention, and (3) the robot verbalizing the intention to caregiver(s) and/or peer(s). As the basis for the social mediator, we chose the NAO robot. Due to its form factor, functionality and appearance the robot has seen utilization in a plethora of child-related research [17], [18, e.g.] with a recent review by Rudenko et al. [19] identifying it as the most used robot in child-robot interaction research.

(1) Expression of Intent: We chose Non-verbal Communication Cards (NVCCs) as the main AAC strategy as it represents the arguably one of the easiest to learn variant of low-tech AAC for children. They are also cheap, easy to replicate, and resistant to damage from falling and tearing. By utilizing this AAC strategy, that is already embedded in the context of our civil partner, we enable children to express their needs themselves through NVCC. Here, we are explicitly deciding against automatisms like automatic emotion recognition [20, e.g.], which could undermine the children's autonomy.

(2) Detection of Intent: On a technical level, we needed to enable a robust and accurate recognition of cards as incorrectly identified cards and, therefore, intentions might lead to frustration and rejection by the children trying to express themselves. While approaches to recognize and identify whole cards are certainly possible, we, decided to embed an easily recognizable visual code on each card that can be detected by the robot. Here we decided to utilize the fiducial ArUco markers, as the arguable standard of fiducial markers officially supported by the NAO platform [21]. With the possibility to create variable marker and dictionary sizes, the inter-marker distance can be maximized to allow an even more robust recognition. Which is important as we, to this point, do not know how many cards will be needed.

(3) Verbalization of Intent: After detecting the card and recognizing the embedded wish or intention, the robot then articulates it for the child while turning its eyes green to also give visual feedback to the child. This might lead to a scenario as follows: Tim shows the "Toilet" NVCC to the SMR that then articulates the intention for him verbalizing "Tim wants to go to the Toilet". Having Tim's needs verbalized, both peers and caregivers can now react to it. We decided to stay at this level of detail and only utter the child's intention and not go beyond that. Giving further instructions on how to proceed (e.g. "Please help Tim go to the toilet") could make the robot bias caregivers towards a certain act. This, in turn, is not desirable, as each child needs a tailor-made response [22] which is best found by the caregivers that know the child and should not be automated.

B. Possible further Communication Channels between Robot and Caregiver

Due to the high connectivity of today's SARs, one might argue that the concept can be augmented with further (asynchronous) channels of communication between robot and caregiver. As an additional way of communication we, therefore, propose that an additional text-based device (like a laptop, tablet, or smartphone) can receive and display detected intents to caregivers. This could enable caregivers to not only receive immediate needs in a visual form but also open the possibility of presenting a history of uttered needs, keeping an overview by marking needs as cared for and prioritization within needs not cared for yet. Such a device could also display useful additional information about the children who communicated with the robot (e.g., allergies).

III. Exploratory Interview Study

To reach an initial evaluation of the suitability of our concept and to better understand caregivers' concerns, we conducted an exploratory interview with six participants who professionally work with children.

A. Participants and Procedure

Five women and one man took part in the study (age range 19-43, M=28.3). Participants (see Tab. I) had 1 to 27 years (avg. 8.5 years) of experience working with children. Four of them are caregivers working in a kindergarten, daycare, or after-school care. One participant was a primary school teacher, another one was working in child psychiatry. Three participants had worked with children with disability.

1) Evaluation of the Concept: Starting the interview, we presented the participants with the SMR as well as three sets of NVCCs. These contained laminated cards with a glossy finish, matte finish as well as un-laminated cards. Afterward

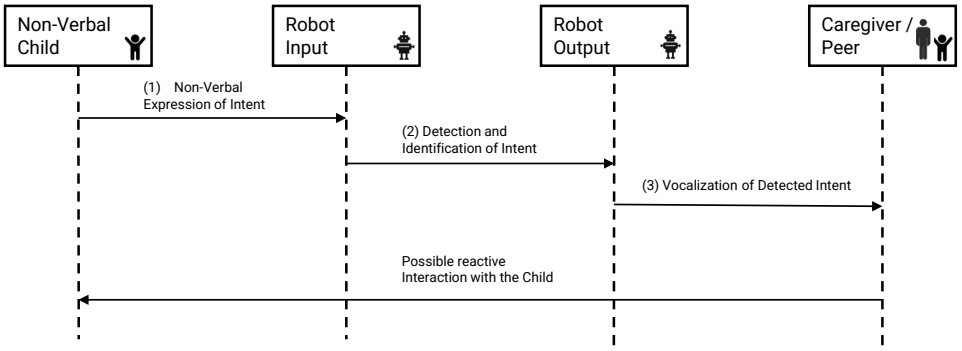

Fig. 1. Diagram depicting the mediation process defined by the our SMR concept as described in Section II-A.

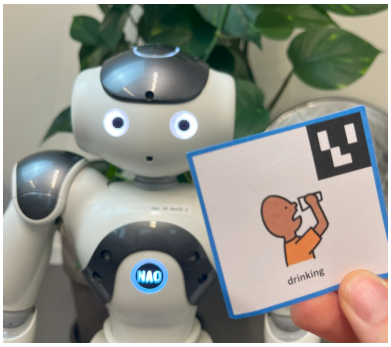

Fig. 2. Picture of a Non-Verbal Communication Card in front of a NAO robot.

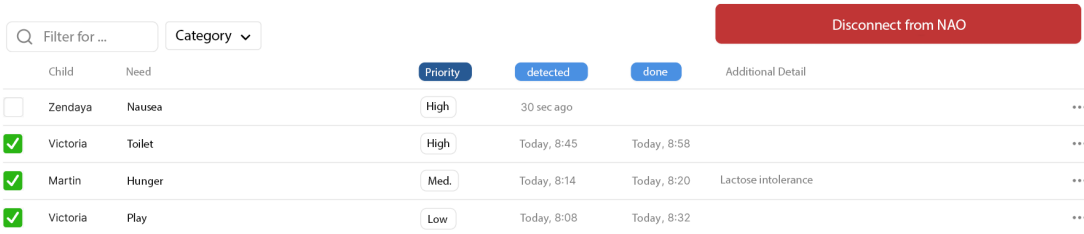

Fig. 3. Screenshot of the companion app utilized in the study that displays children's names, requests, and additional detail.

TABLE I
LIST OF PARTICIPANTS OF THE INTERVIEW STUDY

ID	Age	Gender	Profession	Prof. Exp. with Children	Length	Experience with Disabilities
P1	26	Male	Caregiver	Daycare, After-School Care, Youth Center	6 years	None
P2	27	Female	Caregiver	After-School Care	6 years	Child with Intellectual Disability, Autism
P3	43	Female	Caregiver	Kindergarten, Mother Care	27 years	Various Types
P5	25	Female	Prim. School Teacher	Teaching & Supervision	2 years	Autism, Wheelchair User
P4	30	Female	Caregiver	Kindergarten	9 years	None
P6	19	Female	Student	BFD Child Psychiatry	1 year	None

participants were asked to take the perspective of a child who wants to utilize the robot as a social mediator. We then started the interview focusing on (1) the concept of scanning the NVCCs and their adequacy for the task and potential issues, (2) their impression on the auditory feedback, its adequacy and potential issues, as well as (3) challenges with the system.

2) Evaluating further Information: We also presented the possibility of a additional mode of communication in the form of a companion app to display and keep track of intentions for caregivers (see Fig. 3). Here, we focused on different features that could be implemented in such an application. Overall, we aimed at the question if a general register of verbalized needs would be useful for caregivers, and which functions such an application could implement, and how priorities should be communicated. In the end, we explored caregivers' perspectives and concerns, how such an application could impact their work as a caregiver, and the potential effects on their relationship with the children.

B. Data Analysis

To analyze the interviews, we utilized a thematic coding approach [23]. After transcribing, three authors familiarized themselves with the transcribed interviews, subsequently iterating over the data and identifying relevant passages that were then labeled with certain codes. They then set together to summarize the identified codes into final themes. Note that the interviews were conducted in German language. Direct quotes were, therefore, translated from German to English by the authors.

IV. Results and Discussion

Here, we discuss our findings, structured into four themes.

A. Card Recognition and Card Characteristics

The results show that robust *recognition* of the communication cards as the means to convey the child's intent to the robot is essential for our concept. Participants emphasized the robot's quick and reliable response, even when stress testing through intentional strong trembling or fast motions. However, positioning the communication cards proved initially problematic, as the robots camera only allows reliable recognition when the cards are held in front of the robot. The participants suggested circumnavigating this technical limitation by placing the robot in a well-accessible position [P6] and showing children how and where to present the cards, making them understand the limitation of the robot's field of view [P3, P6]. Participants did not identify differences in reliability between cards laminated with a glossy or matt

finish and those not laminated at all. In turn, they advocated that to achieve longevity, cards should be laminated. Firstly, because especially smaller children "tend to tear" [P6] things, and secondly, because things "often end up in the mouths of children" [P5].

B. Verbalization of Intent

Participants had suggestions for improvement regarding voiced intent, the robot's voice, how children would be addressed, and further feedback on audiovisuals.

They suggested voicing intent in the first person instead of using personalized cards that leveraged third-person language (e.g., "Tim wants to go to the toilet"). One participant [P1] argues that this might be necessary to avoid confusion from other children using a personalized card unintentionally or intentionally as they might see it as a kind of game. To also make it less likely to appear as a toy, [P5] argued that the sentences should be as short as possible while remaining correctly expressed. Another participant [P3] made a remark on the strength of the vocalized statement, arguing that intent should be voiced in a firm manner, e.g., instead of using "wants to", the robot should say "needs to".

In this implementation of the SMR, we utilized the NAO robot's standard text-to-speak output. Three of the six participants encountered problems understanding the first vocalization and needed to rehear and get used to it. While the acclimatization phase was short, they noted that comprehensibility could be improved. This could e.g., be archived by using recordings instead of voice synthesis. Participants suggested that recordings from real humans would be warmer, more understandable, and also reduce the possibility of children being scared of the robot [P1]. Conversely, [P6] argued that hearing a "cool" robotic voice might potentially raise interest.

Additional feedback in the form of the NAO robot's eyes changing color to green upon successful recognition, was received as "very pleasant" [P5]. Participants, nevertheless, suggested further potentially helpful feedback in the form of sign language [P2] or simple thumbs-up gestures [P3]. Another participant [P4] voiced that she uses confirmatory follow-up questions as a pedagogical tool and that the robot could do the same. Also the robot might adjust its feedback depending on the urgency of the intention by e.g., flashing its eyes and raising its arm [P6]. As one of our examples of vocalization had a slight grammatical error, the participants stressed that the robot should be verbalizing in full, grammatically correct sentences.

C. Possible Additional Information For Caregivers

Participants shared mixed feelings about the companion app. The additional, non-auditory possibility of keeping a better overview in loud surroundings like a daycare [P4] was perceived as positive. With only being able to do one thing at a time, having a log of expressed needs could also support them in working through everyone's needs [P6]. Being able to not only display a child's need but also additional child-specific information (e.g., allergies) could also benefit new colleges.

Nevertheless, participants also voiced concerns about the practicality, as an additional application and device would burden the daycare routine. Participants also raised concerns about children communicating with the robot and having needs logged in an additional device could diminish immediate communication between caregivers and children as logging might allow delaying attention. Additionally, privacy concerns were voiced regarding the storage of additional details and tracking needs throughout the day. One participant [P5] articulated that while a logging application could relieve the organizational level, it might lead to overstimulation and interfere with pedagogic goals.

D. General Feedback and Issues to Consider

Generally, participants appreciated the concept and felt that the system could be able to support non-verbal children in communicating their needs. Especially as "some children might have difficulties directly communicating with humans. With the cards, this will get easier for them" [P6]. Nevertheless, they also articulated possible issues: Participants noted that some children might have an initial negative reaction to the robot and find it "spooky" [P2, P4] that a machine is talking as they might only know inanimate machines like dishwashers [P1]. Additionally, participants commented that children could also misunderstand the supportive nature of the robot and misuse it as a toy. Further appraising the SMR concept as a whole, while regarded as a potentially useful tool to strengthen autonomy in non-verbal children, participants also remarked that, in their view, the robot should not be the last step for the children. Caregivers should be "careful that children do not want to only communicate through the robot" [P6] and use it as a stepping stone to eventually engage in direct communication between child and caregiver" [P5].

V. Conclusion and Future Work

We explored the concept of a socially mediating robot to support non-verbal children in inclusive daycare settings, leveraging non-verbal communication cards for child-robot interaction. We contribute an initial prototype along with an exploratory evaluation with caregivers in preparation of a field study involving non-verbal children. In the next step of our research, we look forward to supplementing the views presented here with children's perspectives, exploring whether our system can, in fact, support communication and self-determination in an ethnographic study. Here, we will focus on children's preferences and needs with respect to such a system, a careful examination of whether non-verbal children wish to engage in verbal expression by means of a robot and the ethics thereof, and the implications of the introduction of a socially mediating robot in the wider daycare context.

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