Alexism: ALEXa supporting children with autISM in their oral care at home

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ABSTRACT

Oral health care can be a challenging experience for children with autism, for their parents and for dentists. Recently, some technology-enhanced systems have been proposed to help people with autism to cope with distressing situations originated by unknown social-life contexts, such as dental care settings with intense sound-visual stimulations. Results were positive in mitigating anxiety at the dental clinic but seem to fail in supporting proper oral hygiene at home. Thanks to the increasing spread of household Intelligent Personal Assistants (IPA) and Vocal Conversational Agents (VCAs), we envisage new opportunities considering the Voice-enabled IPAs not only as support on daily activities but also to enrich and simplify access to healthcare procedures from home. This work attempts to extend the use of technology-enhanced systems for dental care by exploiting the potential of the Vocal User Interface, Amazon Alexa, as an instructional agent with children on the spectrum. To this purpose, we developed a personalized Alexa Skill with two different functionalities: (i) support the child during the routine transition toward the target activity: move to the bathroom to brush their teeth; (ii) act as a persuader and a timer to guide the child during the procedure observing the proper brushing time. We conducted a three-week preliminary study with three children of different autistic profiles. The goal was to collect opportunities and issues deriving from the device introduction in the home context and test the device usage to favour dental care. Results and feedback were encouraging and gave insights to improve this approach.

CCS CONCEPTS

• **Human-centered computing** → **HCI design and evaluation methods**; *Personal digital assistants.*

KEYWORDS

Autism spectrum disorder; dental care; vocal user interface, Intelligent Personal Assistants, Amazon Alexa, personalization

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1 INTRODUCTION

Autism spectrum disorder (ASD) is a severe neurodevelopmental condition including a variety of specific symptoms in the areas of social interaction, communication, restricted interests, and repetitive behaviours [5]. Usually, it manifests in early childhood (before age three) and the severity of symptoms varies significantly from individual to individual. Literature reports that individuals with ASD generally have worse oral health than their neuro-typical peers [13, 15] even if a correlation between ASD and oral disease has not been found. What is well recognized is that multiple factors could act as barriers in dental care access for people with autism [14]: (i) specific dietary habits; (ii) stress and anxiety during care procedures; (iii) frail sensory sensitivity; (iv) presence of comorbidity and self-injurious behaviour.

Stress and anxiety deriving from unknown people, contexts, and social dynamics worsened by an extreme sensitivity to specific sensory input (lights, sounds, smells, tastes, touch, need for balance and body awareness, etc.) make the dental clinic environment at high risk for individuals with autism [16, 19]. A plethora of works in literature demonstrate the effectiveness of technology-enhanced systems to help people with autism master new skills and competencies [4, 7, 12, 18]. In this sense, technology could be effective even to learn how to familiarize, cope and adapt to new contexts and distressing social situations [11, 13]. Few and recent works confirmed increasing attention toward improving access to healthcare environments [2, 3] for children with autism. Results were positive in mitigating anxiety, involving and motivating little patients with autism during dental care procedures at the clinic, but the current practice seems to fail in supporting oral hygiene at home, where extra strategies are necessary. Furthermore, considering that the autism spectrum has different degrees of severity and that each person is a world, there is no one-size-fits-all strategy to follow, each approach must be highly personalized.

The increasing spread of Intelligent Personal Assistants (IPA), including Voice-based Conversational Agents (VCAs) such as Amazon Alexa and Google Home, Apple Siri and MS Cortana, delivers a new potential for special needs people offering them support in

their everyday needs and challenges. Such agents promote self-care, practise conversational skills, and improve their social communications and so on [1, 6, 8, 17]. Wang et al [21] investigated the use of the Amazon Alexa platform to reduce users' public speaking anxiety, such as individuals with autism. Specifically, an Alexa-guided tutoring session to decrease user anxiety was created. Previously Hiroki Tanaka et al. [20] have exploited a conversational system for delivering multimodal social skills training to people with autism, showing interesting results.

Cha et al. [8] explored how Voice-based Conversational Agent could help adolescents with autism manage their everyday needs and difficulties, including anything from self-care to efficient communication. The authors also suggested design implications for promoting positive opportunities while mitigating the existing challenges of VCAs for adolescents with ASD [8].

In our vision, one of the main challenges is to propose solutions that effectively address the needs and expectations of different spectrum profiles. All the promising studies mentioned, are intended to tackle people (young and adults) with moderate autism (medium and high functioning) who have fairly high verbal and receptive skills. Here a few questions come up that are worth noting:

How can we envisage the role of a vocal conversational agent when the child is non-verbal (low-functioning autism)? Can the conversational agent have other roles (motivator, trigger, persuader) where the conversation is not feasible?

Thus, the work herein we present is an attempt to extend the use of Vocal User Interface, Amazon Alexa, as an instructional agent rather than a pure conversational agent with children on the spectrum. To this purpose, we developed a personalized Alexa Skill with different functionalities in order to support routine transitions towards target activities connected with oral care and act as a persuader during oral care procedures. We conducted a three-week preliminary study with three children of different autistic profiles. The goal was to collect opportunities and issues deriving from the device introduction in the family home context and test the device usage to favour dental care.

2 DESIGN AND IMPLEMENTATION

As mentioned before, the main goal of the study is to exploit the use of Alexa as an additional strategy to improve adherence to oral-care procedures at home and to be integrated into the current practice proposed in a past study [3] conducted with oral care professionals, children with autism and their parents. To this end, we analyzed data collected from previous parents' interviews to gather general requirements, and we conducted a new semi-structured interview with the dentist, part of the teamwork, focusing on oral care behaviour at home. Results highlighted that the children involved lacked generalization, showing their improved cooperativeness where familiarization procedures mainly act. In a different environment, like home, the lower presence of positive stimuli than in the clinic reduces children's motivation. The first question that arose was:*"Since most of the stimuli just tested were visual, could a different interaction modality, such as a Vocal User Interface, favour children engagement to maintain a correct oral hygiene at home"*(Research Question). To investigate this possibility, we designed a study step by step identifying main requirements (R1-R7) for both the actors (child and vocal interface) and the interaction paradigm.

Device Role. A third-generation Alexa echo-dot has been chosen as a device to implement a vocal user interface because it is off-the-shelf and a low-cost device (R1). The Alexa should act as the dentist representative (or delegate) when the child is at home (R2). It will report the tooth washing trend to the 'real' dentist. In this sense, it applies and implements the authority and liking persuasion principles presented by Cialdini in [10]. Alexa should have two main roles: (i) Support the child during the routine transition from the current toward the target activity: move to the bathroom to brush their teeth (R3); (ii) act as a persuader and a timer to guide the child during the brushing procedures observing the correct time (R4). The latter is because children on the spectrum may have difficulties focusing on activities; even when they correctly start doing something, it is challenging to keep them concentrate (in fact, parents reported an insufficient brushing time for all the children involved).

Customization features. The first customization feature is the voice choice. The Alexa vocal user interface can be used through its standard voice or a custom registered voice. Both options could have an impact on the interaction outcome with the child. By exploiting the dentist's voice, we can favour familiarization and recreate clinical user experiences, both positive and negatives. On the other hand, using the standard Alexa voice introduces an external and authoritative person to guide the child on self-care procedures avoiding at-risk situations. For these reasons, we chose the standard Alexa voice (R5). Since children on the spectrum may be characterized by difficulties affecting language skills, the dialogue should be as easy as possible, being feasible even with non-verbal children. To this end, the Skill implements the possibility to provide YES/NO answers as well as single words or more complete sentences. At the moment, children that are completely non-verbal need their parents support to invoke the Skill (R6). Finally, the Vocal Application should call the child by name to maximize the user's engagement (R7).

Interaction Paradigm. We developed an Alexa Skill called *My Dentist* (Skill Invocation Name) designed according to the requirements listed above (R1-R7). The Vocal User Interface is implemented through a custom Interaction Model including a set of intents and a list of sample utterances: an intent represents an activity that satisfies a user's request, and it is activated by one of the sample utterances specified in the interaction model. Utterance is the specific phrase that user will use when making a request to Alexa.

We defined two different custom intents to implement the two roles selected for the conversational agent: the first one is called *Change Routine* intent and corresponds to the activity specified by R3; while the second one is called *Start Washing Teeth*, and it is related to the activity specified by R4. Users can communicate with Alexa by linking the Skill Invocation Name with one of the sample utterances defined in the interaction model to activate a specific intent, i.e. "Alexa, tell My Dentist that..." <simple utterance>, or other simpler combinations. Examples of implemented utterances for the *Change Routine intent* are: "I'd like to wash my teeth"; "I've finished the breakfast/lunch/dinner". When the *Change Routine*

[1]High functioning: "Requiring support", Medium functioning: "Requiring substantial support", Low functioning: "Requiring very substantial support"[5].

	P1	P2	P3
Autism functioning profile[1]	High	Medium	Low
Collected Questionnaires (1 per day)	7	8	3
Questions	**Responses**		
Does the child seem interested in Alexa's presence?	Regularly	Regularly	Regularly
Does the child respond when Alexa asks for something?	Regularly	Sometimes	Sometimes
Does the child perform the task that Alexa proposes (or tries to do it even partially)?	Regularly	Regularly	Regularly
Does the child show initiative by asking Alexa for something?	Regularly(6/7)	Never	Never
Does the child use Alexa for self-stimulation?	Never	Never	Never
Does the child have problematic behaviours in the presence of Alexa?	Never	Never	Never

Table 1: Result from questionnaires

intent is executed, Alexa first says hello using the child's name (R7), then introduces herself by her name and as dentist's friend (R2) and finally remembers the child that it's time to wash the teeth; i.e. *User*: "Alexa, tell *My Dentist* that I just finished the lunch." *Alexa*: "Hello Brian! My name is Alexa, and I'm your dentist when you are at home! It's time to wash your teeth, tell me when you are ready". Then, when Alexa stops speaking, waits a few seconds for the user's answer (i.e. "I'm ready); otherwise, she ends the execution. The *Start Washing Teeth* intent is activated by sentences such as: "I'm ready to wash my/the teeth", "Let's start washing the teeth", "I'm ready", (i.e. "Alexa, tell My Dentist I'm ready"). Alexa will answer: "Ok Brian! Let's wash the teeth together! Let's listen to a song while you are brushing the teeth"; then Alexa will play a two minutes song (proper brushing time). After the song, Alexa will greet by saying, "We're done, for now, I'm very happy, and Elisa (the dentist name) will be happy too. See you next time to brush your teeth together again!". Through the last sentence ("Elisa will be happy too"), we fulfil requirement R2 and apply Cialdini's authority and liking principles [10] as the dentist has the authority figure and at the same time creates the feeling of familiarity for the kid (We like things that are familiar to us [9]).

3 PILOT TEST

The main contribution of the work herein described is to report the use of the Alexa vocal interface as a support for oral care in children of different autism spectrum profiles exploiting its role as an instructional agent rather than a pure conversational agent.

3.1 Recruitment

To this end, we recruited three children with autism seeking access to dental care at a public hospital in Pisa. A doctor in a local no-profit autism association facilitated the identification of children among those not previously involved in the advanced oral care protocol [3], thus reducing the potential bias in the experiment. The pilot study aimed to examine the feasibility of introducing Alexa device in the family-home context and its specific usage to favour dental care. Among recruiting criteria was no previous experience with Alexa; in this way we can observe how the children approach Alexa and how instructions and conversation would evolve during the interaction. Selected participants were: P1 a female age eight with low severity of ASD symptoms (high functioning), P2 a male age 11 with medium severity of ASD symptoms (medium functioning), and a male, P3 a male age 9 with high severity of symptoms (low functioning).

We obtained informed consent from all the parents participating in the study. We firstly informed them about the study: 1) This study is not a clinically validated therapy; 2) The participants are free to quit whenever they want. We also provided a privacy policy to guarantee the anonymization of collected data, the correct storage and processing. Finally, we instructed them about the limitation of VCAs as speech recognition technology is imperfect and sometimes could have problems in understanding the speech requiring the user to repeat.

3.2 Pilot design

To start, we carried out individual meetings with each children's parents to introduce the scope of the study, the functioning of Alexa, and to show them a Demo on how to interact with the Alexa Skill. To maximize parents' cooperation, we highlighted that the distal goal is to achieve the child's autonomy in performing proper daily oral hygiene at home. Later, we invited parents to use the Alexa Skill every time the child has to brush her/his teeth for at least seven days. To collect near real-time feedback on the daily use of Alexa's My dentist Skill, we asked the parents to fill out a daily online questionnaire to report their subjective feedback regarding the child-Alexa interaction. An expert of the research team developed the questionnaire. Although we proposed to use the Alexa Skill at least for one week, after a follow-up call, in agreement with the parents and taking into account the children's good acceptance of the novelty introduced, we decided to extend the pilot study up to three weeks, requiring to fill in the questionnaire for at least seven consecutive days. Finally, at the end of the test period, we conducted a semi-structured interview with parents to refine the collected data and better justify the results.

4 RESULTS AND DISCUSSION

4.1 Questionnaires

We collected eighteen questionnaires along the first week of the test, parents of P1, P2 and P3, provided seven, eight, and three reports respectively. Specifically, parents were asked to:

- Rate the frequency of the interaction between the kid and Alexa (i.e. Asking questions to Alexa, responding to Alexa's questions, and performing the requested task) on a three-point Likert scale (0, never; 1, sometimes; 2, regularly).
- Report the kid's feelings toward the VCA.

Regardless of their autistic profile, children showed high interest and felt comfortable in the presence of Alexa; none of them used Alexa for self-stimulation or manifested problematic behaviour; all of them sought Alexa even for extra routines not connected to oral care. On the other hand, the children profile had an impact on the interaction with the device: while the high functioning child has always responded to the Alexa questions and frequently asked Alexa for other topics than oral hygiene, the other two children did not show autonomous initiative interacting with Alexa and only a

few times responded to her questions. All the children performed or tried to perform what Alexa asked them.

Table1 will summarise questions and answers gathered from parents.

4.2 Interviews

The interviews have been conducted in a semi-structured way using open-ended questions via Zoom individual sessions. We proposed the same questions of the online questionnaire to grab the missing data and enrich the responses by allowing the parents to speak freely. Additionally, we asked parents to inform us about logistic issues (if any) in the device usage.

Based on the interviewees perspective, Alexa has extended the children motivation and autonomy in terms of time and willingness to do oral hygiene. The support of Alexa made children more enthusiastic and cooperative to proceed with their oral care and also more aware of the correct brushing time. Parents of P2 (low/medium functioning): "Before Alexa, I had to insist on brushing his teeth for as long as necessary, but now he is brushing his teeth for the whole period of the song. The mother of P1 (high functioning): "Before using the vocal skill, there were problems in washing the teeth; she did it unwillingly while now she has acquired the routine and does it by herself; she is autonomous enough to prepare the toothbrush and does it herself, and then when she is ready, she invokes Alexa." According to P1 parents, the kid with high functioning had no problem in invoking Alexa for both intents (Change Routine and Start Washing Teeth) on the contrary, P2 parents and P3 parents (parents of children with low/medium functioning) claim they prefer the second modality to call Alexa since the conversation is less verbose and being the children not completely autonomous in the interaction, they preferred to directly move to the *Washing Teeth* functionality. It became clear also that the child with low severity of symptoms prefers diversity in Alexa's dialogues while the two children with medium/high severity of autism like the repetitive behaviours of Alexa. It was worth noticing that all the parents highlighted the importance to evoke the dentist presence through its name (Alexa Skill personalization) at the end of the oral procedures (Alexa says: Good job Brian, Elisa (dentist name) will be very happy). This feedback shows the positive effect of the authority and liking principles of persuasion [10]. Perceiving a concrete relationship between the real dentist and Alexa is a key point in the children/Alexa interaction; the mother of child P1 reported that in particular contexts should be exploited the dentist's voice rather than the Alexa Voice because it is more familiar and should better persuade the child as happen in the clinic. P1 mother reported that her daughter asked her if Elisa really knows Alexa and if Elisa is informed that now she is brushing her teeth regularly. The interviews also identified some difficulties during the Skill invocation described as too verbose and hard to remember; one child tried to activate the Skill by saying: "Alexa talk" and "Alexa teeth".

4.3 Lessons learned

The findings of this study suggest the positive role of the VCA in supporting oral care for children with autism. Children and families involved in this study showed a positive level of involvement and satisfaction, parents feedback revealed the importance of personalizing Alexa conversations considering individual needs and expectations and different profiles of autism. In particular, the following points are critical aspects to be considered when using VCA technology to communicate with a kid on the spectrum.

- Avoid verbosity: using short sentences, preferably just a word to invoke the Alexa Skill
- Better Skill automatization, linking the Alexa Skill to another specific routine, e.g., the Skill should be activated at a specific time without the need to invoke it.
- Personalize the interaction: diversify the dialogue depending on the child autistic profile, e.g., expand dialogue, phrases and collaterals for the kid with low severity autism and provide a more repetitive interaction paradigm for kids with high severity autism.
- Describe teeth brushing steps to keep the child's attention and guarantee more proper dental hygiene.

5 CONCLUSIONS AND FUTURE WORK

Children with autism have more significant difficulties in their oral care compared to neurotypical children as they may exhibit sensory sensitivities, fear of unfamiliar contexts and lack of socio-cognitive understanding. Although a few high-quality interventions have been designed to improve their oral care procedures at the clinic, they seem to fail in supporting oral care at home [2, 3]. Moreover, a limited number of studies identified that using VCAs for autism healthcare conditions is still in a preliminary stage. In this paper, we presented initial testing of a novel approach using a conversational agent, Amazon Alexa, to support ASD children's oral care at home in a personalized way.

By exploiting data collected in a previous study [3] enriched through a new semi-structured interview with the dentist, we developed an Alexa Skill to support children with autism to carry out their dental hygiene procedures properly. In the present approach, Alexa acts as an instructional agent and a persuadee exploiting some of the main persuasion principles of Cialdini to support and sustain a behaviour change [10]. We tested the first version of the developed Skill recruiting three families for three weeks. Parents completed a daily online questionnaire to evaluate the approach of children to the dental care procedures using Alexa Skill. A follow-up interview was conducted to refine the data collected and better justify the results obtained.

Results highlighted the possibilities of this approach, and allowed us to answer the research question that motivated this work: Vocal User Interfaces could improve children engagement favouring to maintain correct oral hygiene at home. Nevertheless, it also revealed the limitations of this preliminary study and the challenges to be faced. Future works will go mainly in three directions: (i) Improve the Skill personalization allowing the dentist to set up the preferences about the interaction methods, dialogues and rewards; (ii) Implement the feedback provided by parents; (iii) Perform a more extensive study with an adequate number of participants and a longer observation time in order to investigate how users' motivation and engagement vary over time.

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