Empowering interactive surfaces with body-based interactions to provide step-by-step guidance to children with autism spectrum disorders. *Gillian R. Hayes (UC Irvine), Monica Tentori (CICESE)*

1. Problem Statement

Children with ASD require continuous assistance from caregivers[1] to help them successfully perform activities of daily living (ADLs, e.g., such as toileting, hand-washing, and eating) [1] even as they grow into adulthood, thereby jeopardizing their independence [2]. For example, one study indicated that 86% of the time, children with ASD require help from a caregiver from a distance of less than three feet [3]. This level of assistance raises substantial concern for parents and caregivers around the lack of autonomy in everyday activities [4]. Caregivers following children to provide directions, prompts, and guidelines can enable them to accomplish their goals, but these supports, paradoxically, might hamper the children's independence [5] and their opportunities to fit into society [6]. Indeed, the ability to accomplish ADLs without physical help is considered a requirement for independent functioning and self-management [7]. Although children with ASD can often learn to execute some specific steps of activities without help, they may still lack the capabilities to complete all of the steps or follow them in sequence. They might forget the potential order in which those steps might be executed, forget to execute some of them, forget the next step, or get "stuck" in the middle of an activity.

Interventions to support individuals with ASD to provide step-by-step guidance often involve the use of visual supports (*i.e.,* those things we see that enhance the communication process [8]) that sometimes use words, images, or tangible objects to represent activities that will take place or have taken place) arranged in temporal order. These visual supports contribute to children's understanding of time, events, and places, and have been shown to reduce the symptoms associated with ASD [8], and help children with autism to manage their schedules [9], remediate their speech and language disabilities [10] and provide feedback on their pronunciation [11]. A special type of visual support that provides children with autism with step-by-step guidance for accomplishing their daily tasks are "cookbooks," like a chef uses a cookbook to create a meal [12]. Cookbooks use visual aids including the exchange or display of a variety of images, drawings or photographs to represent tasks, needs, goals and rewards. Each step is represented with a visual image and text annotation (Figure 1). Caregivers often place these cookbooks throughout homes and schools to support children with ASD conducting ADLs (*e.g.,* a cookbook for washing hands is usually placed on the mirror in front of the washbasin). Paper-based laminated cookbooks are not interactive and children disengage when they run out of new ways of "interacting" with them. As a consequence, they fail to follow them or finish the activity.

Figure 1**.** A cookbook to providing step-by-step guidance for the activity of "going to the bathroom

Interactive technologies have the potential to detect when children with ASD are beginning to disengage with their visual support, provide a more appealing and exciting learning experience, provide new therapeutic advances, and enable clinicians and caregivers to monitor progress more closely. In particular, natural user interfaces (NUI) enable interaction of users with digital information through physical objects (Ishii 2008), providing the needed interactivity currently lacking in paper-based cookbooks. An "interactive surface" that takes into account the body movement of their users as an implicit input can provide the engagement children with ASD need when completing their ADLs. Such an environment could also automatically record the information clinicians' need to measure progress (*e.g.,* time of sustained attention). Likewise, new models of NUI (*e.g.,* body-based interactions[13], proxemic interactions [14]) with their ability to control ubiquitous environments with body-movements could empower current surfaces in ways that are more accessible to children who may have motor impairments and other difficulties in interacting with computational systems. Such "interactive surfaces" could help children to understand how their actions and experienced sensations have a counterpart in the real world.

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[1] *For simplicity of reading, we will regularly refer to the stakeholders involved in the care of children with autism including family, therapists, psychologists and teachers as caregivers.*

Finally, by automatically recording input events—physical interactions and movements by the children—the system can make available a wide range of data for diagnosis, measurement, and monitoring not currently in existence.

The primary objective of this project is **the development and evaluation of interactive surfaces empowered with touch and body-based interactions to provide step-by-step guidance to children with autism**. Building such a system is not an easy task and opens new research questions regarding child interaction with natural user interfaces, a part of our larger research agenda:

R1: What body-based interactions can and do children with ASD exhibit when conducting ADLs?
R2: How can vision-based algorithms be used to accurately estimate such body-based interactions? What measurements could be automatically estimated from such algorithms?
R3: What are the design challenges for developing "effective interactivity" for interactive surfaces displaying cookbooks?
R4: How do "body-based interactive cookbooks" impact the proactivity, behavior and engagement of children with ASD during ADL completion?

The results of this work will advance scientific understanding of the potential role of technologies—particularly natural user interfaces—in support of children with ASD. Additionally, this work will generate important pilot data that will enable the submission of large-scale deployment and clinical-trials grants to be submitted to funding agencies in both the US and Mexico. Finally, the lessons learned during this project will benefit other researchers in the areas healthcare, assisted cognition, and developers of NUI and ubiquitous technologies to support long-term healthcare.

2. EXPECTED OUTCOMES

The project goals and deliverables include:

- A NUI for controlling an interactive visual support for children with ASD completing ADLs
- Results of a pilot evaluation of the system deployed in a concrete scenario

In addition to the substantial research goals of this effort, we will also use this project as a testbed for successful long-term collaborations between computer science researchers and clinicians, across multiple countries. Specifically, we will:

- Consolidate and solidify binational research ties and networks through the submission of collaborative research projects between computer science and clinical experts from Mexico and USA.
- Promote interdisciplinary and international collaboration among the academic institutions participating in the project by sharing educational materials and integrating students on projects.

We will disseminate the results of the project in three ways. First, we will publish results related to system design, implementation, and usability evaluation in the major HCI, Health IT, and Ubicomp conferences (*e.g.,* CHI, AMIA). Second, we will include a section on the project website to publish the developed software, and collected data[1] when project participants consent to it. MSR will be credited in the application, on our websites, and in the acknowledgments of the resulting papers from this project.

3. RELATED RESEARCH

Research around natural user interfaces (NUI) has extensively proposed some devices and applications in support of children with autism (e.g., Mediate [15]). Some projects have research how to use haptic technology to stimulate the "tactile experience" of individuals (e.g., TouchMe and squeeze me [16], Therapeutic Holdig [17]*)*. Other projects using interactive surfaces and digital pens have explored how to support musical therapies to deal with sensory disorders related to sounds (e.g., *Reactable* [18] and play [19]). Finally, some other projects have crafted specialized devices that provide visual stimuli (e.g., Mediate[15] , T3 [20]). Research exploring new models for body-based interactions has explored how to support motor skills providing an exertive sports-like experience (e.g.[21]). However, little has been said as to how such technology could be integrated into interactive surfaces, and how this technology changes current reactive model of following cookbooks with a proactive scheme were children are truly engaged and interacting with the environment.

4. BENEFITS TO THE COMMUNITY: The research and educational agendas set forth in this proposal have the potential for both short and long term broad impacts to society. In the short term, these research projects

[1] *Collection of a corpus of data containing interview transcripts, video transcripts, and photographs*

will benefit children with ASD and their caregivers directly participating in the trials of these technologies. The success of this pilot work will then enable us to conduct larger scale trials; leading eventually to NUIs being incorporated into best practices for the treatment of ASD and other related neurodevelopmental disorders. Our past projects have closely involved teachers and therapists in the design process, a practice we plan to replicate here. Thus, an additional benefit to this community is the exposure of people who are not normally involved in technology design and research to these activities. One teacher with whom both PIs worked has now started her own private practice and is pursuing graduate work focused on technologies for autism as a result of her experience in working with our research team. Finally, work on technologies in support of children with special needs tends to attract women and students with disabilities, both underrepresented groups in computer science and STEM generally. Thus, an additional impact and benefit is the recruitment and retention of underrepresented groups into computer science research.

5. Schedule

We will use an iterative process to design and validate concepts for the system (see Table 1). We will obtain our design requirements for the NUI using data from existing fieldwork and interviews. The final evaluation study will seek to verify whether touch and body-movements is an appropriate interaction model for children with autism to manipulate NUIs for step-by-step guidance.

Table 1. Detailed timeline for this proposal.

Objective	Activity Description	Quarter			
		1	2	3	4
Understand the practices the body-base interaction when conducting the ADLs following cookbooks	Update literature review NUI and technologies for autism	X			
	Analyze in-depth interviews, observations and surveys with clinicians and caregivers to uncover design implications for NUI in support of completing ADLs	X			
Design, development and usability testing of innovative visual support system	Conduct iterative design of the NUI	X			
	Development of a NUI using body-based interactions		X	X	
	Development of an algorithm to detect body-based interactions				
Understand preliminary use of interactive visual support	Multi-method evaluation of system in use			X	
	Analysis of the collected data				X
Expand binational interdisciplinary research ties	Follow-up meetings and internships	X		X	
	Collaborative writing		X	X	X

6. Qualifications of the Research Team

A multidisciplinary team with expertise in a wide range of technical, and clinical issues and methods will conduct this project. The participating institutions and involved researchers are described below.

UC Irvine: UC Irvine is a top tier research institution, particularly in the areas of HCI, Ubiquitous Computing, and Technologies for Autism. The UCI PI, Gillian Hayes, is the Director for Technology Research at the Center for Autism and Neurodevelopmental Disorders of Southern California, a major research, education, and clinical care center serving more than 10,000 families coping with ASD every year. Dr. Hayes has published scholarly articles in top HCI and ubiquitous computing venues including 7 best paper nominations (top 5% of submissions) and one best paper. These articles have focused on topics including ubiquitous computing for treatment and diagnosis of ASD as well as understanding the social, political, and privacy-related implications of these technologies. Through the proposed work, she will be able to use the techniques that have proven successful in her past work to expand her understanding to include new input techniques, an important area for advancement in both computer science and medicine. Dr. Hayes will supervise two PhD students on this work, Sen Hirano and Kerri McCanna, both who are focused on developing technologies to support people with special needs. Mr.

Hirano's undergraduate and MS theses were focused on ubicomp technologies for pediatric health, including autism, and he brings substantial experience to this work.

CICESE: CICESE is a research center and higher education institution located in Ensenada, Mexico. It offers undergraduate and graduate degrees in several fields of science, including Computer Science, and is considered one of the top academic research institutions in the country. The CICESE PI, Monica Tentori, directs an interdisciplinary lab focused on the design, development, and evaluation of ubicomp technologies for health and education. Dr. Tentori has published scholarly articles in top HCI and ubiquitous computing venues including both Spanish and English language venues, which demonstrates her commitment to both international research and the support of development of scholarly knowledge in Latin America. Dr. Tentori will supervise three graduate students on this work, Lizbeth Escobedo, Karina Caro, and Rodrigo Zalapa. All three are focused on natural user interfaces in their research, and Ms. Escobedo has already published extensively in the area of technologies for autism.

Collaboration: Drs. Hayes and Tentori already have an established working relationship, having collaborated for the last five years. Although their institutions are in two different countries, they are only a few hours drive away and meet regularly both by Skype and in person. By involving both institutions, this work can leverage substantial resources already available. Additionally, continued collaboration is likely to support not only the research mission of this proposal but also the larger ideals that Microsoft holds surrounding engagement with Latin America and cross-cultural collaboration.

7. Evaluation

During the third quarter of the project, we will conduct a preliminary evaluation to ensure the feasibility of the system and the vision-based algorithms. We will deploy the system at the Center for Autism and Neurodvelopmental Disorders of Southern California, where 5 clinicians will use the system regularly for one month and approximately 20 children with ASD will also be allowed to use the system for short durations during their clinical visits. We will also deploy the system at the Pasitos Clinic in Tijuana, Baja de California, where 8 children with ASD and 2 teachers will use the system for one month regularly.

The study will include three stages: pre-deployment, deployment and post-deployment. Traditional best practices will be used in both pre and post-deployment, with the interactive NUI being used during the deployment condition. To evaluate the impact of this system, we will capture and analyze logs of computer behavior, self-reported measures and potential users' perceived utility and easy of use of the system. Interviews will be conducted with the clinicians, teachers, and students who use the system to understand their acceptance of the system and its usability and usefulness. We will also observe their behaviors while using the system. We will measure the quantity of prompts related to staying on task, behavior problems, and number of times the children complete ADLs successfully. We will also measure the number of correct answers and prompting (by both teacher and system) related to learning objectives. We will conduct t-tests, ANOVA and Tukey post-hoc to investigate the significance of our results.

8. Use of Microsoft Technologies: We will use the Microsoft Kinect as the primary input device for the NUI and tablets as the primary output devices. Existing software from our other research projects will be incorporated, but we do not presently have the need to incorporate code from commercial sources other than the Kinect API.

9.Use of Funds: We are requesting 25,350USD to be delivered to UC Irvine as lead institution.

Equipment ($7,300)

- *Personal computer:* **2** PCs for development and server during pilot-testing ($2000/unit).
- *Tablets*: **6** mobile devices for development and in-lab testing ($400/unit).
- *Kinnect:* **6** kinnect cameras for development and testing. ($150/unit)

Personnel ($14,825)

- *Faculty.* One week of summer salary is requested for the UCI PI ($2,795)
- *Research assistant.* Partial funding is requested for a graduate student, Ms. McCanna ($12,030).
- All other personnel on this project will be funded through other sources as described below.

Travel ($2,400): We will hold regular co-localized meetings, alternating between the US and Mexico.

Participant compensation ($875): We will recruit families and clinicians of children with ASD to participate in evaluating the NUI. These individuals will be compensated for their time at an estimated rate of $25 for participation in interviews. We expect to recruit approximately 35 participants.

10. OTHER SUPPORT: We will leverage substantial other resources to complete this project. Drs. Hayes and Tentori are primarily supported by faculty salaries at their institutions. Mr. Hirano has a fellowship from the NSF, and all CICESE students are supported by funding from CONACYT. This work builds on empirical data collected by projects funded by the NSF, AutismSpeaks, CONACYT and UC Mexus.

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