MOSOCO: A Mobile Assistive Tool to Support Children with Autism Practicing Social Skills in Real-Life Situations

Lizbeth Escobedo[1], David H. Nguyen[2], LouAnne Boyd[3], Sen H. Hirano[4], Alejandro Rangel[1], Daniel García-Rosas[1], Monica Tentori[1], Gillian R. Hayes[4]

[1]Computer Science School, UABC
{lescobedo, arangel, jose.daniel.garcia.rosas, mtentori}
@uabc.edu.mx

[2]Nokia Research Center
david.h.nguyen
@nokia.com

[3]Division of Special Education, NOC SELPA
lboyd@ocde.us

[2]Department of Informatics, University of California, Irvine
{gillianrh, shirano}
@ics.uci.edu

ABSTRACT

MOSOCO is a mobile assistive application that uses augmented reality and the visual supports of a validated curriculum, the Social Compass, to help children with autism practice social skills in real-life situations. In this paper, we present the results of a seven-week deployment study of MOSOCO in a public school in Southern California with both students with autism and neurotypical students. The results of our study demonstrate that MOSOCO facilitates practicing and learning social skills, increases both quantity and quality of social interactions, reduces social and behavioral missteps, and enables the integration of children with autism in social groups of neurotypical children. The findings from this study reveal emergent practices of the uses of mobile assistive technologies in real-life situations.

Author Keywords

Assistive technology, autism, child-computer interaction, social skills, augmented reality, mobile applications

ACM Classification Keywords

K.3.1 [Computers and Education]: Computer Uses in Education; K.4.2 [Computers and Society]: Social Issues-Assistive technologies for persons with disabilities

INTRODUCTION AND MOTIVATION

Autism is characterized by social skills impairments [1]. Children with autism exhibit problems when initiating and terminating interactions, learning the interests of others, and joining social groups [12]. Direct instructions for skill acquisition are an effective way to teach them social skills, helping to cope with these social challenges [35].

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Most of the available social skills tools use visual supports (*i.e.,* "those things we see that enhance the communication process" [19]. See Figure 1) and social stories (*i.e.,* "picture or written description of social situations" [13, 32]). Taken together, these tools go beyond the teaching of basic social skills and tackle such broad social issues as how situational contexts evolve in ongoing social interactions [13].

The Social Compass curriculum is a behavioral and educational curriculum identified as the best social curriculum for social skills training. It uses social stories and paper-based visual supports for teaching children with autism social skills [6]. The minimal social skills required for a "basic and complete social interaction" are addressed by six core lessons from the Social Compass curriculum: eye contact, space and proximity, start interaction, asking questions, sharing interests, and finishing interaction [33].

Each Social Compass lesson is composed of eight steps and is conducted in groups of both students with autism and neurotypical (NT) students. First, (1) the teacher introduces the social skill to be learned and (2) its related visual support. Then, (3) the teacher reads a social story that helps students connect the visual support, the social skill and the social situation. Later, (4) the teacher demonstrates how the skill is used in social contexts, and (5) students rehearse the skill in pairs. Next, (6) students role-play to practice the skill in four scenarios and (7) self-rate their performances. Finally, (8) students are encouraged to practice the newly learned social skill in different real-life social situations. A central aspect of the Social Compass training—as with

Figure 1. The visual supports of the Social Compass' basic social skills lessons. From left to right: eye contact, space and proximity, start an interaction, asking questions, sharing interests, and finish an interaction.

other social skills training [12, 23, 32, 35]—is enabling students to use newly learned skills in daily social contexts, supporting maintenance and generalization in real life.

Although the Social Compass curriculum has been successfully used during social skills activities in classrooms [6], there are still open questions as to how students might generalize their newly learned social skills to situations outside the classroom. However, there is currently limited support for this kind of mobile, dynamic instruction. To offset this challenge, we explored the use of mobile and augmented reality technologies to provide "anytime and anywhere" support for students practicing social skills in their daily lives.

In this paper, we first describe the design and implementation of the **Mobile Social Compass** (MOSOCO), a mobile assistive application that extends the Social Compass training and supports real-life social situations [33]. Then, we present the results from a deployment of MOSOCO. Finally, we close discussing with directions for future work.

RELATED WORK

Interactive technologies have the potential to provide a wide variety of support to children with autism. For example, interactive visual supports [15] help children with autism manage their schedules [17], remediate their speech and language disabilities (*e.g.,* [5, 27]) and provide feedback on their pronunciation (*e.g.,* [10, 14]).

Other projects have focused more directly on the development and practicing of social skills. Both games (*e.g.,* SIDES [29]) and multitouch displays (*e.g.,* Tablets [21]) have been developed to engage children with autism in social activities and enable novel forms of social expression. These entertainment-based assistive technologies also help children with autism learn how to work with others, be patient and understand emotions [29]. These research projects have made the compelling argument that children with autism are more willing to initiate play and to interact appropriately when using entertainment-based assistive technologies. However, there is limited evidence of a sustained improvement in their social skills following the use of these tools.

To cope with this challenge of sustainability of skill development, the StoryTable project focused on the use of storytelling to encourage socialization and enable practicing of appropriate social skills [11]. This research has shown that support during social engagements increased appropriate expression of emotions and responses to peer questions by children with autism [11]. However, most of these assistive technologies are often available only for use inside classrooms or during group therapies. Children with autism still struggle when generalizing what they learned to real-life situations outside the classroom [3].

Supporting real-life social situations poses new research questions and strains the design and use of currently

Figure 2. The MOSOCO system

available assistive technologies. One of the main challenges in this context is mobility. Although mobile systems have been theorized as an effective educational method enabling "anytime and anywhere" social skills practicing and learning [8, 28], mobile assistive technologies that support socialization and social skills practice for children with autism in this context are scarce. Some mobile applications for encouraging and supporting socialization of NT children have been proposed (*e.g.,* Camelot [34], Mobile Stories [8]), others have explored other domains, (*e.g.*, Personal Travel Assistant [7]), but none of these solutions have been used to support the socialization of children with autism.

These related efforts open new research questions around how mobile assistive technologies for encouraging socialization and learning and practicing of social skills improve the quality of interactions of students with autism and their NT peers. Additionally, the lack of exploration of tools for both children with and without autism opens questions around whether these tools might foster integrated social groups.

In light of the related literature, this work has three contributions. First, although many other researchers have explored the use of assistive technologies for social skills practice in classrooms (*e.g.*, [9, 16, 20]), we examine the usability and usefulness of socially assistive technologies in real life situations outside classrooms. Second, we present a mobile assistive tool that could be useful to other researchers in designing and evaluating mobile assistive technologies for use in real-life situations. Third, the results of our deployment study reveal how new social practices mediated by MOSOCO can improve the quality of interactions and social skills in generalized settings.

THE MOSOCO SYSTEM

MOSOCO is a mobile augmented reality application inspired by previous research on the Social Compass curriculum [33] (see Figure 2). In our previous work, we focused to analyze interactions among students, which led to design insights. Those insights, along with the Social Compass curriculum, inspired the design and development of MOSOCO. MOSOCO facilitates practicing social skills in real-life situations, guiding students through the six fundamental social skills of the Social Compass curriculum. MOSOCO provides children with autism with interactive

Figure 3: Students using MOSOCO during recess (left) two students making eye contact (right) Learning and tagging PIP's interests

features to encourage them to make eye contact, maintain appropriate spatial boundaries, reply to conversation initiators, share interests with partners, disengage appropriately at the end of an interaction, and identify potential communication partners. MOSOCO runs on an Android smartphone wirelessly connected to a server. MOSOCO uses the smartphone's camera to augment a real-life social situation with visual support—mimicking the Social Compass curriculum that augments social stories with paper-based visual supports.

MOSOCO was designed with both individual and group features in mind, augmenting each individual student's social skills, needs, and capabilities, and enabling synchronized group interactions and shared experiences. Individual features include: a unique identifier for each student using the system (typically a name), visualization of student progress in the form of stars that can be earned, an interaction self-report form, and social cues, *i.e.,* what a user should do (*"DOs")* and should not do (*"DONTs")* when interacting with others. Collaborative and group features include: the **Interaction Visual Schedule** (IVS) (*i.e.,* a six-step visual schedule that provides step-by-step guidance through the six basic social skills learned during the Social Compass training), a **Potential Interaction Partner** (PIP) suggestion (*i.e.,* a student who might like to interact with the student using the device), and a roster of connected students (*i.e.,* a listing of student profiles including photographs and personal interests).

When they first start MOSOCO, students are instructed to find a suggested PIP. MOSOCO suggests the PIP by showing the partner's name and photograph (see Figure 4). When the system detects that the user is in close proximity to the suggested PIP, both students are automatically "paired up," indicating that they have started an interaction. At this point, their Interaction Visual Schedules (IVS) are synchronized. Students may also manually pair themselves with another student.

Once MOSOCO's IVS is activated, the first visual support, eye contact, is colored. MOSOCO suggests skill-appropriate do's (*e.g., "smile if somebody looks at you"*) and don'ts (*e.g., "don't stare"*). These suggestions mimic verbal support available from teachers during the Social Compass classroom activities and can be used to practice the skills (Figure 3). MOSOCO monitors skill completion to mimic teacher support further. For example, the system detects eye contact through a vision-based algorithm for eye detection. If MOSOCO infers that eye contact was not properly achieved, it shows a warning notifying that a social misstep has occurred alongside a picture and text-based advice suggesting how to recover from it (*e.g.*, "*look at your partner*'s *eyes*"). Some common social missteps observed in our data include students using an inappropriate tone of voice (*e.g.,* shouting), avoiding eye contact or staring, invading personal space, and interrupting or breaking an interaction (*e.g.,* students with autism usually break an interaction without an explicit farewell). Once MOSOCO detects that both students have made eye contact, it emits a sound and highlights the next step. Students repeat this process to follow each of the rest of the IVS steps until it is time to "end a conversation" (step 6). During a successful sustained interaction, students perform "verbal or physical social activities" (Figure 3). Verbal interactions include activities like asking questions and learning and marking interests from the Social Compass curriculum. Physical interactions include traditional activities performed during recess, such as playing sports or board games.

After each interaction, students complete self-report forms to grade themselves on the six practiced social skills. They select "thumbs up" or "thumb down" on the interface, matching the simple self-grading students do during classroom social skills activities. If no social missteps were detected directly by the system, students earn stars based on the number of times *both* partners grade the interaction with a "thumbs up," encouraging students to help each other master the different skills. Finally, after the interaction and self-evaluation, MOSOCO calculates a new PIP suggestion for both students giving them the opportunity to interact with other students.

By receiving this information through a personal device, each student gets direct assistance and reinforcement for practicing their social skills, similar to the kind of human prompting and reinforcement they might receive during classrooms activities. Meanwhile, every activity is logged in the background, enabling automatic report generation for teachers to measure student progress.

METHODS

MOSOCO was deployed in a public school in Southern California during regularly scheduled lunch and recess breaks. All students enrolled in the Social Compass training were between the ages of 8 and 11 (m=10.08, sd=0.90). From this group, we selected three students with autism who demonstrated minimal social skills but otherwise demonstrated age-appropriate functioning; for each of them, we invited three NT students to serve as their PIPs (n = 12 total). This ratio of NT students mimics the school population. The evaluation included three stages: *pre-deployment* (3 weeks)*, deployment* (3 weeks) *and post-deployment* (1 week).

During pre-deployment, students participated in the standard Social Compass curriculum in the classroom, which included direct instruction from trained specialists and paper-based tools. Researchers then installed MOSOCO and gave a training session on the system to the students and teachers. During the deployment phase, the students used MOSOCO during the Social Compass class and during their breaks. Finally, during post-deployment, the students participated in no lessons, and the system was not available to them.

To meet the regulations of the school and the university research ethics board, students enrolled in the study were confined to a private playground area during recess and lunch breaks (approximately 25 minutes per day). This area (150x50 ft) was separated from the rest of the playground by cones but incorporated common landscape elements (*e.g.,* a tree, a wall, and benches) and traditional school playground items (*e.g.,* balls, ropes, board games).

Data Collection

At the beginning of each session, researchers set up video cameras and sectioned off the playground for the study using bright orange cones. The sectioned-off playground area was surrounded with six HD video cameras, thus recording the children's interactions from six different angles. Researchers observed the students during both the Social Compass training and breaks, including lunch and recess for a total time of observation of just under 11 hours, (pre-deployment: 4 hr. 3 min., deployment: 4 hr. 37 min., post-deployment: 2 hr. 12 min.).

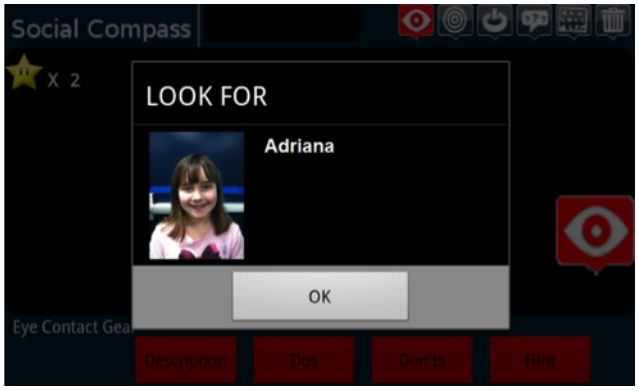

Figure 4: MOSOCO suggesting a PIP

Weekly interviews were recorded and conducted with the participants across each study phase. Interviews were face-to-face and semi-structured, and students were divided in three groups (*i.e.,* g1 = 5 NT students, g2 = 4 NT students, g3 = 3 students with autism). Interviews generally lasted between 15 minutes to half an hour, in keeping with the short blocks of time available to talk with school students.

During pre-deployment, students were asked about daily routines and general communication practices. During deployment, students were asked to discuss how the use of the system went during that particular week, comment on how MOSOCO impacted their interactions and social groups, and encouraged to tell stories and discuss what they found interesting, surprising, or different that week. At the end of the study, the teaching staff and students completed surveys about their experiences with MOSOCO and took part in a 60-minute group interview. Unlike in the previous interviews in which the students were broken into small groups, in this final interview, all students met together. Recorded interviews and videos were transcribed.

Analysis

All field notes, interview and videos transcripts were inspected together using a mixed-methods approach. Researchers first analyzed the data for evidence of whether MOSOCO supported the needs of students. Researchers used open coding [31] and multi-phased affinity analysis [24] to uncover emergent themes from the interview data, in particular in relation to uses of the system. We then developed a coding scheme focused on student social experiences. This coding scheme was cross-analyzed during discussions among the research team to validate and refine its categories and properties.

A quantitative analysis was conducted to estimate the time students spent in different interactions and social groups as well as the number of social missteps committed. Using our coding scheme, the research team coded the recorded videos for interactions, behaviours, and social missteps. Inter-observer reliability[1] was acceptable (r=.912). For each participant under each condition, we calculated:

- *total and descriptive statistics* (*i.e.,* average and standard deviation) of interactions, social missteps, and topic of conversations
- *average time in a sustained* interaction, social misstep and topic conversation

[1]Refers to the degree of agreement between two data sets, scored independently by two different observers.

Finally, a single t-test was used to compare students with autism social missteps and behaviours, and an independent sample t-test was conducted to compare the number of physical, verbal and total of interactions using and not using MOSOCO, of both students with autism and NT students. The data presented a normal distribution.

RESULTS

New social practices mediated by MOSOCO emerged during our deployment. In particular, MOSOCO had an impact on the practicing and learning of social skills and changed the makeup and character of student peer groups.

General Use and Adoption

Overall, students positively received MOSOCO, finding it useful, fun, and helpful. Students showed excitement while using the system, and learned how to use it with minimal training in less than an hour. At the beginning of each session, they typically ran to the area where the phones were stored to start using them.

> *"It's really cool… I was very comfortable… I'm always waiting for this part of the school day." (s10, student with autism)*

> *"It was good, really good, and really awesome." (s11, student with autism)*

Students were more interested in using MOSOCO and other smartphone applications than the typical playground items available, calling out features they liked.

> *"I liked that you can earn stars. [That] was fun." (s1, NT student)*

> *"…I'm more interested in the phone and [MOSOCO], because I can learn a lot of different things." (s2, NT student)*

The primary motivation for using MOSOCO was to learn and to practice social skills, with all students reporting that they learned the Social Compass lessons. When discussing what they learned specifically, students referenced the six fundamental social skills (*e.g.,* "space and proximity," "ending a conversation," and "eye contact").

> *"I got to learn, because I didn't know about how far [away from another person] you are supposed to be." (s4, NT student)*

> *"… I've learn how to end [a conversation properly]." (s12, student with autism)*

> *"[MOSOCO] helped me how to make eye contact and ask questions." (s10, student with autism)*

Both sets of students expressed that they would like to use MOSOCO for longer integrated in their everyday lives, rather than only in the restricted areas of the study.

> *"I'll want to do it again. Yeah I think it would be helpful for kids that are still learning [the Social Compass curriculum]." (s4, NT student)*

During the three weeks of intervention, all of the students mastered the features of MOSOCO and the smartphone itself. This allowed them to explore uses for both the smartphone and MOSOCO, sometimes circumventing the prescribed lessons. For example, at the end of the third week, students started to "skip" practicing of some of the more basic skills in MOSOCO, shortening interactions to earn more stars while competing with other students.

> *"….I pressed ok ok ok and then I got so much stars, and I was like wow!" (s5, NT student)*

The students provided suggestions for encouraging greater adherence to the lessons during interviews:

> *"To really go with the person suggested by [MOSOCO], it would be interesting to have in [MOSOCO] more sophisticated functions, like face detection gear." (s4, NT student)*

> *"Find games that are like appropriate—that are mixed with the social compass—you have to do eye contact. Oh, and then you get a point or something like that? Make it more game like." (s7, NT student)*

Another, particularly remarkable interaction that exemplifies how students mastered the smartphone occurred during the third week of use. Even though all of the phone's buttons were deactivated, Student 5 (NT) closed MOSOCO's application and launched other applications. He then taught this skill to other students who began occasionally to listen to music, select different ringtones, take pictures, and play games with the GPS.

> *"Well I found this app thing that said; GPS Test. So I hit it so I could test it. It's cool; it also tells you your speed." (s6, NT student)*

> *"I just spent time with myself listening to ringtones sitting down." (s3, NT student)*

These results demonstrate that assistive technologies are important and useful outside classrooms but that classroom management strategies will continue to be needed to support students in staying focused on their tasks rather than playing with the technologies in other ways.

Impact on Student Behavior and Performance

During the deployment phase, the smartphone and MOSOCO evolved from a novel artifact and a "toyish" application to a true assistive support and means for social skills learning and practicing outside the classroom. Overall, the use of MOSOCO positively impacted student interactions with each other. Students learned the basic steps of a "proper" interaction, how to avoid and identify missteps, and how to help others interact.

Social Skills Practice and Learning

Generalizing skills beyond classroom learning is a challenge for any student, but particularly so for students with autism. Thus, the ability to practice social skills

outside the classroom was a key feature of the MOSOCO system.

"It really does help me practice the Social Compass lessons." (s11, student with autism)

"[It helps me] to do the social things, eye contact, proximity, and all those things, so I can practice them." (s6, NT student)

In addition, students noted that the system provides them confidence when interacting with others, reassuring them of what they should or should not be doing.

"I forgot something; I'll look into [MOSOCO's social cues]." (s12, student with autism)

"It usually gives me hints." (s5, NT student)

"The eye contact and all the other tools and the do's and don'ts—I found those useful for any of the conversations I start." (s8, NT student)

MOSOCO can help students learn by repetition, in keeping with many other therapies for children with autism (*e.g.,* discrete trial training [30] and rote learning [22]).

"It helps me practice and practice." (s10, student with autism)

"To reenact" (s11, student with autism)

After so many repetitions, students were able to quickly recall the goal of the lesson and how to use the social skill in a given particular situation.

"[MOSOCO] helps you, because if you forgot to put that into your brain, it then remembers you [sic]." (s10, student with autism)

Students with autism and NT students differed somewhat, however, in their motivation for continued use of the system once the novelty wore off. While students with autism continued describing wanting to practice newly learned social skills, NT students adopted "mentoring" behavior. They described feeling responsible for assisting the practicing of social skills with the students with autism and helping them to improve their interactions.

"I like to help those shy children [the students with autism] to have a fun time. It's awesome." (s4, NT student)

"Yeah! I practice with [a student with autism] eye contact and all those things." (s5, NT student)

Most of the interactions we observed with NT students involved hints and explanations about a particular social skill. When children with autism would get "stuck" in a step, NT students would help them to "stay on task." This mimics the physical prompting given by teachers during classroom lessons.

Improving the quality of interactions

Both NT students and those with autism repeatedly expressed that MOSOCO helped them to improve the quality of their interactions.

"Talking certainly to a person in the way that they taught us: how to talk 'formally.' " (s7, NT student)

"It helps me like to socialize better." (s10, student with autism)

The time students with autism were involved in social missteps was 56% lower on average using MOSOCO (no-support: 2 hours 2 min 13 sec; using-MOSOCO: 54 min 38 sec; $t=3.42$, $p=.003$). This reduction can be attributed to greater student awareness and improved ability to identify social missteps using the prompts provided by MOSOCO. Additionally, the system augmented understanding of the usage of specific social skills given particular situations.

"Like sometimes before Social Compass, when I was doing eye contact, I looked away, but after the lessons I know eyes should go on." (s5, NT student)

"[MOSOCO] helped reduce the social missteps." (s10, student with autism)

Having social skill awareness with MOSOCO, the total time a student continually remained engaged in a social misstep reduced 76.52% (no-support: 3 min 33 sec; using-MOSOCO: 50 sec; $t=3.75$, $p=.002$). In addition to reducing missteps for students with autism, MOSOCO supported NT students in learning how to be more understanding and permissive if such missteps were presented. NT students developed new strategies for handling the social missteps instead of mocking or teasing the students with autism as they had done before.

Of course, for young children, encountering this kind of difference can still be challenging, as exemplified by the student below who describes being understanding most of the time but resorting to antisocial behaviors at other times to handle social missteps.

"I ask [a student with autism] what he wants to tell me and then we just get along, but sometimes I just ignore him because he does that [referring to social missteps] way too many times" (s5, NT student)

As with social missteps, we observed that other behavioral issues (*e.g.,* rocking, jumping or making noises), traditionally demonstrated by students with autism when interacting with others were substantially reduced during the deployment of MOSOCO (no-support: 50; using-MOSOCO: 1). This large difference warrants further investigation with a larger sample. These behaviors may have been limited by the interest in and engagement with the smartphone and MOSOCO.

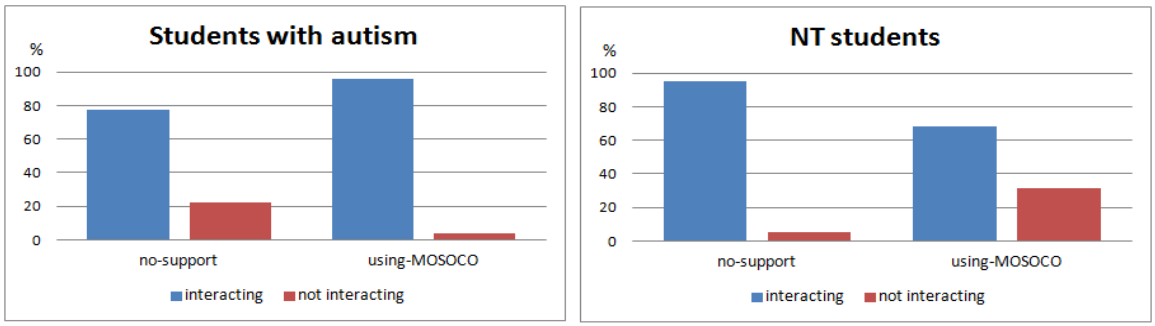

Figure 5. Percentage of students' number of interactions: Children with autism (left) and NT children (right)

Students with autism struggle to make eye contact when interacting with others [26], a problem one might imagine could be exacerbated by concentration on a mobile device. However, all students agreed that with MOSOCO they never had problems making eye contact during an interaction.

> *"It tells me to find somebody, and then I found a person and then I hear the buzz sound and it tells me to do eye sight, I mean eye communicate. Yes you have to communicate with somebody's eyes I guess." (s4, NT student)*

Similarly, "how to end a conversation" was another basic social skill that students agreed MOSOCO helped them to improve. Before the use of MOSOCO, students said that is very common to end up being alone because their partner walked away without saying anything.

> *"I've been improving on how to like end conversations, usually I'm like 'bye' then walk away." (s5, NT student)*

> *"First you would say 'hi' and then walk away without ending the conversation. Now you know how to end the conversation…" (s10, student with autism)*

Students made references to their interactions before using MOSOCO, highlighting that this application serve as a milestone for improving their social behavior.

> *"I've been like starting and ending conversations differently. We had less way less blanks [using MOSOCO]." (s1, NT student)*

Eleven of the twelve students expressed that MOSOCO helped them to understand that an interaction has an "interactive behavior," involving at least three of the basic social skills.

> *"In the beginning, you have to make eye contact, and the next step is proximity I think, and then asking questions and then asking interests, and then is cleaning up the conversation—like how to end it, like say "bye" or something." (s2, NT student)*

> *"…you have to make good eye contact, study your things to make sure you made the right move, ending the conversation instead of just walking away." (s10, student with autism)*

MOSOCO also helped students improve awareness of space and proximity when interacting with others. Beyond just understanding the anatomy of a "proper" interaction, students learned about the implications of not maintaining socially acceptable distances.

Students also learned that one of the main goals of social interactions is to know the personality of your interaction partners (*i.e.,* interests, likes, and dislikes). They began to recognize the need for multiple conversation topics and to develop new relationships through these conversations.

> *"[MOSOCO] guided us through a 'proper' conversation and taught us how to input emotions and feelings." (s1, NT student)*

These findings indicate that MOSOCO helped both students with autism and their NT peers to enhance the quality of interactions by encouraging them to follow basic steps. The reminders then solidified these directions during interactions.

Student interactions and social groups

In this work, we were interested in two types of interactions. First, given that MOSOCO is largely about helping students with autism communicate with peers, we were interested in investigating how their one-on-one interactions can be assisted or improved by mobile assistive technologies. Second, we were interested in how communication patterns amongst students influence social groups through interactions mediated by MOSOCO.

Student-Student

Overall, the number of interactions between students increased 56.73% when using MOSOCO (no-support: 386 interactions; using-MOSOCO: 605 interactions) (Figure 5). Surprisingly, we observed less time spent not interacting with others for students with autism during use of MOSOCO (no-support: 27; using-MOSOCO: 7), NT students spent more time alone (no-support: 14; using-MOSOCO: 136) (Figure 5). We hypothesize that this result could be related to the interest of NT students in interacting with the smartphone, like other youth their age [2]. The large differences in these initial comparisons warrant further detailed exploration. In contrast, students with autism, who are typically considered at a greater risk for

fixating on a tool, appeared to embrace the application as a support that seamlessly mediated their interactions.

Although in our observations, NT students interacted physically with other students less while using MOSOCO (no-support: 145; MOSOCO: 13), students with autism interacted physically more with MOSOCO (no-support: 50; MOSOCO: 60). Likewise, students using MOSOCO displayed substantially, but not significantly, more verbal interactions than without (no-support: 160; using-MOSOCO: 389). These preliminary results warrant further detailed exploration with a larger sample to understand the potential trends we see in these non-significant comparisons. However, these initial results imply that MOSOCO may be better at supporting conversations than physical games, which is in keeping with the goals of social skills training in schools. Students' highlighted that after the use of MOSOCO they got to know their partners better, knowing their interests and dislikes. Additionally, we observed conversations that were qualitatively more intimate during the deployment than in the pre-deployment condition, an effect that could be in part due to the greater familiarity the students had with one another having been in class together for weeks.

With MOSOCO we observed that students with autism learn new and traditional strategies for starting an interaction, even though it has been reported that children with autism find it difficult to properly start a conversation [18], read others body language [4] or join a group of children playing [25]. Students expressed that MOSOCO helped them to understand body language and recognize invitations for starting an interaction.

> *"[MOSOCO] helped me play with others." (s12, student with autism)*

In our observations, students with autism spent more time continuously engaged when using MOSOCO (no-support: 6 min 8 sec; using-MOSOCO: 8 min 49 sec). This result warrants further investigation with a larger sample size as well as a more detailed observation of the types of engagement and the potential ramifications of use of MOSOCO on those activities.

Group Interactions

Social skills used during one-on-one interactions also bled over into groups. In particular, students exhibited new strategies for joining a group of children already playing. Before the deployment of MOSOCO, the strategies were fairly *ad hoc* and tended to encourage socialization with known classmates:

> *"I just look around for one of my friends." (s1, NT student)*

While using MOSOCO, however, the students appeared more motivated to interact with everyone. This motivation enabled students to flow more easily between groups or to enter large groups without explicitly requesting to do so. What could be happening here is that MOSOCO is providing students a "ticket to talk". MOSOCO provides the "ticket" for them so that it is easier to start conversations and talk with each other.

> *"We see each other in the face and we just play." (s4, NT student)*

After the removal of MOSOCO during post deployment, NT children integrated children with autism into their playgroups, and the students with autism joined without resistance. This kind of social integration was not seen during our baseline data collection nor reported by any staff members prior to that. Moreover, this change did not go unnoticed by the students with autism who told us during interviews that now they can join groups more easily.

> *"All you do is just go and have eye contact and they know you're playing with them and they know they're playing with you." (s10, student with autism)*

MOSOCO provided new strategies for the creation and transformation of social groups. Students universally reported that before using MOSOCO they had clearly defined social groups of friends with a sort of social protocol dictated by the social group's leader for admitting new members. These social protocols, typical of school circles, tend to demand from an individual an attempt to be integrated into the group.

> *"She has to agree and I have to agree and she has to agree too." (s9, NT student)*

The complexity of these interactions combined with limited social skills means that most children with autism tend not to be part of a social group and instead spend recess by themselves. However, after using MOSOCO, we observed that students with autism learned new strategies for creating and entering a predefined social group.

> *"Just walk up and stand in line. Then they play." (s10, student with autism)*

This kind of breaking down of the barriers of strict social groups provides some indication that even in schools with no students with autism, such tools might be useful. Additionally, making group integration a more straightforward process allowed students with autism to enjoy topics of conversation and the company of classmates rather than just the execution of an activity (*e.g.,* a game).

> *"I just face them and then I say hello and then they start talking to me and then I talk so we start a big conversation." (s7, NT student)*

CONCLUSION AND FUTURE WORK

Appropriately designed assistive technologies can play a crucial role in improving social learning and social skill practice in real-life social situations for students with autism and their NT peers. A key contribution of this work are the results of the deployment of MOSOCO in order to understand the design space and the user experience of this

mobile assistive tool in real-life social situations. The exploration of 12 students' use and experience with MOSOCO throughout its deployment provides a set of emergent practices of the use of assistive technologies in real situations complementing classroom activities.

Our results demonstrate that MOSOCO is easy to use and helps students practice their social skills. In our evaluation, use of this tool reduced students with autism social missteps 56% and behavioral issues 98%, increases the number of interactions and their quality 52% of both students with autism and NT students. We found out that instead of the smartphones pulling children out of interactions, students were motivated towards social interactions and used the system without additional prompting by teachers. This behavior occurred because both students with autism and NT students were interested in sharing what they discovered, practicing the newly learned social skills and earning the rewards designed into MOSOCO. By freeing students from teachers' prompts, MOSOCO also allowed students to discover other functionalities of the smartphone that played a positive role in improving student's interactions. A deeper and bigger study is needed to explore this sort of assisted independence and its relevance to long-term MOSOCO use. Additionally, our results indicate that using mobile assistive technologies in real-life social situations have an impact on children's social groups. But open questions remain as to how social group dynamics are currently changing due the use of an assistive technology that mediates topics of conversation, with which potential users more likely choose to interact, and the creation and transformation of their existing social groups—an analysis in this direction is currently in progress.

Future work should also focus on use of tools such as these outside of schools with interaction partners who have limited knowledge of the tools and lessons. Additionally, the experience of teachers, other school staff, and parents in setting up and using such tools for students should be explored with new tools built to support these activities if necessary.

The deployment and evaluation of MOSOCO exposed tensions around its use outside classrooms and contributes important implications for the design of assistive technologies in the future, especially those destined for use in real-life situations and in mobile contexts. Our results indicate that students were highly interested in earning stars so assistive technologies should incorporate the potential for game-like interactions to earn points and rewards. Also, we noted that social cues play an important role for helping students "stay on topic" when interacting with peers. However, social cues were sometimes triggered at inappropriate times, as the application was highly unaware of the topic of conversation. Context-aware tools with voice recognition capabilities will enable the application to recognize the conversation context and react accordingly.

There are some limitations to this work. First, the design of MOSOCO is based on the application of one particular classroom-based social skills training. Use of this tool in schools in which the Social Compass *curriculum* is not currently the norm would broaden our understanding of its general applicability. Likewise, open questions remain in exploring other assistive technologies based on a different social skills training techniques in this context. Finally, as in any deployment study, perfectly controlled conditions are not possible, and some effects may be related to the sustained engagement of the students in the Social Compass *curriculum* over the course of the study rather than to tool use alone. Also our study is limited by the small number of participants. With the current sample, it's not possible to derive findings that can extend across larger populations. We want to clarify that our effort centered on acquiring a vast and detailed understanding of the practices of a few individuals across the multitude of experiences of a shared playground. Therefore, the significance of our results lies on the qualitative nature of the inquiry and analysis. We leave open for future work the study of the impact of MOSOCO with a bigger sample or in another context.

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