Can Non-Humanoid Social Robots Reduce Workload of Special Educators : An Online and In-Premises Field Study

Nabanita Paul[1], Siddharth Ramesh[1], Chiranjib Bhattacharya[1], Jayashree Ramesh[2], Priya Vijayan[2]

***Abstract*— Although Socially Assistive Robotics have been used in Autism Spectrum Disorder (ASD) interventions, such studies often exclude Special Educators (SEs) and often use expensive humanoid robots. In this paper, we investigate whether non-humanoid toy robots can act as teaching aids in ASD Education, in particular, can they reduce the workload of SEs. We target two most common yet divergent problems from Individualized Education Plans (IEPs) of ASD children - communication and gross motor skills. We present results from three studies a) toy robot Cozmo assists SEs in verbal lessons in school premises, b) mini drone Tello helps SEs in exercise lessons in school premises, and c) Cozmo, SEs, and ASD children connect remotely, as mandated due to the Covid-19 pandemic, for verbal lessons. All three studies showed improvement in learning outcomes and reduction in prompts from the SEs, denoting reduced workload. The effect of a robot's virtual presence in online ASD interventions has not been studied before. However, our results show that children spent more time on lessons in online intervention with Cozmo, suggesting that using robots should also be considered when designing online interventions. Furthermore, the roles of Cozmo were analyzed, and we found children showed increased spontaneous interaction when Cozmo acts as a Co-Instructor. Thus, preliminary results indicate toy robots, as opposed to expensive humanoids, may have significant potential in aiding SEs in Autism education.**

I. Introduction

Autism Spectrum Disorder (ASD) affects communication, social interaction, and motor skills [1] in as many as 1 in every 160 children worldwide [2]. Since the symptoms are heterogeneous, interventions catering to each child need to be designed and delivered by Special Educators (SEs). Moreover, one SE often has to teach multiple ASD children due to resource constraints. Thus, there is a tremendous workload on SEs.

Tablets have been used as assistive tools in various ASD interventions [3], [4] due to the affinity children with ASD (CwASD) show towards technology. However, robots maybe a better interaction partner for CwASD as opposed to a computer screen [5]. Robots can elicit increased social response from ASD children [6] possibly due to their embodiment. Socially Assistive Robotics (SAR) is an emerging field where robots assist users through *social* interaction [7]. Social robots have helped in interventions addressing developmental challenges in ASD such as Joint-Attention [8], [9], Imitation [10], and Social interaction [11]. Naturally, there has been a growing interest in using social robots in academics of CwASD [12]. However, the utility of SAR in special education institutions is ambiguous, as most studies exclude SEs, focus on only one ASD challenge, or use expensive humanoids. Thus, to incorporate social robots in ASD education, it is important to design interventions including SEs and using cost-effective robots.

[1]Department of Computer Science and Automation,Indian Institute Of Science, Bengaluru, India (nabanitapaul,chiru)@iisc.ac.in, sidramesh95@gmail.com

[2]Academy for Severe Handicaps and Autism(ASHA) (jayashreeramesh,priyavijayan).asha@gmail.com

Fig. 1: (Top-left) Cozmo with happy expression, (Remaining) Ongoing Verbal Lessons in *Speak With Cozmo*

Language and social communication are among the most common challenges faced by CwASD, such as pragmatic, semantic, grammatical, or phonological impairments. These lead to problems such as echolalia, difficulty in spontaneous speech and contingent response, using isolated words, and unable to take turns in a conversation [13]. Several studies have shown robots can encourage social communication when used in ASD interventions, but the robots used are custom-designed like KASPAR [14], Probo [5], Troy [15] or are humanoids like NAO [16]. The form-factor and functions of these robots vary greatly and each of the studies focus on one goal under social communication. Additionally, only [16] deploys NAO in special education institution where the cost and complication of using the humanoid robot were reported to be a limitation. Although low-cost COTS[1] toy robots such as Keepon [17], and Pleo [11] have helped in ASD communication interventions, these robots were non-verbal. Hence, it is unclear how CwASD will interact with toy robots endowed with speech. Another common problem in ASD is motor abnormalities with varying degrees of dyspraxia, a deficit in gross and fine motor skills, or postural instability,

[1]Commercial Off-the-shelf

which can affect the daily living skills of CwASD, with some of them requiring regular occupational or physical therapy interventions [18], [19]. Most studies for motor interventions use expensive humanoid robots as well [20].

In special education institutions, an Individualised Education Plan (IEP) is used to document every child's learning objectives for an academic year. It pertains to goals ranging from formal education to special needs such as social communication and motor skills [21], [22]. For commercially available toy robots to be used in IEP lessons of CwASD, we need to test their efficacy over a range of IEP objectives. Furthermore, the roles in which toy robots are deployed can change, affecting the interaction dynamics which need to be studied. Additionally, as the education shifted to a virtual format due to the Covid-19 pandemic, we investigate if robots can be helpful as a teaching aid in an online setting. The virtual presence of a robot in an online ASD intervention has not been studied before, understandably, but could be impactful for remote education in epidemic scenarios.

Therefore, we study the effect of toy robots as teaching aids in special needs education by varying the target IEP lessons, roles these robots play in the interventions, and the physical setting of the interventions[2]. We focus on the following broad questions:

1) Can a verbal COTS toy robot be useful in multiple verbal communication lessons?
2) Can a mini-drone increase compliance and decrease dependence on physical help that is usually required in the exercise lessons under IEP?
3) Does a toy robot help virtual IEP classes any more than when only the SE and child connect virtually?
4) What different roles can these robots play in IEP lessons, and how do the childrens' responses differ for each role?

Towards this end, we conduct 3 studies - toy robot Cozmo assists SEs in verbal lessons of ASD children, mini-drone Tello is used by SEs to help CwASD in exercise lessons, and Cozmo, SEs, and children connect remotely (due to Covid-19 pandemic) for verbal communication lessons. The first two studies were conducted at ASHA[3]. The contributions of this paper are summarized as follows:

- We show how Cozmo can help in IEP language objectives that include *Contingent response*, turn-taking in conversation, spelling recall, *Pragmatic Language*, and *Phonetic Learning*.
- We show how exercise lessons assisted by a mini-drone, Tello, can make even the non-compliant children perform necessary exercises.
- We find the robots reduce dependence on SEs in all three studies, indicating an increase in the participants' spontaneous interaction with the robots.
- We show how Cozmo can also facilitate in an online education format by increasing CwASDs' sitting tolerance, improving learning outcomes, and decreasing workload of SEs as compared to sessions with only SEs and children.
- We find that Cozmo's roles can be categorized as either that of a *co-instructor* or a *model student* (defined in section III-E). Although participant's spontaneous verbal interaction increases when Cozmo is present, preliminary results show that spontaneous interaction was greater when Cozmo plays the role of a *co-instructor* than when Cozmo plays a *model student*.

[2] https://teaching-through-sar.github.io/

[3] Academy for Severe Handicaps and Autism (ASHA) is one of the oldest and largest special needs institution in Bengaluru, India

II. Methodology

We repurposed toy robot Cozmo (by programming behaviour for individual lessons, and using human voice instead of the out-of-the-box robotic voice of Cozmo), and programmed mini-drone Tello (to maneuvre autonomously) for the following three studies :

1) **Speak with Cozmo** - The SE , toy robot Cozmo and the child meet in a classroom for verbal lessons.
2) **Exercise with Tello** - The SE uses mini-drone Tello to motivate and guide the child in exercise lessons.
3) **Learn with Cozmo Online** - The SE, Cozmo and the child connect over a video call for virtual IEP lessons.

Table I lists IEP objectives of each study and their locations.

Study	Target IEP Objectives	Location
Speak With Cozmo	Contingent Response, Expressive and Receptive Language, Spelling Recall, Turn-taking in Conversation, Communication in Non-native Language	School Premises
Exercise With Tello	Age-appropriate motor skills from Normal Development Checklist [23]	School Premises
Learn With Cozmo Online	Pragmatic Language, Phonetic Learning, Social Communication (Answering without Cue Cards)	Online (Video Call)

TABLE I: Target IEP objectives and locations for each study

A. Hypotheses

We formulate following hypotheses inspired by the broad questions we listed in section I:

H1: Participants will show improvement in learning outcomes and spontaneous interaction, i.e., reduced dependence on prompts from SEs, in the *Speak with Cozmo* sessions.

H2: Participants will perform exercise spontaneously , i.e., with reduced assistance from SEs in *Exercise With Tello*.

H3: Participants will show improved learning outcomes, engagement and spontaneous responses during *Learn with Cozmo Online* sessions as compared to online sessions with only the SE and the participant.

B. Robots and System used

Cozmo [24] is a mobile robot by Anki. It is equipped with OLED screen displaying a face that emotes (fig. 1), a camera, a speaker, and a programmable interface (Cozmo SDK) that was used to program the lessons. The setup involved Cozmo

(a) Speak With Cozmo (b) Exercise With Tello (c) Learn with Cozmo Online

Fig. 2: Experimental Setup of 3 studies

stationed on its charging dock, a phone to connect Cozmo to SDK, a laptop to run the programs, and another phone used by SEs to control Cozmo through a custom web interface.

Tello is a mini drone by DJI [25] which weighs around 100g with dimensions 98×92.5×41 mm (L×B×H) (fig. 3f). Tello is programmable through an SDK, which was used to automate the drone's maneuvering according to the exercise specifications. The drone maneuvers were programmed with respect to the room dimensions and visual markers were attached to the floor to guide the drone during the lessons.

C. Experimental Setup

Speak With Cozmo: For each session the participant, their SE and Cozmo met in school premises (fig. 2a). Each session comprised four verbal lessons discussed in section II-D. In addition to lesson specific responses, Cozmo also provides positive reinforcement (e.g. "`Good Job!`") or a redirection (e.g. "`Let's try again`") based on the participant's response. Each session lasted for about 20 to 30 minutes. The robot was operated using Wizard-of-Oz [26] method and the audio was recorded to be later annotated for analysis. For qualitative evaluation, each participant's SE made a note of progress at the end of every session.

Exercise With Tello: A large hall in the school premises was designated where the sessions would be conducted. Each participant was accompanied by their SE and the drone maneuvered autonomously once being inititiated by the experimenter (fig. 2b), who was stationed far away in the same hall. Each session comprised four exercise lessons listed in section II-D. A clinical psychologist was also present away from the exercise zone, who evaluated the performance of the participants during the sessions.

Learn With Cozmo Online: For each session, the participant (sometimes accompanied by their parent), their SE and Cozmo (i.e., one of the experimenter having Cozmo) connected over audio-video call (fig. 2c) for the verbal communication lessons. Rest of the interaction dynamics is similar to *Speak with Cozmo* sessions.

D. IEP Lessons

The lessons, extracted from IEPs, along with the target behavior and roles of the robot are discussed here.

Speak With Cozmo: All the participants had similar IEP objectives and hence had following common lessons.

- *Talk to me:* Cozmo asks 7 self-introductory questions, each preceded by a model answer, e.g. "`My name is Cozmo. What is your name?`" to facilitate response. This lesson is aimed at improving participants' *Contingent Response* [27], which addresses *Echolalia* [28], and communication in non-native language, i.e., English.
- *Story Time:* SEs read a story to the participant and Cozmo asks related questions. Visual cue (pictures) was also provided if required. This lesson targets *Receptive* (ability to perceive information) and *Expressive* (ability to convey thoughts in words) language and communication in non-native language, English.
- *Spell it out:* Cozmo asked the participants to spell words from the story of *Story Time*. They could verbally answer or write the spelling and then pronounce.
- *Read with me:* Cozmo reads out a line from a given script. The participant waits for his/her turn and reads the next line of the script and so on. This focused on *Turn-taking in conversation* [29].

Exercise With Tello: Each session consisted of four rudimentary exercise lessons which were a subset of regular occupational and physiotherapy sessions from the participant's IEPs. These exercises were aimed at improving certain innate physical traits, such as posture, bilateral coordination, linear movement and visual-motor skills amongst others [30].

- *Arms raise*: Tello takes off from a given location and varies its altitude between 1.5m to 3m off the ground. SEs instruct the participants to raise the arms up and down synchronously with Tello's position (Repeated over two rounds of 8 counts in each round).
- *Bilateral Arm raise*: Tello takes off and alternatively sways from left to right. The participants raise their respective arms synchronously with Tello's position. (Repeated over two rounds of 8 counts).
- *Squat*: Tello alternatively takes off and lands with a fixed time delay between each actuation. SEs instruct the participants to squat and stand-up synchronously with Tello's actuation. (Repeated over 8 counts).
- *Sprinting*: Tello rises to an altitude of about 3m and traverses along the perimeter of a rectangle (7m×3m). SEs instruct the participants to sprint and follow the drone along the perimeter. (Two rounds of sprinting)

Learn With Cozmo Online: The participants in this study had disjoint language goals in their IEPs. Thus each participant needed separate lessons as listed below.

- *Reading three-letter words*: This involved a range of

Phonetic Learning (learning to pronounce words by phonetic sounds [31]) tasks like pronouncing the words, matching words to pictures and vice versa, and identifying words associated with pictures. Cozmo, when prompted by the SE, uttered the ideal response for each task, following which the SE asked the same question to the participant. Cozmo thus acted as the *model student* who the participant would hopefully mimic and learn the words in the process.

- *Saying Please*: This lesson was modeled after social-stories intervention [5], where a story is narrated to the participant by the SE and Cozmo asked questions to the participant based on the story to test comprehension of the passage. This targeted *Pragmatic Language* (language skill that allows us to use appropriate words in different social situations [32]) that the participant needed to learn, specifically the act of requesting.
- *Saying What and Help*: In this Cozmo was used to teach two *Pragmatic* components of language to the participant - asking for help and '`what`' questions. Whenever there was new word encountered, Cozmo spoke out "`What is this?`" and whenever the participant was stuck on a difficult word, Cozmo uttered "`Please help me`" to prompt them to ask for help.
- *Answering without Cue cards*: This set of lessons focussed on teaching *Social Communication* (similar to Pragmatic Language [33]) to the participant, specifically asnwering '`Yes/No`' to questions asked by the SE without cue cards that are often used by CwASD. The SE conducted two-three IEP lessons and whenever the SE asked a '`Yes/No`' question without cue cards, Cozmo uttered '`Yes/No`' which the participant was hoped to mimic.

E. Evaluation Metrics

Each of the following metrics is used in one or more of the studies, details of which will be covered in III.

Prompts: Prompts can be any verbal or non-verbal gesture made by SEs to elicit response from the participant.

Accuracy: Ratio of correct responses to the total number of responses by the participant.

Out of Turn Utterances: Number of times the participant speaks out of turn in *Read With Me* lesson. An utterance is considered out of turn when either a) the participant reads out Cozmo's sentence or b) the participant starts reading his own sentence before Cozmo has completed reading.

Initiations: Number of times SEs reveal part of the ideal response to the participant in *Spell It Out* lesson.

Translations: Number of times SEs translate Cozmo's question to the participants native-language.

Performance rank: This provides a scale to show the average performance and involvement of the participant for each given exercise. Used in *Exercise With Tello* study.

Overall Eye-gaze: This metric provides an estimate of the amount of eye contact the participant maintains with the drone during an entire session of *Exercise With Tello*.

F. Participants and Screening Criteria

For each of the studies, pilots with many CwASD were conducted to see their reaction to the robots. The details of the final participants, the screening criteria used and their ASD diagnosis results are presented in table II.

Study (No. of Participants in Pilot)	Screening Criteria	Final Participants Details
Speak With Cozmo (20)	• is verbal • has cognitive thinking • responsive to robot speech	• 5 CwASD (All male) • 13-17 years • Mild autism (mean ISAA [34] score of 85.6, S.D 8.3)
Exercise With Tello (55)	• perform exercises poorly or not at all (without drone) • positive affect in drone's presence	• 3 CwASD (2 male, 1 female) • 12-13 years • Motor skills in the age group of 4-5 years based on Normal Development Checklist [23]) for 2 participants while third's is age-appropriate but exhibits non-compliance
Learn With Cozmo Online (7)	• same as *Speak With Cozmo* • have internet bandwidth sufficient for video call	• 4 CwASD (3 male, 1 female) • 4-17 years • Mild autism (mean ISAA score of 88.7, S.D. 11.6)

TABLE II: Participant Details and Screening Criteria

III. Results and Discussions

A. Speak With Cozmo

We conducted a longitudinal study of 3 weeks, with two sessions per week for each of the 5 participants, henceforth identified as P1 to P5. Session 1 was conducted without Cozmo (the SE assumes the role of Cozmo) and the remaining 5 sessions with Cozmo. For *Spell It Out* lesson, only P1, P3, and P5 participated based on their language exposure. Figures 3b and 3a show the lesson specific outcome measures for each participant for the first and the last sessions, i.e., without and with Cozmo.

Improvement in Learning Outcomes: For *Talk To Me* lesson, we see accuracy improves for 4 out of 5 participants and remains the same (100%) for P1, showing improvement in *Contingent Response* of the participants. In *Read With Me* lesson, figure 3a shows out-of-turn utterances either decreases or remains the same (zero) with Cozmo except for P2, who was reluctant to respond without the SE prompting in his native language, *Kannada*. Thus, improvement in *Turn taking in Conversation* is inconclusive. In figure 3b, we see 4 out of five participants needed no translations by the last session in *Talk To Me*, and for *Story Time*, translations decreased for all or remained at the same low value. Thus *Communication in Non-Native Language* improved for all but one. For *Story Time* figure 3b indicates the accuracy increases or remains constant for all participants, indicating improvement in *Receptive and Expressive Language*. And finally, for *Spell It Out* figure 3a shows the number of

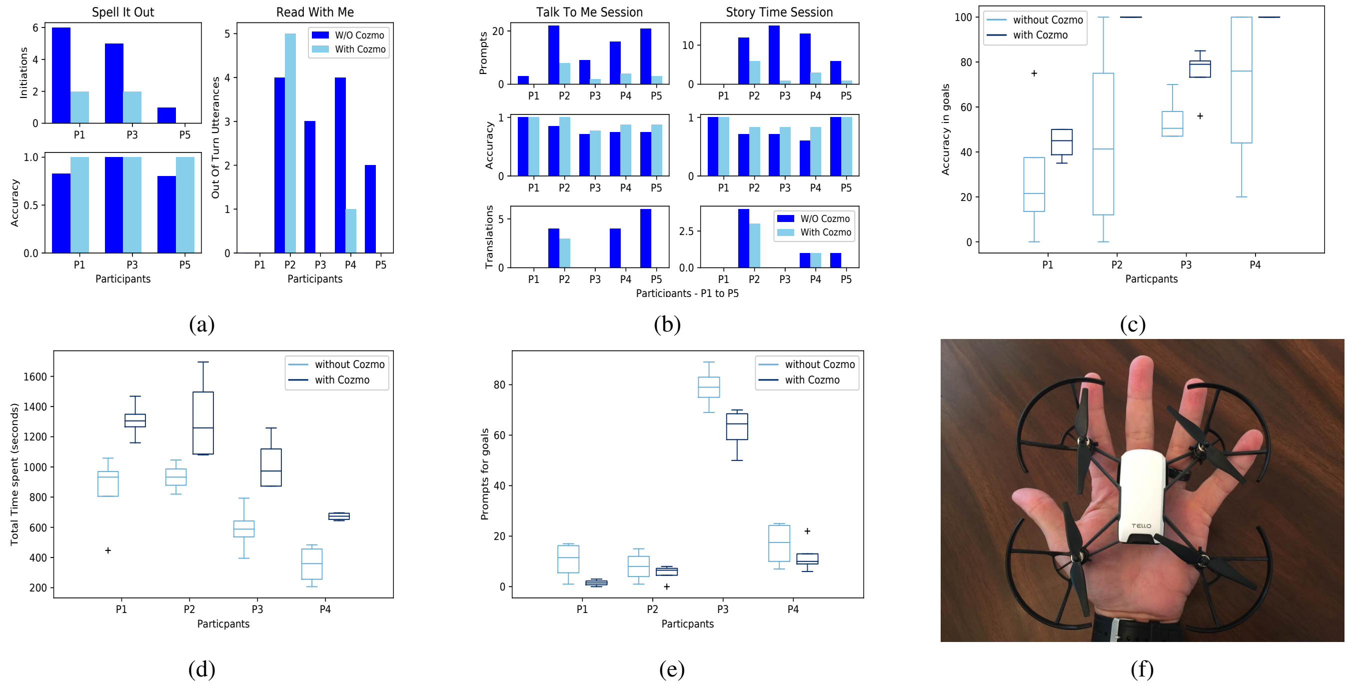

Fig. 3: (a) Measures for *Spell It Out* and *Read With Me* (b) Measures for *Talk to Me* and *Story Time*; Measures for *Learn With Cozmo Online*: (c) Accuracy (d) Total Time(seconds) (e) Prompts (f) Size of mini-drone in *Exercise With Tello*

initiations for P1, P3 decreased with Cozmo, and P5 did not need any. All of them showed perfect accuracy with Cozmo by the last session, with the accuracy of P1 and P5 increasing. Thus spelling recall also improved. Thus, learning outcomes in almost all IEP objectives improved for all participants.

Improvement in Spontaneous Interaction: Prompts, Initiations, Translations are all measures of help required by participants from SEs during each lesson. In figure 3b we see that the number of prompts decrease for all participants in both *Talk To Me* and *Story Time* lessons. We also see the number of initiations and translations decrease (becoming 0 in a few cases) by the last session with Cozmo. Furthermore, qualitative findings reported by the SEs indicated that P5, who struggled with sentence construction, tried to respond to Cozmo in full sentences during *Talk To Me* lesson. Another participant, P1, who was non-compliant in repetitive tasks such as spelling and writing, wrote the spelling on his own on receiving negative feedback from Cozmo during *Spell It Out*. Thus, both quantitative measures (prompts, initiations, translations) and qualitative findings indicate an increase in the participant's spontaneous interaction.

Above results indicate that **H1** could be true.

B. Exercise With Tello

We opted for a longitudinal study of 10 sessions, spanning eight weeks. The participants were selected based on their abysmal performance or non-compliance during their regular exercise lessons. During the regular lessons in school, each of the chosen participants required 2 SEs to help them - one SE to demonstrate the exercise activity for them to watch, and another SE to physically help them move limbs and perform the exercises. During *Exercise With Tello*, only one SE was present to instruct the participant verbally. Thus, the evaluations were only possible during the drone session, and baseline measurement (i.e., without drone and with only one SE) is not recorded due to poor or no performance.

Figure 4 shows the 3 measures that were recorded for every participant and every exercise lessons over 10 sessions. As evident in the figure, all three participants consistently performed the exercise lessons even without physical assistance from the SE. There were few lessons where P3 did not comply, but it could be due to the P3's hypoactivity or mood swings [35] while performing those particular exercises. Furthermore, in qualitative findings, SEs listed that P3 always slouched and exhibited poor neck posture, but due to looking up at drone, her neck posture had improved. P2, who has an abnormal gait, even attempted to sprint in *Follow the Drone* lesson. Thus barring 2-3 observations, all three participants showed improved spontaneous participation during the *Exercise With Tello* sessions, indicating **H2** could be true.

C. Learn With Cozmo Online

A longitudinal single-subject study was conducted for 8 sessions over 4 weeks, with 2 sessions per week. Out of the 8 sessions, 4 sessions were conducted without Cozmo (the SE assumed the role of Cozmo), and the rest of the 4 sessions include Cozmo. The outcome measures are presented in a box-plot in figure 3, showing the comparison of values between sessions with Cozmo and sessions without Cozmo.

Improvement in Learning Outcomes: Each participant in this study had separate lessons, as indicated in II-D. For each of the participants, accuracies during "With Cozmo" sessions are much higher than accuracies during "Without Cozmo" sessions (3c). This indicates that accuracies in *Pragmatic Learning, Phonetic Learning*, and *Answering without Cue Cards* increase when participants interact with both Cozmo and the SE as opposed to interaction with only the SE.

Improvement in Engagement: We use the total time for a session as a measure for engagement. Although other measures such as eye gaze are used in literature, in our lessons, participants had to also write in their notebooks, thus shifting their gaze frequently from the screen. Figure 3d shows that the total time spent for all the participants is higher during sessions involving Cozmo as compared to sessions without Cozmo, thus indicating improved engagement with Cozmo.

Improvement in Spontaneous Interaction: Figure 3e shows the prompts by SEs reduces for all participants when Cozmo is used in the sessions. Although the median value of prompts in the two distributions is very close for P2, number of prompts in "With Cozmo" sessions are lower than the median for prompts in "Without Cozmo." Thus, we can conclude prompts decreased when sessions included Cozmo, indicating improved spontaneous interaction. We also record higher spontaneous interaction by the participants with Cozmo as compared to interaction with only SEs, in table III.

Thus, improvement in learning outcomes, engagement, and spontaneous interaction indicate **H3** could be true.

D. Safety Precautions for Exercise With Tello

Given the form-factor and lightweight features of Tello, it poses no significant threat in any form. However, propeller guards were retrofitted as a safety precaution (fig. 3f) to prevent any possibility of injury. Also, SEs were advised to instruct the participating children not to handle the Tello anytime during the session physically. Conversely, the participants were also screened based on their compliance to the SEs to preempt CwASD from bruising themselves. Damage to Tello is also improbable as Tello is relatively sturdy for its size to handle head-on wall collisions.

Cozmo's Role(Lesson)	**ASU with only SE**	**ASU with Cozmo + SE**	**Increase in ASU**
Model Student (Saying What and Help)	2.5	6	140%
Co-Instructor (Answering without Cue Cards)	0.25	3.75	1400%

TABLE III: Average Spontaneous Utterance(ASU) for each role

E. Roles of the toy robots

Studies have mentioned SAR can be deployed in different roles [36]. While conducting our experiments with Cozmo, 2 specific roles emerged during the design process. One is *Co-Instructor role*, where Cozmo asks questions to the participant. Another is the *Model Student role*, where Cozmo is established as a peer in learning who models the target behaviour that the child is expected to mimic. Sometimes, Cozmo assumes the role of both *Co-Instructor* and *Model Student* in the same lesson (e.g., in *Saying Please* lesson, Cozmo asks questions as well as reads lines from the script with the participant). Thus, to compare the behaviour of participants during the two roles of Cozmo, we selected lessons where Cozmo had only one role throughout, shown in table III. We compare the average spontaneous utterances by the participants. Utterances are considered spontaneous when they are not a response to lesson questions or a response to question asked by Cozmo or SEs during the session and are contingent on the events happening during the session (e.g.,"`Wake up Cozmo`", "`Good Morning`", "`Over`"). As noted in table III, there is an increase in spontaneous utterances by participants with Cozmo compared to sessions with only SEs. Moreover, the increase in the spontaneous utterance is much higher when Cozmo assumes the role of *Co-Instructor*.

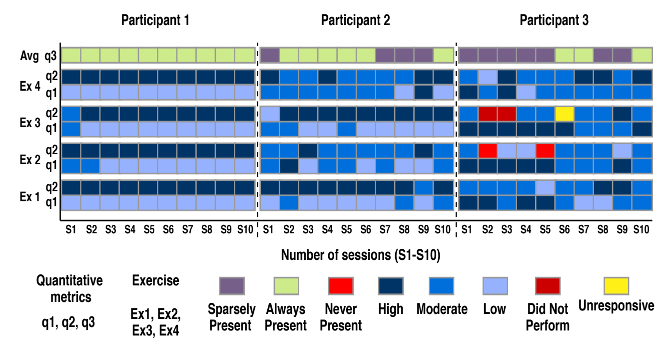

Fig. 4: Measures for *Exercise With Tello* (q1= Prompts, q2 = Performance, q3 = Overall Eye-Gaze)

IV. Conclusion

In the three studies, we included IEP objectives from the most common yet divergent problems in ASD: verbal communication and motor coordination challenges. Improvement was recorded in almost all of the IEP goals, and the assistance required from SEs in the form of prompts or physical assistance decreased in all three studies, indicating a reduction in workload of SEs. Furthermore, we examined the roles that Cozmo played during the interventions and found that spontaneous verbal response increased when Cozmo acted as a *Co-Instructor*. Spontaneous responses from the children could also result from the robots' appearances, as toy robots may feel non-threatening as opposed to humanoids. Moreover, we discovered online interventions with Cozmo increased compliance of CwASDs and even improved on their IEP goals. Thus, robots assisting SEs in virtual format may also open new doors in remote ASD education. However, our results are preliminary, limited by the small sample size, number of sessions, and absence of post-study evaluation. Longer studies targeting more ASD students need to be conducted to validate our findings further.

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