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Playful Telepresence Robots with School Children

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ABSTRACT

Telepresence robots offer potential enhancements to real-time classroom participation and social interaction for remotely located children. This mixed-method study, including observation and questionnaires, examines the safety and effectiveness of these technologies in an educational environment, with 22 children aged 9-11 using GoBe mobile telepresence robots. Participants were divided into eight groups. They engaged in activities designed to simulate driving experiences, including navigating an obstacle course, participating in a treasure hunt, and parking the robot. Through thematic analysis of observation notes and statistical analysis of task performance measurements, we identified challenges such as initial connection issues, navigation difficulties in tight spaces, and inconsistent docking. These underscore the need for improvements in network compatibility, user interface, and automation. Our findings indicate that children are capable of safely operating the robots and collaborating effectively. Further, our data indicates that there may be gender differences affecting confidence and adjustment to driving tasks. This study suggests enhancements in robot design and instructional practices to better integrate telepresence robots into educational settings, ensuring their safety and utility for children.

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CCS CONCEPTS

• **Human-centered computing → Ubiquitous and mobile computing**; **Empirical studies in HCI**; **User studies**; • **Social and professional topics → Children**; • **Applied computing → Education**; • **Computer systems organization → Robotics**.

KEYWORDS

Telepresence, Children, School, Play, Navigation, Safety

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1 INTRODUCTION

Telepresence robots enable humans to perform physical tasks and act as social actors from a remote location in real-time. The mobile and physical form of this technology has garnered growing interest within the HCI community, prompting research into specific robotic telepresence experiences such as wayfinding [16, 20, 25, 33, 37, 60, 64, 65, 85, 90], object finding [6, 17, 18, 30, 32, 67], and gender dynamics [5, 15, 16, 33, 73, 79]. Interest in using robotic technology in educational contexts has increased, as it shows great potential to provide inclusive and equitable educational opportunities. From this viewpoint, these robots can be used to alleviate the limitations of physical attendance [23, 28, 84, 93], facilitate computer-mediated audiovisual communication, and afford embodied classroom participation and engagement [19, 38, 57, 59, 93]. Figures from the UK in 2022/23 suggest that, at any time, 1 in 15 school aged children are absent from school with around a half of these (circa 250,000) being absent for reasons that could be mitigated against with telepresence style technology [1]. Recognizing the significant potential of telepresence robots to enhance educational experiences, for those temporarily or more permanently excluded from physical attendance at school, several prior studies (e.g. [38, 56, 58]) have paid attention to their use and experience in school settings. However, these research studies did not emphasize the practical aspects of driving robots. Consequently, little is known about whether children can effectively control telepresence robots during complex tasks, such as navigating spaces, avoiding obstacles and people, finding and reaching objects, and parking, all of which are crucial for safe and effective operation in educational environments.

Our mixed-method user study highlights the challenges and opportunities presented by children's use of a major commercial product from Blue Ocean Robotics – GoBe robots [75]. Eight students aged 9-11 were recruited to drive robots, while fourteen others observed. We made "thick" ethnographic fieldnotes to describe the drivers' experiences of interacting with the GoBe robot to perform three pre-defined tasks and collected quantitative user evaluation through a post-test questionnaire. Our goal in investigating children's experiences operating mobile telepresence robots, was to explore the technologies robustness, and their potential as educational tools for children. We selected foundational tasks like wayfinding and object finding which were critical to educating using the robot. Finally, we explored children's behavior using the robots, how they responded to robots, and their visions for the potential of telepresence robots in schools.

Given prior research on the STEM participation gap related to gender [77–79], we wish to explore whether telepresence robots are gender equitable for children. Core to this research is discussion of gendered differences of prior exposure to video games and STEM toys [13, 51]. Please note that much of the literature on the psychology of gender has explored gender differences in terms of spatial navigation [55], simulation sickness [69] or self-efficacy [5]; however, it has largely done so by relying on sex alone, effectively erasing trans identities from the narrative [52]. More recent psychological literature, such as Jackson and Bussey [36], acknowledges the shortcomings of differentiating between sex and gender, creating space for the exploration of more appropriate ways to consider transgender identities. Our aim is not to classify users, but rather to consider the relevance of gender for design given our interest in self-efficacy [5] and participation gaps in STEM [51]. Furthermore, we build on Brulé and Spiel [10]'s discussion of gender in participatory design which conceptualizes identity as a social construct, subject to redefinition and refinement. By drawing on West and Zimmerman [94], they extend their argument to discuss how gender is also socially constructed. In the remainder of the article, they emphasize the importance of using a participant's own self-description of gender as the starting point for participatory design. Thus, in this paper, we have adopted this identity-focused use of gender, given its utility for design.

Our research contributes to the field of telepresence robot studies by examining whether children can safely operate such technology in an educational environment. To guide our study, we therefore pose an open, exploratory question: *What factors, including gender, influence the safe operation of telepresence robots by children?* In doing so, we provide user feedback and actionable design implications for the GoBe team, focusing on interaction designs that are suitable for children, and highlight best practices for introducing this novel technology to children.

2 RELATED WORK

2.1 Telepresence and Children

Telepresence robots vary significantly depending on their field of application. For example, in healthcare, surgical telepresence robots allow surgeons to perform operations remotely, often featuring precision control, high-definition cameras, and specialized surgical tools [48]. In contrast, social-presence telepresence robots are designed to facilitate interactions and communications. These robots usually prioritize user-friendly interfaces, mobility, and audiovisual features to mimic the presence of an individual [35].

As social-presence telepresence robots feature mobility and video communication capabilities [42, 47, 66], they are typically used, and well-received, in educational settings for their potential to support children with physical attendance limitations [28, 84, 93]. In educational settings, telepresence robots generally possess a wheel-based platform for mobility, a 'head' that presents cameras and screens, a microphone array for clear audio communications, and speakers which allow the remote students to be heard clearly by the classroom students. Common examples of telepresence robots used in classrooms include Double 3 [21], TEMI [81], GoBe [75], and Ohmni[61]. In our study we focused on the GoBe robots. Telepresence robots offer significant social and educational benefits, offering a medium for audiovisual communication, maintaining the presence of homebound children in the classroom [19, 38, 57, 59, 93] and serving as a 'communicative reminder' of the child's presence [59, 93].

Despite the perceived social benefits of telepresence, challenges remain in facilitating seamless interactions between remote students and those in the classroom, with issues in initiating conversations and navigating the robots [14, 29, 83]. To improve the user's experience, studies suggested implementing speed control to prevent collisions [4], enhancing autonomy [92], enabling access to educational materials directly [57], improving battery life [46], improving sound localization for better communication [14, 70, 82], simplifying the navigation interface and the incorporation of private communication channels [14], and personalizing the telepresence robot for a more human-like feel [2, 14, 24, 93]. Furthermore, researchers called for addressing technical challenges like connectivity and system setup, advocating for a partnership between robot designers and educational institutions to ensure effective integration and support [24, 57].

Despite enthusiasm for telepresence robots [28, 46, 84, 93], there is a need for educational institutions to adapt their infrastructures to fully leverage this technology [23, 93].

2.2 Telepresence and Wayfinding

Many HCI studies have explored the intricacies of wayfinding, examining spatial complexity [85] and spatial knowledge, specifically emphasizing landmarks [20, 33, 37, 60, 65, 90], maps [16, 37, 64], and path representation [25]. Nevertheless, a common trend among these investigations is the reliance on adult participants, leaving a discernible gap in the scholarly literature related to children. Notably, Nys et al. [60] and Jansen-Osmann and Fuchs [37] incorporate children into their research, underscoring disparities in their visuo-spatial abilities, orientation behaviors, and wayfinding performances when compared to adults. Their findings demonstrate that both landmark and route knowledge increase with age [16, 37], with Jansen-Osmann and Fuchs [37]'s highlighting propensities of younger children to orient themselves more at route starting points and turn around more frequently than adults. However, similar to other studies in the field, these two studies are situated within the context of complex virtual environments rather than mobile robotic telepresence. This highlights the need for further exploration of telepresence specifically within the domain of children's wayfinding.

2.3 Object Finding and Attention with Telepresence

Several studies have been conducted to better understand the process of object finding in both physical [6, 17, 30, 32, 85] and virtual environments [17, 18, 67], with Heshmat et al. [32] standing out for their use of mobile telepresence technology in locating physical objects within outdoor geocache activities. Their investigation underscores the importance of physical embodiment in navigation and creating a sense of social presence, but also illuminates the myriad challenges inherent in navigating outdoor spaces using telepresence technology, such as limited environmental awareness and the difficulties of managing different surfaces, including uneven pavements [32]. User experiences may be inherently limited by telepresence affordances such as blind spots and misinterpretations [43]. This directly affects the usability of telepresence robots, as it relies on the quality of video streaming or "eyesight" [89], influenced by variables such as the camera, network connection, and image processing algorithms. HCI scholars are also exploring how perception and cognitive load affect user performance in handling information transmitted by telepresence systems [39, 53]. According to Sweller [88]'s Cognitive Load Theory, humans can process only a limited amount of information at a time due to attention and memory constraints. Similar to this is Posner [68]'s Spotlight Theory, which suggests that attention functions like a beam or a moving spotlight, focusing on specific stimuli while excluding others, which is an important aspect to consider given Velinov et al. [91] 's review on telepresence robots that found the driving interface of the robot to be distracting within the context of learning within the classroom. Considering cognitive demands and spotlight theory, such distractions may detract from the primary purpose of telepresence robots in education. In HRI literature, McNeese et al. [54] and Keidar et al. [39] argue that robots often overload humans with information, ultimately negatively affecting the robotic interaction experience [50]. Thus, the degree of familiarity with the driving interface, which may be an effect of previous exposure to digital technologies [45], is a factor to consider. Consequently, many are advocating for telepresence automation [43, 63] to enhance usability by reducing the operational burden on users. A collaborative effort, which introduces a collective working memory that reduces the cognitive load on the driver [40, 41], also aids with the usability. However, a significant oversight lies in the absence of a comprehensive account of the information processing through the object-finding process itself. Equally notable is the lack of narrative regarding users' subjective experiences when engaging with telepresence technology during these object-finding tasks. These gaps in the literature emphasize the need for further research to explore the cognitive and experiential dimensions of utilizing telepresence technologies in object-finding activities.

3 METHODS

Our study was conducted during a one-day MESS workshop [34] comprising of many different activities, an outreach program designed to engage children aged 9 to 11 in Science, Technology, Engineering, and Mathematics (STEM) at the University of Central Lancashire (UCLan). MESS days provide six or seven activities for children and children move around the activities during the day in small groups in a roundtable fashion. We had ethics approval at both universities (#STEMH291 & #REC1766) and consent from children's guardians prior to MESS days and actively sought assent from the children on the workshop day. The children came to the University for the MESS day with their school teachers. Our paper relates to a single activity, within the MESS day, in which children, in groups of 2 or 3, used GoBe telepresence robots and learned about the rules and techniques necessary for driving and operating them. Led by the project's research leader, who acted as the teacher, the study pursued two main aims through observation, questionnaire, and participatory design: first, to explore children's behaviors and perceptions of driving GoBe telepresence robots; and second, to examine potential gender differences in robot driving.

3.1 Participants

Across several 20-25 minute sessions, eight children aged 9 to 11 drove the robots. We asked these children to self describe their gender - "What is your gender?" and provided three choices as a response: boy, girl or prefer not to say. Our question adopts best practices for surveying gender in HCI [86] and engages with discourse around identity and participatory research with children

[10], thus encouraging a deeper reflection on “lived bodily experiences” [96] and “promote(ing) attentiveness toward the fluidity of gender” [86, p. 63].

Given several members of our team’s positionalities as trans and queer individuals, from our own lived experience we recognized how traumatic forcing children into a binary male/female gender can be. This decision is further supported by concerns about necropolitics and the erasure of transpeople in science [31, 52], as well as literature demonstrating that trans children who are supported in their gender identity have better mental health outcomes [62] relative to those that are not supported [74]. Finally, we confirmed the appropriateness of this approach by building on established best practices for ethics in HCI research with children [26, 71]. Ultimately, we believe this was a child-appropriate question that mitigated harm. Overall, three stated their gender as boys and five as girls. Another 14 children participated in the treasure hunt and participatory design activities without driving; however, gender information on these observers was not collected due to our research focus.

Children logged into the GoBe server from the University of Central Lancashire to drive a robot located 225 miles away at the UCL (London). Children could choose from three robots: Emmet, Wildstyle, and UniKitty, named after the LEGO Movie Characters (see Figure 1). While we had initially hoped to see if these avatars impacted selection, in practice, on the day, children selected whichever robot was working at the time (see later discussion).

Figure 1: LEGO Minifigures for UniKitty, Emmett, and Wyldstyle (left to right).

We provided the children with a brief demo of how to drive the robot and we distributed a safety handout that advised them to:

(1) Look where you are going! Look at the screen when driving, not your friends in the classroom.
(2) Try not to hit people or things. Robots are expensive and a bit wobbly. If you hit something small by accident, it will not break the robot. Just be careful.
(3) Drive slowly. Keep the speed on slow, as you are a new driver.
(4) Stay away from stairs!
(5) Put the robot back on the charging dock when done. Hit “P” or use the onscreen buttons when nearby to Park.

Note that, given safety concerns, the testing area was stair-free. The nearest stairs were behind two separate sets of double doors. Regardless, as stairs represent the most significant safety risk for the robots that the children were driving, we felt it important to warn them about this in case they encounter telepresence robots in the future. Children’s driving was always supervised by an adult on both ends of the call. The children navigated their robot from the first author’s office to a colleague’s office and then back, completing three activities within about 20 minutes. As we were working with children who expect help from their teachers, we provided encouragement when they encountered driving difficulties, and if they were obviously struggling, we gave them a reminder that they could back up the robot which tended to help. All children resolved their driving issues independently, except for one driver who required assistance after becoming stuck in the corner by a bookshelf.

3.2 Apparatus: The GoBe Robot

As mentioned in Section 2.1, a number of telepresence robots have been introduced to classrooms such as Double 3, TEMI, Gobe, and Ohmni. Double 3 by Double Robotics features a self-balancing, two-wheeled base for smooth navigation and flexible height adjustment. Double 3 has an array of 3 seniors to understand its environment, enabling it to navigate safely and avoid obstacles [21]. TEMI by Robotemi combines advanced Al capabilities for smart assistants, which allow it to recognize and follow users and provide voice-activated commands [81]. Ohmni by OhmniLabs features a foldable, three-wheeled base for easy transportation and setup [61].

Figure 2: GoBe Telepresence Robots, ©Blue Ocean Robotics

In this study, we used the GoBe telepresence robots by Blue Ocean Robotics [75] (see Figure 2), share some common features of other telepresence robots but offer the most comprehensive camera system with multiple cameras. The robot features three cameras: a 180° Ultra Wide Full HD camera, a 360° Full HD camera for floor views, and a 4K Superzoom camera, a feature that was not activated during the study. For audio communication, the GoBe robot is equipped with microphones and speakers. Its audio system includes a 4x4W omni-directional speaker with echo and noise-cancellation functions. For mobility and remote control, it includes four wheels, cursor control, and sensors to assist the drivers. This design allows users to interact with their environment remotely, fostering physical presence for long-distance social interactions.

Our study specifically examined the GoBe telepresence robots' high-definition video capabilities to support immersive activities like treasure hunts. The primary reason they were chosen though was a pragmatic one, as of the commonly used robots these were the only ones that were human sized and large enough to push open the fire doors that were omnipresent in our building.

These robots were purchased from GoBe, and while we have an ongoing service plan contract for support from them, GoBe are not our partners, so there are no conflicts of interest.

3.3 Procedure

At UCL, our data were collected by a team comprising one faculty member and two graduate students. This team was responsible for delivering safety driving instructions to the students, facilitating the activities, and recording observational ethnographic-style field notes [76]. Data from the site where the children were (UCLan) was gathered by the sixth author who interacted with the children and facilitated the log on to the driving interface for them. The study involved three main activities: the obstacle course, treasure hunt, and parking task. The remaining authors participated in the study design, the write up and the analysis.

- Obstacle Course: Children logged in and drove the telepresence robot through a short obstacle course between two offices (see Figure 3). First, they navigated a sharp right-hand turn at a doorway. Then, they moved down the hallway, and finally, made a right turn into the second office. The inside and outside of doors were marked with cones to help visualize the obstacle. In the second office, children maneuvered the robot through three pairs of offset cones, requiring slaloming around furniture. At the end of the office, they were encouraged to use the robot to push a small diameter ball through a pair of cones representing a goal. They then returned to the first office as they needed to park; however, this time, as they navigated down the hallway, they were asked to weave through a slalom course of 3 cones. Once inside the first office, they then went through two more pairs of cones. Finally, they were asked to cross a finish line. To ensure safety, children were instructed to drive the course at the robot's minimum speed. We recorded their task completion time and the number of cones hit. We asked children their opinion of whether they were able to stay on course with the choices of "Yes", "No" and "Mostly", with an opportunity to fill in a blank to explain. Finally, we asked the children to tell us how many cones they hit.
- Treasure Hunt: In this activity, the children were tasked to "Help Wyldstyle, Emmet, and Unikitty find their LEGO animal friends!" They navigated freely between the two spaces, searching for images of 10 LEGO Minifigures dressed in animal costumes (see Table 3). Unlike the actual minifigures, which were too small to visualize, we used printed pictures: six measured 4" square and four were 6" tall, with the notably taller giraffe included in the 6" category. Both drivers and observers logged figures as the robot moved through the course. Four minifigure images were located in the first office (including two large ones), two smaller ones were in the hallway, and the remaining four were in the 2nd office (including two large ones). See figure 3 for a diagram of placement. These images were covered during the obstacle course, and only revealed during the treasure hunt. No prizes were awarded, as it was expected many children would successfully locate all minifigures.
- Parking: Finally, the children were instructed to park their robot at its recharging dock. They drove the robot toward the dock and faced it. When the robot came within a foot or two of the dock, an onscreen prompt told the children they could press-and-hold P to park, or press an onscreen "park" button. The robot would then automatically turn around, and back up into the charging dock. The robot would need to depress the bar in the back of the docking station to complete the circuit to allow it to charge. Prior to the study, we re-calibrated the LiDAR to make this task easier. However, we observed often the robot lacked adequate momentum to press the charging bar backward far enough, such that users would leave the robot in the right general area, often leaving it improperly positioned for charging. If children could not charge the robots themselves, this would represent significant extra overhead for teachers.

Following the activities, post-test feedback from the children was collected using two printed questionnaires, an effective format for this age group as suggested by Read and MacFarlane [72]. The post-test comprised five questions with the first three employing a smileyometer from Read and MacFarlane [72]'s publication. The three questions were:

- Was driving the robot hard? (Very Hard, Hard, Okay, Easy, Very Easy)
- Was parking the robot hard? (Very Hard, Hard, Okay, Easy, Very Easy)
- Was using the robot fun? (Very Dull, Dull, Okay, Fun, Very Fun)

Efforts were made to ensure the terms of the 5-point Likert scale were balanced and the middle item was neutral.

In the spirit of participatory design, we wanted to explore children's vision for classroom uses of telepresence robots, so we asked:

- What would you like to use a robot for at school?
- If you could play a game with the robot, how would the game work?

The instructions then read, "Draw pictures if it helps!" Children were given up to ten minutes to complete the questionnaire.

In total, 22 questionnaires were collected from children (drivers and observers), and 21 pages of fieldnotes were jointly generated for qualitative insights.

3.4 Data Analysis

We employed inductive thematic analysis [7, 8, 11] to analyze field notes (between the first, second, fourth and fifth authors). Ten meetings were held (once a week) to discuss codes and interim results, ensuring transparency and quality in the qualitative coding process. Eighty-four codes were generated in the open coding stage, focusing on areas such as object finding, navigation, safety, gender presentation and perception, best practices for teaching with telepresence, and children's visions of the future of telepresence.

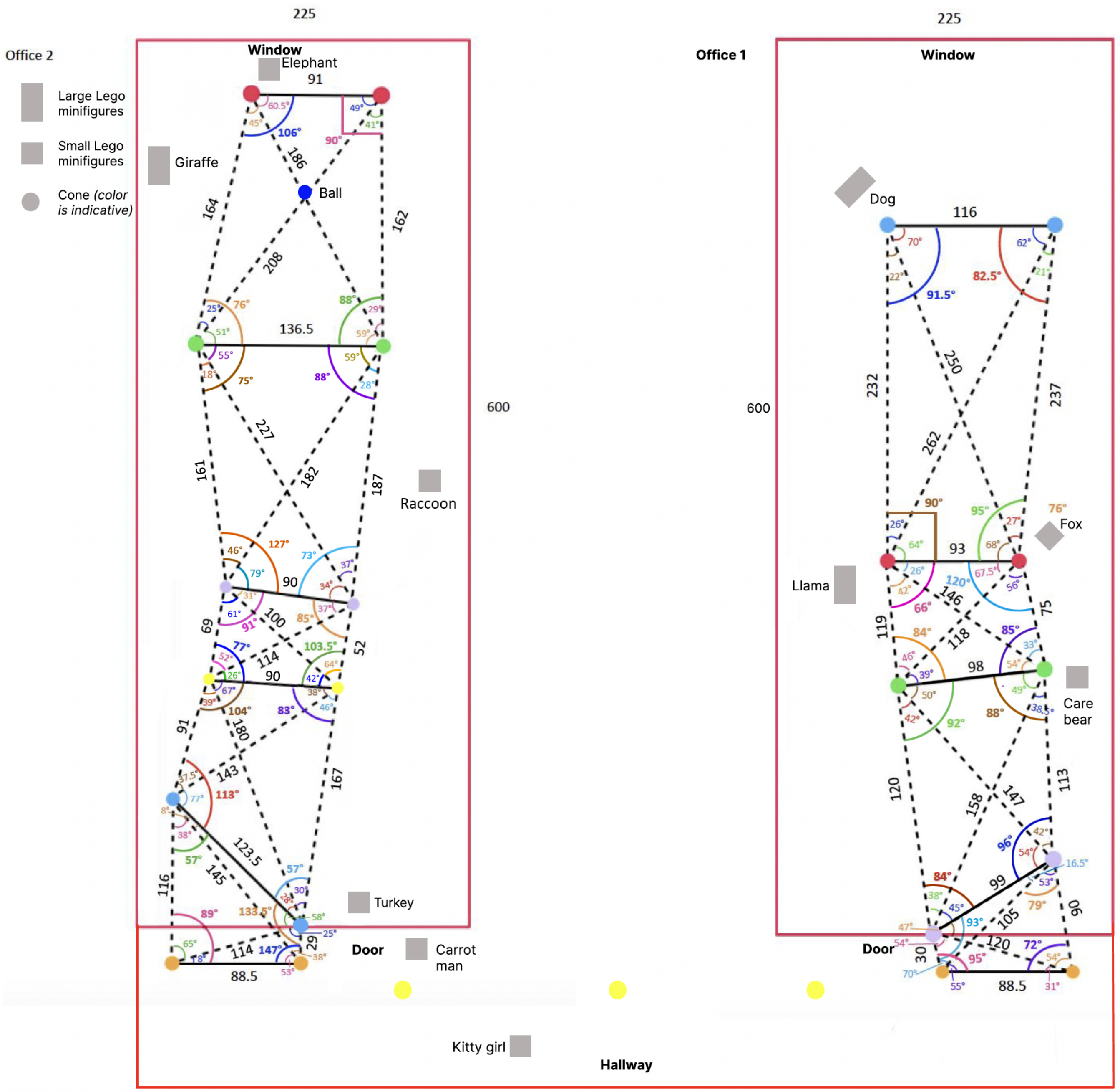

Figure 3: Obstacle Course and Treasure Hunt Design. Note that figure is not to scale, but measurements and angles, written on the diagram, are accurate.

These were aggregated into 7 themes, which we use to present our analysis. These aggregated themes, such as "gender differences in confidence on problem-solving" and "behaviors toward figure sizes" were chosen as the focus for this paper.

Descriptive statistical analysis was performed on the post-test questionnaires. Questionnaire items from both drivers and observers were averaged to provide an overview of children's perceptions and attitudes towards their experience with GoBe telepresence robots. Additionally, we utilized inferential statistical analysis, including Chi-squared of Independence, Mann-Whitney U, and Student t-tests to examine the significance of differences between groups on measures of task performance. The p-values associated with these tests were interpreted to determine the statistical significance of the findings, with values below a predetermined threshold (P<.05) indicating significant results. This quantitative analysis complemented the qualitative findings, offering a comprehensive understanding of participants' experiences and perspectives. We acknowledged that our statistical analysis was based on a relatively small sample size. Reflecting this limitation, we primarily focus on qualitative findings especially when exploring gender-specific experiences of the GoBe telepresence robots.

4 RESULTS AND DISCUSSION

We discuss our findings in detail from activities designed to simulate robot operation in schools, including an obstacle course, treasure hunt, and parking. In sum, our study shows that children were able to navigate obstacles without colliding with people, although they struggled in cluttered spaces. Further, children were capable of driving robots and locating objects simultaneously through collaborative working. Moreover, we found that positive reinforcement effectively addressed action mistakes and improved children's operation performance. However, parking and unstable internet connection posed a significant challenge. Our post-test data suggest that children lacked a deep understanding of telepresence robots and would benefit from more nuanced training by educators to enhance their use.

4.1 Connecting

Despite GoBe being a commercially available product, only 9 out of 16 connection attempts by children were successful. Children often had to try multiple times to connect and switch robots, ultimately having to connect to any available robot instead of their preferred choice. We believe this issue stemmed from network incompatibilities between the UCL and GoBe, which are resolvable going forward, but schools should be mindful that onboarding regarding networks is non-trivial. Blue Ocean Robotics has acknowledged the networking challenges and assured us that the quality of the solution has greatly improved recently. They state that initial setup and support for similar issues are integral to their service package. As researchers, we report this assertion to provide a comprehensive view, maintaining our neutrality regarding these claims.

4.2 Wayfinding: the Obstacle Course

Children performed well on the obstacle course. Of primary importance is that, despite the tight spaces, the children did not hit the three facilitators with the robots — this had been a significant concern for our university's health and safety representatives regarding handling heavy object and equipment operation [49].

All drivers successfully completed the obstacle course. Completion times ranged from 2 to 7 minutes, with a mean of 4 minutes and a standard deviation of 74 seconds (see Table 1). A t-test showed no significant effect for gender ($t(6) = -1.005$, $p = .353$); we caveat this with the fact that this was a very small sample.

While all drivers completed the course, many children hit cones while driving (see Table 2). Drivers hit between 0 and 6 cones, with an average of 1.74 cones hit and a standard deviation of 1.74. Of the 23 cones hit, most were struck after sharp turns: 3 cones were hit leaving the first doorway (sharp right turn), 7 at the Goal (u-turn), and 5 at the 1st slalom cone (sharp left turn). Proportionally fewer cones were hit when course corrections required turns of less than 90°, indicating that children struggled more with significant turns than with minor adjustments. We conducted a Mann-Whitney U test (with the caveat that this is a very small sample) which showed no significant effect for gender ($Z(8)$ = -0.604, p = .546) on the number of cones hit.

Table 1: Task Time and Number of Cones Hit by Drivers

Participants	Gender	Task Completion Time (seconds)	Cone Hit Counts
1A	Male	225.9	3
3A	Female	419.5	6
5A	Male	217.6	1
6A	Female	190.8	2
7A	Male	178.9	2
9A	Female	277.8	0
11A	Female	182.5	3
12A	Female	257.6	4

As well as hitting cones, some children collided with other objects in the rooms. Three students hit chairs, but in these instances the drivers were able to reverse and disentangle the robot from the chair, albeit with some difficulty. One participant ended up in the corner behind the goal and wedged the GoBe robot between a wall and a bookshelf. As they could not figure out how to reverse out of the corner, this required the PI to lift the 45 kg / 99.2 lb robot to free it. These incidents indicate that the clutter of a school classroom, like bookbags and coats, could pose a wide range of challenges for children. Our observations also suggest that children found it difficult to maneuver the robot in reverse. When facilitator intervention was required, the robot's weight proved to be a significant hurdle. Nonetheless, all children successfully managed to propel the ball through the goal, demonstrating the robot's potential for playful activities like robot football.

In sum, children adeptly navigated an obstacle course using telepresence robots. There were no collisions with people or damage caused, addressing initial health and safety concerns. Although children encountered challenges with spatial navigation, particularly in cluttered spaces, there were no significant gender differences in performance.

4.3 Object Finding and Attention: the Treasure Hunt

Our participants each found between six and nine of the ten objects, with an average of 7.64 objects found. We observed no significant difference between reports from drivers and observers, suggesting there were no attentional disparities. This is promising, especially considering a potential application of robots in museum field trips, where typically one person drives and several others observe. Our data suggest that children who are presented with a less novel task of watching another student drive are still able to participate in tasks in a virtual world, which has promising educational possibilities.

Table 2: Number of Cones Hit by Location

Participants	Hallway *(slalom, 3 turns)*	Goal Post *(180° turn)*	Office 1 Orange *(narrow, 90° turn)*	Office 2 Blue *(45° turn)*	Office 2 Purple *(narrow)*	Office 2 Yellow *(narrow)*	Total
1A	1	2	0	0	0	0	3
3A	1	2	0	1	1	1	6
5A	0	0	0	0	1	0	1
6A	0	1	1	0	0	0	2
7A	1	1	0	0	0	0	2
9A	0	0	0	0	0	0	0
11A	1	1	1	0	0	0	3
12A	3	0	1	0	0	0	4
Total	7	7	3	1	2	1	21

Behaviors toward figure sizes. We had two sizes of figures, and both drivers and observers showed similar rates of finding small and large figures. Drivers found 70.83% of the small figures and 84.38% of the larger ones. Observers found 76.19% of the small figures and 76.79% of the large figures. The difference between small and large figures found by the drivers is not statistically significant with which it was found ($\chi^2(1, N = 141) = 0.113$, $p = .737$). While we recognize our sample size is quite small, our findings align with Heshmat et al. [32], who also reported no differences based on object size.

Our qualitative data further supports this conclusion, showing that participants tended to physically *"move in closer"* during inspections about 18.75% of the time, regardless of figure size. Each of the 8 drivers was exposed to 6 small figures and 4 large figures. Of the 48 instances with small images, the "moving in closer" behavior occurred 9 times, (by 1A, 6A, 9A, 11A, & 12A). Similar behavior was seen when looking for the large figures, and out of 32 instances, participants (1A, 5A, 6A, 7A & 9A) moved closer 6 times. These findings establish that this behavior is not exclusive to images of a particular size. It is possible that the GoBe camera's ability to capture fine details or potential network issues influenced participants' behavior. GoBe's planned zoom-able camera upgrade may address this usability issue, but future work is required to investigate that alongside the impact of bandwidth and image processing algorithms on video quality [89]. These results underscore the crucial role of teachers in instructing children on how to effectively utilize the features of the robots.

Driving patterns and discovery frequency. There was no significant association between the size of the figure and the frequency with which it was found ($\chi^2(1, N = 80) = 1.944$, $p = .163$). However, there was a significant association between the location of the figure and the frequency with which it was found ($\chi^2(2, N = 80) = 20.293$, $p < .001$). The objects that were found less often tended to be in the first room, regardless of size. For instance, the object most commonly missed was the Fox (S): this was attached to a plaque on the right-hand side of the room, just before the finish line, and was only seen by 2/8 drivers and 4/14 observers. The other most commonly missed items were also in the first office (bear (S), 10/22; llama (L), 14/22; dog (L), 13/22), whereas the most commonly found items were all in the second office (elephant (S), raccoon (S), giraffe (L) — all found by 100% of participants). The open question is whether this was caused by the study design or is a behavior related finding.

In exploring this, it is necessary to understand the operation of the task. First, the two rooms differed in their clutter. The first office was cluttered and visually dense with books and hardware, whereas the second office only contained a desk and furniture as its occupant had moved out. Secondly, the time spent in the two rooms and the views were not equal. Students began in the first room, turned left out of it, drove into the second room, turned 180°, and then drove out of that towards the first room again. As the treasure hunt task was limited to ten minutes, only two of the participants managed to drive back into the first room. This meant they all saw the walls of the second room twice, and from two different perspectives, but that 6/8 (3A, 5A, 6A, 9A, 11A, 12A) of the participants ran out of time before reaching their end point in room one. Thus, these children did not see the first office from both directions or varied angles. It is also important to look at the extent to which children used the robot to look around. While it is true children could have rotated the robot freely in either room, only three (6A, 9A, and 11A) rotated the robot 360° when searching. 6A rotated in the first room, 9A right before leaving the second room after being prompted by her friend, and 11A upon returning to the hallway. Thus most children did not create a full mental map of the space, and only one driver rotated in the first office; this contributed to an impoverished awareness of that space.

Cognitive demands of navigation and object finding. Our qualitative data also shed light on the cognitive demands of navigating telepresence robots and locating objects as explained by Sweller [88]. This may help explain why more figures were found in the second office, which was largely empty, compared to the first office, which was cluttered and presented more challenges. Additionally, during the treasure hunt activity, drivers had to both focus on operating and navigating the robot and identifying minifigures. The majority (5/8) of our participants encountered difficulties with navigation while looking for objects: for instance, 9A and 11A stopped moving abruptly, and their groups exploded into *"frantic whispering and giggles"* of *"What happened? Why can't I move?"* and *"What did you do?" "I didn't do anything!"* when they accidentally switched off the keyboard driving function. Similarly, when 11A *"hit the right blue cone and bottom shelf"*, she seemed to focus on the navigation camera to correct the error, which led her to miss the dog figurine on the main camera. On the other hand, 7A was so focused on the main camera (in order to identify raccoon (S)) that he did not realize he was grazing the base of the robot on a chair. This is in

Table 3: Found Figures

	Minifigure	Driver	Observer	Total Found	Size	Room	When	Angle to Path	Description of Location
	Llama	75%	57.1%	63.6%	Large	Office 1	On Approach	Perpendicular	Whiteboard
	Kitty Girl	100%	92.9%	95.5%	Large	Hallway	On Approach	Perpendicular	Wall
	Carrot Man	87.5%	92.9%	90.9%	Small	Hallway	On Approach	Perpendicular	Bulletin board
	Raccoon	100%	100%	100%	Small	Office 2	On Approach	Perpendicular	Partially obscured, under shelf
	Giraffe	100%	100%	100%	Large	Office 2	On Approach	Perpendicular	Computer monitor
	Elephant	100%	100%	100%	Small	Office 2	On Approach	Straight on	On column
	Turkey	75%	85.7%	81.8%	Small	Office 2	On exit, having rotated	Straight On	Wall by door
	Bear	37.5%	50%	45.5%	Small	Office 1	On re-entering room	Straight On	On screen of Beam+ robot
	Fox	25%	28.6%	27.3%	Small	Office 1	On re-entering room	45°	On award plaque
	Dog	62.5%	57.1%	59.1%	Large	Office 1	On re-entering room	45 °	Computer monitor

keeping with the discussion around attention and spotlight effect where people focus only on visual information pertinent to the task at hand. This finding is consistent with Velinov et al. [91] who found the driving interface of telepresence robots to be distracting, highlighting the struggle of simultaneously operating the robots while observing two separate camera feeds.

As well as the explanation over the limited time in office one, we posit that this attention and spotlight effect likely influenced object discovery. In the second office we saw 5/8 participants found the turkey (S) image — which was next to the door on the inside wall of room 2 - primarily *"on their way out"* of office 2. Our ethnographers noted this *"indicated that (participants) did not look to the side of the door upon entering office 2"*. Spotlight attention could also explain why the bear (S) was rarely found: it was placed on a parked robot that was facing the exit of room 1, so would have been most easily seen when re-entering the room, which only two groups did. Participants such as 1A and 7A, who noticed the bear (S), only did so upon entering room 1. We have data that suggests children would have seen the bear if had they had more time. For instance, 6A, whose time ran out as soon as she reached the door of room 1, *"let out a disappointed expression and said, "Awh! I see something there though!"*. Similarly, 9A *"seemed to notice the bear the moment she entered but the <university> facilitator said her time has run out. She let out a disappointed sound."* Thus, it is unclear if the study design or object placement were the primary factor for unfound objects. While future work could investigate these nuances, the key take-away is that objects viewed from multiple angles were more likely to be found.

Furthermore, the cognitive stressors of handling different types of stimuli while driving the robot placed an additional burden on our participants' working memory. In the context of driving the robot and searching for images, participants are mainly engaged in visual processing to navigate and locate; however, when additional auditory stimuli are introduced, it may divert cognitive resources [41] away from the visual task. Just like how driving difficulties can spotlight attention on the driving and not the treasure hunt, conversations can too. For instance, our ethnographers noted a similarity between 9A and 11A, who both did not find anything in room 1 and *"drove straight out of the office"*. 9A and her friends were *"actively talking and might have gotten too distracted"*. Similarly, 11A *"shared the screen (navigation) with her friend"* and engaged in *"subtle conversations"* in room 1. Perhaps the presence of auditory stimuli may have temporarily distracted the drivers' attention from thoroughly searching room 1. Additionally, sharing the screen with another person potentially requires attention to navigation or coordination. These findings are reminiscent of Heshmat et al. [32] who observed distracted participants driving off sidewalks or accidentally heading to areas with people who had previously asked for privacy. Our participants likely experienced a similar division of cognitive resources, highlighting the real challenges for children to balance controlling the robot, maintaining communication with their group, and actively searching for objects in the physical location.

Impact of collaborative efforts. Having other people help out with the object finding task was one way of distributing the cognitive demands of navigating and object-finding as we frequently heard calls of aid from other non-driving observers. For instance, 5A almost overlooked turkey (S), but one observer interrupted his driving by saying *"Wait, there's something there!"*, prompting 5A to find the image. 6A was also in the middle of rotating around the first room, when one of the observers *"could be heard saying "Look there!" and pointed to the direction of Fox (S)"*. This highlights a collaborative effort that introduces a collective working memory [40, 41] — the non-driving participants can assist in object detection when the driver's attention is focused on navigation, leading to more figures found. Overall, these findings underscore the collaborative strategies employed by several participants to overcome the cognitive demands of simultaneously navigating and object-finding, and thus enhance their performance in the task.

Ultimately, our data showed children were able to drive and find objects simultaneously, demonstrating the feasibility of this technology for educational purposes. However, teachers' guidance may be pivotal in helping children effectively utilize it. The observing children also showed engagement with tasks even when not driving themselves., highlighting the potential of telepresence as a collaborative educational tool. Additional research is required to understand collaboration, spatial mapping, and cognitive load among children and telepresence robots.

4.4 Parking

A key finding of this study is that the parking feature for the GoBe robot was not functioning at an acceptable level to be usable in the classroom. The feature was intuitive: all eight drivers approached the dock and pressed the P key on the keyboard. Only one child attempted to park using the onscreen interface. Of our eight participants, only 2 were able to park on their first try (5A, 6A), One participant succeeded after switching to the onscreen UI (11A), one participant (one of our best drivers) succeeded in reversing the robot onto the charger and engaging the docking clamp after auto-parking failed (1A), and the other 4 children were unable to dock the robot (3A, 7A, 9A, 12A). Thus, three quarters of of our children were unable to automatically dock, and given we can not assume children will be good enough drivers to dock manually, if this were a busy classroom environment it is reasonable to expect the robots would be left off the charger. At 45 kg / 99.2 lbs, these robots are heavy and difficult to dock by hand, and teachers are likely to be too busy to do so. Robots left off the dock would be expensive and unusable technology in the classroom. However, we note that Blue Ocean Robotics internal reports also highlighted the confusion between the onscreen interface and keyboard shortcuts. As a result, the option to press and hold 'P' has been discarded in newer updates, indicating a proactive approach towards addressing user experience issues. We have observed improvements in parking, but we acknowledge this was not part of formal data collection.

4.5 Post-test Data

On the post test, we asked drivers and their classmates about their perceptions of driving the robots. Generally, children's opinions of the robots were positive. When asked whether driving the robots was hard or easy on a five point Likert scale, drivers responded on average 3.75 (between okay and easy), and classmates responded on average 3.63. These scores were brought down by group 9, who perceived the whole effort as either hard (driver) or very hard (classmates). When asked if parking the robots was hard or easy on a five point Likert scale, drivers responded on average 3.75 (between okay and easy), and classmates responded on average 3.19. Finally, we asked children about their perception of whether using the telepresence robots was fun. Drivers had a very good experience, rating this 4.88 (between fun and very fun), whereas classmates rated it 4.71. Overall the robots were perceived as being fun and not too difficult to drive; however, negative experiences by groups that were unable to park impacted these experiences. The number of male participants was too small to make a Mann-Whitney U test of differences in perception by gender viable. The median scores did not show any large discrepancies, however. ("Was driving the robots hard?" M = 3, F = 4; "Was parking the robots hard?" M=4, F=4; "Was using the robots fun?" M=5, F=5.).

We asked the children to describe their vision of the future of telepresence robots both at school and at play. The data was limited, with about half the children electing to skip both questions. No children drew pictures despite our invitation.

Our young participants primarily envision telepresence robots serving two roles in schools: providing logistical and administrative support, and enhancing learning experiences. In the details given here, it should be noted that children with an A suffix were drivers and those with B and C suffices were observers in the related groups; thus all participants with, for example a code starting with 4, were in group 4. Students imagined these robots performing logistical and support tasks such as distributing textbooks (3A), aiding in the search for objects or people (6A, 6B, 6C, 7A, 7C, 9C), executing office tasks (5B, 5C), marking assignments (3C). From their viewpoint, robots could take over routine tasks currently managed by teachers, thereby freeing up teachers to focus more on instructional activities in the classroom. However, the envisioned roles often reflected traditional support functions typically carried out by humans, possibly due to a lack of awareness of the technology's limitations, such as the absence of a robotic arm capable of performing certain tasks. This observation indicates a need for further guidance to help students to understand the capability of such technology rooted in its physical design. Students also envisaged telepresence robots enriching the learning experience in class, supporting academic engagement from any location without the need for physical interaction (3C), and aiding in the delivery of science classes (3B). These applications highlight students' appreciation of the advanced telecommunication capabilities of telepresence robots, offering co-located physical interaction opportunities that surpass those of traditional screen-based video conferencing technologies.

In our inquiry into how students would engage with robots in game-play, 7 out of 22 participants (note that only 8 students responded to this question)—expressed interest in involving robots in active physical games, such as hide and seek or football. Additionally, three children envisioned engaging with robots in obstacle courses, as they had experienced during this study. This indicates a desire for robots to serve not only as companions in play but also as navigational aids, potentially offering a simulated vehicle driving experience that is both fun and exciting for children. However, this data might also suggest a level of uncertainty among the children about the full scope of possibilities for using this technology. While open-ended tasks in children's participatory design (PD) regarding potential uses of robots have often led to creative applications, the responses here seem to hint at a narrower vision. For example, activities such as hide and seek (11C), football (3A), and obstacle courses (9C, 11A, 11B) suggested by children were not only experimental tasks assigned to participants (e.g., ball kicking and treasure hunt) but were also potentially influenced by the children's direct experiences in school. This observation underscores the importance of guiding children through the envisioning exercise in order to encourage broader ideas about how robots can be integrated into play and learning scenarios beyond what they just experienced during the workshop time. Our data suggests a gap in the children's understanding of telepresence robot design, affordances, and technical potentials. Overall we would argue this data suggests that children were uncertain about how this technology could be used. While other open ended participatory design tasks involving children have resulted in creative ideas, our data suggests that when presented with the logistical practicalities of a real robot, children have a much less clear vision.

In summary, our study identified initial connectivity challenges with telepresence robots, but once resolved, children navigated them proficiently despite difficulties with sharp turns and tight spaces. During the treasure hunt, they effectively located objects, especially in less cluttered areas, highlighting the impact of attention and environment. Parking proved challenging, requiring assistance for most children. Gender differences emerged in navigation, with boys adjusting and recovering more quickly than girls. Collaborative efforts helped mitigate these challenges, showing the robots' potential to enhance cooperative learning.

5 FURTHER DISCUSSION

Next we will move to the discussion of our findings in relation to gender, building on prior work in HCI and gender. For example, Rode and Poole [79] identify gendered archetypes that influence technological self-efficacy and ability in digital housekeeping. Ricci [73] and Chang et al. [15] investigate the means by which telepresence robots can physically represent their users and the impact that self-representation has on perceptions of user authority. Beckwith et al. [5] explore gender differences in tinkering, finding that males tinker more than females, though females' tinkering is more productive to their effectiveness in debugging. In relation to our designed activities, several prior works highlight gender-specific variations in wayfinding performance [20, 44, 85] and preferences [16, 33]. For instance, Cutmore et al. [20] observed that men tend to acquire route knowledge from landmarks more rapidly than women, while Lawton [44] noted that women are more inclined to utilize route strategies but are also more susceptible to spatial anxiety. However, it is imperative to approach these findings with caution, as Pazzaglia et al. [65]'s study reported no statistically significant differences in gender-related wayfinding performances. However, these studies predominantly involved adult participants navigating complex virtual environments, thereby revealing gaps in the literature pertaining to gender differences in wayfinding performances among children, particularly in the context of telepresence technology.

While our quantitative data was not statically significant regarding gender, our qualitative data captured reactions from children when they made mistakes, such as hitting cones and obstacles, which we can examine for gender differences. It is critical to note that it is considered appropriate to interpret qualitative evidence even with small numbers of participants in HCI [9, 11], and elsewhere Rode [76] has argued that reflexive work makes valid contributions to HCI and needs to be evaluated in terms of its own paradigms and values, rather than positivist values of statistical significance and generalizability. That said, we do not prioritize qualitative insights over quantitative ones in this work. Instead, we aim to emphasize the importance of diverse methods and interpretations for "dialectic information gathering and knowledge production" relating to gender and computing [3, p. 682]. Consequently, we present that data below with the aim of exploring it further in future work both with a larger sample size, and as a starting point for developing theory.

Gender Differences in Confidence in Problem Solving. All drivers demonstrated resilience and continued effort, but while we could show no statistical difference (measured by speed and cone-hitting) between boys and girls in the obstacle course, boys generally showed quicker adaption to telepresence robot use and recovery from mistakes. Girls, on the other hand, displayed reactions ranging from initial hesitancy, resilience, and positive coping mechanisms. Girls demonstrated a consistent ability to continue the task when encouraged. This may suggest different levels of self-efficacy and comfort level with tinkering [5], or it could reflect gender performativity with respect to agency [80]. For instance, our three male participants (1A, 5A, 7A) confidently drove the robots from the beginning of this activity and our ethnographers observed that 1A *"...started driving without much hesitation and displayed good control of the robots"*, 5A *"instantly showed good handling"*, and 7A *"appeared to have good navigational skills"*. All three male participants were observed driving the robots *"without much hesitation"*, suggesting that they were confident in their ability to control the robots This could be a manifestation of their self-efficacy, or it might reflect their belief in their own ability and skills to execute behaviors successfully. When mistakes occurred they were quickly resolved. For instance, 1A misjudged the angle and hit the door-frame when entering office 2; he *"let out a quiet 'uf' but did not show any signs of panicking on his face...simply reversed and rotated to angle himself better and drive into the room"*. His initial confidence and competence in handling the robot underscore a rapid adjustment to the technology. Although he hit the door-frame, he demonstrated his ability to actively influence the robot's movement and direction through his driving skills. The absence of panic and the immediate corrective action (reversing and rotating to adjust course) illustrate that the participant not only recognized the mistake but also knew how to rectify it efficiently. Similarly, 7A brushed the robot's side and display against a bookshelf and red cones while rotating to exit office 2. He did not show panic. Instead, after receiving confirmation from the instructor that he did not damage the robot or the obstacles, he successfully managed to leave the room without hitting anything else. His actions convey resilience and adaptability: his calmness suggests a level of comfort and confidence with the robot, crucial for effective problem-solving and recovery, and he demonstrated his capacity to adjust his approach based on the situation. Lastly, 5A was considered the best driver among our participants, as he did not hit any obstacles during the activity. During the ball-kicking task in office 2, he initially missed the ball but then re-positioned his robot without seeking assistance. Although his second attempt was also unsuccessful, this prompted him to reconsider a better angle and direction needed to drive his robot effectively. 5A successfully kicked the ball into the target on his own after that. This showed a strategic response to failure and a reflective, adaptive problem-solving approach. His immediate and autonomous adjustments indicate a belief in his abilities and perceived control over the situation, facilitating swift adaptation and effective recovery from errors.

Variability Within Gender Responses. Among our five female participants, three (3A, 9A, 11A) exhibited initial hesitancy and carefulness when operating the robots. For instance, 3A appeared *"...a bit hesitant throughout the drive, exiting the first office door with numerous pauses, stops, and minor adjustments,"* and *"pressed the forward button continuously instead of intermittently."* Similarly, 9A *"hesitated and paused several times, often rotating in place to avoid obstacles."* 11A was considered *"a more cautious driver,"* as she tended to drive slowly, and frequently paused to avoid colliding with the door-frame in Office 1. These initial observations indicate that 3A, 9A, and 11A required a period of adjustment, possibly reflecting a lower confidence in their ability to manage the robot effectively. In contrast, the remaining two female participants, 6A and 12A, did not exhibit such hesitancy to start and operate the robots, but quickly made errors (6A collided with the orange cone and 12A moved in the incorrect direction).

When errors occurred for female drivers, recovery was less successful. 3A struggled to exit office 2 due to a door stopper. She attempted to reorient the robot by shifting left and right but failed to find the correct angle to drive out of the office. Although facilitators provided positive feedback and encouragement, this participant *"gave up and drove straight over the cone"* and began to display passive resistance. For example, when she failed to complete the ball-kicking activity, she *"...was still silent and began to look disturbed."* She refused the facilitator's help by neglecting specific instructions, resulting in more mistakes: *"(she) attempted reversing but not turning, and so always kept hitting the bookshelf again...stuck against the wall next to and to the bookshelf, and the lead researcher had to come over and manually rotate the robot to a clear path."* Interestingly, although 9A and 11A were also cautious at first, when they struggled with rotating to enter or exit the room, they actively engaged with the facilitators' encouragement and instructions, then implemented an effective adaptive strategy. This involved taking more pauses to move and calculate the right angles at turns to increase their control over the robot. Our ethnographers did not observe frustration similar to 3A's, but instead observed both of these participants positively seeking solutions to complete the obstacle course tasks.

Proactive vs. Reactive Engagement. The two girls, 6A and 12A, who exhibited a confident approach to driving, encountered similar challenges related to angles and rotation. These challenges arose during tasks that required precise navigation, such the ball-kicking task or maneuvering through the slalom tasks. Both participants adopted a proactive approach, relying on their skills and instincts to navigate. While 12A did not complete the slalom task successfully, hitting more cones in the process, 6A was able to accurately find the angle needed for successful navigation. Despite the differing outcomes, both 6A and 12A demonstrated an ability to leverage their skills and personal judgment as resources to address the navigation issues they faced. For instance, when 6A inadvertently hit a cone while turning sharply, she did not let this setback deter her. Instead, she swiftly adjusted her approach, successfully reorienting and navigating the robot to continue the task, illustrating her proactive and competent handling of the situation. Similarly, although 12A struggled with the slalom tasks and encountered more obstacles, her persistent efforts to adjust her driving strategy reflect a similar proactive approach. This determination and self-reliance set these two apart from the performance exhibited by the other three girls (3A, 9A, 11A), highlighting an intrinsic motivation that allows them to act independently rather than relying on external guidance for solving problems.

To conclude, our observations reveal a contrast in adaptive strategies, as captured by our quantitative analysis: boys typically showed initial confidence and quick recovery from errors, whereas girls exhibited a range of responses from hesitancy to proactive problem-solving. Our qualitative insights align with prior research on gender differences in technology, underscoring the need for gender-sensitive encouragement and instructional support to enhance self-efficacy and tinkering with telepresence robots. However, we acknowledge that our discussion, while valid, is limited by the sample size. We do not claim that our data is generalizable, but it does reveal important areas of concern that necessitate statistically significant future research. Our findings are critical and identify key areas that warrant further exploration.

6 RECOMMENDATIONS

Based on our discussions, we have several recommendations regarding telepresence robots, including both design improvements and ways to integrate them into classroom practices.

6.1 Design Recommendation

Some of the issues our participants encountered around initializing sessions and docking robots have already been addressed by Blue Ocean Robotics through software updates.

Our data suggests children were reasonable drivers, and with practice, we believe they can be safe drivers. However, we recommend three hardware improvements that would make driving easier:

(1) Collaborative Control: Children had trouble making sharp turns, and had a tendency to hit door frames. The vast majority of the time a child will want to go through the door rather than hit it. Consequently, there is significant scope for shared control interfaces so that drivers can be helped by AI to avoid obstacles and accomplish the most likely goals. This collaborative control approach has been successfully demonstrated with robotic wheelchair users [12] and the same technology could easily be applied to telepresence robots in the classroom.
(2) Reverse Alarm: We noticed children hit objects while reversing. While more practice driving and better use of the rear camera will help alleviate these issues, we also recommend an audible proximity alarm when reversing, given the increased risks of using robots around children.
(3) Unlock wheel button: The robots are heavy, and children are likely to forget to dock the robots or could get them stuck in awkward corners. Currently, you can only unlock the wheels by going through several menu screens to choose the UI element, and this is only possible if the UI is facing away from a wall. We recommend a physical 'unlock' button to aid teachers in quickly moving the robot around the classroom. While in business settings this might be less appropriate as the agency of the driver might be primary, in a classroom, the duty of care for a safe and productive learning environment makes this appropriate.

6.2 Classroom Practices

Some of the issues children experienced can be addressed through instruction and classroom management strategies. For example, teachers can instruct new drivers to rotate the robot as they move so that they can build good spatial awareness of their environment. We recommend teachers request other students to push their chairs in and keep bookbags out of the aisles, perhaps by sliding them under their chair, to eliminate obstacles. As discussed by [23, 95], doing so would benefit both robot users and disabled students. Finally, we recommend gender-sensitive encouragement and instructional support to address some of the hesitancy when driving.

7 LIMITATIONS

The limitations of this paper reflect the mixed method approach of this user study. For instance, our work is built on a relatively small sample size. Although this is not considered problematic for ethnographic work [76], we believe that more longitudinal ethnographic research can provide richer qualitative insights and facilitate the development of grounded theories regarding gender and telepresence. Furthermore, by working with more young participants, this approach could help reproduce further research and contribute to statistical significance. Additionally, future work should consider whether the technical issues, such as initializing connections, networking stability, and docking algorithms have impacted user behaviors. Finally, we focused solely on one brand of robot. Future research should explore the differences in the type of articulation work [22, 27, 87] required for different robots. This consideration is crucial to ensure ecological validity, particularly as organizations may obtain robots from a range of manufacturers, akin to "bring your own device" initiatives that introduce a variety of laptop and cellphone brands within institutions.

8 CONCLUSION

In conclusion, our study of the use of GoBe telepresence robots by children in educational settings highlights their potential for enhancing classroom participation and play. A key finding of our study is that children were excited about this and enjoyed driving and observing the robots. The ability of children to safely drive the robots and effectively engage in tasks such as navigating obstacle courses and participating in treasure hunts underscores the viability of telepresence robots in educational environments. However, challenges such as connectivity issues and robot docking underscore the need for robust technical support and enhancements in design to ensure practical deployment in schools.

Moreover, the study gender differences in resilience and problem-solving approaches among drivers, with boys typically recovering quickly from mistakes —a pattern that aligns with previous research on self-efficacy, self-presentation and tinkering. This observation highlights the importance of implementing gender-sensitive encouragement and instructional strategies to effectively support all students.

We believe social changes to the classroom practices, along with small improvements to the mobile telepresence hardware and software would allow for graceful introduction of robots into the classroom. In our future work, we plan to implement these changes to social practices and deploy mobile telepresence robots in the classroom.

Our findings also contribute to the ongoing dialogue within the HCI community about the role of telepresence robots in educational settings. This study provides empirical evidence supporting their potential as an inclusive technology that can facilitate remote participation in classroom activities, thereby offering a foundation fur further research to optimize their design and functionality for educational use. Looking ahead, minor improvements in telepresence robot hardware and software, and adaptations in classroom management practices could better integrate these technologies into educational environments. Moreover, as we plan future work to refine social practices and collaborate on shared control systems, continued collaboration between technologists, educators, and HCI researchers will be crucial in fully realizing the potential of telepresence technologies to enrich educational experiences for all students. Our future work will use larger samples to explore gender effects, will extend robot manipulation to spaces with additional obstacles and will position and explore telepresence robots in real classrooms.

The enthusiastic feedback from children, combined with their successful navigation and task performance, reinforces our conclusion that mobile telepresence robots hold promise as educational tools. They not only foster engagement and learning but also offer safe and enjoyable experiences for children, making them a valuable addition to modern educational technology repertoires. Therefore, we call for continued research and development to fully explore the capabilities of telepresence robots in enhancing educational outcomes and inclusivity.

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