Lessons Learned: Towards Informal Science Education of Human-Robot Interaction at Children's Science Museums

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ABSTRACT

Robots themselves are interesting as museum exhibits and appeal to a wide range of people [9]. However, human-robot interaction (HRI) is more than just robotics. Informal science education about HRI can occur using "hands-on" exhibits deployed at science museums. I discuss some of the lessons learned from the installation of two HRI exhibits: one at the Discovery Museums in Acton, MA, and the other at the Children's Museum of Atlanta in Atlanta, GA.

Keywords

Informal science education (ISE), museum exhibition, child-robot interaction, public understanding of science (PUS)

1. INTRODUCTION & BACKGROUND

Science centers and natural history museums are among the types of organizations that researchers have found to be highly committed to informal science education; that is, ranking equally high with respect to "promoting STEM[1] understanding" and "practicing informal education" [8]. Thus, a number of world-renown and community-based science centers and natural history museums have hosted a variety of robot exhibits. Robots themselves are interesting as exhibits and appeal to a wide range of people [9].

However, HRI is more than just robotics. Consider the roles of the human and robot and the robot's level of autonomy in the following examples [3, 13]. In many exhibits, museum visitors take the role of the operator and the robot assists in completing a task. The St. Louis Science Center hosted three human-robot interaction experiments from 2004 through 2006 in which two-hundred sixteen participants drove Pioneer robots through a maze [4]. The Personal Exploration Rover (PER) exhibit allowed museum visitors to test for "life" in a Mars-scape with a miniature Mars Rover at the Smithonian [11]. Museum visitors might also act as a teammate or peer to a robot, working together to complete a task. The Museum of Science, Boston hosted an HRI study in which museum visitors built a structure with the help of Nexi, an anthropomorphic robot with a human-like upper torso mounted on a Segway base [5].

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[1]STEM: science, technology, engineering, and mathematics

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Museum visitors might directly interact with robots acting as social agents, or sometimes as bystanders with robots existing in the same environment. Robots can be used as greeters and to assist museum visitors with directions [14]. They can also provide educational content for specific exhibits, acting as a docent or program presenter [12, 14].

HRI is a young field, and as it becomes more established as a research domain, it is imperative that HRI is both recognized and understood by the general public. I believe that museum exhibits with HRI content can help achieve this goal while also dispelling science fiction-based beliefs. In the subsequent two sections, I describe two HRI exhibits with which I have been involved. It is worthwhile to note that the two exhibits had very different goals, which directly impacts the ease with which they could be replicated. The Robotics Telepresence exhibit in Section 2 was designed primarily as a user study with the general public. The CopyBot exhibit in Section 3 was designed as a means for educational dissemination. I then discuss some of the lessons learned. I assert that it is imperative to contribute to the online archive ExhibitFiles [2]. I believe that it is necessary to document the details of an HRI exhibit such that the installation could be replicated by others without HRI and/or robotics backgrounds (e.g., museum curators and staff), which include the exhibit's goal(s), the location and length of installation, demographic information about the museum visitors targeted (e.g., age), the exhibit's content (e.g., photos and/or videos taken of the exhibit, posted instructions), and types of quantitative and/or qualitative data collected. Finally, the designer of the exhibit must provide a commentary about the successes of the installation, suggestions for improvement, and an indication about the ease of replication.

2. EXHIBIT #1: TELEPRESENCE ROBOT

In our prior work [15], we developed a social telepresence robot system to allow people with disabilities (cognitive and/or motor) to take the active role of operating the robot. Our augmented reality telepresence user interface focused primarily on supporting human-human interaction and communication through video, while providing appropriate support for semi-autonomous navigation behaviors. We investigated how well our user interface could be understood and used by people outside of our original target population experienced being in "two places at once" using our robot system. The exhibit was hosted by the Science Discovery Museum in Acton, MA, and the purpose of the installation was to conduct a user study over the course of the week-long installation. The museum visitors included families: typically developed adults and their children, who are developing their cognitive abilities. In the study, 62 groups of participants (ages 2.5 to 15 years) took the role of a telepresence robot operator and used a modified VGo robot and custom user interface to explore a mock art gallery (remote from the participant's location).

2.1 A Remote Art Gallery

A number of telepresence robots have been placed in museums, allowing remote visitors to see a given museum from the robot's perspective (e.g., [7]). We built an art gallery with kinetic, interactive exhibits to give users an interesting and reactive environment to explore through a telepresence robot. An adjacent spectator area, called the "peanut gallery," was partitioned using two walls, and seating was provided to view the robot "in action."

Three IR distance sensors were spaced evenly around the front of each exhibit. The area directly in front of each sensor was defined as an exhibit *hotspot*, a place where the user could interact with the exhibit. Exhibits were programmed to react differently when approached from each angle as well as at a close and far distance. The art gallery featured three exhibits,each with unique content and range of movements. "Monkey" featured two monkeys doing somersaults and sit-spins. "Music" featured a xylophone. "Sunflower" featured three dancing sunflowers.

2.2 Robot System: Margo

We designed an augmented reality user interface [15] for the participants to control a customized VGo telepresence robot using a 22in 3M touchscreen. The interface featured a vertical panoramic video feed stitched together using the 3 cameras inside the "hat" (see Figure 1). An animated icon of the robot's base was displayed just below the video feed. The icon was drawn to-scale and positioned accurately with respect to the video, giving perspective to the size and location of the robot's base relative to objects seen in the video. Three "exhibit buttons," each featuring an icon of the exhibit they represented, were arranged below the robot base icon (Figure 1 right). These buttons could be pressed to direct the robot to autonomously move to a different exhibit; the robot would turn away from its current exhibit and drove in an arc towards the selected one.

As the robot moved, a white dotted arrow, originating from the robot base icon, showed the general trajectory. Once the robot arrived at an exhibit, the display showed "hotspots" and "step buttons" that allowed the user to command the robot into a more specific position. The four hotspots represented alternative viewing locations and were drawn in their actual positions relative to the robot base icon and video feed. They appeared as small pulsating circles with arrows showing the direction the robot would be facing from that location. When moving from one hotspot to another, the robot backed up before turning and then moving forward, thus the exhibit always remained in the video. Finally, the step buttons were two opposing cyan triangles drawn over the robot base icon, representing forward and reverse directions. These buttons could be used to nudge the robot a few "steps" forward or backward from each hotspot.

2.3 Exhibit Installation

Our telepresence robot experience was titled "Two Places at Once! A Robot's Eye View," and our program ran from

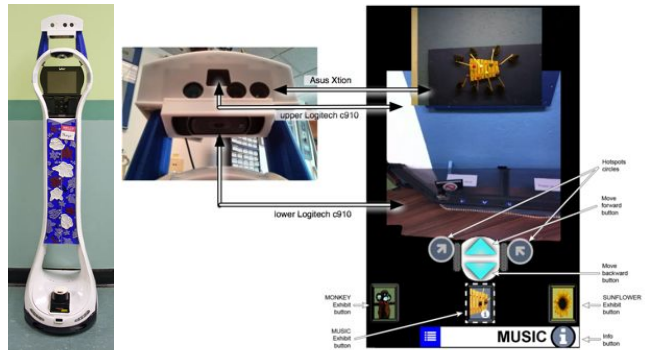

Figure 1: *(Left)* Margo, a modified VGo robot. *(Center)* The three "hat" cameras are stitched together into a vertical panoramic video stream, which provides the base for our user interface. *(Right)* Navigation buttons surround the robot base icon.

July 6 to 10, 2014 at The Discovery Museums in Acton, MA. It should be noted that the section of the museum in which our special program was held is designed to engage children ages 6+ in hands-on science exploration [6].

The museum's monthly program and signs at the museum promoted it: *"Discover what it's like to be in two places at one time using a telepresence robot named Margo. You can drive Margo from the museum's first floor to explore the Artbotics exhibits on the second floor. Timed tickets for a turn controlling Margo will be available when you arrive at the museum. While Margo is recharging her batteries, come meet her and try the Artbotics exhibits in person."* During the open gallery sessions (while the robot was recharging), museum visitors were also encouraged to interact with the members of the research team. Finally, robot coloring sheets and crayons were provided throughout the museum.

2.3.1 User Study

A sign up station was put at the main entrance on the first floor of the museum and staffed by a member of the research team. The training video[2] continuously looped to attract potential participants. The group size was limited to 4 children, accompanied by at least 1 adult. The UMass Lowell Institutional Review Board approved a waiver of informed consent as no identifying information was collected.

Sixty-two participant groups engaged in two tasks: (1) operating the telepresence robot, and (2) visiting the art gallery in-person to watch the robot from the "peanut gallery." Each group visited the gallery once using the robot and once in-person. In this between-subjects study, there were 2 conditions for task ordering, and 4 minutes were allocated for each task. "A" groups (n_A=27) operated the robot first and afterwards watched the robot from the peanut gallery. "B" groups (n_B=35) watched the robot first and then operated it from the kiosk. Upon completion of both tasks, every member of the participant group received a small prize (i.e., a sticker or pin of the telepresence robot).

2.3.2 Data Collection

When a participant group signed up to operate the telepresence robot, we assigned them a number by which all of that group's data was associated. Collected data included the total time spent operating the robot, the number of exhibits visited, and the number and type of user interface

[2] https://www.youtube.com/watch?v=8LZ2RUlksUw

interactions (e.g., button presses, clicks). We noted our observations at the operator kiosk, and recorded the questions the participant groups asked the research team at the training station, at the operator kiosk, and inside the peanut gallery. A screen capture of the interface was recorded; otherwise, no video or audio recordings were collected.

Members of the research team asked the participant groups to complete optional surveys regarding their experiences; when answering, the verbal responses were given collectively or one person responded on behalf of the group. The demographic survey was answered at sign up:

1. Number of children: Ages 0-5, Ages 6-10, Ages 11-15
2. Video conferencing used: Skype, Facetime, None

After operating the robot, we asked the participants to rate on a scale of 1 to 5 (strongly disagree to strongly agree) the degree to which they agreed with a series of statements:

1. I would like to use a robot like this to visit another museum.
2. It was easy to move the robot around in the art gallery.

The post-study survey was optionally answered at prize redemption, after both operating the robot and viewing it from the peanut gallery:

1. On a scale of 1 to 5 stars, how would you rate the exhibit?
2. Which of the three art exhibits looked the same when you visited in-person and when using the robot? [*Choose One*: Monkey, Sunflower, Music]
3. Which of the three art exhibits looked the most different when you visited in-person and when using the robot? [*Choose One*: Monkey, Sunflower, Music]

Finally, we solicited the groups for feedback or comments.

2.4 Commentary

This robotic telepresence exhibit was complex with respect to its purpose, and in turn, the content of the exhibit was also complex. It was necessary due to the user study for this exhibit to be staffed full time with members of our research team. This staffing, however, had the pleasant side effect of the museum visitors being very inquisitive about the robot itself and the research team. As noted by Few et al. [9], robots provide a number of educational opportunities including discussion of how they are constructed, what they are used for, how they are programmed, and what backgrounds the roboticists might have. These discussions with the museum visitors were easily fielded when the robot was recharging and the art gallery was open for people to tour. Several participant groups returned during the open gallery times to speak with the robot's designer.

However, when the user study was in progress, it would have been useful to have additional members of the research team dedicated to this task. At the operation kiosk, this chatter became distracting, for example, when parents of the current participant group or the next participant group asked tangentially related questions. To mitigate the latter, we staged a training area at the signup desk, away from the operation kiosk; additionally, robot coloring sheets were placed at the "on deck" area.

Replication of this exhibit would be difficult, even without the user study component. Given the complex content and in spite of the training video, it would be necessary to keep the exhibit staffed with a docent or volunteer. The children were easily able to use the touchscreen to operate the telepresence robot. However, our preliminary findings indicate that the order in which a participant group completed the two tasks impacted the group's overall experience. One participant noted that they wished they had seen the robot before driving it, because they felt their child did not understand that they were driving a "real" robot until afterwards.

Finally, although the surveys were a means of capturing the visitors' responses, the administration of the surveys disrupted the flow of their visit agenda. It would be beneficial to engage the children directly with physical push buttons for giving a simplified star rating (1 to 3 stars) to the overall exhibit. Similarly, the children can be engaged by voting for their favorite exhibit, and if they would like to visit another museum in the future using a telepresence robot.

3. EXHIBIT #2: COPYBOT

From January 12 to 30, 2015, the Children's Museum of Atlanta hosted the "Look! CopyBot" exhibit [16]. Like the Discovery Museum, the Children's Museum of Atlanta is a hand-on science museum and encourages exploration. The museum's target age range is 8 years of age and younger [10]. The sole purpose of the CopyBot exhibit was to educate the general public about on-going HRI research. Thus, the four MyMuseum robots were given simple and discernible socially contingent behaviors for interacting with museum visitors.

3.1 Robot System: MyMuseum

MyKeepon toy robots are small, yellow snowman-shaped robots with two eyes and a nose. It can rotate left and right, tilt left and right, and "bop" up and down. MyKeepon toy robots were modified into low cost research platforms [1]. The motors were replaced with hobby-grade servo motors and connected to Arduino Unos. All of the electronic components were enclosed in an acrylic base (Figure 2 left). A Logitech webcam was mounted directly below the MyKeepon with a custom 3D printed bracket.

3.2 Exhibit Installation

Prior to the installation of the CopyBot exhibit in The Children's Museum of Atlanta, multiple MyMuseum robots were demonstrated in 2014 at the World Science Festival and the CogSci/AAAI Joint Robot Expo [1]. Similarly, the CopyBot exhibit featured four MyMuseum robots (Figure 2 center), and each robot operated independently. The CopyBot exhibit highlighted the collaboration between researchers at Yale University and the Georgia Institute of Technology (GA Tech); that is, the face perception software used by GA Tech was applied to the MyMuseum robots. The CopyBot exhibit placard provided instructions in age appropriate language:

- *"Make eye contact with me and watch what I do!*
- *Move your head side to side and up and down. Do I follow you?*
- *Find a friend and dance. Who am I watching?"*

The CopyBot exhibit was a standalone exhibit (i.e., not continuously staffed with a dedicated docent or museum volunteer). It was designed to engage the museum visitors in several ways. First, when a visitor stood in front of the robots (Figure 2 center) and made eye contact with one, the respective robot looked back at the visitor to make eye contact; the robots were also capable of imitating visitors "dancing." For visitors under 36 inches in height, parents

Figure 2: *(Left)* MyKeepon modifications [1]; diagram by Ahsan Nawroj (Yale). *(Center)* CopyBot exhibit at The Children's Museum of Atlanta [16]. *(Right)* View of the four MyKeepon robots' webcams running the face perception software; photos by Zhefan Ye (GA Tech).

were encouraged to hold the child in their arms for this portion of the exhibit interaction. Second, each of the four robot's live video streams were displayed on the backside of the exhibit (right). These video streams educated the museum visitors about the robot's eye view and the face perception software, which showed the face detection markers. Finally, visitors were asked to give each of the four robots a name, which were posted on nearby foam boards (center).

No video or audio was recorded for the duration of the CopyBot exhibit installation. As the goal of this exhibit was educational dissemination only, system logs were the only means of collecting performance data (e.g., system uptime).

3.3 Commentary

It was necessary to keep the technical content and presentation as simple as possible for several reasons. First, the CopyBot exhibit was explicitly designed for HRI education of the general public; thus, the exhibit's educational message had to be narrowly focused. Additionally, the exhibit was intended to be standalone; thus, the visitors' interactions with the exhibit had to be self explanatory. Finally, the exhibit was designed to be easily replicated and installed in other science museums.

The museum visitors were able to discover the robot's behaviors without explicit training. However, as an unstaffed exhibit, it is not possible for museum visitors to ask questions about the traditional robotics components or the robot's software [9]. In future installations, it may be beneficial to have daily sessions for the museum visitors to meet the HRI researchers as a means for foster another form of informal science education.

The CopyBot exhibit did not have any explicit means for measuring the visitors' interest. It would be beneficial to know how many museum visitors interacted with the exhibit and how well they liked (or disliked) the exhibit overall. It may be possible to approximate these performance measures through the visitors' naming of the four robots.

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