Robots for Pre-orientation and Interaction of Toddlers and Preschoolers who are Blind

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Abstract

It has been suggested that the first humans to benefit from the emergence of autonomous mobile robots in our everyday environment will be people with disabilities and the elderly [Aylett, 2002]. We report on experiments using legged robots to establish multi-modal interaction with children who are blind.[1] Our results indicate that with very short sessions toddlers who are blind are able to operate a suitably modified SONY Aibo. Moreover, these blind toddlers progressed from the stages of stimulus to interaction and from interaction into engagement. This engagement constituted a pedagogically interesting stage of learning by playing. The exposure to the robot has also sparked their interest for exploring and using other machines and equipment. This indicates that mobile robots can assist in their development and learning for Pre-orientation and interaction.

Keywords: Human Machine Interfaces, Robots in Education. Robots for Individuals who are Blind.

1 Introduction

Sight loss is a common cause of disability in Australia. The Royal Blind Society estimates that almost 300,000 people across Australia are blind or vision-impaired. For Australians older than 75, the incidence of blindness or severe vision impairment is closer to one in six, owing to eye conditions related to aging. Concurrently, life expectancy in Australia has increased significantly (for example females are now expected to live over 82 years![www.AIHW.gov.au]) In 1993, 12% of the Australian population was over 65; by 2021 this will be 14% and by 2041 it will be 22% with an increasing trend towards early retirement[www.AIHW.gov.au]. These retirees will be savvy computer users, and may suffer arthritis and vision impairments.

We believe that robotics in the human environment will immediately and directly benefit people with disabilities, the elderly, patients in different stages of recuperation, and they will help in education environments as well. The June 2003 issue of "The Economist" predicts that 'sentient computing systems' will be 'everywhere within 5 years'. For this to happen, significant progress needs to be made in the intersection of Human-Computer Interaction (HCI) and Robotics.

While research in human-computer interaction has delivered methods and approaches to the design and usability testing of computer usage, it has focused mainly on Graphical User Interfaces or multi-modal interfaces where vision is the main component. It has left untouched issues of physical robots as companions/assistants to communicate with computers. There is a significant area of research in Human-Computer Interaction under the heading of "Accessible Computers" [Bergman and Johnson, 1995]. However, the spirit of this research is analogous to ramps and elevators that make a building accessible to people in wheelchairs. The topics are mostly the development of tools and interfaces so that people who are blind or vision impaired (or with other disabilities) have access to computers as they are known to others. In particular, research has focused on "assistive access". This is add-on "assistive" software to transparently provide specialized input and output capabilities. For example, screen readers allow blind users to navigate through applications, determine the state of controls, and read text via character-to-speech conversion. On-screen keyboards replace physical keyboards, and head-mounted pointers replace mice. A significant change in HCI is the move from "accessibility add-on" to "user-centered design". The later considers diverse user

[1]UNESCO recommends emphasizing the person and not the disability. We will use 'person who is blind' as opposed to 'blind person' where possible.

needs from the beginning rather than the appending of something enable access to a particular group of users.

We believe that robots today are significantly inexpensive and capable of acting as a smart interface, replacing the keyboard, the monitors and the mouse for people with disabilities. This paper presents the first results of a project that uses the SONY Aibo platform and focuses on delivering new tools for the blind. We report on the necessary modifications to SONY Aibo to facilitate its use by people who are blind, and the evaluation of these modifications. We also report surprising results from the educational perspective. It is well known that children progress from a stage of reaction to stimulus to a more advanced stage of interaction with their environment and then move on into a stage of engagement where they learn by interactive meaningful play. The progression for children who are blind can be much more difficult. For example, submerged in an environment with music, blind toddlers will stall, lower their heads, become passive and ignore where things are around them. We have discovered that by providing them a friendly robotic dog by which they control the generation of music and/or movement these children rapidly move to an active stance. They lift their head up, talk to the robot, actively play with it, reach for other people and engage in a demonstration of happiness and excitement. They become aware of where the robot is, and can leave it and reach out for it as they play with it. This demonstrates that the robot facilitates a multi-modal interaction advancing their pre-orientation.

2 Miranda: Aibo for children who are blind

SONY Aibo was released commercially as an entertainment robot [www.sony.net/Products/aibo/aiboflash.html]. It completely fulfills the definitions of the International Federation of Robotics (IFR) and the Australian Robot Association (that follow the ISO standard vocabulary ISO 8373). That is, it has at least three programmable axes of motion, it can be programmed to accomplish a large variety of tasks and after being programmed, it operates automatically. Moreover it is *autonomous* as opposed to a *tethered* robot which has its power supply or its control unit overboard. The RoboCup symposium and competition has expanded its popularity because the 4-legged league uses Aibo [Veloso *et al.*, 1998]. Technically, there are now three different models for Aibo. The first model was released on November 16, 2000.

Miranda is our ERS-210 SONY Aibo that has been used and slightly modified to suit interaction with the blind (see Figure 1).

To evaluate these modifications experiments were performed initially with blind-folded schoolers and later with toddlers and pre-schoolers who are totally blind. These modifications were designed to obtain a physically operable robot for blind people. The assumption is that if these modifications are effective for blind toddlers, they will likely be effective for older blind people. The issues explored here are as follows.

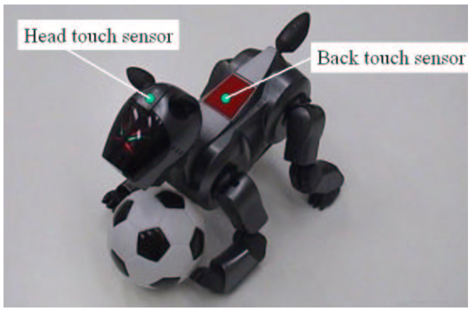


Figure 1: Miranda.

- Can the person who is totally blind turn Miranda on and off? Can this individual tell if Miranda is on or off? Can the blind person easily find the on/off button?
- Can the person recharge Miranda? Can the individual replace the battery? Can the blind person remove the battery?
- Can people who are blind find the touch sensors and operate them as buttons? Can they find the tail? Can they keep track of Miranda's sensors?
- Can the blind person recognize Miranda's posture? Can the person who is blind recognize Miranda's movements?
- Can the blind toddler be stimulated to explore different options of behavior?
- Do children who are blind develop a bond for a machine that offers multi-modal interaction (sound and movement) under autonomous control in the same way seeing children develop a bond for Miranda because it looks like a dog [Bartlett *et al.*, 2004]?

Table 1 summarizes the environments where experiments were performed to evaluate the modifications. It also shows the age ranges of the children involved. The evaluation sessions were recorded on video. Empirical evaluation with blind children of a sensory aid used an older group aged 7 to 11 [Kay, 2000].

On average, no more than 3 trials were necessary for blind-folded children to locate and replace the battery on Miranda(Aibo with our modifications). All (blind-folded) children could easily perform the routine after less than 10 minutes of exposure to Miranda. This included turning Miranda on and off at will. In 50% of

School	Level	Children's age	Group size
Camp Hill State School	1st year primary	5-6 years	10
Narbethong State Special School	pre-school (blind)	4-5 years	4

Table 1: Environments for experiments conducted and age groups.

the cases children became impatient while Miranda was booting; so a longer acoustic cue is necessary than the one provided currently. This is not possible without access to the operating system code. All children could find the sensor, and if requested, produce a dance on Miranda or select a soccer kick and perform the kick. These subjects could also locate the memory stick, extract it from Miranda and replace it. It is remarkable that no more than one training session was required in all cases. None of the tasks created any problems or risks. That is, the Aibo was never damaged, nor were the energy station or any other separate parts. However, as we will describe in more detail later, the standard plug for recharging an Aibo does become damaged when people who are blind or blind-folded try to connect and disconnect the recharger. As a result, the only effective method to recharge is the energy station.

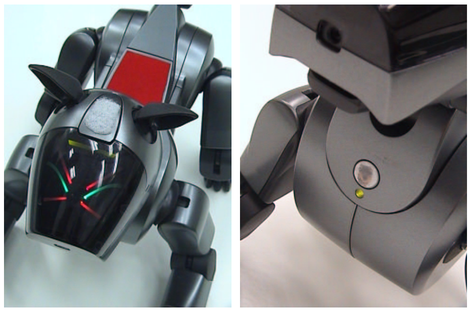
For toddler who are blind, more than one session was performed. All could remember all the features presented at the first session. They could recall the position and placement of the battery, the soggy button, the felt button, the tail and legs and the memory stick.

We now report on the direct evaluation of our modifications. Regarding the touch sensors on Miranda, we found the following:

- The back sensor and the head sensor are moderately difficult to find and use if the child is blind-folded. Although both are identifiable by their position with respect to the body, it becomes much easier if they are marked by textured surfaces.
- The on-off button is significantly much harder to find for a blind-folded person. It is radically easier to find if marked with texture.
- It is much easier to distinguish the on/off button and the touch sensors, and to identify them if they each have a different texture.

Therefore, our final version of Miranda for operation by people who are blind is shown in Figure 2 (a) and (b). Figure 2 (a) shows the head sensor with a soggy texture and the back button with a felt texture. The soggy texture allowed us to describe it as 'hair on the head' while the felt texture allowed us to call it 'a saddle'. Figure 2 (b) shows the on/off button with a smooth-plastic surface.

These modifications allow regular operation of Miranda (supplied with a battery and possibly a memory stick). Although Miranda has another touch sensor under the chin it is not visible as a button. Thus, we opted not to highlight it to the blind. Similarly, the position of its tail can be detected by Miranda, and we did not introduce a modification.



(a) (b)

Figure 2: (a) Miranda's soggy head-button and felt back-button. (b) The smooth-plastic surface of the on-off button.

To operate Miranda with a different program, the memory stick must be replaced. Also, prolonged use (beyond 2 hours) demands battery replacement. We developed experiments to test the operation of these aspects. Although the battery has a shape that is recognizable and indicates the orientation to place it in Aibo, we found that when children were blind-folded, it was difficult to replace the battery. Moreover, it is extremely difficult to know if the battery is flat and needs recharging. The Aibo and the energy station (as supplied by SONY) only provide visual cues for the charge status of the battery. Nevertheless we also designed and tested other modifications that improved battery and memory stick replacement. Although Aibo has a latch that releases the battery, and its shape can be determined by a blind person, it is very hard to locate because its surface is essentially the same as all other parts under Aibo. Using a rough texture (like sandpaper on top of this latch) enables blind children and blind-folded people to more easily release the battery (refer to Figure 3 (a)).

Moreover, this feature allows them to orient the body of Aibo and proceed to find the housing for the memory stick in order to release it. We found that the shape of the memory stick and its connection provide suffi-

(a)

(b)

Figure 3: Modifications to the battery release latch and the energy station.

Figure 4: (a) Subject 3 singing along. (b) Subject 3 in control, manipulating Miranda.

cient tactile cues for the blind to replace it into position. However, although many of the energy station parts are connected with standard plugs, we found that the last plug connection under the energy station was very difficult to realize blind-folded. The solution we designed is illustrated in Figure 3 (b) and consists of two triangles providing distinctive texture and placed on both sides of the small plug-hole. The triangles also indicate a direction for the fact that the male-side of the connection should go well into the base of the memory station. With this modification, blind-folded children were able to locate and carry out the connection/disconnection after relative short illustration sessions.

3 Meaningful play is learning

In order to explore the possibility of using Miranda in the development process of toddlers who are blind we developed several computer programs in which Miranda could salute the children and instruct them on what would happen if they carried out such-and-such actions. This also allowed us to validate that the modifications incorporated into Miranda effectively offered an operational context.

The details of our most successful computer program are as follows. Miranda remains in a state of readiness and will not carry out any action unless it senses something. If not standing on her legs, she will perform a motion to stand back up. If a sensor is touched, she will greet with the words "Hello, my name is Miranda". She will pause slightly and continue with "Push my soggy button to hear some music, push my felt back for some soccer moves".

Pressing the soggy button on the head starts a motion in which Miranda raises her front legs up and down after sitting back and then comes back on all four legs. The video[2] accompanying this paper [www.cit.gu.edu.au/~s2130677/KDDlab/Pictures/Pre-orientation] shows children who are blind controlling Miranda and enjoying the dance. Obtaining a 'soccer action' is more complex. It is the alternative to the dance, but a kick does not happen immediately. Miranda arrives at a state of waiting for the child to choose a soccer kick, and announces this by indicating that the felt button will make her do a head kick while the soggy button will result in a grabbing kick. Head kicks send the ball sideways while grabbing kicks send it forward. The ball has a bell inside and we hoped this routine will allow toddlers who are blind to increase their pre-orientation skills.

The motion feedback of the robot, with her many moves (head, tail, legs and walks) combined with her music and music generation provides a multi-modal in-

[2]The requested MPEG format is 38MB, so we have a WMV alternative format that is only 3MB.

terface to the children who are blind. Children not only listen to the music, but experience the motions and forces produced by the robot. They also have to produce the music and motions by active interaction. Thus, Miranda is much more than an instrument. She acquires a personality and the children who are blind move from reacting to stimulus to interacting with Miranda. They will not only control Miranda with the buttons but reflect their attribution of personality by saluting Miranda back and explaining that Miranda is happy to dance.

To illustrate these remarks, the first clip in the video shows Subject 3 who just after 6 minutes of exposure to Miranda knew exactly how to produce music, find the soggy button (she takes her hand away and brings it exactly into position to repeat the press) for more music. Although the presenter moves Miranda sightly after the dancing moves, the subject has no problem relocating. She adopts a firm posture with her head up, and is confident exploring, and happy to maintain a dialogue with the presenter. It should be noted that Subject 3 is a pre-schooler. Figure 4 shows Subject 3 controlling Miranda.

The second clip shows Subject 1. After 18 minutes of exposure to Miranda this toddler has full control of Miranda's motions and becomes very interested in interactive play. He maintains a firm and confident posture and reaches twice for the hand of the presenter to simulate a dance when Miranda is re-started to make music. This subject was able to locate Miranda when the robotic dog was put somewere else by the presenter, and even became involved in a hide-and-seek game. Repeatedly, the different sounds made by Miranda (either the noise of the motor, the actual music or Miranda's voice) were sufficient for the development of pre-orientation skills. The clip demonstrates that a high level of engagement and learning by exploratory play has been reached. A second session with this subject, and a different program that allowed swapping between songs by re-positioning or pushing the tail had the child interested in the words of the songs (only one song had words). After the session was over, the child sang the first line of the chorus for the lyrics!

By contrast, the third clip shows Subject 2 passive and shy in reaction to Miranda. She keeps her head down, shows no trust in the presenter, and displays a lot of reservation for having Miranda turned on. She is only reacting to the stimulus, as demonstrated by pulling away from any contact with the presenter. She does not participate at all, does not push any buttons. On the clip, we only show a minute, but the behavior exhibited is indicative of the session. We attribute this reaction to personality. It is well known that children who are blind (like any person) have different speeds for assimilating new concepts and exploring the unknown. To confirm this, the fourth clip in the video shows the next session with Subject 2. It is a remarkable change. The child greets Miranda and plays with her. She repeatedly expresses her joy with movement and voice ("I'm so happy to see you Miranda"). She keeps a firm posture with her head up, releases Miranda, knows where to find buttons or the entire body, and is happy to pull her back. She attributes a personality to Miranda("She is excited to see me and dance with me", "She loves it all the time"). She wants to demonstrate her interaction with Miranda to her mother. Subject 2 requests her mother to be silent because she is going to make Miranda talk and later says "Look at her go". This clip corresponds to minutes 24 to 26 of that session but even from the 13th minute interaction for engagement and meaningful play is in place.

Sessions also included the presentation of a remote controlled car. Our experimental design hypothesized that the morphology of an animalistic toy would be more interesting even to children who are blind, because concepts like legs, ears and head are more familiar to them than the wheels and buttons of the radio controlled car (Figure 7).

To confirm the impact of the exposure of Miranda to the children who are totally blind, we provided parents with a questionnaire. The questionnaire (besides obtaining permission for using photos and videos in publications) requested the parents to indicate changes in the children with respect to the following aspects.

1. Increasing/Decreasing interest in instruments with buttons.
2. Increasing/Decreasing interest in animals like dogs.
3. Increasing/Decreasing interest in remote control devices.
4. Increasing/Decreasing interest in interactive play with balls.
5. Increasing/Decreasing interest in interactive play with music (singing along, dancing, touching/shaking musical instruments).

At least four weeks were allowed after the session for the parents to observe the children before completing the questionnaire.

All children demonstrated an increased interest in instruments with buttons. Also there was a willingness to explore and control by interaction the channels of the TV, or a tape recorder. Subject 3 has a special interest for tape recorders and we are developing software for Miranda to record the child's voice and operate it as a tape recorder. Subject 1 has developed an enormous interest in instruments with buttons, radios and remote controls. Subject 2 had no interest in the remote control devices. We even lent the remote control car to her for a period of two weeks. However, she did develop an extreme interest

Figure 5: (a) Subject 1 reaching for the hand of presenter to dance. (b) Subject 1 waving hands as a dance. (c) Subject 1 in control, manipulating Miranda.

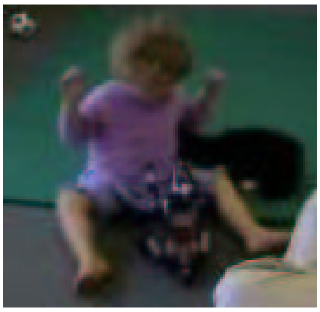


Figure 6: Subject 2 waving hands, with straight posture, head up, aware of location of Miranda.

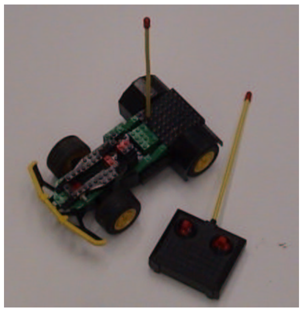


Figure 7: Remote control car to contrast with the notion of autonomous control.

in Miranda. Her mother reports a willingness to meet Miranda, and the child queries her for an opportunity to have Miranda visit. The parents report that they all have no change of attitude for living animals.

We should also say that in the second session we tested the children for their recollection of Miranda's operation. All the children could remember the on-off button and other buttons. They had a very clear idea of the need of the battery to make the robot functional and could find where it goes. They also had a clear recollection that different memory sticks produce different behavior. We believe that the notion of a computer program in the memory stick is certainly not there. It seems to be conceptualized as a 'music cassette' for a tape recorder.

4 Related work

Naturally, there is a wide area of research on cybernetics and prosthesis, but more related to this project is research in the field of robotics focused on specific hardware to assist with disabilities [Shoval *et al.*, 2000]. For instance, a prototype called "GuideCane" [Borenstein and Ulrich, 1997] that looks like an upright vacuum cleaner provides blind people a tool to find their way. It has been developed by researchers in Michigan. The cane is a robot that will gently lead them around any obstacles in their path. In its base is a crescent-shaped array of ultrasonic sensors that scan the area ahead. A built-in computer interprets the data from the sensors, calculates the best route every 50 milliseconds, and steers the device accordingly. At the moment the device cannot sense overhanging obstacles and it can only operate on smooth surfaces.

In addition to the problem of cost (because of the type of sensors), it is not hard to see why such a cane has little acceptability. It cannot cope with stairs. It offers no feedback or communication (audio) to the blind, who unfortunately have to follow it on faith. Simply, the blind person must follow the cane without any explanation, even if the blind person wishes to go North and the cane is taking them South. It is very important to enable people who are blind to remain in control when mobility and orientation are the issues. For example, even with guide dogs (the living animals), the person is the one that knows the path to the destination. The dog is only an assistant in detecting obstacles, and obeys the controls of the person.

There has been a continuous effort in sensory aid development [Kay, 1974; 2000]. In particular, there is a continuous quest to find an aid for the blind to deliver the space between 'touch' distance and some longer useful range. Many of these are based on sound and not on both sounds and movement (as with a robot) [Sandhana, 2003; GDP-Research, 2003; Kay, 2003]. Of course, all the technology for these types of sensors can be mounted on a robot to develop an assitant for mobility and navegation. The advantage of aids today is portability. This puts robotics at the intersection with research on wearable computers.

Given the speed of technological advancement it should not be surprising that robot guides have already appeared. Researchers at Carnegie Mellon University deployed two autonomous mobile robots, with a varying degree of humanoid features, as tour guides in technology museums [Thrun *et al.*, 1999]. These robots typically allow visitors to request a tour (by touching a touch-sensitive screen) [Thrun *et al.*, 2000]. Then, the robot moves from exhibit to exhibit, where it replays programmed sound and video information. Unfortunately, these intelligent systems are not flexible enough to be companions of people with disabilities. Although this work [Thrun *et al.*, 2000] is a step to study human behavior in the proximity of robots, human reactions to them are very much controlled because of the environment [Brooks, 2002].

The limitations with those lines of research mentioned above is that they fail to integrate computer vision, location, collaboration and Human-Computer interaction effectively [Brooks, 2002]. By focusing on assisting the blind, we can certainly target aspects like audio, touch and the morphology of the robot.

Because the robots can carry a wireless card running the TCP/IP protocol (the transport and network protocols of the INTERNET), we believe we can construct robots that can negotiate with others at intersections and in situations in where several must avoid each other to navigate their path. Also, the SONY Aibo is equipped with other sensors for Human-Computer Interaction appropriate for interaction with the blind. It has several touch sensors, microphones and can play audio. Platforms like SONY Aibo's is significantly different from sensors and robotic cars [Jones, 2001]. Our platform are robots that can be used at home, in the office and beyond the context of driving a car on roads.

There has been a recent interest in inexpensive robotics for stimulating interest in technology and facilitating engineering education [Kröse *et al.*, 2000] and in particular, their impact on gender profiles of students [Sklar *et al.*, 2002].

The research problem of robot mobility and orientation has many parallels in the mobility and orientation problems of people in unknown environments. It has even more parallels in the mobility and orientation challenges faced by blind people every day.

The challenges of computer vision, robotic location, orientation and collaboration are tasks that will permit a robot not only to be involved in a physical soccer match, but to assist a human with disabilities. Computer vision allows them to identify objects and obstacles. Because of the capacity to capture images in color, the robot can assist in color transformation for the color blind. Other suitable tasks that the software on the robot can perform to assist vision impaired humans are magnification, object recognition and obstacle recognition. The robots can be equipped with a wireless link, so they can communicate with a computer and relay images for processing on more powerful computers than those on the robot.

An illustration of this more elaborate process could be character recognition. In this instance, the robot would work as an intelligent scanner. Simple computations (like reversing a book for the blind human who has placed it upside-down) can be done in the robot, while parsing and recognizing words would be performed at a base computer. The base computer could re-transmit the understood text for the robot to read to the user. As mentioned earlier, SONY Aibo robots can synthesize sounds.

In fact, we suggest here that many direct applications can be obtained by using the robots as a human-computer interface. The SONY Aibo robots used in the lab have two microphones. They can record an audio from a human voice. Software for limited voice recognition can be mounted on the robot itself, or alternatively, once again, the wireless link could forward the audio to more powerful computers running more accurate voice recognition programs.

5 Our vision - the world ahead

We believe we have an open field at the intersection of human-computer interaction and robotics. The advances in areas like robot navigation, robot collaboration and robot vision will assis those humans in much need of these capabilities. For example, "Nursebot" is a guide (provides directions) for the elderly [Thrun, 2002].

When the first digital calculators came about, they became amazing assistants to engineers, and devices like logarithm tables essentially disappeared. The words "calculator" or "computer" were to be applied to someone (or something) that could make large and fast sums and multiplications. Now, almost everybody uses calculators for anything that involves a few digits and terms. It seems natural, but think how unnatural this was 50 years ago. We believe that we can initiate the exploration of robotics in education, at least as assistants for people with disabilities, perhaps initially as a human-computer interface for accessibility. However, with people with low vision, a significant part will be language and text presentation for comprehension. We believe that legged robots offer solutions to previously unsolved problems, like stairs. We also suggest that animal looking devices will become as familiar as our TVs, and we hypothesize that humans would interact more effectively when they look (and act) like helpful pets.

We believe that new capacities for robotic systems are to be developed if we focus on human-robot collaboration, rather than the original replacement of labor. Interest combinations will be for people with additional disabilities, for example, those who are blind and are restricted to a wheel chair. It is difficlt to imagine a society where fully autonomous vehicles are permitted on public roads. However, for operation as an individual transport, in a constrained environment, autonomous vehicles may find much acceptability, even if the person on board is blind.

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