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# Control of a remote communication system by children

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**Abstract**

When an elementary or secondary school student is away from school for an extended period of time due to illness, the student is provided with a tutor or access to in-hospital classrooms to keep up with his/her studies. This arrangement is not only expensive but isolates the child from normal, everyday classroom experiences. A remote controlled video conferencing system was developed which allows a student access to regular classroom activities while in a remote location (e.g. hospital). The video conferencing system allows two-way visual and audio communication between the class/teacher and the remote student. The remote control provides the student (remote location) with the ability to direct the in-class video camera as desired (pan, tilt, zoom). One of the challenges in the development of the communication system was the design of the interface used by the student to remotely access and control the video camera. Control of remote computer systems is a difficult task (Hammel et al., 1989). The complexity of a video conferencing system magnifies these difficulties.

A Nintendo™ controller was adapted and integrated with the video conferencing system because children identified it as a desirable interface. The Nintendo controller allowed a better physical and cognitive map to the required control tasks than either a keyboard or a mouse interface. A pilot study was conducted with a group of cub scouts with one cub participating from a remote location. Use of the system to participate in the activities was the focus of this study. Results seem to indicate that the system can be used with relatively few errors when performing the majority of the required tasks. However, gaining the attention of the teacher through the system seems to be more difficult.

**Relevance to industry**

This paper describes empirical results in the evaluation of a system for allowing a student at a remote site participate in classroom activities using a robot which not only provides a video and audio connection, but which can also be controlled using a natural interface from the remote site. The specific application is for distance eduation, but can be applied to tele-conferencing and general telepresence. © 1998 Elsevier Science B.V. All rights reserved.

*Keywords:* Distance education; Tele-presence; Mobile robotics

## 1. Introduction

When an elementary or secondary school student is away from school for an extended period of

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time due to illness, the student is either provided with a special classroom in the hospital, or a tutor to keep up with his/her studies. These systems are expensive and isolate the child from normal, everyday classroom experiences.

One of the goals of this research is to investigate and construct a system to maintain social interactions with the school while a child is in the hospital. The system is a modified video conferencing system. The student is represented by and controls the mobile unit which is in the classroom.

There are a number of issues and challenges which make this research project distinct from either research in remote navigation or manipulation of systems, user interface design for children, or video conferencing. A combination of approaches must be used to produce an effective strategy. Mobile robotic arm systems for use by people with disabilities (including children) have been developed and investigated (Masanic et al., 1990; Hammel et al., 1989; Harwin et al., 1995; Dallaway et al., 1995). These researchers suggest that the relationship between remotely controlled systems and individuals with disabilities be supported by integrating human factor principles such as anthropometrics, task functions, user needs and interface design with the technical requirements and limitations of the robot. In addition to the needs of the remote student in this project, the classroom component of the system must support the needs of support staff, teachers, parents, and other children so that effective interaction between the remote student and the class is promoted.

Two means of controlling the mobile robotic system are required: (a) a system for integrating the input and output manipulated by the user to control and monitor the system; and (b) a second system (for override purposes) mounted on the mobile base allowing access to the mobile portion of the system without using the remote control system (Masanic et al., 1990). The system described in this paper requires a third means of interaction: an interface to support two-way communication between the student and the individuals in their remote classroom. Although this is done through an existing video conferencing system, features such as camera zoom, tilt, and pan must be adapted to the classroom environment.

The issues and challenges of providing effective control of remote systems have been well documented in the literature. A number of different strategies have been employed for controlling remote systems. These include: (1) direct manipulation using video monitoring and a joystick, or programmable switches, etc. (Masanic et al., 1990); (2) manipulation of graphic representation of the environment (Zhai et al., 1994); (3) voice control of robots (Hackenberg, 1986; Cammoun et al., 1993); (4) robot navigation using control languages (Masanic et al., 1990; Kameyama and Ohtomi, 1993); and (5) multi-dimensional (3-D, 6-D) manipulation with 3-D or stereoscopic displays (Halpern-Hamu, 1993; Kameyama and Ohtomi, 1993; Zhai et al., 1994).

Many of these control strategies have been investigated for robotic aids performing specific manipulation tasks such as moving physical objects from one place to another as directed by a remote user. The communication system described in this paper must move as directed by a remote student allowing that student to have presence in many ways. For example, gaining attention to ask/answer a question, moving to an appointed group or activity table, and turning toward a speaker.

There is much less research and development in designing interfaces for children than for adults (Robertson, 1994). Alloway (1994) suggests that interface design for children, specifically input device design should be based on children's stated preferences rather than "adult logic or reasons". Commercial computer products are available in the entertainment sector specifically oriented toward children (e.g., Nintendo, and Broderbund). The popularity of these products with children seems to indicate that the interface design is successful (Rimalovski, 1996).

Research in video conferencing has been focused primarily on studying the interactions between adults (Gowan and Downs, 1994). Generally, these interactions take the form of meetings with specific, goal-oriented agendas or tasks (e.g., Montage system developed by Tang and Rua, 1994; Hydra/Brady Bunch systems developed by Buxton et al., 1996), or distance learning activities (Isaacs et al., 1995) where the teacher is giving the class by video.

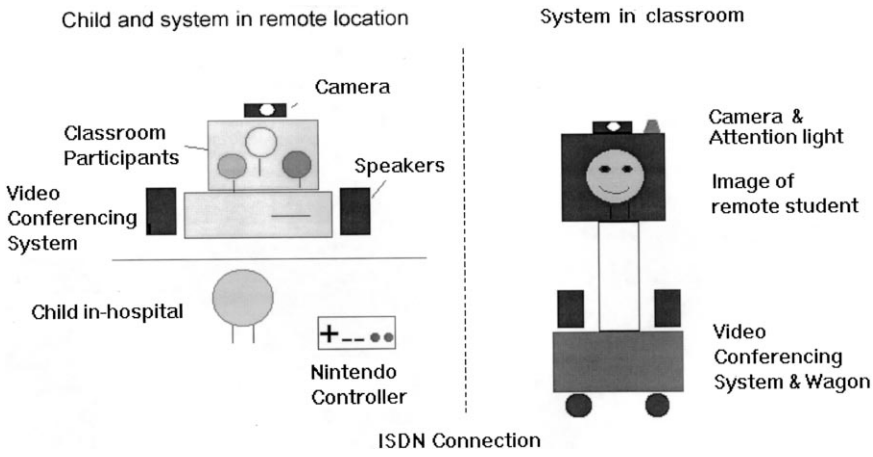


Fig. 1. Schematic representation of the two-way communication system.

Buxton (1992) suggests that a crucial element to the success of video conferencing is the ability of users to have a social presence. The concept of video-mediated presence has been studied in a structured, adult environment where participants are following known and practiced social protocols and roles. For example, meeting protocols and expected meeting behaviour are well established by the time an individual reaches adulthood. Researchers suggest that the interactions between users of a video conferencing session are improved through a more realistic sense of presence and awareness of each other (Tang et al., 1994). In this project, we are attempting to provide children with a video-mediated presence in an unstructured learning environment through a two-way communication system described in this paper. Presence is provided by three representations: physical (robot-like device located in classroom with a head and body); an audio/visual interface (video conferencing system); and control of the system by the remote user.

This paper provides a description of the system and the remote control interface. We also report on a pilot study that was conducted to examine the effectiveness of the system in allowing a student to participate in classroom activities, and the effectiveness of the remote control system.

## 2. System description

The communication system uses video conferencing to provide two-way audio and video via ISDN (Integrated Services Digital Network). An IBM compatible 80386 equipped with a PictureTel PCS100™ video conferencing system provides communications from the remote end of the system (in hospital). On the classroom end, a Mitsubishi Diamond Series 9000™ system is used.

The remote user's image (head and shoulders) and voice are captured by an ordinary video camera and hands-free headset microphone, respectively. The video and audio are transmitted to the classroom end and output on a television and its internal speakers. In the classroom, images and sounds are gathered using a Canon VC-C1™ communications camera and room microphones. The classroom video and audio are transmitted to the remote end of the system and output on the computer screen and through external speakers. Both ends of the video conferencing system allow local video feedback so that the user can see him/herself on the computer screen and the classroom participants can see themselves on the classroom television monitor. Fig. 1 provides a schematic view of the system.

Fig. 2 illustrates the remote end of the communication system. Children's control preferences for

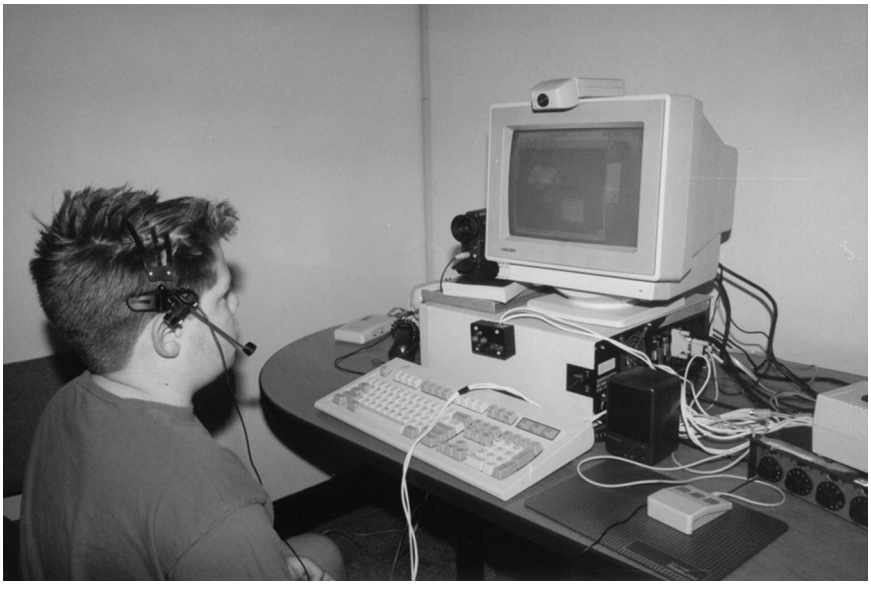

Fig. 2. Image of the remote end of the communication system designed for a single remote user.

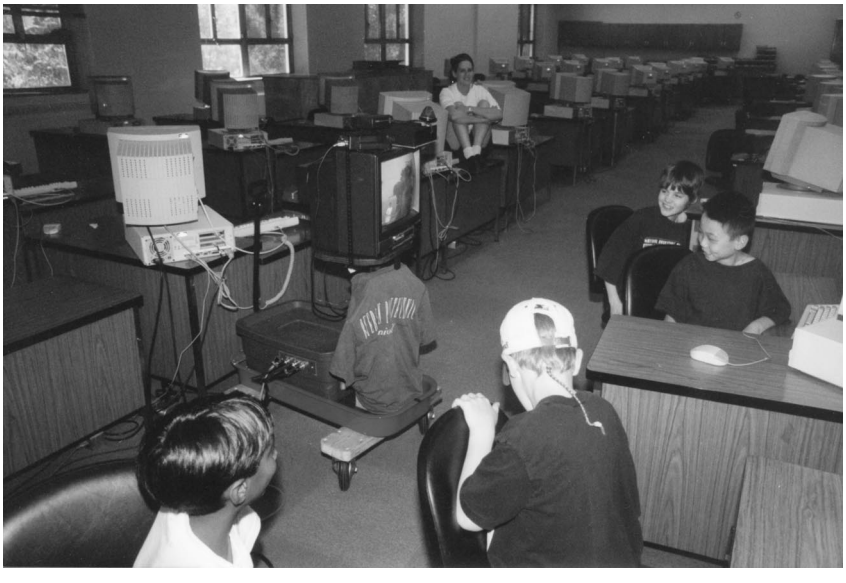

Fig. 3. Classroom end of the communication system designed to represent remote user in class.

this type of system were gathered in an informal study performed early in the life cycle of this research resulting in the specification of Nintendo control pad as an input device (Treviranus and Smith, 1995). A Nintendo™ controller is used as the interface to the video conferencing system to perform the seven control actions associated with the system (left, right, up, down, zoom in, zoom out, attention).

Fig. 3 illustrates the classroom end of the communication system. The classroom end is on wheels so that the remote student can be pulled around the

classroom allowing him/her to participate in a variety of activities. The classroom television is mounted on a pedestal with the centre of the television monitor at 107 cm high or at approximate eye level for a child (age 7–13). The pedestal allows the classroom camera (mounted on top of the television) and the television to pan together left and right in response to left and right control signals from the user. The up, down, zoom in, and zoom out controls tilt and zoom the classroom camera. The attention control signal activates a red light on the top of the classroom television in order to gain the attention of a teacher or classmates without interrupting.

## 3. Methodology

Five male participants, ages 9–11, participated in a 2 h pilot session. The participants were cub scouts who wished to obtain their computer badge. One cub participated in the session from a remote location using the system.

The trial consisted of a briefing and debriefing session, and the computer badge activities. The briefing and debriefing sessions for the entire group were conducted by the investigators to gather pre- and post-subjective assessments of the system, its potential/actual attributes and performance, and the use of the system during the trial.

The activities required for the computer badge are: (1) explaining the purpose of parts of the computer system and defining them as input, output or processing devices; (2) listing 10 uses of the computer at home and/or school; (3) visiting a place where computers are used; (4) becoming familiar with programming commands (BASIC programming was used); and (5) producing a drawing using the computer (Scouts Canada National Council, 1995).

The session was facilitated by two students (graduate and undergraduate level). Activities 1 and 2 were performed in group discussion format and activities 4 and 5 in small groups at one computer. The computer badge activities took place in a computer room at two workstations equipped with IBM compatible 80486 computers with 14 in colour monitors and printers.

Two, 1 h training sessions were provided to the remote student so that he could learn how to use the system before using it in the trial. This included familiarization and practice with the controls to operate the system in the classroom. Training tasks included locating stationary objects in the classroom, and playing 'hide and seek' with an investigator. Feedback and assistance was provided to the student by one of the investigators at all times during training.

During the trial three video cameras, in different locations, were used to collect the data. One video camera was used to tape the activities in the classroom; the second camera was used to capture the facial expressions of the remote user; and the third camera taped the screen of the remote computer. The screen on the remote computer shows both the classroom image and a local window with the user's own image.

Three areas of interest are reported in this paper: use of the system by the remote cub to participate in activities (including control errors), ability to gain the attention of the instructor, and attitudes. The video tapes were used to analyse the pilot session for each area.

Use of the system to participate in activities was characterized by identifying the control tasks employed by the user and then evaluating: the errors by different control task, successful completion of the intended action, and use of the attention light.

Errors are classified as overshoot, undershoot, zoom-off-target, and wrong button. Overshoot error is defined as visually bypassing the intended target. Undershoot error is defined as not going far enough. Zoom-off-target is zooming in on the incorrect target. Wrong button is pressing the incorrect control. Occurrence of these errors for each control task was recorded for analysis. The success of the user in gaining attention in the classroom is measured by the use of the attention light, and whether the request was acknowledged by the instructor.

Subjective impressions and attitudes toward the system and the processes that occur in the classroom were gathered through pre- and post-session discussions as well as from the comments made on the video tapes. The communication system was briefly outlined by functionality rather than phys-

Table 1
List of the questions asked of the participants during the briefing and debriefing sessions of the trial.

| |
|---|
| *Briefing sessiion* |
| 1. What do you think the system can do? |
| 2. What do you think that your friend will not be able to do because he wll not be in the computer room with you? |
| 3. What things do you think that you will not be able to do because your friend will not be in the computer room with you? |
| 4. Do you like or dislike computer? Why or why not? |
| 5. Draw a picture of what you think the system will look like. |
| *Debriefing session* |
| 1. What are the good things about the system? |
| 2. What are the bad things about the system? |
| 3. What did you miss about not having your friend in the room with you? |
| 4. What didn't your friend get to do because he wasn't in the room with you? |
| 5. Do you like or dislike computers? Why or why not? |
| 6. Can you tell us what things your remember about your computer badge session? |
| 7. Draw a picture of the system. The remote participant was asked to draw a map of the classroom. |

ical detail at the beginning of the briefing session. It was simply described as a robot which would allow them to hear and see their friend, and their friend to hear and see them. Table 1 provides the listing of questions asked during the briefing and debriefing sessions.

## 4. Results

Eight control tasks were identified, however, only three tasks had more than four occurrences. Those tasks with fewer than four occurrences were not analysed due to the insufficient quantity of data. The three main tasks evaluated were reading/finding the blackboard (ten occurrences), reading the computer screen (11 occurrences), and finding a person (15 occurrences). Reading the computer screen required the user to employ the zoom function extensively.

A one-way ANOVA was performed on occurrence level for control errors. There is a significant difference between control tasks for three of the four error types: overshoot ($F_{[2,33]} = 7.0$, $F[2,33] = 5.5$, $p < 0.05$); zoom-off target ($F_{[2,33]} = 9.1$, $p < 0.05$). For each error category the task of reading the computer screen had a higher mean than the other two tasks. The mean occurrence level expressed for tasks 1, 2, and 3 is illustrated in Fig. 4. There are no wrong button errors for tasks 1 and 3; and there are no zoom errors for task 3.

A one-way ANOVA was also performed on elapsed time for each task. There is a significant difference between tasks for elapsed time ($F_{[2,33]} = 5.1$, $p < 0.05$). The task of reading the computer screen had a higher mean than the task of finding a person or reading the blackboard (53.1, 16.3, and 11.5 s, respectively). These results seem to indicate that tasks requiring close-up views are more difficult to perform because there are more errors and they require longer time to complete with this particular system.

Twenty-nine of 36 total task attempts were completed. However, six of 15 task attempts to find a person, and one of 10 task attempts to read the blackboard were not completed or partially completed. Fig. 5 illustrates the number of completed versus incomplete task attempts.

The attention light was use for two purposes: (1) to gain attention of the instructor for the purposes of asking a question, answering a question, or contributing to a discussion; and (2) to provide a visual affirmation of the user's opinion without any verbal comment. Five of nine attempts were unsuccessful in gaining the instructor's attention. There were two attempts to use the attention light as a visual affirmation. The instructors were not aware of either of these attempts.

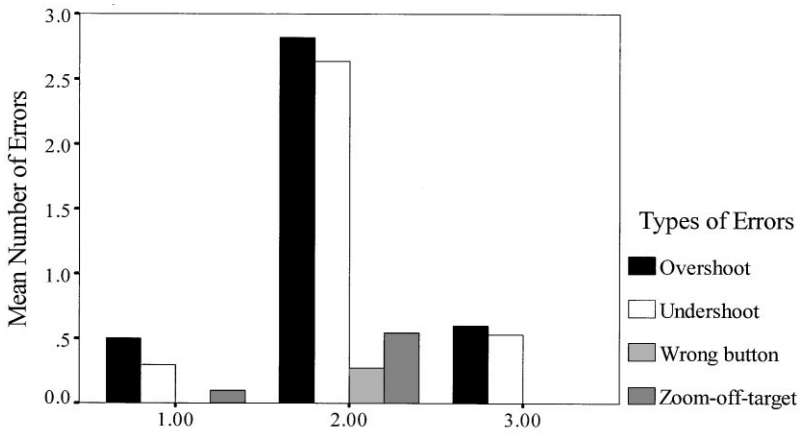


Fig. 4. Mean number of errors for each error catagory by task. Note: Task 1 is reading the blackboard; task 2 is reading the computer screen; and task 3 is finding a person.

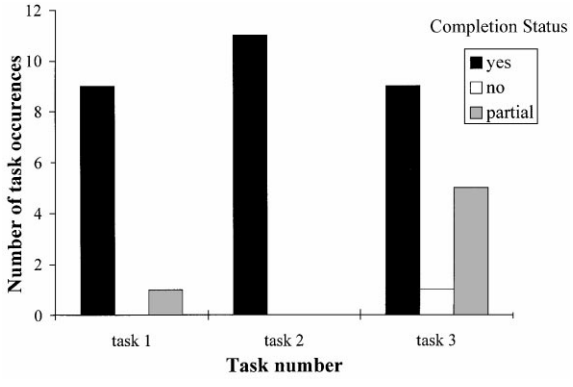


Fig. 5. Number of successful, failed and partially successful occurances for each task catagory. Note: that the total number of occurences in each task is different (10, 11 and 15, respectively for tasks 1–3).

Subjective responses to the questions asked of the participants during the briefing and debriefing sessions were gained through some voluntary contributions but mostly through prompting and suggestions. The cubs agreed before and after the session that it would be difficult to touch their friend and that he would not be able to type on the computer. However, they said that the remote user was able to participate fully and complete his computer badge. All of them liked computers both before and after the session. They all agreed that the Nintendo control was 'really cool'. Their drawings differed considerably before and after the session.

The remote user's comment about the system limitations included not being able to type and draw on the computer, not being able to read the computer screen and the difficulty in physically 'following' people in the computer room. The remote user's map of the computer room seemed to be limited to his field of view at the time he was asked the question. (Figs. 6 and 7)

## 5. Discussion

The mean error values for all of the tasks performed in this session are quite low but the task of reading the computer screen (task 2) seems to be more difficult (error prone and time consuming) than either reading the blackboard or finding a person. Because of the incompatibility between the motion of the monitor scan lines and the video conferencing system, it was not possible for the user to clearly focus on the computer screen. When attempting this task, the user zoomed in very closely and continued to try to obtain a clear view of the screen. This task may become less difficult with an improvement of monitor hardware or video synchronization capability.

The zoom-off-target errors are particularly low because tasks 1 and 3 did not require close-up

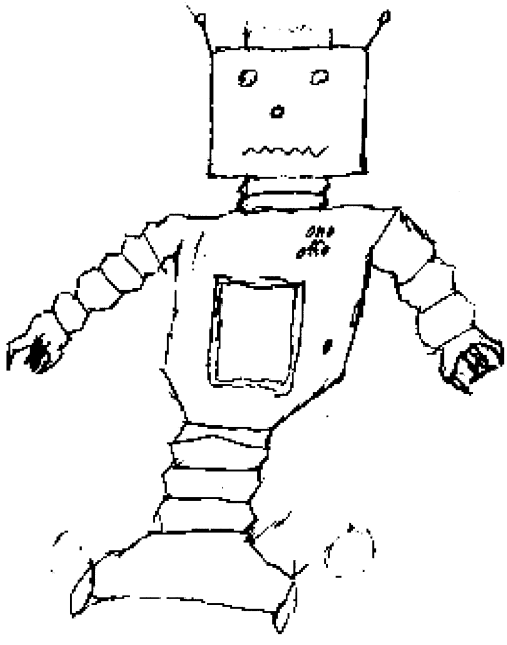

Fig. 6. Drawing of system by one cub from briefing session.

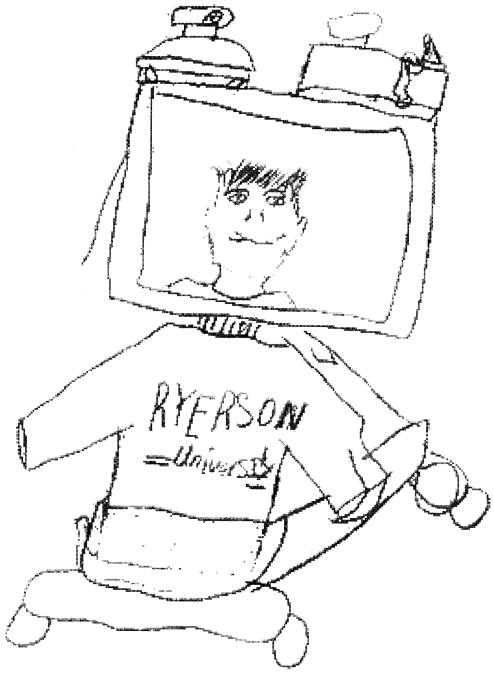


Fig. 7. Drawing of system by same cub from de-briefing session.

views. Other tasks that may require close-up views such as finding a small object in the room were not evaluated in this pilot study. Further research is planned to determine whether tasks requiring zoom controls exhibit the same results as task 2.

The number of incomplete task attempts was higher for finding a person (task 3). This may indicate that other mechanisms were being used to participate in the session. For example, the user was listening to the instructor without completing visual contact. The use of the attention light was largely unsuccessful in gaining the attention of the instructors and the other cubs. Its use to affirm an opinion was missed completely during the session. This may be a result of the short duration of the 'on time' for the attention light. When the attention button on the Nintendo control pad is depressed, the attention light is activated for approximately 1 s. This is insufficient time to allow the instructor to notice this light in the classroom unless he/she is looking directly at the system. Further tests will be performed to determine if attention can be gained more readily by providing a light which stays on longer, on/off control of the light, or a different attention device.

The response to the Nintendo interface for control of the system was very positive. The controller was easily recognized and afforded a natural interface for remote control of the system. The physical limitations of the system were understood by all of the cubs but did not prevent the remote student from participating.

The remote cub's comments about the system limitations with respect to the computer-based tasks, 'following people' and also his limited drawing of the computer room suggest that some system modifications could provide more natural participation in the classroom. Local computer access for the remote user may be necessary if the classroom activities involve computers. A wider angle camera may allow the remote student to have a wider peripheral view and provide greater awareness of the classroom activities and its contents.

In this pilot study, the system was used by a single participant and for only 2 h. Additional studies are required to evaluate the system for other users, and over longer periods of time (weeks rather than hours). However, the initial results point

towards a successful implementation of a communication tool allowing a remote user to participate in his/her regular class(es).

## 6. Conclusions

The positive subjective attitudes toward the system, and the low number of errors for three control tasks are encouraging. The system seems to be effective in allowing a student to participate in classroom activities. The Nintendo interface appears to be an effective control method. Based on the results of this study, further development is planned for the attention mechanism. Further evaluation is required to determine the effectiveness of the system in other classroom settings with a variety of activities and users, and for extended periods of time.

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