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COGNIRON

The Cognitive Robot Companion

Integrated Project

Information Society Technologies Priority

D3.1.1
Evaluation of user studies on interaction styles and personal spaces

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Executive Summary

This report describes the first two exploratory studies carried out as part of the University of Hertfordshire's first phase of the program of research for the COGNIRON Project in Research Area (RA) 3.1. The first study looked at groups of children interacting with a single robot in a party game scenario. The second study carried out an investigation using single adults interacting with a single robot in three specific contexts, relevant to the COGNIRON project. The robots used for the studies were mechanistic in appearance and are the same as some of the other partner institutions are using in their experiments. The main conclusions indicate that humans do not respond to a robot's socially interactive features, movements and signals in a simple one dimensional way. Multiple simultaneous social signals and cues given by the robot must be consistent with each other in order to have the desired social effect and avoid confusion. The appearance and voice quality of a socially interactive robot will be important factors in achieving social acceptance by humans. In particular, the quality of the robot's physical movements was perceived by subjects as a factor that would need to be improved. Further analysis of the data from the two studies is to be carried out over the next six months, and longer term plans for future work are presented.

This work was carried out to satisfy the requirements of part of Research Area (RA) 3 as outlined in Work Package (WP) 3.1 to meet the 12 month target; Deliverable 3.1.1.

Role of Personal Spaces in Human-Robot Interaction in COGNIRON

The work package WP3.1 forms part of the work that will be necessary to implement the COGNIRON Function (CF)-SOC: "Socially acceptable interaction with regard to spaces". This work package aims at providing experimental data on socially acceptable, non-verbal behaviour with respect to social distances and personal spaces as relevant to the key experiments. This will contribute to the development of a useful model of interaction styles for Human-Robot Interaction (HRI).

Relation to the Key Experiments

Our work in RA3 has a main aim of developing initial default settings ("social rules" or maxims) for socially acceptable, non verbal behaviour with regard to social distances. The results from this work are intended to support Key Experiment (KE) 1, also relevant to KEs 2 and 3, with regard to the COGNIRON Function "Socially acceptable interaction with regard to spaces" (CF-SOC), as described in the Key Experiment Specification Document.

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1.0 Introduction

This report details the exploratory study carried out in the subject area defined under Research Area 3 (RA3) to satisfy phase one of the work requirements outlined in Work Package 3.1 (WP3.1). This work package aims at providing experimental data on interaction styles and personal spaces, leading to the eventual development of a model of interaction styles for Human Robot Interaction (HRI). The deliverable (D3.1.1) is detailed in the Key Experiment (KE) Document [2] and the work described contributes towards facilitating the implementation of the COGNIRON Function (CF) outlined in the CF-SOC section of the KE Specification Document [COGNIRON 2004].

The two exploratory studies described in this report were planned from the start of the year 2004, and carried out at the UH premises during the periods from June to the end of August 2004. The data obtained from the exploratory studies were partially analysed during the following months and the main results to date are presented in later sections of this report. Further analysis of the data is still to be carried out in 2005 (COGNIRON project months 13 to 18).

Both trials were conducted using commercially available, human-scaled, PeopleBot robots. The first study took place in June, taking advantage of a larger event run by the FP5 European Project VICTEC [2003]. This involved some 400 children coming to the University of Hertfordshire (UH) and taking part in a large study into computer software evaluation. The COGNIRON team were able to take advantage of this event by providing sessions for 194 of the children over four days of the event. These sessions were used to run interactive games with groups of children and a single robot. This study is described in the section - A Robot Interacting with Groups of Children: A Play Scenario. The main aims of this study were to investigate social spaces and interaction styles in a group scenario involving children, but the study also served as a means for the newly formed Hertfordshire COGNIRON team to get experience in large scale HRI studies with PeopleBot robots.

The trials for the second study, which involved a single human subject in a simulated living room scenario, took place directly after the first study sessions and are described in the section - A Robot Interacting with Single Adults: A Living Room Scenario. The main aims of this study were to evaluate in a task-oriented living-room scenario different social behaviour and interaction styles of the robot from a *human-centred perspective*.

The scenarios and situational contexts described in this report were designed to study interactions between human subjects and robots where they could, as much as possible, be directly compared to results from human-human interactions. Note; since the PeopleBots are very different in appearance and behaviour from human beings, a straightforward application of human-human interaction to human-robot interaction seems implausible. The situations chosen were directly relevant to the scenarios proposed for the COGNIRON Key Experiments (KEs) 1 and 2. The main situational contexts studied were:

1. How robots should approach humans taking account of humans social distances.

2. How humans approach robots and how they perceive the robot's social distance.

3. How human subjects and robots can negotiate dynamic social space and distance requirements within the same shared (work) area.

4. How a robot can attract a human subject's attention, and also indicate intention. Which features are efficient at signalling intention, without being unnecessarily intrusive, annoying or socially offensive?

5. How a robot can offer and supply help (to perform a task) to a human subject when the subject is seated at a desk, while taking account of the subject's personal space and social preferences.

Note: Indicating intention (point 4. above) by the robot is more relevant to COGNIRON Function Intentionality Attribution (CF-IA) which is also being investigated by the UH team. Details of the study which were relevant to CF-IA are covered in the report on RA6/WP6.3 in Deliverable D6.3.1; Evaluation of User Studies on Intentionality and Attribution [COGNIRON, 2004].

Two exploratory studies have been carried out and have collected a large amount of data relevant to the five human-robot interaction situations above and the relevant initial results to date are presented in later sections. At the time of this report deadline (January 2005), analysis of this data has not yet been completed and the current situation is as follows:

Analysis of non video data from both studies is currently well advanced but not yet completed.

Detailed observation and analysis of the video data from the first study is partially completed and from the second study the video data analysis is currently being prepared.

1.1. Brief Overview of Human Robot Interaction Styles and Personal Spaces

The field of research into social and personal spaces with regard to robots, designed for use in the home, is a particular area of research within the wider field of Human - Robot Interaction (HRI). An excellent overview of socially interactive robots (robots designed to interact with humans in a social way) is provided in Fong et al. [2003]. As the study of socially interactive robots is relatively new, there is not a large body of established theories, methods and research experience to draw upon, so experimenters in the field usually use existing research into human-human social interactions as a starting point. Hall [1966, 1968] provided the original basis for research into social and personal spaces between humans, and those methods and results, along with later research, have provided a guide for more recent research, studies and investigations into human reactions to robots [Goetz and Kiesler 2002] [Paiva et al. 2004] [Scopelliti 2004] [Woods, et al, 2004]. The CERO robot assistant study [Severinson-Eklundh et al, 2003] and the Robovie peer tutor robot trials with children [Kanda et al. 2004] are two of the few published works which describe studies involving long term periods of humans interacting with robot companions.

1.1.1. Human-Human Interaction

Existing research into human-human social spaces provides a useful insight into how to tackle the problem of investigating how humans and robots will interact together within a common work area or space. While the methods used to study human-human interaction may be relevant to this type of study, and the aim of many of robot designers is to create robots that will interact socially with humans, it is probable that humans will not react socially to robots in the same way that they react to other humans [Norman, 1994] [Dryer 1999] [Khan 1998]. However, it is useful to compare the differences between human-human interactions to those involving human-robot interactions under similar circumstances. This will provide a way to obtain a (relative) measure of human-robot social reactions.

1.1.2. Human-Robot Interaction

In COGNIRON, since different robotic platforms are used in the three different Key Experiments, our studies with the PeopleBots are more closely linked to KE1 which will use a similar robotic platform. It is usual in studies such as this to use remotely controlled robots in which the desired behaviour to be tested is implemented using human operators. This is commonly termed the Wizard of Oz (WoZ or WOZ) method, after the famous wizard. As a methodology, this has been validated [Maulsby et al. 1993] [Dahlback et al. 1993] and allows the rapid testing and verification of proposed behaviours before they are (laboriously) implemented autonomously on robot platforms. For a recent overview of different experimental methodologies in HRI, cf. Robins et al. [2004].

The two exploratory studies described in this report are initial studies into the area of Human Robot Interactions (HRI) as outlined in WP3.1. Although speech is an incidental part of these interactions, the main emphasis of this work is on the physical, spatial, visual and audible *non-verbal* social aspects of robots interacting socially with humans.

Previous work has generally assumed that robots are perceived as social beings and that humans will respond to a robot in a similar way, for example, as to a pet, another human, or even as to a child or infant. Evidence exists that humans do respond to certain social characteristics, features or behaviours exhibited by robots [Breazeal 2002][Friedman et al. 2003] [Sony, 2004]. A general model of human robot social space, which covers the complete range of behaviour, appearance and context for a robot to interact in a socially acceptable way with a human, is beyond the scope of the COGNIRON project. Therefore the domain has been limited to a robot functioning in a socially acceptable manner, in a domestic companion role in scenarios specifically relevant to Key Experiments 1 and 2.

1.2. Research Questions

The questions posed below were designed to test the initial assumptions made from comparable human-human studies, as being of direct relevance to the COGNIRON Key Experiments, KE1 and 2 in particular, and to provide experience, evidence and results that will direct future work.

1.2.1. Social Spaces and Distances

Previous work in psychology has demonstrated that social spaces substantially reflect and influence social relationships and attitudes of people. Embodied non-verbal interactions, such as approach, touch, and avoidance behaviours, are fundamental to regulating human-human social interactions [Hall, 1968]. Human-robot distance has been suggested as a factor in the assessment of children's friendships and social status, [Kanda et al., 2004]. The hypothesis advanced for testing in this exploratory study is that human-robot interpersonal distances will be comparable to those in human-human interpersonal distances [Hall 1966, 1968]. Previous work in psychology has demonstrated that social spaces substantially reflect, influence and regulate social behaviour in particular contexts. The following situational contexts were selected as being especially relevant to the KE scenarios:

1. Context Free:- At what spatial distances and orientation do the subjects initially approach the robot? Can these distances be correlated with their initial attitudes towards robots? Do we find differences in human subjects' behaviours and attitudes when the robot approaches a subject, or a subject approaches the robot?

2. Negotiated Space Context:- How do a human subject and robot, carrying out separate tasks within the same limited work area, dynamically negotiate and interact to overcome or avoid (potential) interference with each other? Do people prefer to interact with or react to a robot which simply stops or actively gives way to the human subject (Socially ignorant, socially interactive robot behaviour styles)?

3. Shared Task Context:- When the robot approaches a seated human to help or share in carrying out a task, is an indirect, slow and careful approach better than a relatively fast and direct approach (Socially interactive, socially ignorant)?

1.2.2. Behaviour and Attitudes towards Two Robot Personalities

A robot companion is likely to require social, cultural and individual adaptation skills, in order to accommodate different user preferences and requirements. In order to develop a methodology to assess and quantify what a human subject's reactions to robot behaviours signify, this exploratory study focused on analysing human subjects' reactions and attitudes towards two contrasting styles of robot behaviour; *socially ignorant* and *socially interactive*: [1]

1. Do we find differences in people's behaviour and preferences when the robot interacts with people in a socially interactive or ignorant way? In what situational contexts do these differences occur?

2. How to judge if people are comfortable or uncomfortable in a particular situation with the robot? Are there any behavioural indicators that will allow the robot itself to estimate a human subject's comfort level? (This will inform key scenarios on how to design the robot's social behaviour in future).

[1] The terms Socially Interactive, and Socially Ignorant were merely labels to describe two consistent *contrasting* robot social behaviour styles at the preliminary stage of the studies.

2.0 A Robot Interacting with Groups of Children: A Play Scenario

2.1. Introduction

Over four days from the 15th to the 18th June 2004 (Tuesday-Friday), the University of Hertfordshire COGNIRON project team was involved in providing 24 sessions for 194 children (103 boys, 91 girls) visiting the University under the auspices of the *Virtual ICT with Empathic Characters* (VICTEC) project. It was an opportunity to try out and gain experience in some of the techniques that will be used for future trials. Useful results were also gained from the work with the children that complemented and directed the implementation, results obtained and analysis of the second study; a Robot Interacting with Single Adults: A Living Room Scenario, which was carried out directly after this study (see section 3.0).

2.2. Aims and Objectives of the Experiment

2.2.1. Aims

The main aims of this experiment were:

1. To conduct exploratory studies into HRI particularly in the area of non-verbal social interactions with regard to personal spaces between a robot and groups of children.

2. To investigate how a robot can attract the attention of humans, and how humans react to being the focus of the robot's attention.

2.2.2. Objectives

The first objective was to observe and analyse how groups of children behave and react to a robot in three different contexts:

1. When the children initially encountered and approached a stationary robot

2. When the children interacted with a robot at various distances

3. When a moving robot approached a stationary child

The second objective was to study how a robot can influence or attract attention, by using combinations of two attention attraction methods, in order to see if any differences can be perceived in the children's reactions in contexts 2 and 3.

2.3. Experimental Set-up and Method

The VICTEC-COGNIRON sessions started at 11.30 and finished at 13.00 every day; three groups of approximately 20 children (overall approximately 60 children each day) were split into 6 groups of 10, which allowed two sessions to run in parallel in two separate rooms. Therefore, 6 sessions each day were run with each group having a maximum time of 30 minutes for each session.

Each session consisted of the robot playing two interactive games;

1. Rotation Game – The robot revolved in the middle of a circle of children, and after a time, stopped and selected a child by beeping twice and using one of four pointing condition methods. This went on for six rounds; at each round the selected child was removed from the circle and the remaining children moved 0.5m closer to the robot. The main aims of this game were to study the children as they moved closer to the robot, as the robot faced them and the reactions of the selected child.

2. Wander Game – The children stood in a circle as before, but at each round the selected child was removed, but the remaining children did not move in towards the centre. The robot wandered randomly around the circle of children for a time, then selected a child by facing the child from a distance of 800mm and making two beeps only. The main aims of this game were to study the children as the robot moved and faced towards them, and also the reactions of the selected child and the other children.

There were 4 experimental conditions (a 2x2 experimental design). This gave a sample size of about 60 children exposed to each condition, with 6 sessions run using each of the four conditions with the robot moving with:

1. A passive pointer and a passive camera

2. An active pointer and a passive camera

3. A passive pointer and the camera moving

4. An active pointer and the camera moving.

The passive pointer was always in the lowered position, actually pointing to the floor. When activated, the pointer raised so that the hand with pointing finger was pointing directly at the person or object directly in front of the robot (Figure 1). The camera was either stationary, pointing straight to the front of the robot, or when moving, panned from side to side in a random manner (Figure 2).

Note: For safety reasons, the second game (Wander Game) was always performed with the pointer in the down position and selection did not involve active pointing (a lifting pointing arm).

Figure1: PeopleBot Robots fitted with Pointer and Basket. Showing the pointer in raised and lowered positions**.**

Figure 2: Detail of PeopleBot Camera. Arrow indicates panning movement by camera.

The sessions were recorded on videotape. Body movements, postures and behaviours of the child subjects (behaviours) were for behaviour coding during the subsequent observation of the tapes. The exact format of the behavioural observation and analysis was finalised after the twenty-four sessions were completed.

The robots used for the study were commercially available PeopleBot robots. They were fitted with a lifting arm which acted as a pointer. The arm could be raised or lowered under program control. The robots were also fitted with a small basket which was used to hold the presents which were presented at each round of the games. A reward was necessary for the children in order to be consistent with the play context of the study.

2.3.1. Overall Session Format

The sessions were all broadly similar in format. Differences will be described in the detailed experimental conditions that follow below. The two rooms to be used for the study were both 10m long by 6m wide. Each room contained a PeopleBot robot in the centre, initially covered by a black plastic sack. The room was marked out into 6 concentric zones around the robot at 0.5m radii. There was video recording equipment setup in each room consisting of two fixed video cameras, and a feed from the robot onboard video camera. The videos were time coded, for later synchronization and evaluation, and each day's sessions were recorded on a new set of tapes. The tapes were then downloaded and stored on computer readable compressed format (mpeg 1 or 2) on CD or DVD disk, for later evaluation. The robots were programmed to carry out the two games, (see subsection below) which were to be played in each session. The robots were controlled in a semi-autonomous manner, with the operators retaining control of starting the games, and also making sure that the robots did not point to an empty space when selecting, either by stopping the turning robot when it was pointing at a child (Rotation Game), or driving the robot to the nearest child (Wander game). The two robot operators were hidden in an adjoining third room along with the wireless network, recording equipment, and the various data processing computers. During the experiment, the video camera and robot operators took notes, by observing any particularly interesting behaviour of the children interacting with the robot that could be later used for the evaluation. The sessions were co-ordinated by an experimenter and followed the same overall format outlined here:

1. The children entered the room and at the beginning of the session, each child was given a sticker that was attached to their clothing. Each sticker was numbered, so that the child could be tracked through the experiment.

2. The first questionnaire (see Appendix I) was then administered to assess the initial opinions of the children. They were asked to write down their number in the corner of the questionnaire, so that an individual comparison of their responses could be made with those before and after the experiment. This initial questionnaire consisted of two questions and was administered before the children saw the robot.

3. The experimenter then uncovered the robot and let the children move around the robot without giving them any indication of where they should position themselves (for a period of 1 minute or so). The initial responses, reaction, distance and orientation towards the robot were recorded (See Figure 3). The children's initial behaviour and state was also recorded on videotape, and their reactions could be observed, checked and assessed against the paper records after the session. The data collected for this part of the experiment was particularly relevant to Objective 1.

4. Instructions were given as to how to play the Rotation Game (see section 2.3.2), and then it was played. The children were told to line up equally spaced around the outer circle in number order. The data from this part of the study was directly relevant to Objective 2.

5. Instructions were then given how to play the Wander Game (see Section 2.3.4) the game was then played. The children were told to take up the same starting positions for the previous game. This part of the session was relevant to Objective 3.

6. At the end of the session the children were given a short final questionnaire (see Appendix II) consisting of three questions related to their game experiences with the robot.

7. Finally, bags with small gifts were given to the children to show thanks for participating in the study.

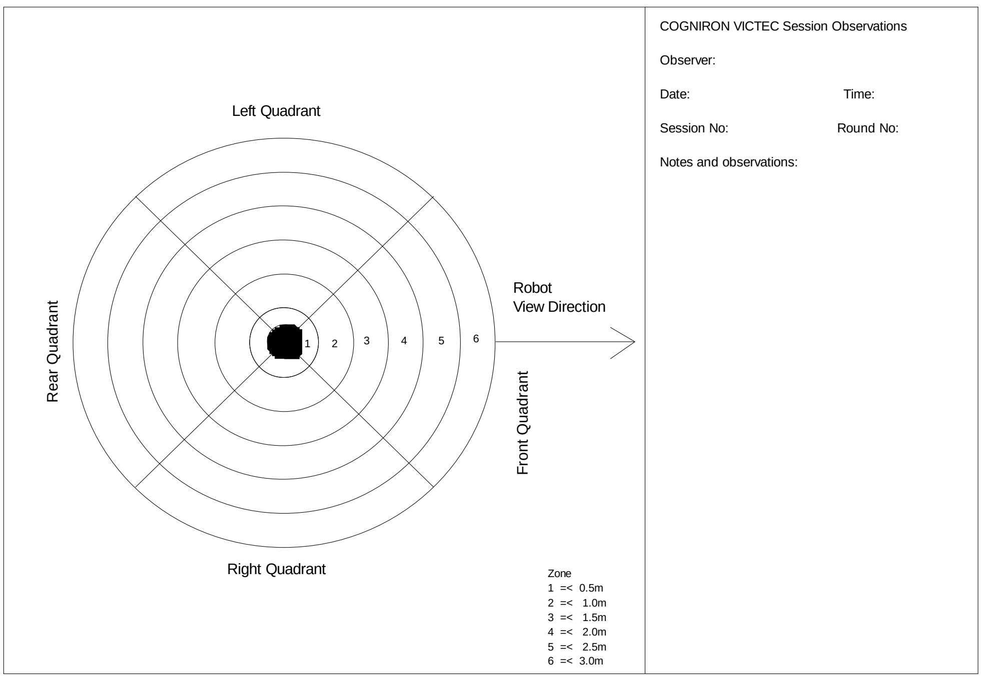

Figure 3: Initial Children's Position, Recording Chart.

2.3.2. Rotation Game

For the first game activity children were asked by the experimenter to form a circle, equally spaced around the robot, initially in the outer marked zone. The robot then rotated on the spot in the centre of the room for a period of time, with various slow, fast, reverse and teasing movements to keep the children interested. The robot's camera was stationary or moving according to the selection condition required. The robot moved in this way for a period of time of between thirty and sixty seconds, then stopped rotating when it faced the nearest child, then it carried out the appropriate pointing/selection procedure (see figure 4). The child selected obtained a small reward and was then removed from the circle. The children then moved into the next circular zone - towards the robot. As a result they naturally moved closer to the robot for the next round of the game. The process was repeated until all the children but four had been removed from the circle. These last children also got a prize so there were no winners or losers as such at the end of the game. This was to prevent any possible influence on the children's opinions at the end of the session as all children could perceive themselves as equal winners.

Figure 4: Children Move Closer to the Robot during the Rotation Game

On each round, the children moved closer and closer to the robot; - this was the main objective of the experiment. As the robot selected an individual child, it devoted its attention to the child being selected. This allowed the behaviour and state of the selected child to be observed, as s/he became the focus of the robot's attention. The reactions of the children (and those of the other children watching) being selected, were also recorded by the fixed video cameras, and by the robots onboard camera system, so detailed observations and assessments could be made after the session.

The robot operators implemented the robot's game playing behaviour by means of a mixture of pre-programmed scripts and direct control. This form of direct control used to simulate future robot behaviour for the purpose of HRI studies is commonly called Wizard of OZ (WOZ) control. For each round of the game, the operator started the robot program, which caused the robot to rotate in a pseudo-random way. During this phase of the movement, the robot's camera could either be stationary or moving, depending on the selection condition, to simulate the robot actively looking for a child to select. The robot carried out a series of rotation movements in the centre of the game circle for a pseudo-random period of time between thirty and sixty seconds. After this time the robot program made the robot turn slowly in a pseudo random direction and the WOZ simply stopped the movement when the first child swung into view from the robot's onboard camera. Each session ran using a pseudo-random sequence of movements. Therefore for each session, the robot's movements playing the Rotation Game were identical (though each round of the game appeared to run in an unpredictable way to the participants). This method allowed the exclusion of genuine random perturbations of the robot's behaviour on the results[2].

2.3.3. Wander Game

The initial set-up for the second game was identical to the first game. The children were told to take up the same position as they did initially for the previous game. This time, for each round, the robot wandered within the circle, apparently looking for a child to select. After a short time a child was selected by driving to the selected child at a range of 800mm, facing the child and making a double beep sound. The child then received a small prize and was removed from the game area. The process was repeated for succeeding rounds as time allowed (usually three or four rounds).

The real aim of this game was to record the children's reactions as the robot approached the stationary children. The video cameras and the onboard robot camera were used to record the children's reactions as they were approached and selected, and also observe other children being approached and selected by the robot. A detailed analysis of the children's reactions was made from the video records at a later date.

Figure 5: A Robot Approaches a Child in the Wander Game

The robot's wandering behaviour was implemented by the following method: The robot has an underlying safety behaviour which uses the built in sonar range system to prevent it from colliding with any object. The robot was programmed to move directly in a straight line until its forward progress was blocked, either by a child or a boundary of the game area. The robot would then turn until the side sonar sensors ceased to register an object close by then drive forward at constant velocity. The effect was to keep the robot moving within the game circle in a random way. The robot moved in this way for a period of time of 1 minute. The robot would then stop and the WOZ operator

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[2] The number generated by this technique is not truly random, as the technique relies on a mathematical function which generates an unpredictable and apparently random number series from a given starting, or seed, number. However, if the generator is seeded with the same number each time it is started, the "random" sequence is the same each time. For this study the same seed was used for each session, so the actual sequence of movements for each round was (pseudo-)randomly different, but the actual rotation sequences were identical for each session.

would then take over the robot control. The operator would drive and orient the robot towards the nearest child at range of 800mm, then beep twice to indicate selection.

2.3.4. Robot Attention Seeking and Indication

While the robot was in the searching phase of the Rotation and Wander games, the robot could either have a stationary camera, or a moving camera to give the appearance of actively seeking a child to select. For the rotation game only, when selecting a child, the robot could simply face the selected child with a stationary lowered arm, or actively point by raising its arm. The robot used one of four permutations of the two attention attraction methods to gain the selected child's attention:

1. The robot's arm used as a pointer (operated by the robot's gripper), which was either actively or passively pointing.

2. The onboard camera was either actively moving or fixed relative to the robot (See Figure 6.).

From the twenty-four sub groups tested, six of the sub-group game sessions were selected for each selection/ attention attraction method. Conveniently, this meant that on each of the four days, the (six) sessions were performed with one of the four possible permutations. This allowed between-subject evaluation of the sessions.

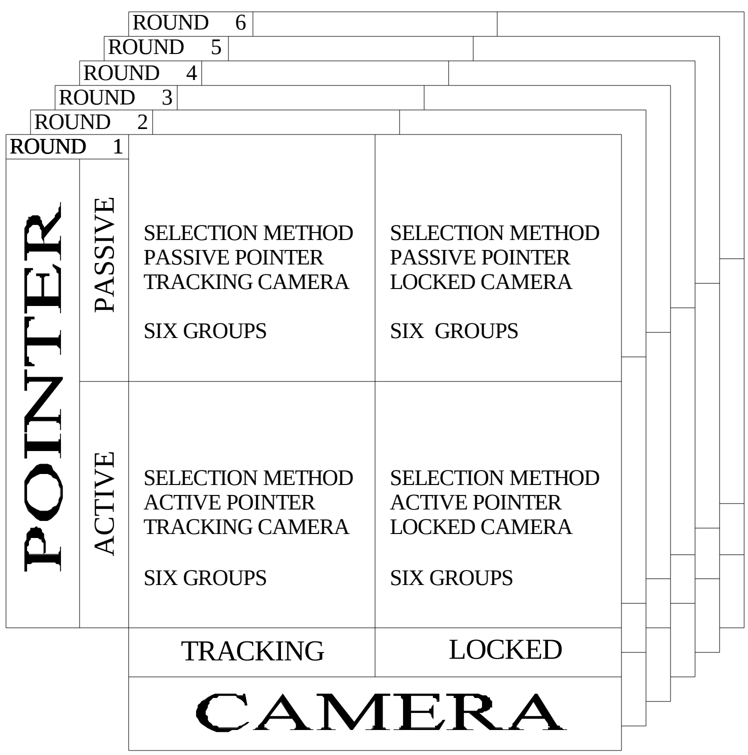


Figure 6: Experimental conditions and schedule of the Rotation Game

2.4. Pre and Post Session Questionnaires

This section presents the main results from the questionnaires and resulting analysis. This was performed using SPSS V12 and standard statistical methods, commonly used in the fields of psychology, ethology and social sciences.

2.4.1. Questionnaires: Design and Methodology

The pre and post trial questionnaires were designed within the constraints of the limited time allowed for completion during the session, and of being readily understood by children of 9 to 11 years old. The main aim was to assess any changes in attitude or reactions during the course of the trial, so the first questionnaire was administered before any contact was made with the robot, and a second after the games had completed. Only five minutes were allocated for each questionnaire, which meant that each questionnaire could contain only two or three questions in addition to essential demographic and tracking information.

The first questionnaire, in addition to age and gender, asked for each child's views on computers and whether they liked the idea of having a robot helper at home. These questions were chosen to see if there was any correlation between enthusiasm for (computing) technology and robots in the first instance.

The post trial questionnaire, in addition to the tracking number, asked for the child's views on how they enjoyed their interaction with the robot and how comfortable they felt. As they now had experience with interacting with a robot, their views were also sought on acceptability of having a robot home helper. They were shown three photographs of robots, with humanoid, pet and mechanical type appearances respectively. All the question responses were made on five point Likert scale.

The second question from questionnaire one, and the first two questions from questionnaire two, were categorized as indicating the level of approval (or disapproval) of robots. These questions were used to track any gross changes in approval or disapproval after exposure to a real robot.

2.4.2. First Questionnaire Responses

The first questionnaire asked for the VICTEC number, age and gender of the child, details of which are given in Figure 7:

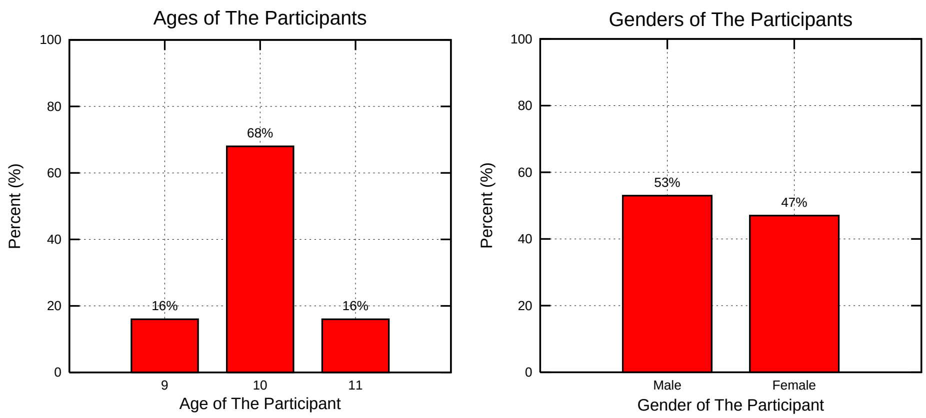


Figure 7: Demographic Details of the Children: Charts

The main part of the first questionnaire consisted of two questions:

3. Do you like computers as part of your everyday life?

4. Do you fancy the idea of having a robot as a helper at home?

The results are displayed in the charts in figure 8:

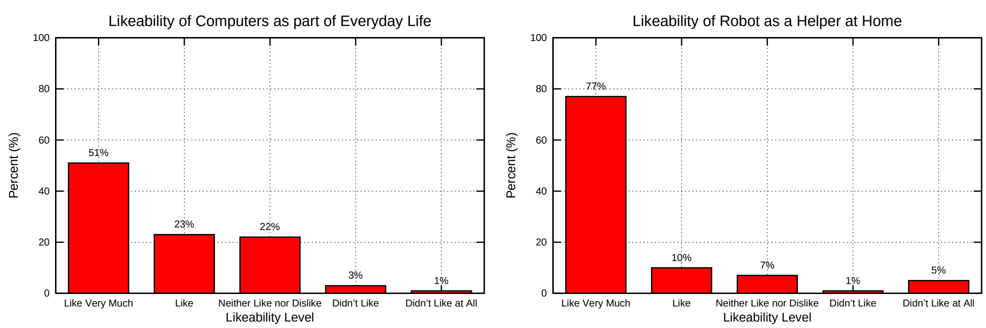


Figure 8: First Questionnaire Responses: Frequency Charts

A Spearman rho correlation test was carried out between the question 1 and 2 responses. As expected, there was a highly significant correlation between these two responses [rs (194) = 0.34, $p < 0.1$].

2.4.3. Second Questionnaire Responses

The second questionnaire was administered after the end of the second game in the last five to ten minutes of the session. This questionnaire asked the children to supply their identification number (to crosscheck with the first questionnaire) and consisted of three main questions:

1. Did you enjoy your interaction with the robot?

2. Did you feel comfortable or uncomfortable being close to the robot?

3. For each photograph tell us how much you would like to have the robot as a helper at home.

For each question or photo rating, the child was asked to provide a rating on a five point Likert scale. For Q1 the rating was 1 = Liked very much, to 5 = Do not like at all. For Q2 the rating was 1 = Very comfortable, to 5 = Very uncomfortable. For each of the robots shown in the photographs the ratings ranged from 1 = Like very much, to 5 = Do not like at all.

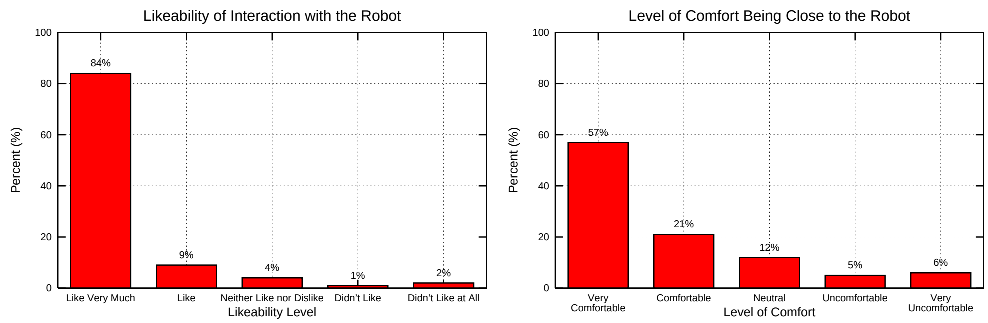


Figure 9: Responses to Second Questionnaire; Frequency Charts

A Spearman rho correlation test was carried out between the responses to questions 1 and 2; Likeability of interaction with the robot and Comfortable being close to the robot. There was a high degree of correlation [rs(194) = 0.2, $p < 0.1$].

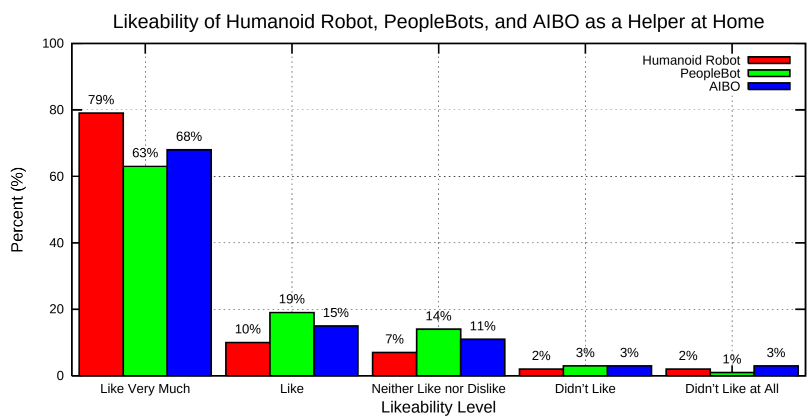


Figure 10: Robot Appearances and Likeability

It can be seen that the Humanoid robot has the highest overall total approval rating at 89%. The Aibo pet robot (83% combined like/like very much) has a similar total popularity to the PeopleBot (82% combined like/like very much).

2.4.4. Gender Differences

Independent-Samples T-tests (Two-tailed) suggests that there is only one significant gender difference in the mean scores for the likeability of having a humanoid robot as a helper at home. Boys indicated that they would like a humanoid robot significantly more than girls [t (194,2) =-2.140; p=0.034; $p<0.05$].

In particular, 82.5% of boys stated that they would like very much having a humanoid robot helper compared to slightly less (74.7%) of the girls. Also none of the boys disliked the idea of a humanoid robot companion in the home compared to the girls, of whom a small number did not like (4.4%) or did not like at all (4.4%).

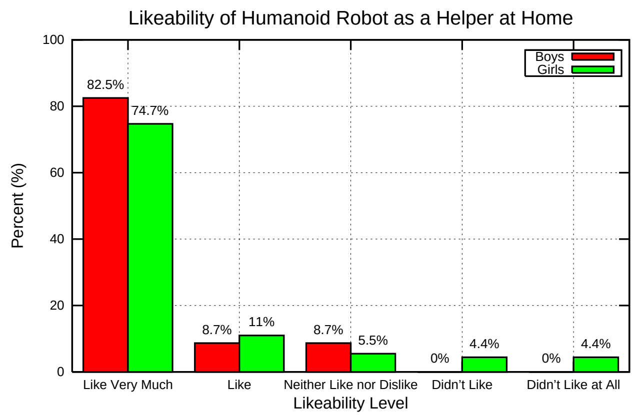


Figure 11: Humanoid Robot Helper at Home; Boy v Girls Comparison

2.4.5. Differences between the experimental conditions

In order to examine differences between experimental conditions, Independent-Samples T-tests (Two-tailed) suggests that no significant differences were found in the children's responses after they had been exposed to the different experimental conditions.

2.4.6. Pre and Post Experiment Robot Approval Comparison

The first and second questionnaire responses were sorted into broad categories indicating approval or disapproval of robots. The accumulated ratings were then turned into percentages for the total approval/disapproval ratings for each questionnaire so it could be seen how the children's approval of robots had changed through the experiment. It can be seen that there was little overall change in the approval/disapproval ratings of the children before and after the experiment.

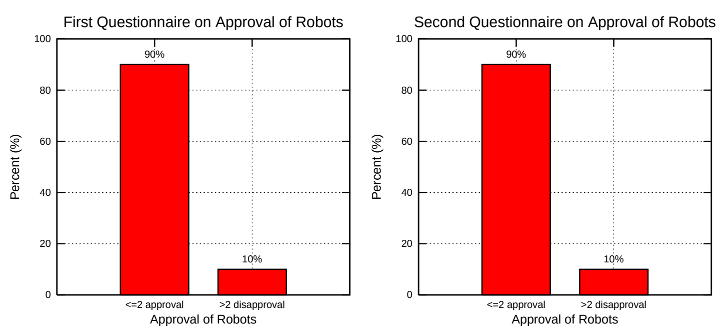


Figure 12: Changes in Robot Approval Rating between Questionnaires

2.4.7. Questionnaires: Summary and Conclusions

Most children, approximately 90%, were broadly approving of robots prior to the trial, and after the trial the same proportion were still broadly approving, indicating that the robot games had not influenced or changed their attitudes towards robot. Due to the relatively short exposure to the robot this result is not unexpected.

As expected, there was a strong correlation between approval of computers and approval of robots. There was also a strong correlation between likeability of the interaction with the robot, and comfort in being close to the robot.

There was no apparent effect, from the children's responses to the questionnaires, of the four different robot pointing and selection conditions used for the games played with the robot.

More children liked the idea of having a Humanoid robot (79%) as a helper in the home rather than the next most popular, an Aibo robot (68%). The PeopleBot robot (63%) was the least popular as a home help. The PeopleBot and the Aibo do not have good manipulator abilities, so this possibly reflects the practicalities of requiring a larger sized robot, with manipulation abilities, to do actual useful work in the home. Also, the PeopleBot had the least anthropomorphic features compared to both the Aibo or Humanoid robots.

Overall, boys were more favourable to the idea of having a humanoid robot helper at home compared to girls in the age range (9 to 11 years) tested. Also there were some girls did who not like the idea of having a humanoid robot at all.

2.5. Initial Distance and Orientation; Analysis and Results

At the start of each session, when the robot was first uncovered, the children in each group were allowed to move into the game arena and allowed to take up their natural positions and orientations to the robot. Each child's position and orientation, the gender of each child, whether a teacher was present, along with any other observations, were made by the camera operators/observers on the record charts. The recorded information was later checked and verified against the video record after the session. This initial position information was recorded before the children had participated in the games (so before any interaction involving experimental conditions) and before the children had seen the robot move. The robot was stationary, though powered up and activated. Therefore, noises from the sonar range sensors and motors were audible throughout the game area. The PeopleBot robot used for this experiment is rather mechanistic in appearance. Therefore the only visual cues that indicate the front of the robot are three possible features:

1. The direction which the robot moves in either forwards or reverse gives an indication of possible front and rear ends of the robot. This would not be apparent until the robot actually moves, which the children do not actually see for this part of the test. Therefore, this would not be a factor to consider for indicating the front of the robot in this part of the study.

2. The Camera mounted on top and to the front edge of the robot. The camera points forward when the robot is first activated and is stationary.

3. The PeopleBots used in the experiment were fitted with a simple arm, on the right hand side, to act as a pointer. The pointer was made of cardboard and thus did not represent a safety risk. This did not move at this stage of the experiment and was in its lowered position (see Photograph in Figure 13). On the left hand side, the robots were fitted with a basket (empty at this stage) to hold the presents which would be given during the course of the game


Figure 13: Children's Initial Distances and Orientation Observations

Some measurements of the initial distance and orientation have not been included in the analysis. This was either because the children had been told explicitly where to stand by a teacher or the experiment supervisor, or because the children were not given an opportunity to take up their initial positions or orientation. The valid results are summarised in the table (Figure 14).

Number of Valid Initial Distance and Orientation Measurements	
Boys Measurements	71
Girls Measurements	60
Total Children's Measurements	131

Figure 14: Table of Number of Valid Initial Distance and Orientation Measurements

2.5.1. Initial Distance Results

The initial distance results are summarised in Figure 15. It can be seen that the boys tended to take position slightly further away from robots than the girls. However, there was more variation in the boys distance relative to the robot as indicated by the slightly larger standard deviation value.

Children's Initial Distances Relative to PeopleBot Robot (metres)	
Overall Averages	
Mean	2.01
Median	2.00
Standard Dev	0.75
Girls Averages	
Mean	1.88
Median	2.00
Standard Dev	0.61
Boys Averages	
Mean	2.29
Median	2.00
Standard Dev	0.73

Figure 15: Table of Initial Distances and Valid Measurements

The initial orientation was also recorded for the valid groups of children and is summarised in Figure 16.

Valid Initial Children's Orientations Relative to PeopleBot Robot.	
Number in front of robot	70
Percentage	53%
Number to right of robot	27
Percentage	21%
Number to left of robot	16
Percentage	12%
Number behind robot	16
Percentage	12%

Figure 16: Table of Initial Orientation of Children

It can be seen that just over half (53%) of all children when entering the same area as a PeopleBot initially take up a position to the front of the robot. Nearly twice as many children took up position on the right hand side of the robot (21%) as on the left hand side or to the rear of the robot (both 12%).

Percentage of Girls in Front	47%
Percentage of Boys in Front	59%

Figure 17: Table of Percentage of Boys and Girls Initial Position in Front of Robot

It can also be seen that a smaller proportion of girls took up an initial position in front of the robot, though the girls did tend to take up a mean initial position which was approximately 0.4m closer to the robot than the boys (Figure 15).

2.5.2. Initial Distance Experiment; Summary and Conclusions

The children initially tended to place themselves at an overall mean distance of 2.0m (St Dev = 0.75) which is consistent with the social distance which would be used by humans to communicate with non-friends, and ranges from 1.2m to 3m. The implication is that most of the children related to the robot as a social entity, even though the PeopleBots used for the study only had one arm (with a hand) which was the only explicit anthropomorphic feature. The robot's onboard video camera possibly acted as a focus of the children's attention also. Due to the play context, the children were probably very eager to interact, and because of the detailed preparation necessary for the event to take place (a school excursion), they were probably primed to expect an interaction to take place.

The initial distance and orientation results presented here suggest that there is a strong tendency for a majority of just over half of the children (53%) to position themselves to the front of the robot initially. There was also an indication that proportionally more boys than girls (59% to 47%) positioned themselves at the front of the robot. However, a larger proportion of boys tended to place themselves further away from the robot (2.31m mean distance, St Dev = 0.75) than the girls (1.88m mean distance, St Dev = 0.61).

From the number of children who positioned themselves at the front of the robot (53%), it is clear that either the camera, the pointer or both together, is a powerful attractor of the children's initial attention, even though the camera, arm and robot were stationary. There may also be a weaker indication that the stationary arm pointer possibly had some effect in causing some children to prefer positions on the robot's right side (21%) as opposed to left side (12%) or behind the robot (12%). However, the entrance to the game area was normally to the right of the robot so this may have affected the observed right/left preference. Further work will include more statistical analysis of the data.

2.6. Video Observation of Games; Analysis and Results

The video of the game sessions was saved for later behavioural and statistical analysis. Due to the limited time available, analysis of the video material from the sessions has not yet been completed. Therefore, the analyses and results presented in this section are only those that have been completed at the time of this report deadline, January, 2005.

Figure 18: Observation of Children's Reactions to the Robot.

2.6.1. Behavioural Activities Chosen for Analysis

The main aim of the analysis was to examine how different levels of seeming "interest" in the environment shown by the robot (as indicated by the state of the robot's camera and pointer, which can be either moving or static) influence the attentive behaviour of the children. We also examined if attentive behaviour of the subjects was affected by the changing distance to the robot during the rotary game.

After preliminary viewing of the videos, Pointing, Talking and Looking were selected as behavioural activities for an initial analysis. These activities were understood as signs of interest and attention shown by the children to the environment (including the robot and other persons).

2.6.2. Data Coding

The selected activities were coded using Annotator software (written by Alexander Kljubin, at the UH Adaptive Systems Research Group). It enables the interactive recording of behavioural variables at fixed time intervals: coded activities can be scored and saved in an excel file during the simultaneous display of a video clip of an experiment. This methodology of behavioural analysis has previously proved beneficial in analysing human-robot interaction [Dautenhahn and Werry, 2002]

A one-second time unit was adopted for this purpose and behavioural activities were not scored as necessarily mutually exclusive.

Behaviour was scored according to the target it was directed at (Robot, other children, other persons such as teacher or the instructing researcher) as shown in the table below:

<table>
<tr><th>Behaviour</th><th>Target</th><th>Comments</th></tr>
<tr><td rowspan="4">POINTING at,

TALKING at,
or
LOOKING at</td><td>ROBOT</td><td>PeopleBot™</td></tr>
<tr><td>CHILDREN</td><td>Other children in the group</td></tr>
<tr><td>OTHER PERSON</td><td>Teacher or the person running the experiment</td></tr>
<tr><td>UNKNOWN TARGET</td><td>When the object of child’s interest was outside the camera view</td></tr>
</table>

Figure 19: Video Annotation Coding of Behaviour and Targets

For the purpose of the analysis, attention targets coded as Other Person and Unknown Target were joined together into a lump-category “else”.

2.6.3. Selection of Children for Coding

From each session one child was selected for analysis and the same child was scored for both the rotation- and the wandering game (in this report only data from the rotary game are considered). Selection was based on the visibility of the child in the video clip and the duration of time he or she spent playing the game (i.e. children that dropped out of the game after the first two rounds were not considered).

2.6.4. Coding Time Frames

The coding started from the beginning of the game (a start signal given to the robot by the person running the experiment) to either the end of the game (when all remaining children were asked to take the present from the robot) or the end of the game for the child selected for coding (when he or she was picked by the robot).

During the rotation game, the moment when children moved to the next circular zone was also coded (from the moment the child selected for coding had both feet on the next circle). Zones are coded from 1 to 5, which correspond to very close to further away from the robot.

2.6.5. Duration of Games with Robot Attention Seeking and Indication

Out of twenty-four rotation games, sixteen giving the best quality data were chosen for analysis. This resulted in a final data set consisting of four different subjects for each of the four experimental conditions.

Condition	Duration in seconds	Robot Attention Seeking
Condition 1	272 287 284 403	Camera Static Pointer Static (csps)
Condition 2	284 158 217 285	Camera Static Pointer Moving (cspm)
Condition 3	280 223 282 159	Camera Moving Pointer Static (cmps)
Condition 4	290 288 207 281	Camera Moving Pointer Moving (cmpm)

Figure 20: Duration of the analysed parts of the game and experimental set up

The table in Figure 20 shows the duration of rotation games and the experimental conditions to which they were subjected.

We found a strong effect of the duration of the game on the frequency by which a subject displayed attentive behaviour (Figure 21). As a result of this, statistical tests could only be performed after controlling for the effect of duration or making (matched) comparisons within subjects.

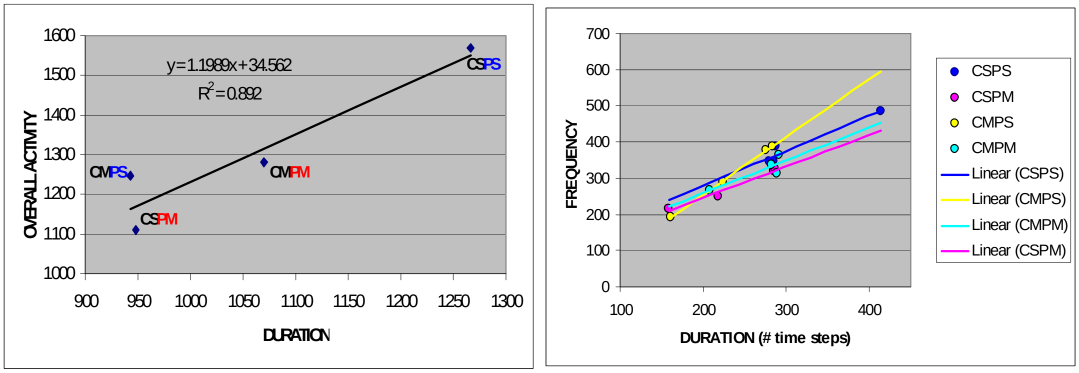


Figure 21: Effect of Duration of Experiments on Attentive Behaviour

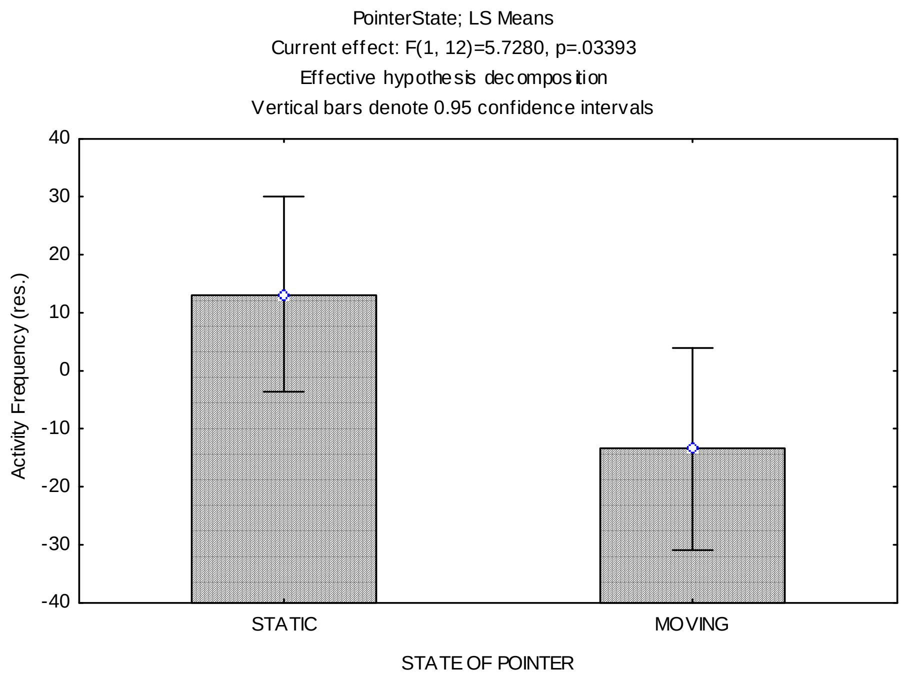
In Figure 21, the effect is shown of the duration of the experiments on the frequency of overall attentive behaviour (the sum of looking, pointing and talking) measured for the whole of an experiment (i.e. summed over the subjects) and for each child separately when subjected to one of the four experimental conditions (cs = camera static, cm = camera moving, ps = pointer static, pm = pointer moving). All regression lines have a slope that deviate significantly from zero and all (Pearson) correlations are significant at $p< 0.05$

2.6.6. Differences in overall activity between experimental conditions

The effect of time was taken into account by using the residuals from the regression between overall activity (the sum of looking, talking and pointing) and the duration of an experiment instead of the raw frequency scores. Residuals were computed for the activity scores of each subject and appeared to meet the assumptions of analysis of variance (Bartlett's, Cox and Hartley statistics for homogeneity of variance; normality of error; no correlations between means and standard deviations of the samples).

A repeated two factor (State of Camera = moving, static, and State of the Pointer = moving, static) ANOVA (ANalysis Of VAriance between groups) was carried out. A significant mean effect for the state of the pointer was found ($F(1, 12) = 5.73$, $P = 0.034$) and indicated that subjects were less attentive to the static pointer, compared to the moving pointer (see figure 22). No significant mean effect was revealed for camera movement and no interaction effect between camera and pointer.

As an alternative procedure an Analysis of Covariance was performed on the raw scores, but with Duration as co-variable. The results were identical to those reported above.

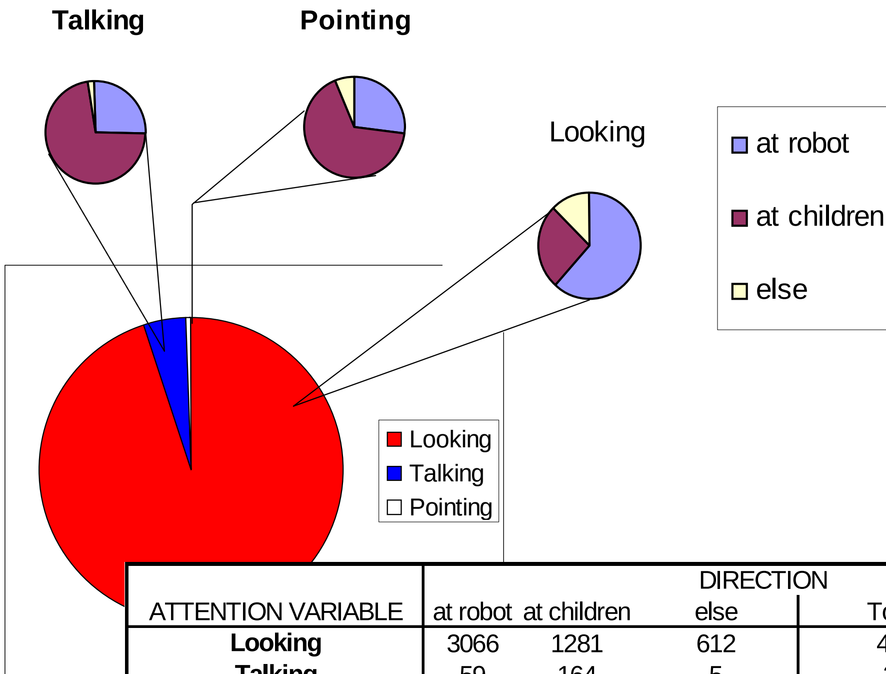


Effect	SS	Degr. of Freedom	MS	F	p
CameraState	168.347	1	168.347	0.353029	0.563437
PointerState	2731.474	1	2731.474	5.727987	0.033929
CameraState*PointerState	54.860	1	54.860	0.115043	0.740336
Error	5722.376	12	476.865		

Figure 22: The effect of the state of the robot's pointer on the overall activity of subjects.

2.6.7. Analysis of Directed Attention

In the previous tests, only the overall attentive behaviour was considered. The figure below shows how attentive behaviour was directed by the subjects. Looking was the most frequently scored activity and was mainly directed towards the robot. Pointing and talking only made up for a small proportion of the overall activities and were in the majority of cases targeted towards the other children.



ATTENTION VARIABLE	DIRECTION at robot	at children	else	Totals:
Looking	3066	1281	612	4959
Talking	59	164	5	228
Pointing	9	22	2	33
Totals:	3134	1467	619	5220

Figure 23: Allocation of direction of attention by the children.

Some of the directed attention variables (after time-correction, i.e. the residuals from the regression with duration) appeared to be significantly correlated among each other, for example pointing to the robot was significantly correlated with talking to the other children (Figure 24). These correlations may be partly due to simultaneous attentive activity: when pointing to the robot, subjects may have talked about the robot at the same time with their group members. However, the reversed correlation (between talking to the robot and pointing to other children) is less easy to explain as is the absence of correlations between talking and pointing to the robot. Further investigations need to be carried out to clarify these matters. Furthermore, it is noteworthy that although looking was the dominant activity, it appeared not to be correlated with any of the other directed attention variables.

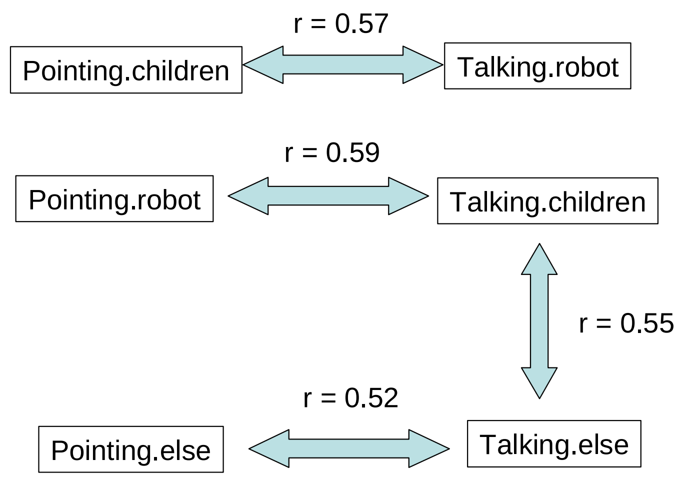


Figure 24: Significant correlations among directed attention variables

2.6.8. Differences within the experimental conditions

In order to examine differences in attention (expressed through Pointing, Talking and Looking) children paid to the Robot, other Children and Other People present in the room, within each experimental condition, ideally a full three-factor (State of Camera, State of Pointer, Direction of Attention) ANOVA should be performed on the (time corrected) frequencies of each of the attention variables. However, because of time constrictions, we another approach was taken.

In order to assess the attention towards the robot in a single measure, for each attention variable we calculated the "AttentionBy·**x**" variable (where x is one of the three attention variables looking at, talking at or pointing at):

$$\text{AttentionBy} \bullet \text{AttentionVariable} = \frac{\text{AttentionVariable} \bullet \text{robot - AttentionVariable} \bullet \text{notrobot}}{\text{AttentionVariable} \bullet \text{total}} \times 100$$

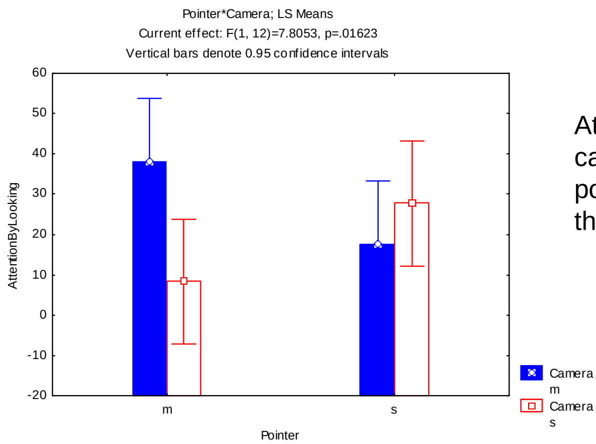
·notrobot refers to the frequency of that attention variable directed at children plus "else" (i.e. not targeted to the robot). Similarly, ·total is the total frequency of the considered attention variable. For example, attention towards the robot by looking at the robot is formulated as:

$$\text{AttentionBy} \bullet \text{Looking} = \frac{\text{Looking} \bullet \text{robot - Looking} \bullet \text{notrobot}}{\text{Looking} \bullet \text{total}} \times 100$$

The division by the total frequency makes this measure independent of duration.

Each of the three "AttentionBy·**x**" variables was subjected to a two-factor (State of Camera, State of Pointer) ANOVA with replication. The results show the significant effect of the interaction between State of Camera and State of Pointer (Figure 25) for AttentionBy·Looking. More specifically, subjects paid more attention by looking at the robot than other items when both pointer and camera were either moving or both were static. Children looked relatively less at the robot when camera and pointing were in conflicting states.

Effect	Univariate Tests of Significance for AttentionByLooking				
	SS	Degr. of Freedom	MS	F	p
Intercept	8477.277	1	8477.277	41.83745	0.000031
Pointer	1.224	1	1.224	0.00604	0.939335
Camera	385.461	1	385.461	1.90235	0.192979
Pointer*Camera	1581.549	1	1581.549	7.80533	0.016230
Error	2431.490	12	202.624		



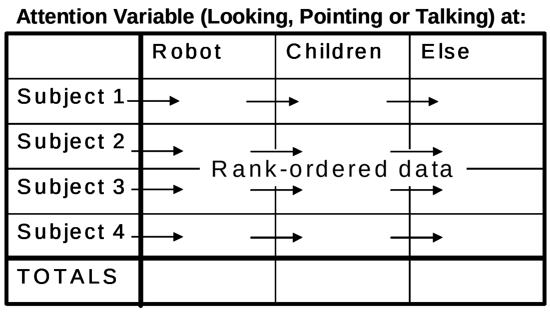
Significant interaction:
AttentionBy·Looking is higher when camera moves but ONLY in case pointer is also moving. Otherwise the reverse association holds

Figure 25: Analysis of Variance for the variable AttentionBy·Looking under the two conditions of camera and pointer state (moving, static)

For AttentionBy·Pointing and AttentionBy·Talking no significant affects due to camera or pointer state were found.

In order to examine in more detail the possible differences in attention (expressed through Pointing, Talking and Looking) children paid to the robot, other children and "else", within each experimental condition, a series of Friedman tests was performed.

The Friedman test is a non-parametric two-way analysis of variance (without replication) for rank-ordered data. The test was applied to compare for each subject how often it displayed attention towards the three targets (robot, children, else = unknown + other persons).



(same table for each of the four experimental conditions)

Figure 26: Set-up of the Friedman tests. Comparisons between the targets of attention are made within each individual.

Friedman tests were carried out separately for each of the three attention variables (looking, talking, pointing) as for each of the four experimental conditions (the set-up is illustrated in Figure 26, the results are summarized in Table 27).

	LOOKING		POINTING		TALKING	
EXP. CONDITION	χ^2	p	χ^2	p	χ^2	p
C = M, P = M	**6.50**	**0.04**	not sign.		not sign.	
C = M, P = S	**8.00**	**0.02**				
C = S, P = M	**12.25**	**0.002**				
C = S, P = S	**8.00**	**0.02**			**8.00**	**0.02**

Figure 27: Table of Results of the Friedman tests.

Pointing

No significant differences could be found in the amount of time the children spent pointing towards the robot, children or "else" within any of the experimental conditions. Pointing towards the other persons, a teacher or the researcher running the experiment did not occur at all.

Looking

For all experimental conditions we found significant differences in the duration of time children spent Looking at the robot, other children or "else" target. In all cases children spent the largest amount of time looking at the robot, less time looking at other children and the least amount of time looking at other persons plus unknown targets (see Figure 28 and Figure 29).

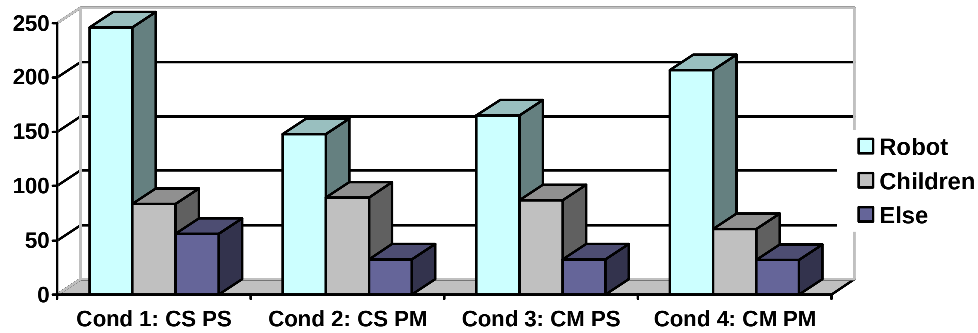


Figure 28: Mean Time (in Seconds) Spent Looking at Various Targets for the Four Experimental Conditions: CS = Camera Static, CM = Camera Moving, PS = Pointer Static, PM = Pointer Moving. The standard deviations are: Condition 1 – Robot SD = 52.5, Children SD=9.46, Else=26.3; Condition 2 – Robot SD = 46.13, Children SD=28.4**,** Else =16.68; Condition 3 – Robot SD = 36.22, Children SD = 39.15, Else=13.07; Condition 4 – Robot 27.39; Children SD=21.74; Else SD=11.02.

Talking

Significant differences in time the children spent talking to the robot, other children or other persons/unknown targets were found only within experimental condition 1 (Camera Static, Pointer Static): in that case children spent significantly more time talking to other children then to the robot or "else"(χ^2=8.000, df=2, p=0.018, $p<0.05$).

Although not significant, the same tendency was observed in the experimental condition 3 (Camera Moving, Pointer Static). Therefore, these two conditions were further analysed together. The outcome of a Friedman test performed for experimental conditions 1 and 3 together was significant (χ^2=12.074, df=2, p=0.002, $p<0.01$) and suggests that when the robot's Pointer was Static, irrespective of the Camera status, children talked significantly more to other children then to the Robot or to other persons/unknown targets (Figure 29).

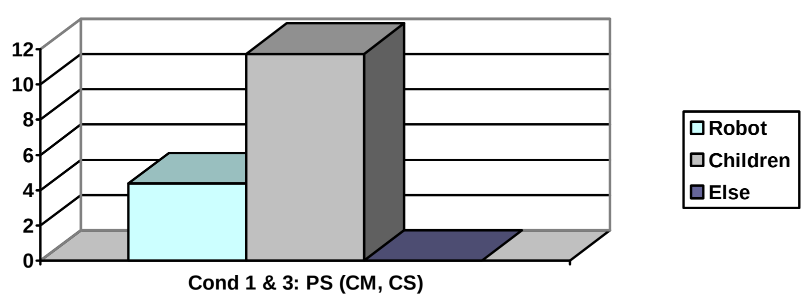


Figure 29: Amount of time spent talking to other children when the pointer was not moving

2.6.9. The Effect of Distance to the Robot

Similar analyses as described above were carried out taking the distance to the robot (i.e. the zones in which the subject was positioned in) into account. We did this by entering a code for zone (from 1 to 5, corresponding with closer to further distance) as an extra factor in the analysis of variance. However, this inclusion lead to serious violations of the assumptions underlying ANOVA and we therefore had to perform separate tests for each of the four experimental conditions. None of the tests showed significant effects.

2.6.10. Children Study Video Analysis; Summary and Conclusions

The analysis showed that within all of the experimental conditions, irrespective of Camera or Pointer status, children spent most of the time during the game looking at the robot. A part of the interest children showed in the robot might be attributed to the novelty effect and expectations. The rotation game was always the first in the series, so children saw the robot moving for the first time and it is these data that were analysed for this report. If this is correct, we should find a lower frequency of looking at the robot for the wandering game. This hypothesis will be investigated in the future.

The lack of significant differences in the amount of time children spent pointing at the robot, other children or "else" might be explained by the rare occurrence of this behaviour during the experiment. Pointing at other persons did not occur at all, probably as a consequence of obeying social norms (the "other person" in the experiment was always an adult). Pointing at the robot or at other children was also quite rare and varied distinctively between children.

It is worth mentioning, that some children started mimicking the start 'thumbs up' signal, given to the robot at the beginning of each game. This could be interpreted as trying to influence robot's behaviour or make a contact with it.

The seemingly "attentive" behaviour of the robot influenced the behaviour of the children in various ways, although not all of the effects are easy to interpret.

Overall activity was highest when the pointer was not moving, which may be due to boredom, leading in turn to increased talking and interactions with the other children. The heightened attention by looking at the robot showed a surprising result: children were less interested when the camera and pointer were in conflicting states. Possibly this "confused" the children or was counter to their expectations of a "balanced" behaviour on the part of the robot. Apparently, human-robot interactions cannot be understood as one-dimensional responses to simple stimuli.

The only significant differences between talking to the robot, other children or other person/unknown targets were found for experimental condition 1 and for the combined data of condition 1 and 3. In both cases children spent most time talking to other children and less to the robot or "else".

Since in condition 1 both Camera and Pointer were static, it is possible that the children interpreted this as a lack of interest from the side of the robot. This in turn might have made the children less interested in the robot and therefore to led them to be engaged in a conversation among themselves instead. This is in line with our observation that the overall activity of the children was highest when the pointer was not moving.

This fact and the outcomes of the Friedman test on the combined data from condition 1 and 3 (Pointer static, Camera Moving or Static) suggest indeed that the robot's pointer was a stronger stimulus for the children then the camera. A possible explanation is that its movement was more conspicuous then that of the camera.

No effect of distance to the robot could be demonstrated, but at the time of writing only overall attentive behaviour was analysed. We are currently testing the influence on "social spaces" for the separate directed attention variables.

3.0 A Robot Interacting with a Single Adult: A Living Room Scenario

3.1. Introduction

This second study to be documented here was run directly after the first study in July and August 2004. This study was primarily devised as an exploratory investigation and involved twenty-eight single subject sessions. Each session was a series of experiments with individual adults interacting with a single robot in a simulated living room scenario. The intention of these experiments was to concentrate on the human-centred perspective; which is concerned with how a robot's behaviour appears to humans, regardless of the cognitive processes that might happen inside the robot (robot-centred perspective). It was important to find out how comfortable people feel with "a robot in the home", and how they react in the presence of a robot in different situations. Results from this study will provide and inform future interesting directions to study in more depth (preferably in long-term studies with repeated exposures). To achieve these medium term aims it is necessary to study a wide range of issues relevant to how people perceive, and are comfortable or uncomfortable with robots. These include issues of privacy, controllability, autonomy, predictability and believability that are very relevant for the COGNIRON Key Experiment scenarios of a "robot in the home". The design of the experiment incorporated aspects of as many of these issues as possible within a small number of experimentally restrained scenarios.

3.2. Aims and Objectives

The main aim of this experiment was to carry out an exploratory investigation into human-robot social interactions in situational contexts which were relevant to the COGNIRON Key Experiments 1 and 2. Therefore, three specific aims were identified:

1. To conduct an initial exploratory study into HRI particularly in the area of non-verbal socially acceptable interaction styles with regards to personal spaces.

2. In particular, to study human-robot social interactions in situational contexts which are relevant to the COGNIRON key Experiments 1 and 2

To achieve these aims the following objectives were identified in order to gain results on social and personal distances between a human and a robot by examining three specific cases of the human-robot social spatial relationship;

1. A standing human approaches a static robot, the robot approaches a static standing human. (Comfort distance).

2. Robot and human both moving in a negotiated situational task context (Whiteboard Task) with two contrasting robot behaviour styles; Socially Ignorant and Socially Interactive.

3. Robot interacting and helping a seated human (Desk Task) with two contrasting behaviour styles; Socially Ignorant and Socially Interactive.

4. To collect, analyse and correlate various types of data from experimental sessions by saving data records from video, questionnaires, internal robot sensors (e.g. sonar) and direct input from the subject via a hand held comfort level monitoring device.

3.3. Experiment Design and Implementation

The sessions were run at the University of Hertfordshire where a large conference room was converted and furnished to provide as homely environment as possible. Also included adjacent was an enclosed section where the WOZ operators, recording and robot control equipment could be housed, monitored and operated. A maximum session time of one hour was set. This was seen as not posing a great deterrent to obtaining volunteers from within the UH, and also minimised the possibility of mistakes through lapses in the robot and video operators' concentration. This second study was seen as a valuable learning experience for the COGNIRON team. From one to three sessions per day were run over the six weeks allocated for the study to take place.

The particular situational contexts identified as relevant for the COGNIRON Key Experiments (Section 1.2) were:

1. Context Free - The distance that a human subject would feel most comfortable when intending to interact with a robot in two situations; where a human approaches a robot, and also where a robot approaches a human. In this report, these distances are referred to as Comfort Distances.

2. Negotiated Space Context - Moving within the same restricted working area and how a robot should behave when moving around within the same (restricted) workspace as a human.

3. Shared Task Context - Helping a human in a task and how a robot should behave and move in order to jointly work with a human in a socially acceptable way.

The subject first carried out context free social space and distance tests involving approaching and being approached by the robot. The subjects were then exposed to the two contrasting styles of robot behaviour and tested as to how they reacted under the two different situational contexts. The same situational context scenarios were enacted twice in order to test both robot behaviour conditions. This allowed within-subject comparison and thus reduced the number of subjects required. The behaviour styles were always referred to as behaviours A and B during the study so that the experimenter who dealt with the subjects did not give any clues, or express prior expectations when describing to the subject how to carry out the experiments. Socially Ignorant robot behaviour was labelled A. Socially Interactive robot behaviour was labelled B. The order of A/B experimental conditions was randomised for each subject's session.

3.3.1. Robot Behaviour Styles and Differences

The robot behaviours to be tested during the main scenario phases of the study were classified into two types:

A. Socially ignorant. B. Socially interactive.

The selection and classification of behaviours into these two categories was done, for this initial experiment, purely on the basis of what changes the robot would make to its (physically optimum) behaviour if there was no human present. Little is actually known about how the robot should behave in order to be seen to be genuinely **socially aware** in the presence of humans [Dautenhahn et al. 2004]**.** To create a set of contrasting social behaviours for testing in this trial, the following general assumptions were made in order to generate the contrasting behaviours, labelled *socially interactive* and *socially ignorant,* for the robot to exhibit.

If the robot made little or no change to its physically optimum behaviour in the presence of a human the behaviour was classified as socially ignorant behaviour.

If the robot took account of the human's presence, by modifying its physically optimum behaviour in some way, this was classified as socially interactive behaviour.

These generated behaviours may or may not be preferred by the subject. In fact, either may be perceived by a subject as more or less *socially aware* behaviour than the other, depending on the experimental context and the preferences of the subject.

For the purposes of this study, the following behaviours were classified as *socially ignorant*:

1. When moving in the same area as the human, the robot always took the direct path. If a human was in the way, the robot simply stopped and said "Excuse me". The robot simply waited until the obstacle (human) was more than 800mm away before continuing.

2. The robot did not take an interest in what the human was doing. If the human was working at a task, the robot interrupted at any point and fetched what was required. It did not give any indication that it was taking any notice of the human, actively involved or interested in the task.

3. When approaching a human seated at a desk, the robot approached by the most direct route, at the fastest possible speed.

4. The robot did not move its camera, and hence its gaze, while moving or stationary unless it was necessary to accomplish the immediate task.

These following behaviours were classified as *socially interactive*:

1. When moving in the same area as a human, the robot always modified its path to avoid getting very close to the human. The robot moved slowly when closer

than two metres to the human and took a circuitous route, especially if the human's back was turned. If their paths crossed, the robot said "After you" and explicitly waited for the human to move away before continuing.

2. The robot took an interest in what the human was doing. It gave the appearance of looking actively at the human and the task being performed. It kept a close eye on the human and anticipated, by interpreting the human's movements, if it could help by fetching items.

3. If the robot talked, it waited for an opportune moment to interrupt.

4. When approaching a human seated at a desk, the robot approached from the front of the desk, taking a circuitous route if necessary. The robot kept the human in view and moved slowly as the robot got closer to the human.

5. When either moving or stationary, the robot moved its camera in a meaningful way to indicate by its gaze that it was looking around in order to participate or anticipate what was happening in the living room area.

The behaviours were implemented by means of a mixture of autonomous programs where possible (E.g. Wandering behaviour with camera movements, for the co-habituation phase, was entirely autonomous) or were controlled directly or initiated by the WOZ operator. Details of the robot program and operation are given in Appendix IV.

3.3.2. Simulated Living Room Set-up

The simulated living room was set up in one of the larger conference rooms adjacent to the Adaptive Systems Research Group's offices and laboratories. This room was made available for an extended period over the months of July and August so that there was no need to disturb the experimental set-up once installed. The original room measured 8.5 x 4.75m and had one outside window on one end wall, a pair of large double doors on the opposite wall, and a single door (Position 1) on one of the longer side walls, closer to the window end wall; see Figures 30 to 32. The room was partitioned off at one end (AA), by means of office partitions and high wardrobe and shelf units, to form an area with the double doors to serve as a control area for the WOZ operators and space for the control, network and recording equipment. Figure 30 shows the control room with the WoZ operators in place. The large projection screen shows six of the camera view, including the view from the robot onboard network camera. The close proximity of the WOZ operators meant that they could hear directly what was being said in the experimental room area, though this did mean that absolute silence had to be observed by the Wizards while the experiment was running.

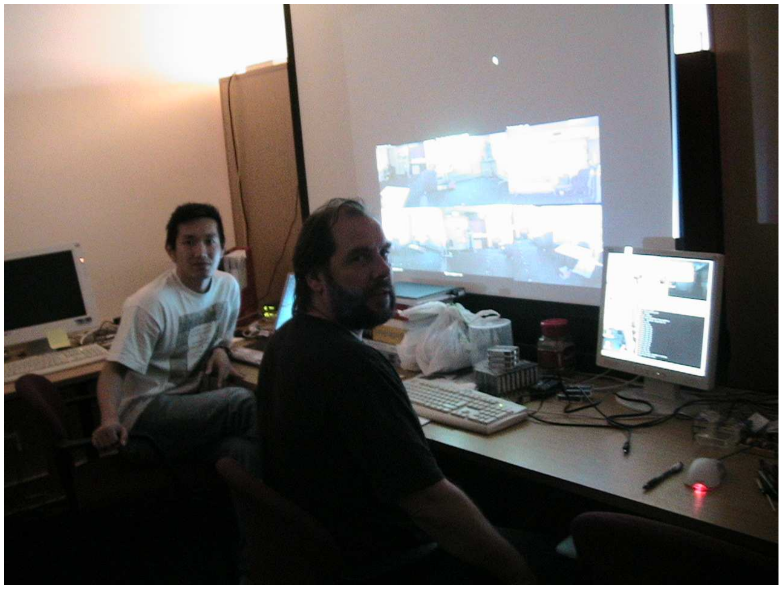


Figure 30: Control Room and the Wizard of Oz Operators

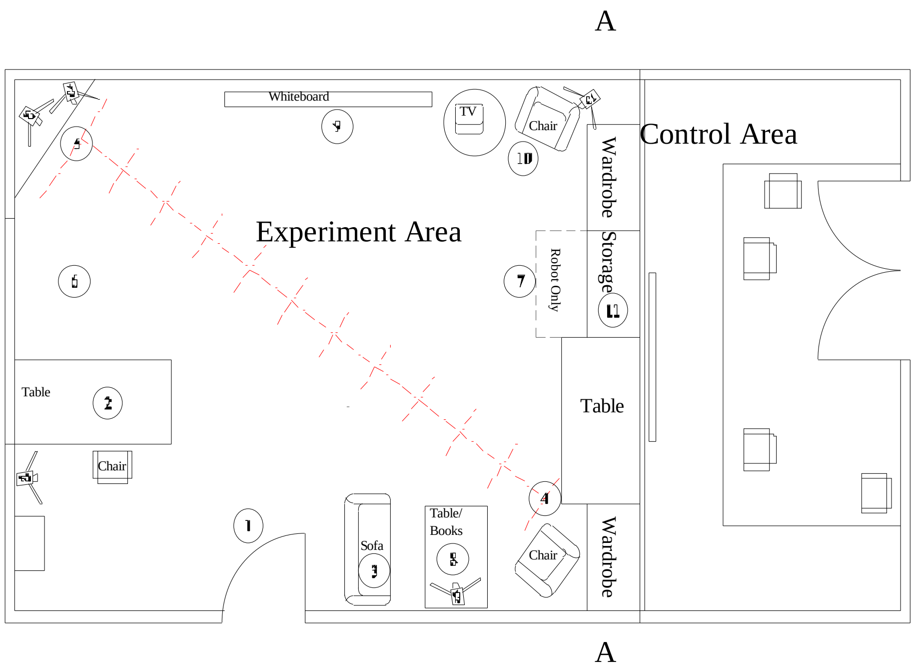


Figure 31: Overview of Experimental Living Room Layout

The room was provided with a whiteboard (9) and two tables. One table reinforced the partition (adjacent to 4) and also was furnished with a number of domestic items – coffee cups, tray, water bottle, kettle etc. The other table (2) was placed by the window to act as a desk, with various items such as a vase of flowers, water bottle and glass etc, for the subject to work at while performing the desk task (see below). There was also a relaxing area, with a sofa (3), small easy chair and a low rectangular coffee table (6).

Directly opposite, next to the white board was another low round coffee table with a television resting on it. There were potted plants on the desk and corner table at (5) and there was also a second small easy chair in the corner (10).

Five network video cameras were mounted on the walls in the positions indicated, so that multiple views of the experiment could be obtained. Another network camera was mounted on the robot to provide a view via the wireless network. The network cables were run back to the control area so that the network cameras video data was recorded onto a dedicated PC. A backup video DV camcorder was also mounted on a tripod in the corner behind the small easy chair, where it could be operated by a WOZ reaching through a small gap in the partition (which was hidden by the wardrobe). In this way, if the network camera systems malfunctioned, there was always a backup video available.

Marks were made on the floor using masking tape at positions 4 and 5, and scale marks made at 0.5m intervals between them. Therefore, human-robot comfort and approach distances could be estimated from the video records, rather than having the experiment supervisor making intrusive measurements or notes during the experimental sessions.

Figure 32: Pictures of the Simulated Living Room

3.4. Experiment Scenarios and Procedure

The experiment was designed so that the scenarios were not highly rich in interactions and human-robot behaviour variables that it was impossible to isolate cause from effect in human robot interactions. Different from the first study involving children in a playful group scenario, the second study focussed on a single adult, in a more "serious", i.e. task oriented context. One of the main problems was to eliminate human unpredictability from the experimental scenarios, while at the same time allowing the human subject free expression of their reactions and behaviour towards the robot, rather than the constraints of the experiment.

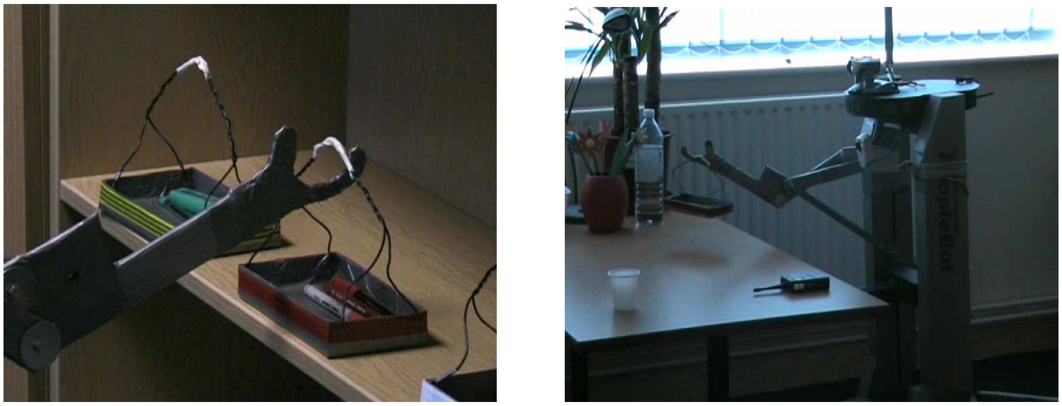


Figure 33: Details of the Robot's End-Effector and Pen Baskets. These were used for fetching required pens for the subject.

The approach taken in the design of the experimental layout, scenarios and room layout was that possible actions by the human were limited, but not explicitly. For example, an area in front of the storage shelf (pens etc.) was labelled "Robot Only". It was not brought directly to the attention of the subject by the supervisor, but this did provide a mental justification for the subjects to allow the (slow) robot to fetch a pen when required rather than to simply get it for themselves. The scenarios, which involved a human working in the same area as the robot, were all designed to keep the human subject busy so that there was little time for the subject to actually indulge in unpredictable (and arbitrary) behaviour. They were also designed to be relevant to KE's 1 and 2. These constraints were necessary to coerce the human subjects into undergoing a similar set of physical and social interaction experiences with the robot. Also with regard to the robot's control capabilities, it made it possible for the robot and the WOZ operators to cope with a simpler scenario situation. There were actually relatively few alternative actions for the subject to take, while actually seeming more complex to those actually undergoing testing. Each experiment session followed the same format:

1. Entry to room and introduction of robot
2. Co-habituation and initial questionnaires.
3. Comfort and social distance tests
4. Whiteboard Task scenario. Social behaviour A or B (randomised)
5. Desk Task scenario. Same social behaviour as 4
6. Questionnaire
7. Whiteboard Task scenario. Alternate social behaviour

8. Desk Task scenario. Same behaviour as 7.

9. Final questionnaires.

The various elements of the experiment are described below. These were supervised by an experimenter who introduced and explained the scenario, and the tasks to be carried out to the subject. She interfered as little as possible with the actual experiment. The experimenter sat in a chair in a corner of the room reading a paper whenever she was not required to deal with the subject. The experimenter responded when addressed by the subjects, but did not actively initiate any communication or interactions while the experiment was running. The aim was to create a scenario that was as close as it could be to the subject interacting with a robot in the subject's home with no other person present for reassurance or social referencing.

3.4.1. Entry to Room and Introduction of Robot

Upon arrival at the experiment site, the subject was shown into the simulated living room. A script was used as a checklist to make sure that all instructions and information given to each subject was consistent, rather than a series of words to be followed in a rigid way. When the subject entered the room the robot came forward to meet the subject. The robot said "Hello there" by way of greeting. The subject's response was recorded on video for later analysis. Although the study was not directly concerned with studying human-robot dialogue, the introduction scenario did employ limited dialogue, and it was important that the subject was not surprised, at a later time in the study, when the robot actually did talk[3].

Figure 34: The Robot Introduced Itself to the Subject

[3] A COGNIRON partner institution (University of Bielefeld) was interested in human robot dialogue and shared some of the videotaped examples of human robot dialogue from this study (in English).

3.4.2. Habituation and Initial Questionnaires

After the greeting phase, the subject was given a series of questionnaires to complete while the robot moved around in the room. This was to allow the subject to habituate to the robot's presence. The design of the questionnaires and analysis of results is mostly relevant to WP6.3 and COGNIRON Function-Intentionality Attribution (CF-IA). This is described more completely in the RA6, WP6.3 Report (D6.3.1). *A summary of relevant data and information from this report is given in Section 3.5*. This usually took approximately ten minutes, during which time the robot wandered randomly around the room. The experiment supervisor remained in the room, but was silent, reading a paper and being as unobtrusive as possible.

The robot random wandering behaviour was adapted from one of the demonstration programs provided with the robot. The robot drives straight ahead until it gets close to any object. If the object is to the side of the robot, the robot steers away from the side the object is on. If the object is in front, the robot turns and drives off on another heading. The robot will not collide with any objects due to it's built in anti-collision (sonar based) system, which stops the robot if an object is too close. The robot is equipped with infrared sensors, which are used to detect tabletops (and automatically stop the robot before a collision). However, these sensors were affected by the fluorescent lights used in the room and could cause the robot to falsely assume a table or other object was in the way. A manual override was employed to drive the robot past any of these "false table" detections.

3.4.3. Comfort and Social Distance Tests

Before starting this phase of the test session the subject was given a comfort level device. This device consisted of a small box that could be easily held in one hand. On one edge of the box was a slider control, which could be moved by using either a thumb or finger of the hand holding the device. The slider scale was marked with a happy face, to indicate the subject was comfortable with the robot's behaviour, and a sad face, to indicate discomfort with the robot's behaviour. The device used a 2.4GHz radio signal data link to send numbers representing the slider position to a PC mounted receiver, which recorded the slider position approximately 10 times per second. The data was time stamped and saved in a file for later synchronisation and analysis in conjunction with the video material.

Figure 35: Photograph of Hand Held Comfort Level Monitoring Device

For this next part of the experiment session, the robot was driven to point 5 next to the corner table and turned to face along the distance scale towards point 4. See Figure 35. The subject was told to start at point 5 and to move towards the robot until they felt that they were at a comfortable distance away from the robot. They were than told to move as close to the robot as they could, then to move away to a comfortable distance. They were then told to repeat these steps again as a consistency check. The comfortable approach, closest and comfortable withdrawal distances were measured for each of the two tests by later close observation of the video records.

The next part of the comfort distance tests was to measure the subject's comfort distance with the robot moving towards the subject. The subject was told to stand at point 5, and the robot moved directly towards him or her. The subject was told to say, "Stop", when the robot was as close as the subject desired. The distance of the robot when the subject said, "stop" was recorded. Note: The robot did not always stop very quickly due to slow reactions by the WOZ and a noticeable lag in the network video monitor display in the control room. The distance was estimated later from close observation of the video records.

3.4.4. Whiteboard Task and Desk Task: Scenarios and Contexts.

The next phase of the experiment consisted of two parts:

1. The Whiteboard task which consisted of a robot and a human working on separate tasks in the same restricted work area.

2. The Desk Task which consisted of a robot and a human co-operating to carry out a task.

The Desk task carried straight on from the Whiteboard task, so that the subject did not get the impression that there was actually any discontinuity between the two tasks.

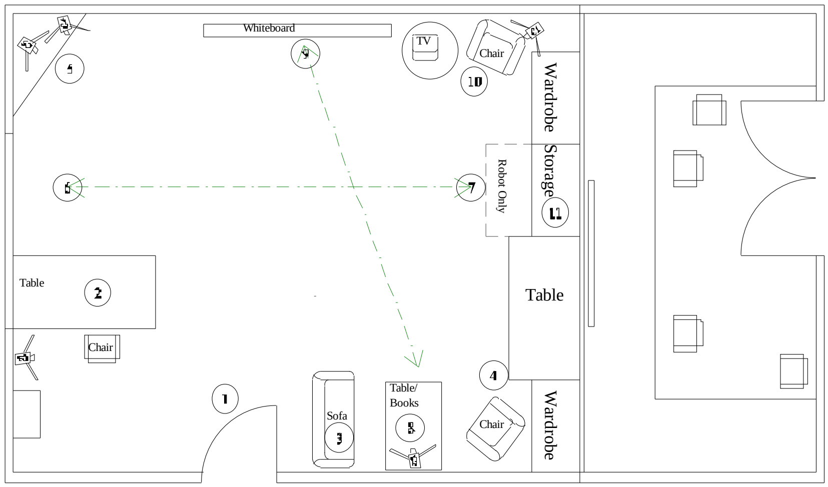


Figure 36: Robot and Subject's Movements during the Whiteboard Task Experiment

Whiteboard Task

The subject was given the task of reading the titles and authors from a pile of eight books piled on the small table (position 8) and then moving across the room and writing the information on the whiteboard (position 9) one book at a time. The robot was simply moving from one end of the room to the other in a predominately longitudinal direction within the room. As the subject was moving in a transverse direction across the robot's path there was a strong probability that there would be several instances where physical blocking of each other's paths occurred. The robot would not be able to collide with the human, due to its underlying safety behaviour that caused the robot to stop automatically at a distance of 0.5m. However, the physical interactions and reactions of the subject could be observed when the robot and subject interfered with each other's motion. On top of, but not pre-empting, the inbuilt overriding safety behaviour, the robot was made to exhibit one of the two behaviour styles, A or B. The aim of this phase of the experiment was to record and later analyse the subject's reactions from the video and comfort monitoring device data. The main interactions of interest were when the subject and the robot crossed each others paths, and also when the subject was working at the whiteboard and the robot was passing behind the subject's back. This phase of the experiment finished when the subject had copied all the book information to the whiteboard, and was typically between six to ten minutes in duration.

Desk Task

The next phase was the Desk Task scenario and involved the robot helping by fetching some extra pens, from the storage shelves (position 11), for the subject who was seated at the desk (position 2). The subject was asked to copy the information from the whiteboard onto a sheet of paper then highlight certain items in a particular pen colour. While the subject was actually working, the robot should notice that additional highlighting pens were required. The required pens were then to be fetched by the robot from the storage area using the specially made baskets that could be picked up and carried by the robot (see Figure 33). The robot was made to exhibit the same social behaviour as exhibited in the previous restricted area interaction phase. This phase was completed when the subject had finished copying and highlighting the required information. This phase typically took from five to ten minutes.

When this scenario was completed, the subject was given a questionnaire to gauge their feelings towards the previous scenario. Once the questionnaire was completed, the whole Whiteboard Task and Desk Task helping scenario was carried out again. This time however, the robot exhibited the alternative social behaviour. The sessions were carried out with alternate robot social behaviours (A and B) tested in the first scenario so that any bias due to habituation and tiredness would cancel out over the 28 testing sessions carried out over the whole study.

After this second scenario, the subject was then given three questionnaires to complete the testing session. This was in order to obtain their view of the robots performance and to compare their current views from their initial views and outlook towards robots. A summary of the relevant questionnaires analysis and results are given in Section 3.5.

3.4.5. Data Collection and Recording Methods

The data collected during each session consisted of the following:

1. Measurement of comfort distances by marked scale on floor: The floor was marked up at 0.5m intervals across the longest unobstructed diagonal as described previously. The data readings collected consisted of three readings - initial approach, closest approach and withdrawal positions – duplicated for a test of consistency. The second reading was the point at which the subject indicated the robot to stop when the robot was approaching the human at the robots maximum speed of approximately 1m/s, duplicated for a test of consistency

2. Automatic measurement of "comfort level" by a hand held device: while the subject was undergoing testing, they held the radio transmitting "comfort" level recording device as described previously. The data was time stamped and recorded in a single computer file for future analysis. Questionnaires (pre, during and post testing): Two questionnaires were administered before the session, one after the first scenario was completed, and another three when the second scenario session was completed. The full analysis of the questionnaires is relevant to CF-IA and is covered in the RA/WP6.3 report (D6.3.1). A summary of relevant points and results for CF-SOC are given in Section 3.5.

3. Video recording of sessions: The sessions were recorded by five network video cameras, from five different viewpoints. Along with the view from the robot camera, this material was recorded on the monitoring computers hard drive for later analysis. A fixed single Digital Video (DV) Camcorder also made a backup recording, of as much of the room as was possible, to act as a backup in case of problems with the network cameras.

4. Sonar data. The readings from the robot's sonar arrays were saved in a file for future analysis. The sample rate was approximately one set of sonar distance readings 10 times per second from the three arrays of 8 sonar range sensors. Each set of reading was time-stamped from the onboard clock which was

synchronised with the network video camera master clock. The sonar readings therefore could be calibrated with the recorded video at a later date for analysis.

3.5. Questionnaires, Data Analysis and Results

The questionnaires in this study were primarily aimed at examining people's perceptions and attitudes towards different types of robots in terms of personality characteristics. Most of the results obtained are therefore relevant to the CF-IA, so these are described completely in the RA6, WP6.3 Report (D6.3.1). The analysis is briefly outlined here, but only as much as necessary to follow the relevant parts which are summarised below.

The main research questions for the WP6.3 study were:

1. Is there a relationship between subjects' personality characteristics and their attribution of personality characteristics to the robot? Do they attribute intentionality to the robot?

2. Do different groups of subjects depending on their gender, age, occupation, educational background attribute different personality characteristics to the robot?

3. Are subjects able to recognize differences in robot behaviour styles?

A psychological approach was adopted using a questionnaires and a quantitative statistical framework to analyse the results. The hope is that the results from this exploratory study will assist in the future progress of the research project which aims to develop the technologies and capabilities that will be needed for a domestic companion robot. The subject sample set consisted of 28 adult volunteers [male: N: 14 (50%) and female: N: 14 (50%)] and was recruited from the University of Hertfordshire. A small proportion (7%) was under 25 years of age, but no one less than 18 took part. Approximately 43% were 26-35 years old, 29% were 36-45 years old, 11% were 46-55 years old and 11% were over 56 years of age. 39% of the participants were students, 43% were academic or faculty staff (e.g. lecturers, professors) and 18% were researchers in an academic institution. Approximately half of them came from a robotics or technology-related department (e.g. computer science, electronics and engineering), whereas the other half of the participants came from a non-technology related department, such as psychology, law and business. All subjects completed consent forms. The subjects were not paid for participation. However, at the end of the trial they were given a book as a present.

3.5.1. Relevant Questionnaires Results

The subjects were asked to give their opinions after the session. There were three questions which asked their views on what they found most interesting about the robot, what they found most annoying, what improvements they would like to see made to the robot, and any comments about their experience during the session. The responses are reproduced below. The numbers in the tables refer to the number of times that a particular subject response occurred. Some subject's responses may be included in two or more categories where they have made multiple points, or referred to several categories in a single response.

What the subjects found most interesting about the robot.

1. The robot's camera pointing towards me, robotic arm, robot talking with me, the room atmosphere with lots of cameras. Overall, it's a very good robot both technically and socially.

2. The robot seems to communicate well or respond well to what I was doing.

3. My level of comfort grew with the robot the longer I was in the room; I wanted to know if it was thinking for itself or being controlled. I felt that it was interesting when it spotted I did not have a pen and helped out. I also enjoyed the fact that it spoke.

4. Getting the pen for me, general attitude.

5. Ability to get me the right colour of pen required, polite 'you go first' attitude and behaviour, mostly it amused me.

6. It understood what I meant: first time it took time but the second time, it was fast so I felt very relaxed to do my work.

7. Its helpfulness in completing the tasks, assisting while allowing me to finish the tasks.

8. Verbal communication, varied vocabulary, just use of functional language made me feel more comfortable.

9. Its spatial awareness.

10. Robot was helpful and I almost thought of it as human-like at the point which amazed me.

11. The way it spoke and moved without being intrusive.

12. It was considerate and polite to me.

13. Ability to recognise I needed a pen.

14. Trying to be helpful.

15. Its slow speed.

16. The appearance of the robot was interesting, the mobility, the communication was quite amusing.

17. This experiment gives the feeling of having a look at a future situation.

18. When I needed pens it brought them to me; it gave way to me during my task.

19. That it decided I needed extra pens.

20. Fetching pens showed potential usefulness; polite when getting in the way.

21. Able to navigate freely without contact collisions; impressed with accuracy of retrieving objects.

22. Ability to recognise I needed a pen.

23. It has a degree of autonomy; it is a great bonus to have minor tasks done for you.

24. I was surprised that I felt very at ease with the robot.

25. Watching the behaviour of the robot; not knowing how the robot would behave next.

26. It appeared to observe my actions and act accordingly; it did not seem entirely programmed.

27. It is polite.

28. Human-like interchange such as; ‘Hello’, ‘After You’.

The responses above can be sorted into broad categories and the frequencies tabulated as follows:

Approving Robot Response Category	**Frequency**
Robot is helpful	8
Robot talking	7
Robot movement	6
Robot fetching pen	6
Robot is polite	5
At ease with robot	5
Robot is responsive	4
Robot autonomy	4

Figure 37: Interesting Things about the Robot Categories

What they found most annoying about the robot.

1. The robot’s sound, and not walking with two legs like a human.

2. Looking at you when you’re doing something, especially when you need to concentrate.

3. I felt uncomfortable by its continued moving around and activity, particularly when it was behind me, and got too close, it felt it was too busy.

4. When it spoke critically, background noise as it moved around because it did not seem to be doing anything.

5. It was slightly in the way when I was copying from the board; cameras felt as if they were watching a lot, although it did not make me feel uncomfortable.

6. Only the noise that it made.

7. Slowness and its attentiveness towards me. I would neither have a cat nor a dog.

8. At the desk, the robot felt too ‘human’ and I had the sense of being too closely observed, I felt uncomfortable.

9. It responded to me rather than entering into any sort of physical or communicative challenge.

10. In the second experiment, the robot was getting in my way as it wandered across the room.

11. Slowness at getting pens, quicker to do it myself and noise when moving

12. Nothing at all.

13. When it was lurking behind me as I wrote on the whiteboard and when it appeared to be monitoring me intensely at the desk.

14. Hanging around the desk and wandering around when it did not seem to be doing anything.

15. Small vocabulary.

16. The electric ‘sizzling’ sound was a bit unpleasant; I wondered whether you would get an electric shock if it came too close.

17. Robot should not behave as a person.

18. Noise; it moved a bit too much when I was writing down the names of the books on the whiteboard.

19. Occasionally it got in the way.

20. I wasn’t sure when it was going to come towards me; I couldn’t really have a conversation with it.

21. When writing, it came over uninvited and watched me.

22. When writing, it came close to the desk and watched me; move around the room.

23. Noise, especially distracting when behind you.

24. Occasionally it got in the way.

25. The robot having a camera.

26. When writing, it came close to the desk and watched me; move around the room while I had my back turned.

27. It did not ask whether I needed the pens, but just went for it; I had the feeling it stared at me when I was writing the book titles.

28. Occasionally it got in the way.

The annoying robot responses above can be sorted into broad categories and the frequencies tabulated as follows:

Annoying Robot Response Category	**Frequency**
Robot movement	15
Looking (Attentiveness)	11
Robot Noise	7
Robot Speech Quality	5
Spatial Distance	2
Robot Personality	2

Figure 38: Annoying Things about the Robot Response Categories

Final Comments on the subjects experiences during the session

1. I like the robot very much, as I am very much interested in Robotics and making a walking robot. It’s a very good idea to develop a human robot. Thanks very much for inviting me for this project as I had seen robots only on television, and today I got the chance to see an actual robot and to interact with it.

2. It should look friendlier, gentle, not like a killing robot (e.g. its arm). It makes me think of terminator.

3. It was moving about too much in a relatively small space. Speech could have been softer in terms of accent. I would have liked to have chatted with the robot.

4. Clearer speech
5. Cameras could be less obvious so you don't feel as watched
6. More human kind of appearance and speech, excited about helping with the project.
7. Remain quiet in a specific place until needed.
8. I would be interesting to interact directly with the robot.
9. *I believe that the robot exhibits behaviours that appear to be human controlled because I am not totally sure the robot is autonomous, my reaction to it is perfectly directed towards the human controller.*
10. I loved the robot; I can't wait to see it performing more tasks.
11. Does everything need to be in correct/ same place for it to operate?
12. It should be more functional in terms of motion.
13. It was very interesting to learn something about the development of robots.
14. It should respond only to commands and be faster.
15. Enjoyable experience for me.
16. It would be interesting if robot had a female voice.
17. This was a very interesting experience.
18. I enjoyed the experiments very much.
19. Speech should be more human-like.
20. I could see one robot being useful at work, fetching tea, photocopying, taking messages etc. The home version would have to be smaller for lots of homes.
21. Very interesting experiment, I am glad I took part.
22. I saw 'I robot' a couple of weeks ago which made me more scared than perhaps I might have been!
23. More human-like, have a personality would probably make interaction feel more natural.
24. More human-like, than machine.
25. This was a fun experiment.
26. As the experiment progressed I felt very comfortable with the robot; I was able to trust it was not going to malfunction and walk into me.

27. A more human-like voice; ask question before acting.

28. No need to constantly move around when not performing a task; Very interesting.

The responses above can be sorted into broad categories and the frequencies tabulated as follows:

Final Comments Response Category	**Frequency**
Liked Experience/Robot	11
Speech Suggestions	7
Appearance Suggestions	5
Movement	5
Direct Interaction	2
Felt In Control	1
Looking (Attentiveness)	1
More Functions	1
Sound	1
Habituation Effect	1
Question	1
Thought Robot was Human Controlled	1

Figure 39: Final Comments after Session; Categories

Note; the response from subject number 9 (emphasized in italics above) indicated that the WoZ approach did not seem to work for this subject. The subject suspected that the robot was (partially) remote-controlled. However, the illusion of autonomy seems to have been successful for the remaining 27 subjects who did not give any indication in their comments that they suspected the robot to be remotely controlled.

Suggested changes to the robot

At the end of the questionnaire, when the subjects were asked if they think that anything should be changed regarding the robot, 93% replied positively. Given a yes/no choice from three possible changes (appearance, speech and behaviour) 43% agreed with changing the robot's appearance, 40% reported change the robot's speech and 43% suggested change the robot's behaviour. Other freely suggested changes are given below:

Freely Suggested Changes to Robot	Frequency
Change Speech; Clearer, gentler, human-like or female speech	6
Pen should be brought only after request or command for a task	5
Less noise, remain more quiet and still	5
More human-like appearance/eyes	3
Less speedy movements and observe at a greater distance	2
More gentle/friendly/have personality	2
More behaviours	1
More colour, More chatty	1
More movement	1

Figure 40: Categories of Freely Suggested Changes the PeopleBot

3.5.2. Adult Study Questionnaires; Summary and Conclusions

From the results and response categories given above, it is possible to identify the factors which the subjects thought have most importance to them in interacting with the robot. Changing speech, appearance and behaviour were identified by approximately 40-43% of the subjects as things they would change when given a yes/no choice as to what they would change about the PeopleBot robot used for the trials.

More significantly, speech and appearance rank particularly highly in the freely suggested list of things that are perceived as important to subjects. Perhaps more significantly (as it was a freely occurring response from the subjects) references to the robot's movements are ranked third overall as a particular behavioural factor which occurs in the subjects' responses. This suggests that it is important for the robot to move in the presence of humans in an acceptable way.

The freely written annoying robot responses also indicate that being looked at closely by the robot was high in the score of things not liked. This reinforces the initial (subjective) observations made of the video recordings, though in the initial questionnaire responses, documented fully in the D6.3.1 Report [COGNIRON 2005], the subjects initially indicated they would actually like the robot to pay close attention to what they were doing. Also, the high pitched whine of the robot's motors, and especially the clicking sounds from the sonar, were perceived as irritating by many of the subjects.

3.6. Distance Experiment Data Analysis and Results

The first part of each session was devoted to obtaining each subject's context-free human-robot comfort distances as described previously.

3.6.1. The Human Approaches the Robot.

Each subject was told to approach the robot as closely as they felt comfortable to do so. The subject was asked to then approach the robot as closely as possible, then to withdraw to a comfortable distance again. This procedure was carried out twice. This ensured a consistent set of four comfort distance results for each subject. The measurements were made from the video record after the session, and were estimated using the marks on the floor which were at 0.5m intervals. The distances were estimated to the nearest 250mm, with an accuracy of ±125mm.

The mean of the four comfort distance results for each subject was calculated and the frequency histogram was plotted, with the ranges set at 0.25m intervals. The results are presented in the chart below (Figure 41):

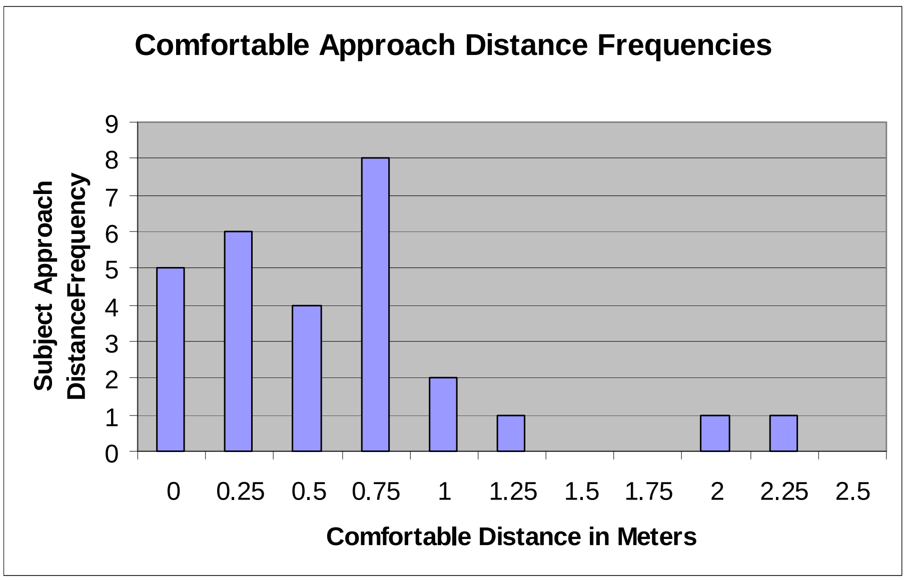


Figure 41: Human Approaches to Robot; Comfortable Distance Frequencies

The generally recognised personal space zones between humans are well known from Hall [1966, 1968] and are (in northern Europe) and are here summarised in table form in Figure 42. The zones are copied from Lambert [2004]:

Personal Space Zone	Range	Situation
Close Intimate	0 to 0.15m	Lover or close friend touching
Intimate Zone	0.15m to 0.45m	Lover or close friend only
Personal Zone	0.45m to 1.2m	Conversation between friends
Social Zone	1.2m to 3.6m	Conversation to non-friends
Public Zone	3.6m +	Public speech making

Figure 42: Summary of Personal Space Zones

3.6.2. Distance Experiment; Summary and Conclusions

It was expected that most of the subjects would either approach the robot to a distance corresponding to the Personal or Social Zone. The largest proportion (50%) of subjects did indeed approach the robot to a distance corresponding to the normal Personal zone for human-human conversation of between 0.45m to 1.25m. while five subjects (18%) approached at larger distances corresponding to the Social zone. However, there were a relatively large number of subjects (32%) who approached the robot at a distance corresponding to Intimate or even Close Intimate on the proximity scale. Clearly, these subjects were not intimate friends with the robot, so the subjects probably perceived the robot as an object or machine rather than as a social being.

As a large minority of the subject tested did not have a technical background, it may be that they were less ready to interact socially with what they perceive to be merely a machine or object, no different to a washing machine, table or television. It is intended to test this hypothesis in the early part of 2005 by looking at the demographic and personality data for the subjects to see if there are any significant correlations between the questionnaire data and the social comfortable distance data.

3.6.3. Robot Approaching the Human

At present, the data for the case where the robot approaches the human subject has not yet been analysed and will be carried out early in 2005.

3.7. Comfort Level Data Analysis and Results

At present, the data downloaded from the hand held subject comfort level device has been saved and plotted on a series of charts. The raw data was heavily corrupted by static from the network cameras used to make video recordings of the session. However it has been possible to digitally clean up and recover a useful set of data. A sample of the raw data and the cleaned up version is given below for illustration:

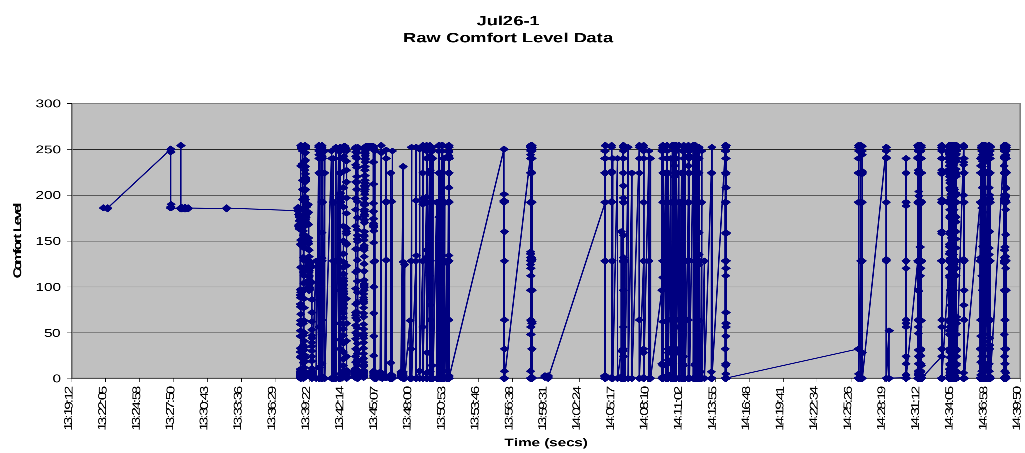


Figure 43: Raw Data as Received from Handheld Comfort Level Monitoring Device

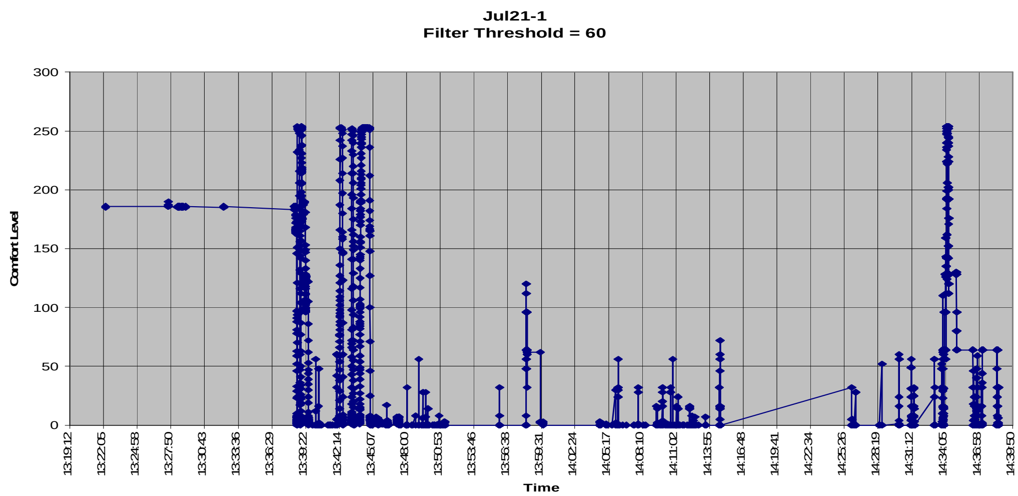


Figure 44: Digitally Filtered Data from Handheld Comfort Level Monitoring Device

The resultant cleaned up files have been checked and a representative sample has been verified against the video record. This was to ensure that where possible, many of the comfort level movements recorded in the cleaned up files, can be seen to correspond to video sequences where the subject can actually be seen moving the slider on the comfort level device. This was to make sure that the filtered files were producing a reliable indication of the comfort level perceived by the subject. All twenty eight of the comfort level files have now been processed, and a visual inspection has been made. At present, no further analysis has been performed on these results. It is planned to carry on the analysis early in 2005. For future trials, it is intended to incorporate error checking and data verification into the RF data transfer link to the recording PC in order to reduce problems with static.

3.8. Video Data Observation, Analysis and Results

At the time of this report deadline, no detailed observation and analysis has been performed on the recorded video material. Some initial observations have been made of the video material. These observations are subjective and have not been substantiated, so are presented here as anecdotal evidence which may possibly provide a clue to fertile paths for future investigations:

Twice, the robot dropped the pens it was fetching due to operator error. Both times the subject got up to help the robot. Several times, subjects took the pen pallet from the robot as soon as it was in reach, rather than wait for the robot to place it on the desk.

There was little verbal interaction between robot and subjects, and no attempt by any of the subjects to initiate verbal dialogue (even by technologically experienced users).

Subjects did not generally like the close attention paid by the socially aware robot when seated at the desk. Most “looked” uncomfortable (this was also reinforced by some of the comfort level recorded readings which have been analysed, and also questionnaire responses) while being observed closely by robot when seated at desk.

Most subjects appeared relieved, once the robot spoke to indicate either it was going, or actually went, to fetch required pens. One subject visibly jumped when the robot spoke.

Most of the subjects quickly learned to avoid the socially ignorant robot in the negotiated space tests, which was easy as the robot was relatively slow. Subjects tended to treat the robot like a moving car when crossing the road.

With regard to the main video analysis, discussions are currently underway as to the behaviours to be coded and the methodology to be used for analysis. The table in Figure 48 contains the latest available draft of the proposed analysis to be performed early on in 2005.

Video Coding For Single Adult-Robot Trials				
Annotate Group			**Context**	**Region**
A	**Robot Movement**	**Robot movement relative to subject pose** Approach (A) Receding (R) Stop (S)	White Board Task Table Task	White Board Region Desk Region
	Subject Movement	**Subject movement relative to robot pose** Approach (A) Receding (R) Stop (S)	White Board Task Table Task	White Board Region Desk Region
A	**Passing**	**Subject choose to walk across robot's path** Front (F) Behind (B)	White Board Task Table Task	White Board Region Desk Region
	Posture	**Subject current posture relative to its previous norm posture** **Leaning** – **Subject pan and tilt posture (motion vector) relative to the robot position** Toward (T) Away (A) **Turning** – **Subject rotating posture (rotating vector) relative to the robot position** Toward (T) Away (A)	White Board Task Table Task	White Board Region Desk Region
B	**Facial Expression**	**Subject facial expression** Smile (S) Frowning (F)	White Board Task Table Task	White Board Region Desk Region
B	**Acknowled-gement**	**Subject shows sign of acknowledge to robot's vocal communication** Vocal (V) Physical (P)	White Board Task Table Task	White Board Region Desk Region

Figure 45: Proposed Subject Behaviour Coding Scheme for Single Robot and Adult Study.

4.0 Summary, Conclusions and Future Work

4.1. Summary and Discussion of Both Studies

4.1.1. Initial Social Distances and Orientation

In both studies, both with child subjects and adults, a majority of all subjects took up an initial position relative to the robot which was consistent with treating the robot as a social being with respect to social space zones. The children generally took up a mean distance which would, amongst humans, be reserved for talking or interacting with strangers. However, most adults took up a position which would be used, in a human-human context, for talking with friends. In both cases, this could however simply be a convenient distance for viewing the robot, so more tests are required to confirm the reasons for these observations. A small proportion of each group took up an initial distance as far from the robot as possible.

However, amongst the adults, there was a sizable minority (32%) who took up an initial position relative to the robot which was so close that it would be classified as that reserved for intimate friends. This probably means that they did not see or treat the robot as a social being. Pamela Hinds and colleagues [Hinds et al. 2004] have looked at the effect of robot appearance on humans carrying out a joint task with a robot. They found that humans treat mechanistic looking robots in a subservient way (i.e. less socially interactive) compared to more humanoid looking robots. Also expectations are lower as regards abilities and reliability for mechanistic looking robots. The PeopleBot robots used in the studies were fitted with a moving articulated arm. However, they are still very mechanistic in their appearance. It is possible, therefore, that many subjects in the second experiment simply did not recognise the robot as anything more than any other household object or machine (such as a refrigerator or television) so there was no social dimension to their initial approaches to the robot. Amongst the children, only a very few went so close to the robot initially, possibly indicating seeing the robot as a social entity. This may reflect their generally greater enthusiasm for robots as helper and perhaps their lesser discrimination and self-consciousness in interacting with the robot in a play context.

The social distance experiments were performed at the beginning of the sessions, for both child and adult studies. With more opportunity for habituation, the perception of the subjects may have changed over the course of the experiments. It would be useful to perform distance experiments both before and after exposure to robot scenarios to see how subjects' perceptions change with exposure to robots. Also there is a need to perform long-term studies (over periods longer than one hour) and repeated exposure of the subjects to the robot.

The adult study did not consider the initial orientation of the subjects to the robot, due to lack of space in the experimental room, but the children's study did gain results that indicated that the only two possible anthropomorphic features which distinguished the front and back of the robot, the hand/arm and the camera, did exert a powerful effect on where the children chose to orientate themselves when initially encountering the robot. There are also some indications that the arm/hand also exerted a left/right bias to the children's initial orientations, though this needs further study to confirm.

4.1.2. Questionnaire Responses

Most children (90%) were broadly approving of the robots prior to the trial and the same proportion were still broadly approving at the end of the trial.

The relevant questionnaire responses from the adult study analysed here were limited to the subjects views about the robot's behaviours (social interactive and socially ignorant), things they liked or disliked about the robot, and how it could be improved. The main findings are summarised here:

The adults generally thought that the robots appearance was not anthropomorphic enough indicating a need to do experiments with different robot appearances. This view was substantiated by the questionnaire results from the children's study which indicated that most children preferred a humanoid robot as a home helper, particularly boys.

Many subjects disliked the noises from the robot. The comments included mild irritation at the servo motor whine. The crackling sounds from the robot sonar devices were most disliked – one subject actually perceived a risk of electric shock. Humans are much quicker than the robot in their movements and some subjects expressed irritation or dissatisfaction with the slowness of the robot. In their responses, the adults raised the topic of the robot's manner of movement nearly as often as comments or suggestions on the robots appearance or speech. This was unexpected, as no questions explicitly referred to the subject of the robot's movements were included in any of the questionnaires.

Closed dialogue was used by the robot in the adult study in order to discourage verbal interaction, which was intentional. However, even based on their limited exposure to the robots voice, many subjects suggested that the robot's voice quality, expression and tone should be improved. Therefore, it seems that voice quality will be an important factor in making a robot comfortable to interact with. It would be desirable to carry out further experiments trying out a range of different robot voices such as: male, female, different volumes, pitch, speed and expressions.

Some adult subjects expressed a preference for the socially interactive robot's behaviour when in the negotiated space scenario (Whiteboard Task) as it was "more considerate", though some preferred the socially ignorant behaviour as they thought it was more predictable.

When performing the shared task scenario (Desk task), many subjects seemed to prefer the socially ignorant behaviour style. More investigations are required, but it seems the subjects preferred behaviour that resembles the required behaviour of a butler or servant from the last century.

4.1.3. Video Analysis

At present some analysis of the children's study has been performed. The video observation results indicate that the moving pointer arm had an effect on the children's overall activities, but the state (moving or static) of the camera had no significant effect, on its own or in conjunction with the state of the arm pointer. Further analysis of the video results suggests that the arm/pointer had a more powerful effect in attracting children's attention when used on its own. These observations are reinforced by the initial social distance results from the children's study that suggested that possibly either, or both the arm and camera had an effect on the children's behaviour with regard to initial position, and that the pointer arm possibly had an effect on the initial orientation of the children. It is clear that there is not a simple one dimensional response by humans to simple (anthropomorphic) stimuli from the robot. It also seems that if the set of the robot's anthropomorphic stimuli are not consistent with each other, then humans will receive mixed signals and be confused.

More analysis of the child study video material is required to verify and explore these results more completely.

No substantive analysis of the adult study video material has been performed. Some initial subjective observations have been made and some of the main points are given in section 3.8. In particular there was no attempt by any of the adult subjects to initiate a verbal interaction with the robot. The video material is also much sparser in observable reactions from the adult subjects, as compared to the children's study. This is probably because only a single subject was present in the room alone with the robot (the experimenter deliberately ignored what was happening in the experimental room. She never initiated interaction with the subject and only responded when specifically addressed by the subject, or when she had to give explanations about the experimental procedure). Also, the subject was busy concentrating on the various tasks most of the time. Such a scenario with one robot and one person in a room with the person being occupied by other activities is however more relevant in a "home scenario" which Cogniron studies, at least more relevant than a playful entertainment scenario. Also adults may be more guarded in their reactions generally, as compared to children.

4.2. Conclusions

The results gained as part of these two studies, using PeopleBots, do not provide general results that can be applied to any other type of robot or in any other context. The PeopleBots are mechanistic, but not particularly robust, in appearance, so any results could only *possibly* be extrapolated to include similar robots.

Substantial individual differences have been found in how people behave towards the PeopleBot robot, although most of the human subjects participating in the studies seem to be receptive to treating the robot as a (limited) social entity after only a short period. It seems that children in particular are more generally accepting, and approving, of robots than the adult subjects studied. The social distance results so far have indicated that a substantial minority of adults (32% in our adult sample) do not even recognise the PeopleBot robot as a social being at first encounter. They probably view it more as a smart machine and therefore may not want to become "friends" with a robot companion. It cannot be assumed that people automatically treat robots socially, apart from simple elements of anthropomorphism cf. Reeves and Nass [1996].

There is a small but significant proportion of both children and adults, in the two studies documented here, who are very uncomfortable in the presence of the PeopleBot robot.

The responses given in the subjects questionnaires, after the interactive sessions, indicate that robots certainly need to be more anthropomorphic in appearance than the

PeopleBots, but more importantly, more humanlike in terms of its communication skills. This is not just a matter of technical improvements in voice recognition systems, appearance and abilities, but also the quality and expression of the voice, how the robot moves, and how the various anthropomorphic features and systems work together to give a consistent set of non-verbal social behaviours, cues and indicators.

The subject's responses to questionnaires, after interacting with a socially interactive and a socially ignorant robot, did not indicate a preference for one type of behaviour at all times. Different elements of socially ignorant or interactive behaviours matter depending on the contexts, user preferences, scenarios and task areas. Many adults did not like the robot to be too socially interactive, or even to show too much autonomy.

A true robot companion needs to be individualized, personalized and adapt itself to the user [Dautenhahn, 2004]. Different robot social models, perhaps with very different initial personalities, may be more acceptable to different users (E.g. A discreet servant or even a silent servant, with no obvious initiative or autonomy). The robot should then automatically refine and adapt its social model (character) over a longer period of time, depending on feedback from users and the robots own autonomous learning system.

4.3. Future Work

In the next six months further qualitative and quantitative analysis of the video data, questionnaires and other data and results from the two studies will be ongoing. It is of prime importance in this period to publish the results gained from these two studies.

Later, after month 18 of the COGNIRON project, further studies are currently being planned in order to concentrate on the following areas:

1. More work is required to investigate which robot social models provide reasonable starting points for adaptation to different types of users and what their preferences may be.

2. With regard to the proposed users of robot technology, our results to date indicate that factors such as familiarity with technology and subjects' personality profiles may be important. Further investigations into the demographic, experience and personality profiles of potential users of robot systems will be undertaken in order to identify important factors which may be important to tailoring appropriate robot social behaviour.

3. To investigate and identify what parameters can be used to systematically define and create robot social behaviours. This is the first pre-requisite to creating a genuinely social robot which can, in the longer term, automatically modify these parameters in response to user feedback; i.e. to adapt its social behaviour to accommodate to the user's individual preferences and requirements.

4. It is desirable to investigate how to obtain results that can be applied in a more generalised way to different types of robots with different appearance and capabilities.

5. There are few published results available from human-robot interaction over periods of time longer than an hour or so. There is a need for long-term studies which involve longer periods and repeated exposure to robots in a greater range of contexts.

WP3.1 described in the next implementation plan for Cogniron (project months 13-30) will address some of these issues in order to progressively advance our understanding into the design and implementation of socially acceptable robot behaviour styles.

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6.0 Appendices

Appendix I: VICTEC Pre – Trial Questionnaire

CAN YOU HELP US? ***No………***

It would be great if you could answer the following questions.

About you: please tick the box

Gender: ☐ **Boy** ☐ **Girl**

Age: 9 ☐ 10 ☐ 11 ☐ 12 ☐

How to complete the questions

A scale is used for some of the questions. Please circle or cross the number (1-5) that matches what you think. Below is an example.

Like Very Much — Don't like at all

1 **2** **3** 4 **5**

1) Do you like computers as part of your everyday life?

Like Very Much — Don't like at all

1 2 3 4 5

2) Do you fancy the idea of having a robot as a helper at home?

Like Very Much — Don't like at all

1 2 3 4 5

Appendix II: VICTEC Post Trial Questionnaire

CAN YOU HELP US? **No………**

It would be great if you could answer the following questions.

How to complete the questions

A scale is used for some of the questions. Please circle or cross the number (1-5) that matches what you think. Below is an example.

Like Very Much — Don't like at all

1 **2** **3** 4 **5**

1) Did you enjoy your interaction with the robot?

Liked Very Much — Didn't like at all

1 2 3 4 5

2) Did you feel comfortable or uncomfortable being close to the robot?

Very comfortable — Very Uncomfortable

1 2 3 4 5

3) For each photo tell us how much you would like to have the robot as a helper at home!

Like Very Much — Don't like at all

1 2 3 4 5

Like very Much Don’t like at all

1 2 3 4 5

Like very much Don’t like at all

1 2 3 4 5

Thank you for doing these questions!

Appendix III: Robot Program Listings

The PeopleBot program listings, used for the Children Game Scenario Studies are given in this appendix. The Rotation Game was written in Python, the Wander Game in C++. Both programs used the ARIA Robot operating system to provide access to the PeopleBots systems, services and hardware resources.

Rotation Game Program Listing – Python

```
# VICTEC Childrens Game Program for Robot
# M L Walters. 11 May 2004. Version 0.3


# first set up the python robot extensions and a few utilities

#Load the Aria system, creates and initializes a robot object called barbie
import barbie

#Create a random number generator
import random
ran = random.Random(2)

#Now connect to the robot (barbie)
barbie.connect()


#A couple of utility functions
def makeRandTurn():
      turnangle = ran.randrange(-1,2,2) * ran.randrange(20,175)
      turnvel=ran.randrange(200, 2200,400)
      barbie.moveInc(0,turnangle,turnvel,1)
      print "turnvel = ", turnvel



def makeRandPan():
      pantimes = ran.randrange(5,8)
      for n in range (1,pantimes):
            panangle = ran.randrange(-1,2,2) * ran.randrange(10,60)
            barbie.look(panangle)
            barbie.ArUtil.sleep(500)
```

```
#finally create the program as a function we can call at the interpreter
command line
def playround(lookp=0, gripp=0, stepforward = 0):
	"""
	This is the main program call that moves the robot in the first game
	victec.playround() with no options is no active camera or pointer, or
step forward
	victec.playround(1) with active camera
	victec.playround (0,1) with active pointer, playround (1,1) both
active
	Include a third parameter;- eg; victec.playround (1,1,500) to move
forward/back to
	selected child
	"""
	#This is the main program that moves the robot for a round
	barbie.gripperPark()
	print "Running ok"
	n = 0
	n1 = ran.randrange(10, 15)
	while n < n1:
		makeRandTurn()
		if lookp == 1:
			makeRandPan()
		n = n +1

	# Then work the gripper if required
	barbie.look(0)
	barbie.robot.setRotVel(15)
	a = raw_input ("Press RETURN to stop")
	barbie.stop()
	if gripp != 0:
		barbie.gripper.liftUp()
		barbie.ArUtil.sleep(1500)
		barbie.gripper.gripperHalt()
	if stepforward != 0:
		barbie.moveInc(stepforward)
		barbie.ArUtil.sleep(3000)
		barbie.moveInc(-stepforward)
```

Wander Game and Adult Study Program Listing – C++

```
#include "Aria.h"
#include <stdio.h>
#include <time.h>

FILE *f1, *f2, *f3;
char timeBuf[256];
struct tm *tm_ptr;
time_t the_time;

void getCurrentDateTime()
{
  (void) time(&the_time);
  tm_ptr = localtime(&the_time);
  //strftime(timeBuf,256,"%A %d %B %Y, %H:%M:%S",tm_ptr);
  //printf("%s",timeBuf);
}

void getSO_DateCurrentTime() //Used with sonar data name
{
  getCurrentDateTime();
  strftime(timeBuf,256,"%A %d %B %Y, %H:%M:%S",tm_ptr); //
}

void getFN_DateTime()  //Used with file name;
{
  getCurrentDateTime();
  strftime(timeBuf,256,"%d-%m-
%Y_%H%M%S",tm_ptr);//10062004_15h15m20soFB.txt
}

char * AddStrings(char *First, char *Second)
{
  char temp[256];

  strcpy(temp,First);
  strcat(temp,Second);
  strcpy(Second,temp);
  return Second;
}

class UH_DisplaySensory
{
public:
  UH_DisplaySensory(ArRobot *robot);
  ~UH_DisplaySensory(void){};
  void driveDisplaySensory(void);
  void displayTableTop(void);
  void displaySonar(void);
  void displayBumppers(void);
  void displayRobotCoor(void);
protected:
  ArRobot *myRobot;
  ArFunctorC<UH_DisplaySensory> myDriveDisplaySensoryCB;
  ArTime myLastPacketTime;
};
```

```
UH_DisplaySensory::UH_DisplaySensory(ArRobot
*robot):myDriveDisplaySensoryCB(this,
&UH_DisplaySensory::driveDisplaySensory)
{
  myRobot = robot;
  myRobot->addUserTask("Display", 25, &myDriveDisplaySensoryCB);
  myRobot->comInt(40, 2);
  myLastPacketTime = myRobot->getIOPacketTime();
}

void UH_DisplaySensory::driveDisplaySensory(void)
{
  displaySonar();     //Display sonar data
  //displayTableTop();  //Display Table top data
  //displayRobotCoor(); //Display Robot Orientation
  //displayBumppers();
}

void UH_DisplaySensory::displaySonar(void)
{
  char c='|';
  int i;
  //  printf("%c ",c);
  getSO_DateCurrentTime();

  //printf("%20s","\nFront Bottom Sonar  ");
  fprintf(f1,"%s%c ",timeBuf, c);
  for (i = 0; i < myRobot->getNumSonar() && i <= 7; ++i)
    {
      //printf("%6d", myRobot->getSonarRange(i));
      fprintf(f1,"%6d,", myRobot->getSonarRange(i));
    }
  fprintf(f1,"\n");

  //printf("%20s","Front Top Sonar     ");
  fprintf(f2,"%s%c ",timeBuf,c);
  for (i = 8; i < myRobot->getNumSonar() && i <= 15; ++i)
    {
      //printf("%6d", myRobot->getSonarRange(i));
      fprintf(f2,"%6d,", myRobot->getSonarRange(i));
    }
  fprintf(f2,"\n");

  //printf("%20s","\nBack Bottom Sonar   ");
  fprintf(f3,"%s%c ",timeBuf,c);
  for (i = 16; i < myRobot->getNumSonar() && i <= 23; ++i)
    {
      //printf("%6d", myRobot->getSonarRange(i));
      fprintf(f3,"%6d,", myRobot->getSonarRange(i));
    }
  fprintf(f3,"\n");

  fflush(stdout);
}
```

```
//==============================================================
void UH_DisplaySensory::displayRobotCoor(void)
{
  // printf("/*%f, %f, */ %f",/*myRobot->getX(),myRobot->getY(),*/myRobot-
>getTh());
  printf(" %f ",myRobot->getTh());
  //printf(" orientation %f",myRobot->getTh());
  fflush(stdout);
}
//===============================================================
void UH_DisplaySensory::displayTableTop(void)
{
  int j;
  unsigned char value;
  int bit;
  if (myLastPacketTime.mSecSince(myRobot->getIOPacketTime()) == 0)
    return;

  value = myRobot->getIODigIn(3);
  for (j = 0, bit = 1; j < 2; ++j, bit *= 2)
    {
      if (value & bit)
        printf(" %d ",1);
      else
        printf(" %d ",0);
    }
  fflush(stdout);
}
//================================================================
void UH_DisplaySensory::displayBumppers(void)
{
  unsigned int i;
  int val;
  int bit;
  printf("=== B  U  M  P  P  E  R  S
=====================================================\n");
  printf("\n");
  printf("%5s", "Left");printf("%13s", "FRONT");printf("%12s", "Right");
  printf("%8s", "Right");printf("%12s", "BACK");printf("%12s", "Left");
  printf("\n");

  val = ((myRobot->getStallValue() & 0xff00) >> 8);
  for (i = 0, bit = 2; i < myRobot->getNumFrontBumpers(); i++, bit *= 2)
    {
      if (val & bit)
      printf("%6s", "trig");
      else
      printf("%6s", "clear");
    }
  printf(" |");
  val = ((myRobot->getStallValue() & 0xff));
  for (i = 0, bit = 2; i < myRobot->getNumRearBumpers(); i++, bit *= 2)
    {
      if (val & bit)
      printf("%6s", "trig");
      else
      printf("%6s", "clear");
    }
  printf("\n\n");
}
```

```
//============================================================
class UH_Wander
{
public:
  enum State
    {
      STATE_StartWandering,
      STATE_StopWandering
   };

  enum gripperState
    {
      State_Parking,
      State_Ready,
      State_Lifting
    };

  UH_Wander(ArRobot *robot);
  ~UH_Wander(void);
  void userTask(void);
  void activate(void);
  void deactivate(void);
  void cameraTask(int cam_mode);
  void startWandering(void);
  void stopWandering(void);
  int random_range(int lowest_number, int highest_number);
  void CamTurnLeft(void);
  void CamTurnRight(void);
  void CamTurnUp(void);
  void CamTurnDown(void);
  void CamTurnHome(void);
  void beep_beep(void);
  void SensorInterpTask(void);
  void gripperLiftUp(int duration);
  void gripperLiftDown(int duration);
  void gripperLiftingTask(void);
  void gripperLoweringTask(void);
  void gripperJogLiftingTask(void);
  void gripperJogLoweringTask(void);
  void gripperStop(void);

protected:
  unsigned int i, gripperLiftTimer, beep_beep_Timer;
  State myRobotState;
  gripperState myGripperState;
  int cameraPanFrequency;
  int pan;  //var for panning the camera
  int tilt; //var for tilting the camera
  int set_beep; //Beep_beep flag
  int gripperLiftDelay;
  int gripperJog;
  int gripperImStop;

  ArRobot *myRobot;

  ArFunctorC<UH_Wander> myActivateCB;
  ArFunctorC<UH_Wander> myDeactivateCB;
  ArFunctorC<UH_Wander> myUserTaskCB;
  ArFunctorC<UH_Wander> mySensorInterpTaskCB;
  ArFunctorC<UH_Wander> myGripperLiftingTaskCB;
```

```
  ArFunctorC<UH_Wander> myGripperLoweringTaskCB;
  ArFunctorC<UH_Wander> myGripperJogLiftingTaskCB;
  ArFunctorC<UH_Wander> myGripperJogLoweringTaskCB;
  ArFunctorC<UH_Wander> myCamTurnLeftCB;
  ArFunctorC<UH_Wander> myCamTurnRightCB;
  ArFunctorC<UH_Wander> myCamTurnUpCB;
  ArFunctorC<UH_Wander> myCamTurnDownCB;
  ArFunctorC<UH_Wander> myCamTurnHomeCB;
  ArFunctorC<UH_Wander> myGripperStopCB;

  ArActionKeydrive *keyDrive;  //Driving the robot using keyboard

  ArActionStallRecover *recover; //Robot perform recovery manuavers when
the wheels are stall
  ArActionBumpers *bumpers;  //
  ArActionAvoidFront *avoidFrontFar; //avoid obstacles with the following
parameters@ obstacle distance mm, avoid velocity, turn amount, use talbeIR"
  ArActionAvoidSide *avoidSide;
  ArActionConstantVelocity *constantVelocity;
  ArActionLimiterTableSensor *tableSensorLimiter;
  ArActionLimiterForwards *speedLimiterNear;
  ArActionLimiterForwards *speedLimiterFar;
  ArActionLimiterBackwards *speedLimiterBackward;

  ArGripper *gripper; //Create gripper object and connected to robot
  ArVCC4 *ptu;
};

UH_Wander::UH_Wander(ArRobot *robot) : myActivateCB(this,
&UH_Wander::startWandering),
                               myDeactivateCB(this,
&UH_Wander::stopWandering),
                               myUserTaskCB(this, &UH_Wander::userTask),
                               mySensorInterpTaskCB(this,
&UH_Wander::SensorInterpTask),

myGripperLiftingTaskCB(this,&UH_Wander::gripperLiftingTask),

myGripperLoweringTaskCB(this,&UH_Wander::gripperLoweringTask),

myGripperJogLiftingTaskCB(this,&UH_Wander::gripperJogLiftingTask),

myGripperJogLoweringTaskCB(this,&UH_Wander::gripperJogLoweringTask),
                               myCamTurnLeftCB(this,
&UH_Wander::CamTurnLeft),
                               myCamTurnRightCB(this,
&UH_Wander::CamTurnRight),
                               myCamTurnUpCB(this, &UH_Wander::CamTurnUp),

myCamTurnDownCB(this,&UH_Wander::CamTurnDown),

myCamTurnHomeCB(this,&UH_Wander::CamTurnHome),

myGripperStopCB(this,&UH_Wander::gripperStop)
{
  ArKeyHandler *keyHandler;
  myRobot=robot;
  myRobot->addUserTask("Start Wandering",25,&myUserTaskCB);
  myRobot->addSensorInterpTask("Start Wandering",25,&mySensorInterpTaskCB);
  ArLog::log(ArLog::Terse, "userTast start now");
```

```
  myRobotState = STATE_StopWandering;
  myGripperState = State_Parking;
  i=0; pan=0; tilt=0; set_beep=0;
  gripperLiftTimer=0; beep_beep_Timer=0;
  gripperLiftDelay=0; gripperJog=0;
  cameraPanFrequency=0;
  gripperImStop=0;
 // see if there is already a keyhandler, if not make one for ourselves
  if ((keyHandler = Aria::getKeyHandler()) == NULL)
  {
    keyHandler = new ArKeyHandler;
    Aria::setKeyHandler(keyHandler);
    if (myRobot != NULL)
      myRobot->attachKeyHandler(keyHandler);
    else
      ArLog::log(ArLog::Terse, "No robot to attach a keyHandler to,
keyHandling won't work... either make your own keyHandler and drive it
yourself, make a keyhandler and attach it to a robot, or give this a robot
to attach to.");
  }

  // now that we have one, add our keys as callbacks, print out big
  // warning messages if they fail
  if (!keyHandler->addKeyHandler('M', &myActivateCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'M',
will not work correctly.");
  if (!keyHandler->addKeyHandler('m', &myActivateCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'm',
will not work correctly.");

  if (!keyHandler->addKeyHandler('N', &myDeactivateCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'N',
will not work correctly.");
  if (!keyHandler->addKeyHandler('n', &myDeactivateCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'n',
will not work correctly.");

 if (!keyHandler->addKeyHandler('I', &myGripperLiftingTaskCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'I',
will not work correctly.");
  if (!keyHandler->addKeyHandler('i', &myGripperLiftingTaskCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'i',
will not work correctly.");

 if (!keyHandler->addKeyHandler('K', &myGripperLoweringTaskCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'K',
will not work correctly.");
  if (!keyHandler->addKeyHandler('k', &myGripperLoweringTaskCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'k',
will not work correctly.");

  if (!keyHandler->addKeyHandler('U', &myGripperJogLiftingTaskCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'U',
will not work correctly.");
  if (!keyHandler->addKeyHandler('u', &myGripperJogLiftingTaskCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'u',
will not work correctly.");

  if (!keyHandler->addKeyHandler('J', &myGripperJogLoweringTaskCB))
```

```
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'J',
will not work correctly.");
  if (!keyHandler->addKeyHandler('j', &myGripperJogLoweringTaskCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'j',
will not work correctly.");

  if (!keyHandler->addKeyHandler('G', &myGripperLiftingTaskCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'G',
will not work correctly.");
  if (!keyHandler->addKeyHandler('g', &myGripperLiftingTaskCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'g',
will not work correctly.");

 if (!keyHandler->addKeyHandler('B', &myGripperLoweringTaskCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'B',
will not work correctly.");
  if (!keyHandler->addKeyHandler('b', &myGripperLoweringTaskCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'b',
will not work correctly.");

  if (!keyHandler->addKeyHandler('F', &myGripperJogLiftingTaskCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'F',
will not work correctly.");
  if (!keyHandler->addKeyHandler('f', &myGripperJogLiftingTaskCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'f',
will not work correctly.");

  if (!keyHandler->addKeyHandler('V', &myGripperJogLoweringTaskCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'V',
will not work correctly.");
  if (!keyHandler->addKeyHandler('v', &myGripperJogLoweringTaskCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'v',
will not work correctly.");

  if (!keyHandler->addKeyHandler('A', &myCamTurnLeftCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'A',
will not work correctly.");
  if (!keyHandler->addKeyHandler('a', &myCamTurnLeftCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'a',
will not work correctly.");

  if (!keyHandler->addKeyHandler('D', &myCamTurnRightCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'D',
will not work correctly.");
  if (!keyHandler->addKeyHandler('d', &myCamTurnRightCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'd',
will not work correctly.");

  if (!keyHandler->addKeyHandler('W', &myCamTurnUpCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'W',
will not work correctly.");
  if (!keyHandler->addKeyHandler('w', &myCamTurnUpCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'w',
will not work correctly.");

  if (!keyHandler->addKeyHandler('X', &myCamTurnDownCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'X',
will not work correctly.");
  if (!keyHandler->addKeyHandler('x', &myCamTurnDownCB))
```

```
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'x',
will not work correctly.");

  if (!keyHandler->addKeyHandler('S', &myCamTurnHomeCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'S',
will not work correctly.");
  if (!keyHandler->addKeyHandler('s', &myCamTurnHomeCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 's',
will not work correctly.");

  if (!keyHandler->addKeyHandler('H', &myGripperStopCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'H',
will not work correctly.");
  if (!keyHandler->addKeyHandler('h', &myGripperStopCB))
    ArLog::log(ArLog::Terse, "The key handler already has a key for 'h',
will not work correctly.");


//Robot moved randomly ---- Done
//Robot moved at constant speed with slow down velocity
//Robot don't use the table top sensors but will use both its based's
breakbeam sensors to stop the it from colliding with table
//Press forward and the robot will start moving forward at constant
velocity but velocity will decress depands on obstacle distance
//Press stop and the robot will stop
//press G once and the arm will lift up and again will lift down  ---------
---need to set the timing and change a rule
//Press A D W S to navigate the camera         --------------done
//====================================================
  gripper = new ArGripper(myRobot);
  ptu = new ArVCC4(myRobot);
  keyDrive = new ArActionKeydrive;
  recover = new ArActionStallRecover;
  bumpers = new ArActionBumpers;
  avoidFrontFar = new ArActionAvoidFront("Avoid Front Far",
800,300,5,true);
  avoidSide = new ArActionAvoidSide("Avoid Side",500,5);
  constantVelocity = new ArActionConstantVelocity("Constant Velocity",
400);
  tableSensorLimiter = new ArActionLimiterTableSensor;
  speedLimiterFar = new ArActionLimiterForwards("Speed Limiter
Far",200,600,200);
  speedLimiterBackward = new ArActionLimiterBackwards("Speed Limiter
Backward",-500,-650,-250);

  myRobot->addAction(recover, 100);
  myRobot->addAction(tableSensorLimiter, 99);
  myRobot->addAction(bumpers, 90);
  myRobot->addAction(speedLimiterFar, 89);
  myRobot->addAction(speedLimiterBackward, 80);
  myRobot->addAction(avoidFrontFar, 79);
  myRobot->addAction(avoidSide, 70);
  myRobot->addAction(constantVelocity, 50);
  myRobot->addAction(keyDrive, 40); //need to check this

  ptu->init();
  deactivate();
}
```

```
UH_Wander::~UH_Wander()
{
  ArKeyHandler *keyHandler;

  if ((keyHandler = Aria::getKeyHandler()) != NULL)
  {
    keyHandler->remKeyHandler('M');
    keyHandler->remKeyHandler('m');
    keyHandler->remKeyHandler('N');
    keyHandler->remKeyHandler('n');
    keyHandler->remKeyHandler('G');
    keyHandler->remKeyHandler('g');
    keyHandler->remKeyHandler('B');
    keyHandler->remKeyHandler('b');
    keyHandler->remKeyHandler('W');
    keyHandler->remKeyHandler('w');
    keyHandler->remKeyHandler('S');
    keyHandler->remKeyHandler('s');
    keyHandler->remKeyHandler('A');
    keyHandler->remKeyHandler('a');
    keyHandler->remKeyHandler('D');
    keyHandler->remKeyHandler('d');
  }

  myRobot->remUserTask(&myUserTaskCB);
  myRobot->remAction(constantVelocity);
  myRobot->remAction(recover);
  myRobot->remAction(bumpers);
  myRobot->remAction(avoidFrontFar);
  myRobot->remAction(avoidSide);
  myRobot->remAction(keyDrive);
  myRobot->remAction(tableSensorLimiter);
  myRobot->remAction(speedLimiterNear);
  myRobot->remAction(speedLimiterFar);
  myRobot->remAction(speedLimiterBackward);

  delete recover;
  delete bumpers;
  delete avoidFrontFar;
  delete avoidSide;
  delete constantVelocity;
  delete keyDrive;
  delete tableSensorLimiter;
  delete speedLimiterFar;
  delete speedLimiterBackward;
}

int UH_Wander::random_range(int lowest_number, int highest_number)
{
  int temp, range;
  double rand_temp,ll;
  if (lowest_number > highest_number)
    {
      temp = highest_number;
      highest_number = lowest_number;
      lowest_number = temp;
    }
  range = highest_number - lowest_number +1;
```

```
  rand_temp = rand();  //Used var instead of direct function access to
overcome bug
  ll = RAND_MAX;
  rand_temp = lowest_number + range * rand_temp/(ll+1);

  return  int (rand_temp);
}

void UH_Wander::gripperLiftUp(int duration)
{
  gripper->liftUp();
  gripperLiftTimer=ArUtil::getTime();
  gripperLiftDelay=duration;
}

void UH_Wander::gripperStop()
{
  gripperImStop=1;
  gripperLiftDelay=0;
  myGripperState=State_Ready;
}

void UH_Wander::gripperLiftDown(int duration)
{
  gripper->liftDown();
  gripperLiftTimer=ArUtil::getTime();
  gripperLiftDelay=duration;
}

void UH_Wander::gripperJogLoweringTask()
{
  if (gripperLiftDelay==0)
  {
    gripperLiftDown(100);
    gripperImStop=0;
  }
}

void UH_Wander::gripperJogLiftingTask()
{
  if (gripperLiftDelay==0)
  {
    gripperLiftUp(150);
    gripperImStop=0;
  }
}

void UH_Wander::gripperLiftingTask()
{

  if (gripperLiftDelay==0)
    {
      if (myGripperState==State_Parking) //Initial position
      {
        ArLog::log(ArLog::Terse, "Gripper is Lifted and ready to lift
object");
        beep_beep();
        gripperLiftUp(6150);
        gripperImStop=0;
        myGripperState=State_Ready;
```

```
      }
      else
      if ((myGripperState==State_Ready)|| (myGripperState==State_Lifting))
//Pointing
        {
          ArLog::log(ArLog::Terse, "Gripper  Lifting Object");
          if (myGripperState == State_Ready)
            {
            beep_beep();
            gripperLiftUp(850);
            gripperImStop=0;
            }
          else
            {
            gripperLiftUp(200);
            gripperImStop=0;
            }
          myGripperState=State_Lifting;
        }
    }
}

void UH_Wander::gripperLoweringTask()
{
  if (gripperLiftDelay==0)
    {
      if (myGripperState==State_Lifting)
      {
        ArLog::log(ArLog::Terse, "Gripper is lowering object");
        gripperLiftDown(650);
        gripperImStop=0;
        myGripperState=State_Ready;
      }
      else
      if (myGripperState==State_Ready)
        {
          ArLog::log(ArLog::Terse, "Gripper is parking");
          //gripperLiftDown(6000);
          gripperImStop=0;
          gripper->liftDown();
          myGripperState=State_Parking;
          beep_beep();
        }
    }
}

void UH_Wander::beep_beep()
{
  set_beep=1;
}

void  UH_Wander::SensorInterpTask()
{
  if (set_beep==1) {
    system("echo -e '\a' &> /dev/console");
    set_beep=2;
    beep_beep_Timer = ArUtil::getTime();
  }

  if (((ArUtil::getTime()-beep_beep_Timer)>=250) && (set_beep==2)) {
```

```
      system("echo -e '\a' &> /dev/console");
      set_beep=0;
  }
}

void UH_Wander::cameraTask(int cam_mode) //Randomly panting the camera.
{

  if (cam_mode == 1) {
    cameraPanFrequency++;
    if (cameraPanFrequency == 10) {
      pan = random_range (-80,80);
      ptu->panTilt(pan,0);
      cameraPanFrequency=0;
    }
  }
  else
    if (cam_mode == 2)
      ptu->panTilt(pan,tilt);
}

void UH_Wander::userTask()
{
  switch (myRobotState)
  {
  case STATE_StartWandering:
    if (i==0) {
      ArLog::log(ArLog::Terse, "Start Wandering");
      activate(); //activate wandering mode until a random time is met.
      i=ArUtil::getTime();
    }
    cameraTask(1);//Randomly moved the camera
    if (60000<=(ArUtil::getTime()-i))
      myRobotState=STATE_StopWandering;
    break;

  case STATE_StopWandering:
    if (i!=0) {
      ArLog::log(ArLog::Terse, "Wandering Mode Finished, Please drives to a
child  and press G to beep twice.");
      deactivate();//deactivate wandering mode when a random time is met.
      ptu->panTilt(0,0);
      i=0;
    }
    break;
  }

  cameraTask(2); //to rotate the camera, control by user.

  if (gripperImStop==1)
    gripper->liftStop();
  else
    {
      if (((gripper->isLiftMaxed()!=1) && (myGripperState==State_Parking))
&& (gripperLiftDelay==0))
      gripper->gripperStore();
      //Automated to stop the gripper motion
      if (gripperLiftDelay!=0)
      {
        if (gripperLiftDelay<=(ArUtil::getTime()-gripperLiftTimer))
```

```
          {
            gripper->liftStop();
            if (gripperLiftDelay > 300)
            beep_beep();
            gripperLiftDelay=0;
          }
      }
    }
}

void UH_Wander::startWandering()
{
  myRobotState = STATE_StartWandering;
}

void UH_Wander::stopWandering()
{
  myRobotState = STATE_StopWandering;
}

void UH_Wander::activate()
{
  keyDrive->deactivate();
  tableSensorLimiter->deactivate();
  speedLimiterFar->deactivate();
  speedLimiterBackward->deactivate();

  recover->activate();
  bumpers->activate();
  avoidFrontFar->activate();
  avoidSide->activate();
  constantVelocity->activate();
}

void UH_Wander::deactivate()
{
  constantVelocity->deactivate();
  recover->deactivate();
  bumpers->deactivate();
  avoidFrontFar->deactivate();
  avoidSide->deactivate();
  myRobot->stop();
  myRobot->clearDirectMotion();

  //tableSensorLimiter->activate();
  speedLimiterFar->activate();
  speedLimiterBackward->activate();
  keyDrive->activate();
 // myRobot->deactivateActions();
}


void UH_Wander::CamTurnHome()
{
  pan=0;
  tilt =0;
  ArLog::log(ArLog::Terse, "Camera Home Set");
}

void UH_Wander::CamTurnLeft()
```

```
{
  if (pan>-80)
    pan-=10;
   ArLog::log(ArLog::Terse, "Camera Left Set");
   printf("%d",pan);
}

void UH_Wander::CamTurnRight()
{
  if (pan<80)
    pan+=10;
  ArLog::log(ArLog::Terse, "Camera Right Set");
  printf("%d",pan);
}

void UH_Wander::CamTurnUp()
{
  if (tilt<80)
    tilt+=10;
  ArLog::log(ArLog::Terse, "Camera Up Set");
  printf("%d",tilt);
}

void UH_Wander::CamTurnDown()
{
  if (tilt>-30)
    tilt-=5;
  ArLog::log(ArLog::Terse, "Camera Down Set");
  printf("%d",tilt);
}

//================================================================
int main(int argc, char** argv)
{
  char soFB[256]="soFB.txt", soFT[256]="soFT.txt", soBB[256]="soBB.txt";

  getFN_DateTime();
  AddStrings(timeBuf,soFB);
  AddStrings(timeBuf,soFT);
  AddStrings(timeBuf,soBB);
  f1 = fopen(soFB,"w");
  f2 = fopen(soFT,"w");
  f3 = fopen(soBB,"w");

  ArSimpleConnector simpleConnector(&argc, argv);   // set up our
simpleConnector
  ArRobot robot;// robot
  ArKeyHandler keyHandler; // a key handler so we can do our key handling
  ArSonarDevice sonarDev;// sonar, must be added to the robot, for teleop
and wander


  UH_DisplaySensory DisplayStuff(&robot);
  // parse the args and if there are more arguments left then it means we
dsidn't understand an option
  if (!simpleConnector.parseArgs() || argc > 1)
    {
      simpleConnector.logOptions();
      keyHandler.restore();
      exit(1);
```

```
    }

  // mandatory init
  Aria::init();

  Aria::setKeyHandler(&keyHandler);// let the global aria stuff know about
it
  UH_Wander Wandering(&robot);
  robot.attachKeyHandler(&keyHandler);// toss it on the robot
  robot.addRangeDevice(&sonarDev);// add the sonar to the robot
  if (!simpleConnector.connectRobot(&robot))// set up the robot for
connecting
    {
      printf("Could not connect to robot... exiting\n");
      Aria::shutdown();
      keyHandler.restore();
      return 1;
    }

  robot.comInt(ArCommands::ENABLE, 1);
  robot.comInt(ArCommands::JOYDRIVE, 1);
  robot.runAsync(true);
  robot.waitForRunExit();
  // now exit
  Aria::shutdown();
  fclose(f1);
  fclose(f2);
  fclose(f3);
  return 0;
}
```