# Robot to Human Approaches: Comfortable Distances and Preferences

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## Introduction

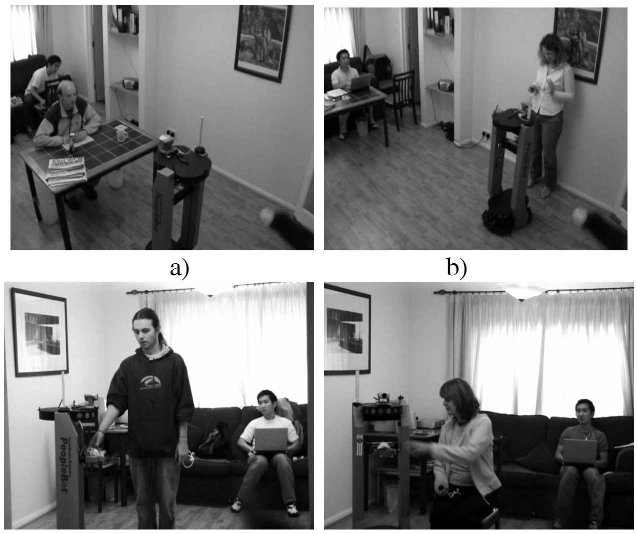
This is a three page extended abstract for review and consideration for submitting a full paper to the AAAI Symposium: Multidisciplinary Collaboration for Socially Assistive Robotics. As domestic and office robots will have to carry out useful tasks in the same workspace as humans it is important that robots will have to respect people's social spaces and shared workspace preferences. The proposed paper will present results from Human Robot Interaction (HRI) trials carried out at the University of Hertfordshire which examined how robots must behave when fetching and carrying objects to and from human subjects in a domestic 'living room' scenario. The studies are part of our long-term goal to investigate requirements and 'social rules' (a 'robotic etiquette') for a robot companion which is able to a) perform useful tasks in a home environment and b) behaves in a manner that is acceptable and comfortable to humans [Dautenhahn, 2005]. As fetching and carrying objects is an important component of a wide range of useful tasks for a robot companion in the home, the eventual aim of these studies is to provide a set of rules and parameters that can be used to provide guidance to the designers and builders of domestic (servant) robots in the future. The main research question addressed is therefore:

*How should a robot approach a human when fetching an object to the human?*

## Robot to Human Approach Trials

Previously, an extensive series of exploratory and pilot Human Robot Interaction (HRI) trials have been carried out with one of the main objectives of addressing the above question [Woods et al. 2006a, Dautenhahn et al. 2006, Koay et al. 2005, Walters et al. 2005a, 2005b, 2005c, and Walters et al. 2006]. In light of encouraging results from the small scale exploratory and pilot studies, a larger scale main study was instigated which investigated further aspects of how robots should approach and serve human subjects in a socially acceptable way. The specific aspect relevant to the proposed paper submission was to investigate how a robot should approach a seated human. Other aspects of this study also included investigating the relationship between subjects' personality traits and their approach preferences [Syrdal et al. 2006] and comparing results from video based HRI trials with live trial results [Woods et al. 2006b].

In previous publications, reporting on the pilot trials, we only considered the robot approach directions in the context of questionnaire data indicating subjects' preferences. The current paper analyses data from the main trial combining questionnaire data with data obtained from subjects using a Comfort Level Device (CLD) [Koay et al. 2006a, 2006b]. The integration of data from different experimental measurements is hoped to deepen our understanding of the issues involved.



a) b) c) d)

**1) Views from the Robot Approach Direction Trials. a) Seated at table, b) Standing against wall, c) Standing in middle of room, d) Seated without table.**

Four different scenarios were studied in the trials where a robot approached the subject who was located in the living room:

1. Seated on a chair in the middle of an open space.

2. Standing in the middle of an open space.
3. Seated at a table in the middle of an open space.
4. Standing with their back against a wall.

These particular interactions were chosen as they were typical approach situations which would be encountered in a wide range of fetching and carrying tasks that a domestic robot might be expected to carry out. The trials were performed in the living room of the Robot House. Of a total of 42 subjects, the first 20 subjects and the final subject experienced scenarios 1 and 2 the remaining 21 subjects were exposed to scenarios 3 and 4.

## Experimental Setup

In order to provide a more ecologically valid experimental environment, a standard British or Northern European style apartment near to the University was rented. This is referred to here as the "Robot House", and the main living room was furnished and used as the venue for the HRI trials. The robot used for the trials was a commercially available PeopleBot™ with standard equipment fitted, including a pan and tilt camera unit and a standard short reach lifting gripper which was adapted to form a simple tray in order to fetch and carry objects as required. A chair and table were moved to the central position as required for the trial scenarios where the subject was to be seated in the middle of the room or at the table.

The age of the subjects varied from 18 to 56 years and 36% were female, 64% male and 9% (4 subjects) were left handed or ambidextrous. All trials were based on the same general situation where the robot brought a snack to the human subject. Each time the robot approached from a different relative direction. The subject instigated the approach by speaking to the robot. The robot then approached the subject under autonomous control with the operator ready to take over direct manual control only in case of error or emergency stop conditions. For each trial, the approach directions were experienced in a random order.

Two video cameras recorded each trial; one fixed overhead wide-angle camera with an overview of most of the experimental area, and a tripod mounted video camera which recorded a closer view of the subject. The fixed camera video recordings of the HRI trials were post processed and overlaid with a 0.5m square grid so that measurements of human and robot distances and positions could be estimated. During the trials, participants were encouraged to use a small wireless signaling device when ever they felt uncomfortable with the proximity of robot. The device, which was developed from the latest incarnation of the Comfort Level Device (CLD) [Koay et al. 2006b], consisted of a small key-fob sized transmitter with a single button which was easily pressed by the trial participant. The signal was received by a receiver and a small light was illuminated when ever the CLD device button was pressed. The receiver was mounted to the fixed video camera so that the light flashes were recorded onto the corner of the video recordings of the trials. In this way, the video recording was automatically annotated with the participants discomfort signals. The distance between the robot and human participants was able to be estimated (to the nearest 0.25m increment on the overlaid grid 0.5m grid) each time the CLD signal was perceived on the post processed video recording. These (uncomfortable) distance measurements form an important part of the key trial data to be considered in the proposed paper.

After each HRI approach trial a questionnaire was administered to gain the subjects' categorical ratings of the most preferred and least preferred approach directions, the approach directions judged as most and least efficient and also other information regarding speed of approach and stopping distance. Other questions allowed the subjects to rate efficiency and comfort on five-point Likert scales (using 1 to signify highly negative, 2 fairly negative, 3 as neutral 4 as fairly positive and 5 as highly positive). For example, for rating task efficiency this translated to 1 = not efficient at all to 5 very efficient, and for comfort this translated to 1 = very uncomfortable to 5 very comfortable.

## Provisional Results and Discussion

Based on the responses from questionnaires [cf. Woods et al. 2006b], overall the front left and right approaches were rated by subjects as the most comfortable for all the different scenario scenarios. The rear approaches and front direct approaches were generally rated as being the least comfortable across different scenarios. However, subjects standing in the middle of the room actually preferred the direct frontal approach for task efficiency reasons. This is in contrast to the other scenarios, but could be due to the fact that the subject was standing and would have been taller than the robot, therefore not finding the robot intimidating in any way, in contrast to the seated conditions, where the subjects were shorter than the robot.

The results from the uncomfortable distance measurements were obtained. Unfortunately, most participants did not use the CLD device and the sample size was restricted accordingly. The sample size was too small to provide a good basis for proper statistical tests. The descriptive frequency charts however, support the same general findings obtained from the questionnaire data. This is an important finding and if confirmed it would allow some aspects of human users' preferences to be inferred from the simple CLD signaling device. The CLD could then actually be used while HRI trials are in progress and thus avoid or reduce the need for time consuming post trial questionnaires. There are also other advantages with regard to immediacy and not having to rely on participant's memory for their reactions to more complicated HRI scenarios. During the HRI trials the robot could also adapt its behavior based on the CLD data received.

These trial results provide further statistical evidence reinforcing results from previous studies, extending the findings to four fundamental HRI scenarios which may occur in a typical robot 'serving' or 'object fetching' task scenario with standing and seated humans. Results

indicated some general social and physical robot behavior rules that should be incorporated into robot approach behavior when interacting with humans. Different social approach rules apply depending whether the interacting human is sitting, standing in the open or against a wall or obstacle. Future work in this area will have to investigate how initial default settings of social rules can be adapted during long-term human-robot interaction as a requirement for a personalized robot companion [Dautenhahn, 2005].
The expansion of this abstract into a full paper will provide the opportunity for a more rigorous statistical treatment of the data obtained from the CLD signaling device and associated video annotation data. Also a more complete discussion of the scientific, methodological and robot design implications from the study outcomes will be facilitated.

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