The Role of Autonomy and Interaction Type on Spatial Comfort in an HRI Scenario

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ABSTRACT
This extended abstract presents findings from a live HRI study carried out in the UH robot house. The participants (33 in total) were approached by a robot for 3 different interaction types and the amount of control the participant had over the robot's approach was varied. This study focuses on the participant post-experimental evaluation of their comfort with the robots approaches in these different scenarios. The results indicate that both the degree of control and the purpose of the interaction independently influence how comfortable participants were with the spatial behaviour of the robot.

General Terms
Design,Experimentation, Human Factors, Theory

Keywords
HRI Proxemics,

1. INTRODUCTION
The field of assistive robotics encompasses a wide variety of technologies and applications [1, 2], ranging from devices to assist users and carers in physical tasks like lifting devices [3], to socially assistive robotics technologies [4] aimed at assisting through social interaction. What will be common for all such technologies, is that they will operate in human centered environments, where their presence may impact and possibly, disrupt the everyday life of their users, and other individuals entering these environments. This suggests that to study how such technologies may perform their tasks in a socially appropriate manner in home environment is a highly salient field of study.

1.1 Towards this study
The purpose of this study was to investigate participant's evaluation of the spatial behaviour of a robot within different interaction scenarios as well as different degrees of robot autonomy. While we have previously examined these issues [5-8], and for instance, found clear preferences in approach direction preferences across our sample as well as the influence of individual difference in such preferences, this study attempted to see how these general preferences were affected by particularities in a given interaction type.

2. METHOD
The experiment took place in the Robot House, a flat rented by our research group for the purpose of allowing the trials to take place in a more naturalistic environment (as opposed to a laboratory setting), closely resembling a normal home. The 33 participants were divided into two groups,: 21 short-term participants who took only part in the initial experiments; and 12 long-term participants who took part in a 6-week study encompasssing a variety of experiments including a repeat of this particular experiment in week 2 and in week 5. There were no systematic differences between the groups in terms of demographics and the experiments were conducted in the same manner for both groups. The robot used for the study was a Peoplebot (commercially available from ActivMedia Robotics).

2.1 Procedure
After filling out a brief demographic and personality questionnaire, the participant would be seated in a chair in the living room area of the robot house and given a signaling device and instructed in how to use it in order to signal spatial preferences. The robot would then approach from each subject a total of 12 times, from different directions, for different scenarios, and with differing degrees of participant control over its approach movement. After the trial, the participants were invited to fill in a questionnaire in order to evaluate the interaction. The different conditions were described below:

Participant Control:
Participant control had two levels: Human in Control (HiC), wherein the use of the signaling device would stop the robot's approach to the participant; and Robot in Control (RiC) wherein the signaling device was only used to record the participants preferences, and did not impact the movement of the robot.

Interaction Scenario:
There were 3 different interaction scenarios.

Manuscript received January 7th, 2008. The work described in this paper was conducted within the EU Integrated Project COGNIRON ("The Cognitive Robot Companion") and was funded by the European Commission Division FP6-IST Future and Emerging Technologies under Contract FP6-002020.

No Interaction:
The participant was told that the robot would move around the room and would not interact with the participant. In the HiC condition the robot would approach until the participant used the signalling device and then change direction and move away. In the RiC condition the robot would approach the participant until it reached its preset safety distance before moving away.

Verbal Interaction:
The participant was told that the robot would approach in order to practice a set of verbal commands, the robot would approach the participant and stop either at the signal of the participant (HiC) or at its preset safety distance (RiC) and the participant would then give it movement commands.

Physical Interaction:
The participant was told that the robot would approach with three wooden cubes underneath three cups in its gripper tray. The participant was instructed to look under each cup in order to find the cube that had a different colour to the other two. Its approach was similar to the Verbal Interaction approach.

Direction:
In our previous studies, we found a clear preference for frontal approach directions, and so used only Front Direct (The robot approached directly to the front of the participant), and Front Side (The robot approached to the side of the participant while still in full view from the participant's front).

3. Results

The participants comfort at the robot's approaches was nvestigated using 5 point likert scales, ranging from 1 (Very Uncomfortable) to 5 (Very comfortable). Participant responses were assessed using a repeated measures ANOVA.

3.1 Initial and Short-term Trials

There was a main significant effect for Interaction Type ($F(2,62)=3.878$, $p<.05$) The effect is described in Figure 1, below. No interaction received the lowest comfort rating from the participant, followed by Verbal interaction, and Physical interaction received the highest comfort ratings.

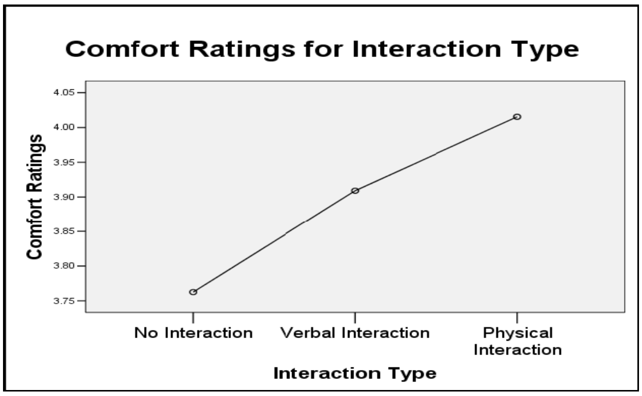

Figure 1. Comfort Ratings for Interaction Type

There was a trend for the HiC condition to be considered more comfortable than the RiC condition as well as a trend where Front Side approaches were considered more comfortable than Front Direct approaches by the participants but these trends were not significant for this sample size. However, an interaction effect approaching significance ($F=(1,31)=3.667$, $p=.06$). was found between the two and can be found in Figure 2 below .

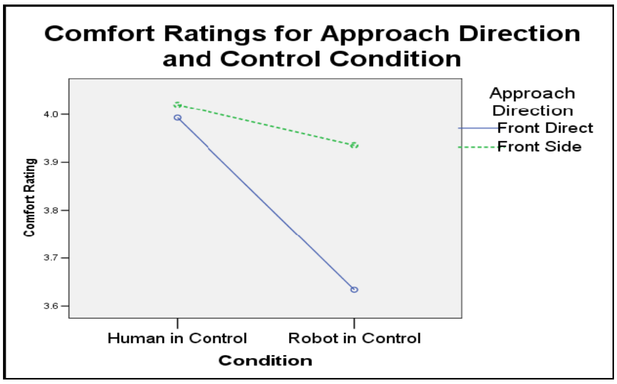

Figure 2. Comfort Ratings for Approach Direction and Autonomy.

Figure 2 suggests that while there is not difference between approach directions in the HiC condition participants distinguished between the two directions in terms of comfort for the RiC condition, and felt more comfortable with the Front Side approaches.

3.2 Long-term Trials

The sample for the long-term trials was quite small (12 participants) and as such inferential statistics were problematic. A Main Effect approaching significance was found for the week of the trials ($F(1,10)=3.413$, $p=.09$) and is described below in figure 3. Figure 3 suggests that, overall, participants rated the robot approaches as more comfortable in week 5 than in week 1 and 2. While no other significant results were found, trends suggested that differences between interaction types, degree of robot autonomy and approach direction decreased over time. Also, participants tended to rate the verbal interaction scenario as having the most comfortable robot approach.

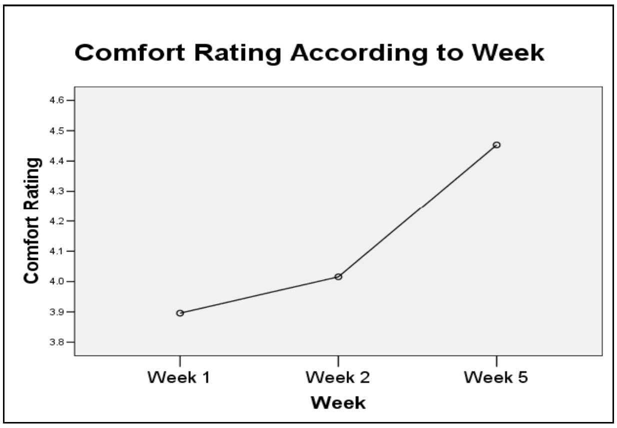

Figure 3. Comfort Rating according to week.

3.3 Open-ended Questions

Participants were invited to explain their choices in open-ended questions in the questionnaire. Results from these show two primary themes emerging. The first is that of control.

Many participants stated a strong preference for having control over the robot's approach. The second was that of understanding the purpose of the robot's movement. Participants would explain their differentiation between the No Interaction and the two other scenario types in terms of not knowing the robot's purpose. Participants would also differentiate between Physical and Verbal interaction in terms of purpose. Participants who rated the Verbal Interaction approach as the most comfortable, referred to the enjoyment value of the subsequent interaction as important for their rating. Participants rating the approaches for Physical Interaction as more comfortable, on the other hand, referred to the need for the robot to approach in order for the participant to reach its gripper tray. In terms of approach direction, the majority of participants would refer to the Front Side irection as less threatening than the Front Direct, with a small minority arguing that it the Front Direct approach was more visible and predictable.

4. DISCUSSION AND CONCLUSIONS

The results presented here suggest that participant evaluation of comfort with the navigational behaviour of a robot is directly related to the purpose of the robot's navigation. Approaches that are related to meaningful interactions as well as those seen as necessary by the participants in order to facilitate a particular interaction are rated as more comfortable overall. The results from the qualitative analysis seem to indicate that this is also related to the predictability of the robot's behaviour. Another issue is that of the interaction between approach direction and degree of participant control. Approaches directly from the front are often seen as more aggressive and confrontational [9] yet it seems that the ability to directly influence the robot's navigational behaviour off-sets this effect in these scenarios. While these results suggests that the impact of context in which a robot approaches a person decreases with higher degree of familiarity, it is important to note that initial interactions with a robot are important, and may influence the users' interaction pattern with the robot over time. As such, the two tentative recommendations based on these results are that of making certain that the behaviour of the robot within a human-centered environment can easily be interpreted by users as well as allowing users an easily available direct control over the robot's navigational behaviour, as both of these factors may lessen the impact of approaches that are seen as uncomfortable.

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