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Evaluating Social & Ubiquitous Human-Robot Interaction

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Abstract—While many robotic initiatives now share the thesis that robots are a compelling instance of those artefacts which comprise and deliver smart and ubiquitous environments, reconciling the social interface aspect with pervasiveness and ubiquity still remains a largely unexplored area of research. We argue that specific studies must be carried out to explore possible inconsistencies between the keystones of social human-robot interaction and the new features exhibited by ubiquitous robots.

To this end, we conducted a pilot study to explore how the ubiquity of a robot’s sensing capabilities affects the unconscious human perception of the robot as a social partner. Specifically, the experiment investigates whether people prefer a robot exhibiting ubiquitous sensor access or a more traditional robot whose capabilities are confined to its on-board sensors. We report qualitative results from the experiment and how results from the pilot study affect the design of the full-scale experiment.

Keywords—Human-robot interaction, social robotics, ubiquitous robotics

1. INTRODUCTION

Enabling robots to seamlessly operate in ubiquitous and smart environments is an important challenge for robotics research and a key enabler for a range of robotic applications.

On the one hand, the ubiquitous environment is supposed to augment the robot’s interaction capabilities, feeding it information about the user’s whereabouts and state, regardless of whether robot and user are in the same room. On the other hand, the robot may provide the user with a social interface that acts as a representative of the services the intelligent environment offers [1].

Research under the social robotics banner is informed by human models of social interaction and has already produced a body of results that drive effective social interaction between human and robots. Instrumental to effective human-human interactions is the ability to understand and anticipate each other’s intentions and emotions [2], and to adhere to human social norms in order to fulfil user expectations [3]. Effective Human-Robot Interaction (HRI) is, by the same token, based on the social relationship and the mutual understanding between user and robot, improving predictability and trust between the two.

Given the way ubiquitous robots may deviate from natural, human-like capabilities, we argue the importance of conducting specific studies to examine social interaction with ubiquitous robots. These studies should be cautiously aimed toward the validation of previous social HRI results as applied to ubiquitous robots and, in the case that inconsistencies are found, to the identification of suitable guidelines that inform the design of social and ubiquitous robot systems.

This paper constitutes a first step in this direction by describing an ongoing experiment conducted at the UbiRobot laboratory at the CLARITY Centre for Sensor Web Technologies as part of Ambient Assisted Living (AAL) project. The AAL project develops and integrates different technologies to ease independent living for elderly people [4], especially those with Alzheimer’s, dementia and related illnesses. In particular, as in other similar works [1], the aim is to introduce robots that act both as mediator toward the services offered by the smart environment, and as an “attention focus” for user-system interaction.

2. EXPERIMENT

The evaluation of social robots has been the focus of a number of studies. Within the ubiquitous robotics arena, [5] have conducted a psychological evaluation of a socially assistive robot integrated with a smart environment. Their study has focused on elderly people’s attitude and has shown how the acceptability of robotic devices in those settings does not depend only on the practical benefits they can provide, but also on complex relationships between the cognitive, affective and emotional components of people’s image of the robot.

2.1 Design

The specific purpose of our study is to test if augmenting a robot’s sensing capabilities, by giving it access to a ubiquitous infrastructure, affects a person’s unconscious perception of the robot as a social partner. To this end, we designed a between-subjects experiment with three groups. In two of the groups, the robot clearly manifests ubiquitous behaviour.

Participants in the non-ubiquitous group are told that the robot can only use its on-board sensors, whereas participants in the ubiquitous group are told that the robot has access to a ubiquitous sensing infrastructure (an overhead camera and RFID tags placed on specific items). In both groups, the robot clearly manifests sensing capabilities beyond its inherent sensors. In the control group, finally, participants interact...
with a robot that does not exhibit any kind of ubiquitous behaviour.

The three groups allow us to investigate whether people are comfortable interacting with a ubiquitous robot, provided they have knowledge of the robot’s ubiquitous nature, and to compare results to a baseline for human-robot interaction.

### 2.2 Setup and Procedure

We employ the well-known Desert Survival Problem [6], in which participants rank fourteen items, such as a pocket knife or compass, in order of their usefulness for surviving in a desert. The Desert Survival Problem has been previously applied to social HRI (e.g. in [7]) and our experiment follows a similar design in that participants first rank the items on their own before collaborating with the robot on a final ranking.

In the first stage of the experiment, fourteen placeholder items are placed on a desk near the robot. Participants show each item to the robot to obtain some information about it before placing the item on a second table. This ensures that participants interact and get acquainted with the robot. The description for all items is positive and does not refer to other items. A diagram of the setup is shown in Figure 2.2.

Once a participant has moved all items to the second table and ranked them, the robot proposes a different order of the items. This new order is a simple permutation of the participant’s ranking, which ensures that the difference between the robot’s and the participant’s order is the same regardless of the ranking chosen by an individual participant.

In order to test the effect of the robot’s ubiquitous nature, it has to demonstrate knowledge of a ubiquitous fashion, i.e. it has to refer to items or events that are not within the range of its on-board sensors. For the ubiquitous behaviour group, we, therefore, put a screen around the ranking table and the robot was free to observe it.

When the robot proposes its solution to the task, it specifically refers to the ranking selected by the participant (e.g. “I would switch the first and second item.”). By exhibiting knowledge about the particular ranking selected by a participant, despite the desk being shielded from view, the robot clearly demonstrates ubiquitous knowledge.

### 2.3 Pilot Study

The pilot study was conducted using a Wizard-of-Oz approach, whereby the experimenter remotely controlled the robot via a keyboard. 15 subjects (12 M, 3 F) were balanced across the three groups. In order to reduce participants’ expectation of the robot’s intelligence, the robot’s capabilities were clearly stated during the familiarisation phase. Specifically, user-robot collaborative interaction was distinguished in the following steps: (i) initial ranking phase, during which the participant could ask the robot about each item by holding it up for the robot to see. The robot responded by uttering one of the pre-recorded facts associated with each selected object (e.g. “Water is extremely important in the desert. You may not find anything else to drink until you get out.”). (ii) change phase, once the participant informed the robot about having selected a ranking, the robot proposed its own ranking, and the participant was given opportunity to change their ranking. During this phase, the robot only repeated its proposed ranking but gave no justification for its decision.

### 2.4 Measures

We are applying behavioural measurements as well as post-hoc questionnaires to investigate participants’ unconscious perceptions of important indicators of social HRI. Trust is measured as the difference between the robot’s proposed ranking and the participant’s actual final selection. As the robot’s ranking is a strict permutation of the user’s initial ranking, it allows for direct measurement of the amount of conformity to the robot’s suggestion.

For the questionnaire, we adapted previous works by Kidd and Breazeal [7] and others to develop a questionnaire to gain information about subjects’ perceptions and feelings in relation to their interaction with the robot.¹

### 2.5 Results

Levels of engagement were high throughout all three groups. Participants enjoyed the experience and felt comfortable interacting with the robot. They judged the robot to behave appropriately and logical, if somewhat slow, and found it to have a good understanding of the situation.

Nearly all participants (4 out of 5 in the ubiquitous and control, 5 out of 5 in the non-ubiquitous group) conformed to the robot’s advice to change the ranking (even if switching salt and water) but, at the same time, had strong doubts about the robot’s advice. This was slightly more pronounced in the non-ubiquitous group.

Most participants saw the ranking not necessarily as a result of the collaboration between robot and participant, despite claiming to share the responsibility for the final

¹The complete questionnaire, together with a picture of the robot and the setup of the experiment can be found at [http://ubirobot.ucd.ie/content/ubiquitous-robot-experiment](http://ubirobot.ucd.ie/content/ubiquitous-robot-experiment)
ordering. Only in the non-ubiquitous group did participants exhibit the tendency to assume responsibility for the final ranking.

3. Discussion

Overall, the results of this pilot study are very encouraging. People enjoyed the interaction with the robot and had very few problems with the robot or the task. Only two people claimed that they felt stupid interacting with the robot.

Nearly all participants interacted directly with the robot, facing it and showing the items to the robot’s on-board cameras, even in the ubiquitous group, where they knew that the robot was not depending on its own sensors. This result is in keeping with a ubiquitous robot’s function as an interlocutor between the smart environment and the user.

In our observation, after the initial interaction, participants relaxed their body posture and became more comfortable, stepping closer to the robot, as the interaction progressed.

The robot’s perceived slow reaction seems to be a result of performance issues with the network and robot, as we observed a delay of about 2-3 seconds between pressing the right button and the robot actually uttering the dialogue.

Some participants stated that they found it difficult to ask the robot for information, but the vast majority only showed the item to the robot without attempting to actually ask it for any information verbally.

This is most likely a result of the instructions given and the lack of participants interacting verbally with the robot before the start of the actual task. In the final experiment, we will clarify the instructions and include a short chit-chat dialogue in the familiarisation phase.

A few participants stood behind the item desk rather than in front of it. One participant completely ignored the robot and just moved the items from one desk to the other. This participant also ignored the robot’s suggestions as to the ordering and indicated in the questionnaire that “I didn’t speak with him. He was speaking with me so we didn’t interact”.

The lack of clear differences between the three groups suggests that we have to modify the setup and procedure in a way that prompts stronger reactions. With the current setup, participants did not necessarily seem to be aware that the robot was “seeing” something it should not be able to. One solution would be to doubt a participant’s ranking while they are still deciding and referring to specific items and placements while doing so (e.g. “Do you really want to put the water in position 5?”).

Another factor was the robot’s apparent lack of sociability and pro-activeness. For the final experiment, we would like the robot to move more and implement some basic gaze and attention behaviour using its “eyes”, which are pan and tilt cameras.

We also want to employ more behavioural measures, e.g. taking the amount of personal space participants grant the robot as an indicator of the robot’s social presence (as in [8]), as well as including observation and behavioural analysis [9] and interaction analysis techniques [10] based on the observation of participants’ gestures, gaze, and emotional expression during the interactive experience.

4. Conclusion and Future Work

We argued the importance of conducting studies to examine social interaction with ubiquitous robots. These studies should be cautiously aimed toward the validation of previous social HRI results as applied to ubiquitous robots and, in the case that inconsistencies are found, to the identification of suitable guidelines that inform the design of social and ubiquitous robot systems.

The presented pilot study constitutes a first step in this direction and has provided valuable insight into conducting experimental validation of ubiquitous robots.

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