User preferences for socially acceptable person-following robots: environmental influence case studies

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***Abstract*— Person-following is an important aspect in many service robotic applications whilst supporting a person in performing daily tasks. Few studies have actively worked towards making person-following behavior usable, pleasurable or personal. As such, user studies are essential for promoting the interaction design, and increase user satisfaction and acceptance. A specific experimental setup for studying of socially acceptable person-following preferences and algorithmic design is presented here. In six user studies (171 participants in total) following-related factors were examined, of those, two related to environmental influence are specified here. Objective and subjective measurement of the quality of the interaction and user satisfaction were taken. Results and implications are discussed.**

I. Introduction

Person-following is an important aspect in many service robotic applications whilst supporting a person in performing daily tasks (e.g., carrying groceries, physical monitoring, and companionship). To create robots that move in socially acceptable manners it is important to consider a multitude of parameters such as the robots' speed, acceleration and deceleration properties, the lead human's walking speed, angle of following and the appropriate physical proximity, as a function of the environment, context, physical state and human intent. A recent in-depth review [1] identified four categories of factors that influence social considerations of person-following behaviors, including: the characteristics of the person being followed, the features of the robotic system, the task which is performed, and the environment.

In order to design a socially aware person-following robot that meets user needs and desires, it is critical to consider the various factors that influence the way a person would like to be followed by a robot [2]. Still, the majority of published works on person-following robots focused on the technical aspects of making the person-following behavior safe and functional. Most applications set their velocity based on their proximity to an obstacle or to the person or based on specific environmental constraints like safe passage through a door. The distance maintained between the robot and the person it follows is often constant [1] although some implementations used Hall's human-human distancing [7] to select their following distances.

Figure 1. Experimental setup and dedicated person-following robot.

The vast majority of research in person-following has focused on robots that follow people from behind, some work has been done on enabling robots to accompany people side-by-side or at an angle (e.g. [6]). In most studies, the relative position of the robot to the person remains fixed, and changes solely based on environmental considerations. The criteria for selecting the initial angle of following is often unspecified, especially when there is no task-specific reasoning. Very few studies have actively worked towards making the person-following behavior usable, pleasurable or personal. As such, user studies like ones specified here are essential for promoting interaction design, and increasing user satisfaction and acceptance. Furthermore, while relevant human-robot literature is sparse, research in human-human interaction reveals many environmental characteristics that affect distancing behavior [8]. People seem to allow others to come closer to them when they're in larger rooms with better lighting and higher ceilings.

II. Methods

Experimental platform. A specific experimental setup for studying of socially acceptable person following preferences and algorithmic design is presented here (see Fig. 1) with an emphasis on the factors that were considered in six user studies, and in relation to the four categories (human-robot-task-environment). In this setup, a young adult was followed by a robot in various predefined use cases. For this, a dedicated robotic platform, the Pioneer LX mobile robot

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equipped with an integrated on-board computer, an external Kinect camera that was mounted to the robot and was located on a pan mechanism at about 1.5m height to impart to it a higher eye sight to detect people standing on the ground and the on-board laser SICK300, which can detect the human's legs at 20 cm above the ground. The robot utilized a specially developed following algorithm based on the OpenTrack [4] open source project for person tracking (see [3], [11]). The developed algorithms do not use any a-priori information about the environment (i.e., operate with no a-priori mapping) and do not require that the human have any particular carry-on item or specific clothing.

Metrics of evaluation. As pointed out in [1], there is no consistent use of performance variables for assessing tracking and navigation performance in user studies which makes it difficult to compare between systems and the algorithms. Similarly, subjective accounts of the robot's following behavior vary among studies and include multiple constructs like user expectations, appropriateness of the robot's movements, user preference, user comfort or engagement (e.g., by using the number of times the user looked at the robot [3]). Moreover, some use custom questionnaires with Likert scales while others use unstructured interviews with a large variety of different questions, as noted in [12]. This highlights the need for consistent, comparable metrics of evaluation across user studies. Initially, participants completed a pre-test questionnaire which included demographic information, the Technology Adoption Propensity (TAP) index [9] to assess their level of experience with technology and the Negative Attitude toward Robots Scale (NARS) [10] to assess their level of anxiety towards robots. Performance measures applied for the comparison were the number of instances of loss of the human, number of self-recoveries of the robot and the number of safety interventions, the distance between the robot and the human, the length of the robot path, reliability of the human legs detector, reliability of occlusion detections, and the ratio of stable tracking (percent of stable tracking from the entire trial) of the Kinect and laser. The quality of following was assessed objectively and subjectively. The objective measures analyzed were the number of tracking losses and the total time to complete the walk as the robot was following. The subjective measures analyzed were the responses of the participants to post-trial questionnaires.

III. Results

A series of six user-based experiments (total of 171 participants) were conducted with this experimental setup to derive best fit person-following parameters and to evaluate the algorithmic person-following developments. Of those, the outcomes of two experiments that dealt with environmental considerations are specified here in more detail and highlight the importance of incorporating user preferences into the person following algorithmic design.

The first experiment, ***Proxemics and robot movement considerations in a person-following setup was*** aimed to investigate tracking parameters (distance and acceleration) that yield a more natural tracking, and to study whether the robot's tracking and human's experience are affected by the type of environment i.e., open-space vs. corridor-like walking area and the inclusion of a distracting secondary task. Fifty participants reported upon higher positive subjective feelings towards the following and the following distance when experiencing person-following setups in open space vs. corridor-narrow areas. Participants reported on a more natural experience when engaged in a secondary task while walking. The highest percentage of participants preferred a closer proximity from the robot during stationary interaction compared to dynamic interaction but there was also more indifference rankings (see Figures 2 and 3 in the appendix).

The second experiment, was aimed to examine how ***illumination level and visual clutter influence*** user preferences for different combinations of robot following acceleration, angle, and distance. Experimental results with 51 participants revealed that the interaction effect of two levels of illumination and the level of visual clutter in the environment significantly influences the quality of following and user comfort. Analysis of the objective and subjective performance measures indicated a preference for the robot to follow the human more closely, at a slow pace and slightly at an angle in environments with high illumination and low visual clutter. When the illumination level decreased in a high visually cluttered environment, participants preferred that the robot follows less closely and faster.

IV. References

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V. APPENDIX

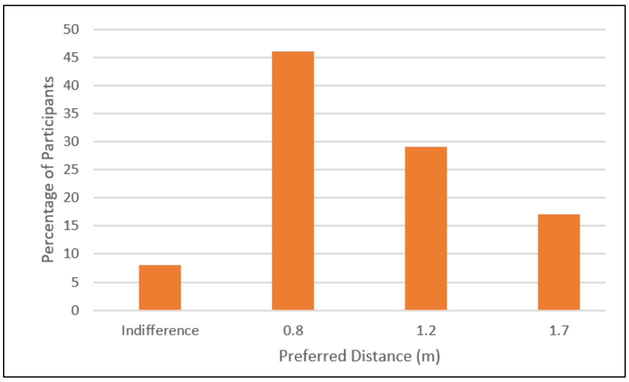

Figure 2: Participants' preference for following-distance during static interaction (robot and participant were stationary).

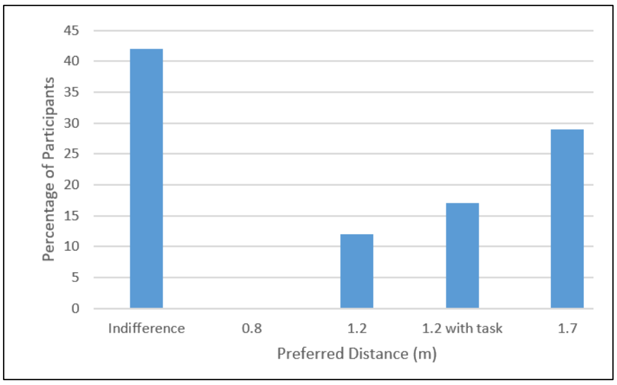

Figure 3: Participants' preference for following-distance during dynamic interaction (robot and participant were walking).