User's Personality and Activity Influence on HRI Comfortable Distances

Silvia Rossi[1](✉), Mariacarla Staffa[2], Luigi Bove[1], Roberto Capasso[1],
and Giovanni Ercolano[1]

[1] Department of Electrical Engineering and Information Technology,
University of Naples Federico II, Naples, Italy
silvia.rossi@unina.it
[2] Department of Engineering, University of Naples Parthenope, Naples, Italy
mariacarla.staffa@uniparthenope.it

Abstract. A robot system that is designed to coexist with humans has to adapt its behavior and social interaction parameters (for example, the interaction distances and the speed of movements) not only with respect to the task it is supposed to accomplish, but also to the human users' habits, actions, and personality. This is particularly relevant in the domain of assistive robotics and when working with vulnerable people. In this work, we are interested in determining key factors to model the user and to adapt the robot behavior accordingly. We provide the first step towards this direction with a case study aiming at evaluating if the users' personality and activities they are currently performing affect the perception of comfortable distances of a robot approaching them.

1 Introduction

The increasing development of a new generation of social robots capable of moving and acting within the human being's living space has outlined a new tendency to model the robots control systems through a so-called human-centered approach. In particular, Socially Assistive Robotics applications are receiving great attention from the scientific, technological, and industrial communities for their potential value in improving the quality of life of a large segment of the population [3]. Most of the projects in this area focused on the development of enabling technologies in order to have autonomous and safe robots. However, current research shows that the majority of people are still skeptical or even against the application of robots in real contexts, and, in particular, for child, elderly, and disabled care [4].

Our long-term goal is to design a robotic system that is in charge of adaptively monitoring the user's Activity of Daily Living (ADL) in the case of people with dementia. Research suggests that a robot ability to adapt its behavior independently and proactively to the changes in the needs and preferences of users [11] can improve acceptability. In this direction, our goal is to design an adaptive behavior of the robotic system that is able to regulate its social interaction parameters (e.g., the interaction distances, proxemics [16], the speed of

A. Kheddar et al. (Eds.): ICSR 2017, LNAI 10652, pp. 167–177, 2017.
https://doi.org/10.1007/978-3-319-70022-9_17

movements [12], and the same modality of interaction) on the basis of personality factors as well as of the cognitive state of the user. We started analyzing embodied non-verbal interactions, such as approaching, following or avoidance behaviors, which are fundamental in regulating also human-human social interaction [17]. For example, in the context of ADL monitoring, a user's monitoring activity may be carried out either by following the user or by trying to anticipate his/her movements, by moving at different speeds or by positioning at different distances from the user.

Previous studies have established that the proxemics behavior of the robot has a strong impact on the level of acceptability and strongly depends on subjective and demographic characteristics. Proxemics is the study of spatial distances used in interaction by human and/or robot agents. The term was introduced by [6], who also classified interpersonal distances between two humans into four categories: (1) Intimate space (a distance up to 46 cm); (2) Personal space (from 46 to 122 cm); (3) Social space (from 1.2 to 3.7 m); (4) Public space (more than 3.7 m). With respect to human-human-interaction, proxemics studies on HRI showed that these distances may be different (shorter) while interacting with a robot. For example [18] showed that in 40% of the analyzed cases participants stood too close to the robot, suggesting that they did not perceive the robot as a social actor. Also in [7, 18], subjects when interacting with robots prefer a distance corresponding to the personal zone that is typically used by humans when talking to friends, and so suggesting that they treated the robot differently from a person.

In the context of proxemics, personality factors affect the way whereas public spaces are shared and the perception of socially acceptable movements. Thus, a robot should be able to perform the same actions, but in a different way depending on the person whom it interacts with. People react and behave differently depending on how their space is occupied when interacting. Thus, mobile social robots must use space appropriately when interacting with people. Moreover, also the current human pose or the activity he/she is performing may have an impact on the subjective evaluation of comfortable interaction distances from the robot [9]. In this paper, which is an extension of a previous work [10], we design a pilot study whereas the human-robot comfortable stopping distance is evaluated with respect to the current human pose and his/her personality. The possibility of learning such user interaction preferences in order to modulate the robot behavior has a great impact on the robot acceptance by the users as well as on their feeling of safety [2].

2 Related Works

The perception of acceptable social distance has been addressed before in literature in particular with respect to different robot factors that influence proxemics, such as the robot's voice, form, speed, and height. Here, we report only works explicitly dealing with proxemics and the user personality.

Walters et al. [17] studied the impact of personality on human-robot distancing with the Peoplebot robot. This study showed that proactive subjects allowed the robot to approach closer. Differently from us, the user's personality has been evaluated in terms of Eysenck Personality Inventory and only in case of standing people. In HRI scenarios with a robot companion or an assistive/therapist robot, some works focused on Big Five Inventory (BFI) [13,14,16]. In particular, in [13], the authors examined the effects of the subjects' personality and of the subjects' pose, sitting or standing, on the preferred approach direction of the Peoplebot robot. Results showed that no consistent significant relationship was found between personality traits and the approach direction. However, the study suggests that higher extraversion scores led to a better tolerance of inappropriate robot behavior. In [14], the authors examined the effects of subject personality on the preferred approach direction of the Peoplebot robot in case of the robot in control or the user in control. Extrovert participants allowed the robot to come closer in the case of the human in control. Here, we do not consider the approaching direction.

The relations with personality and preferred stopping distance in HRI were also studied in [15], where the authors showed that people who are more agreeable move closer toward robots, while people who hold negative attitudes toward robots and are more neurotic stand further away from approaching robots. Finally, [9] is the only works, we are aware of, that considers the effects of sitting and standing human pose while being approached by a robot, showing results that are in line with ours.

3 Case Study

In this work, we conduct an experimental study aiming at determining if exist some key factors for modeling the robot behavior with respect to both the user's personality and the activity he/she is currently performing. Our long-term goal is to dynamically adapt the robot non-verbal interaction behaviors with respect to the user's profile. The goal of this study is to find out in what extent users' personality and activity have an impact on the perception of the robot acceptable movements in the shared space. In particular, we started with an evaluation of users' comfortable stopping distances in the case of a robot that approaches the users in order to monitor their activities or to interact with them. We considered the following experimental hypotheses:

H1: the human-robot stopping distance preferences, when a robot is approaching, are affected by common factors in subjects' personality;
H2: the human-robot stopping distance preferences are affected by the activity the subject is performing;
H3: there is an additive relationship between the two factors or the interaction effect is not present.

3.1 Experimental Procedure and Method

The design of this study is a within-subjects, counterbalanced, repeated measures experiment. That means that each participant is subjected to more than

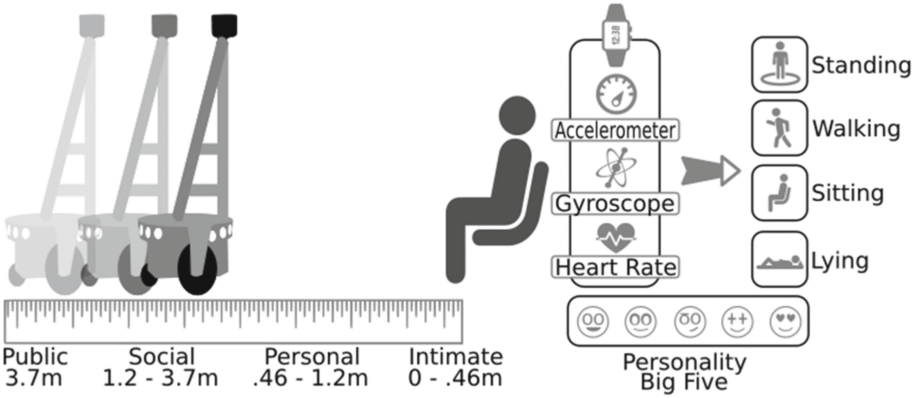

Fig. 1. The experimental scene: the user performs one of the 4 activities (sitting, walking, standing and lying) while the robot is approaching. Accelerometer, gyroscope and heart rate are retrieved from a wearable device to monitor the user

one experiment under different conditions (activity to perform) and that these settings are randomly presented to her. Following the work of [17], we adopted the following experimental procedure:

1. *Co-habituation and Personality*: the user enters a room (an empty lab) and sits on a sofa and starts answering the personality and demographic questionnaire on a laptop. While the subject is filling the questionnaires, the robot wanders randomly around the test area (Fig. 1).
2. *Test*: The user is asked to perform one of the following activities: lying, sitting, standing and walking. The order of the activity is randomly established for each user. During each activity, the robot, starting from a predefined position that is at a distance of 4.5 m (hence in the public space), approaches the person frontally or, in the case of walking, with an approaching angle of 90° with respect to the walking direction. The users are asked to stop the robot (by saying the word "STOP") when the robot comes as close as they felt it is comfortable. Whenever the user stops the robot, the distance of the robot from the user is evaluated by reading the frontal sonar values (in meters) and then the robot stops.

An operator supervised each test seated in the same lab with a laptop far from the user. Each participant was involved in only one experimental session. During the session, the participant was asked to perform each of the four considered activities, and for each activity, the experiment was also repeated three times, with different robot velocities, as a consistency check. Namely, the speeds v of the robot were 0.2, 0.6 and 1.0 m/s. A session lasted on average 15 m.

Activity Recognition. For the activity recognition phase, the Microsoft Band 2 was used. The users wearing this smart watch were monitored through an app installed on a smartphone. The sensors of the fitness band send the measured data to a Deep Belief Network (DBN). The sensors used for the activity recognition are: Accelerometer, Gyroscope, Heart rate. The accelerometer provides the acceleration measures in g units in three coordinates X, Y, Z at 62 Hz. Gyroscope provides angular velocity measured in three coordinates X, Y, Z at 62 Hz. Heart rate provides the number of beats per minute at 1 Hz. The dataset used for the network training is called PAMAP2[1], and it consists in physical activities. The classified assets are 19, however, the activities considered for our training are only 4: lying, sitting, standing and walking.

Personality Evaluation. In literature, several personality questionnaires are used to learn certain traits of the user's personality. Demographics questionnaires and questionnaire based on the BFI are the main choices, as in [14], for establishing the user's personality traits. For our experimental study, we used the Italian BFI questionnaire reported in [8], where users were asked to define a certain number of characteristics that may or may not be applied to themselves, by associating a rate from 1 (Disagree Strongly) to 5 (Agree Strongly) to each question. The results analysis will generate the membership with a certain percentage to one of the five possible macro profiles (Extraversion, Agreeableness, Conscientiousness, Neuroticism and Openness).

Participants. The subjects sample set consists of 50 adult volunteers that were not paid for the participation. In detail, 37 men and 13 women with an average age of 27 ± 9. Most of the participants were master students, for the majority of the cases in Computer Science. They were all Italian but with a good English comprehension level, and 38% of the participant declared to have confidence with robotics applications.

The Robot. The robot used for the experimentation was a Pioneer 3DX with a 16 sonars range. The robot was opportunely modified in order to have a kinect at the height of 1.3 m and a tablet at the height of 1.1 m. The robot behavior was controlled in a Wizard of Oz mode.

4 Experimental Results

From the experimental results, we observed that all the measured stopping distances were in the interval (0.11, 3.6) m, and so in the intimate, personal and social interaction space. Moreover, the average stopping distance value is 0.88 m that is a value in the personal space. In particular, we evaluated the average general stopping distance with respect to the three different robot velocity values considered, namely 1.086 ± 0.29 for $v = 0.2$, 0.791 ± 0.021 for $v = 0.6$, and 0.757 ± 0.027 for $v = 1$, and we observed that a difference in the robot velocity is related to a difference in the stopping distance with smaller distances in the case of higher velocities (significant with $p < 0.001$). No significant differences were found by considering the different velocities with respect to the performed

---

[1] https://archive.ics.uci.edu/ml/datasets/PAMAP2+Physical+Activity+Monitoring.

activity and with respect to heart-rate data. In the following sections, we discuss the results obtained w.r.t. the personality of the subjects and the activity by considering the three velocities as different repetitions for the same activity.

4.1 Stopping Distance w.r.t. Personality

In order to address our three experimental hypotheses, we firstly analyzed the obtained subjects' personality traits (Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness) searching for common factors which could affect the preferred stopping distance. Then, we evaluated if the choice of the stopping distance was also related to the activity (i.e., Lying, Sitting, Standing or Walking) the tester was performing. The statistical analysis showed that there is a significant difference in the stopping distance with respect to all the five personality factors (one-way ANOVA with $F(49, 550) = 11.755$ and $p < 0.001$).

Additionally, we conducted a statistical analysis aiming at finding some insight about possible correlation among different factors (in this case personality traits and actions) influencing the users' preferences, which could be used to predict the more suitable approaching distance for a specific user and, in the future, to model the robot behavior control system accordingly. In particular, for each personality trait, we divided the considered population into two sets per high and low values of belonging to a particular personality trait (with respect to the average value of the possible range of the considered trait). This was possible for four traits but no for the Agreeableness trait, where the considered population has only high values. In Fig. 2, the average stopping distances with respect to these sets for the five personality factors are plotted. One-way ANOVA on high/low average stopping distances shows that no statistically significant difference can be found for the Extraversion ($p = 0.186$), and Conscientiousness ($p = 0.139$) factors. These results are in contrast with the state of the art that suggested (without statistically significant results) that high value of Extraversion should correspond to smaller human-robot comfortable distances [5].

On the contrary, such differences are significant for the Neuroticism ($F(1, 598) = 24.20$ with $p < 0.001$), and Openness ($F(1, 598) = 12.592$ with $p < 0.001$) factors. In detail, people with a high neurotic personality trait stop the robot at higher distances, not allowing the robot to come too close. Moreover, people with a low neurotic trait value would allow the robot to come closer than people that are highly extroverted. Pearson test on results shows a weak correlation between Neurotic values and distances ($\rho = 0.18$ with $p < 0.01$). The same trend is obtained with respect to the Openness factor. However, the stopping distance for high Openness values is comparable with the one obtained for high Extraversion, Agreeableness, and Consciousness. On the contrary, more people with low values of the Openness trait allowed the robot to come the closest with respect to all the other cases.

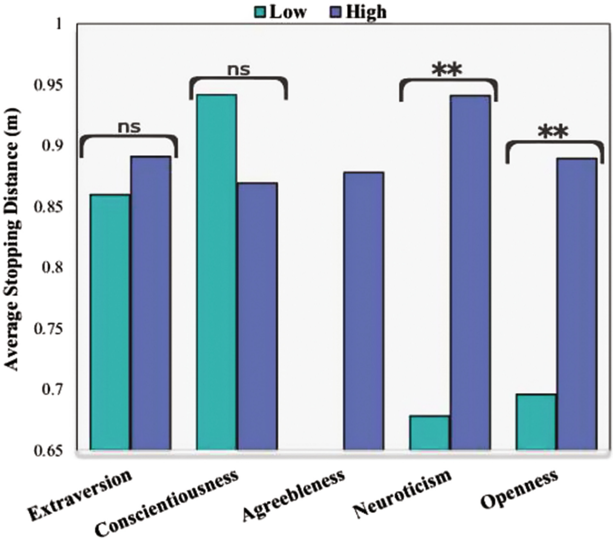

Fig. 2. Preferred stopping distance with respect to high and low level of the personality five factors. ** are for $p < 0.001$

4.2 Stopping Distance w.r.t. Activity

In Fig. 3, the histogram of the preferred comfortable distances (Average Stopping Distance) is plotted in the case of the four considered activities (Lying, Sitting, Standing and Walking). The average stopping distance are significantly different (One-way ANOVA $F(3, 596) = 3.904$ with $p = 0.009$). These results are in accordance with our H2 hypothesis that the perception of the comfort distance depends on the activity the user is performing. Moreover, Spearman test for non parametric variable on results shows a weak correlation between the performed activity values and distances ($\rho = 0.216$ with $p < 0.01$). Moreover, from the observation of these results, we can individuate two main classes of activities: those characterized by a standing pose (Standing and Walking), and the two characterized by a static lower pose (Sitting and Laying). In particular, results show that in the second class a smaller stopping distance is obtained. This effect could be due to the relative size of the robot with respect to the user. Moreover, these results are in line with the one presented in [9], where comfortable stopping distances are evaluated using the Aldebaran NAO robot, and so a robot of a small size, with respect to the standing and sitting human pose. One-way ANOVA computed on results showed that there is a statistically significant difference between the results of these two classes (e.g., $F(1, 598) = 11.426$ with $p = 0.001$ for the Lying-Standing, and Sitting-Walking cases).

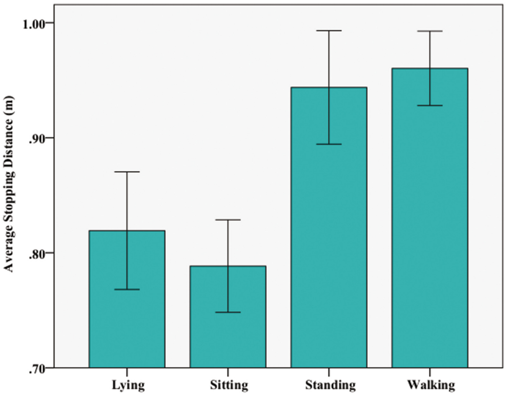

Fig. 3. Preferred stopping distance during the execution of the 4 activities

4.3 Personality and Activity Interaction

Results of a two-way ANOVA analysis are shown in Table 1 with respect to the Extraversion, Neuroticism, Openess and the activity. Results show that the interaction effect between personality factors and current activity is not present, according to our hypothesis H3.

Table 1. Table of ANOVA2 Analysis

Source	Sum Sq.	d.f.	Mean Sq.	F	Prob > F
Extraversion	3.173	3	1.058	8.037	0.000
Neuroticism	6.608	3	2.203	16.737	0.000
Openness	3.068	2	1.534	11.656	0.000
Activity	2.915	3	0.972	7.384	0.000
Extrav.*Activity	1.359	9	0.151	1.148	0.328
Neurot.*Activity	1.873	9	0.208	1.582	0.119
Open.*Activity	0.545	6	0.091	0.690	0.658
Error	52.641	400	0.132		
Total	638.229	600			

Moreover, we evaluated the stopping distance for High-low values of Neuroticism and Openness and the activity. No statistical significance in case of High-Neuroticism values varying the activity (one-way ANOVA $F(3, 452) = 2.047$ with $p = 0.107$), while for Low-Neuroticism values there is a statistically significant difference with respect to the considered activity ($F(3, 140) = 9.088$ with $p < 0.001$). In particular, the smaller distance is obtained in the case of

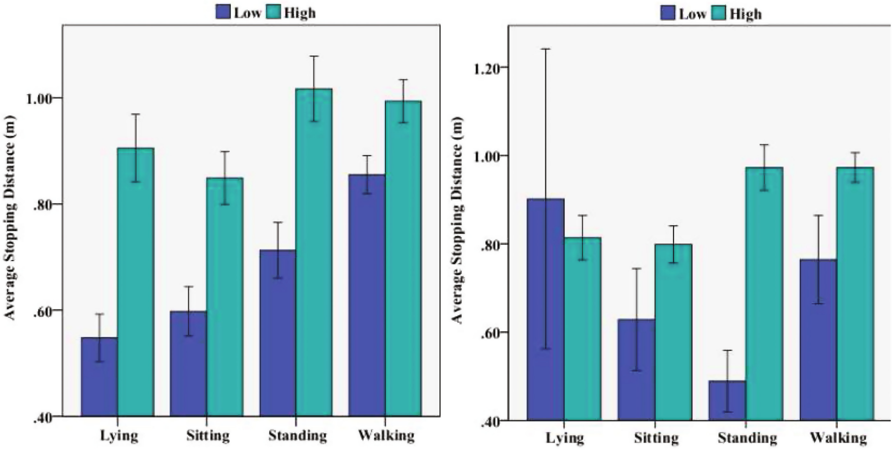

Fig. 4. Preferred stopping distance with respect to high and low level of the Neuroticism (left) and Openness (right) factors and the activity

Low-Neuroticism values and a lying pose, with the larger in the case of walking. All the average distance values for Neuroticism are reported in Fig. 4. On the contrary, for Low-Openness values no significant differences are found by considering the different activities ($F(3, 32) = 0.877$ with $p = 0.463$), while for High-Openness values such differences are significant ($F(3, 560) = 4.598$ with $p = 0.003$). All the average distance values for Openness are reported in Fig. 4.

Finally, for completeness, we also checked whether the gender aspect could have somehow influenced the choice of robot approaching distance. From the ANOVA test performed by dividing the participants by gender, no significant differences were found ($F(1, 598) = 0.246$ with $p = 0.621$).

5 Conclusions

Differently from previous works, which only analyzed the influence of personality factors on the approaching behavior of an interactive social robot, here, we consider additional factors such as the current performing user's activity, which can affect the choices of the users about the more suitable stopping distance. The obtained results will be used to design adaptive robot monitoring behavior of the ADL with respect to the current user and the activity she/he expected to be performing. Two-way ANOVA showed that there are statistically significant stopping distances differences with respect to the user personality and the performed activities, with no interaction component. From a first analysis, it emerged that Neuroticism and Openness influenced such distances, however, in our opinion, a more in-depth analysis that considers all the five factors simultaneously is needed. The same is for the performed activities where two major classes characterized by a static (lower) or dynamical (higher) pose are identified.

It is worth noting that many other factors exsist, that not depend on the particular human user position/action or personality trait, and that can impact on the preferred stopping distance as well as on users' acceptance. These factors can rely on both internal factors such as attentive states [1] or internal motivations and external factors such as the robot morphology and aspect. As a matter of example, we consider the same person in the same position, for example lying, while performing different actions, sleeping or just watching TV. It is clear that in these situation the level of attention and awareness with respect to the robot presence differs from a situation to the other, and it can obviously impact on the choice of the preferred stopping distance. In future work, we will extend our study by considering home activities instead of poses and different robots.

Acknowledgment. This work has been partially supported by MIUR (Italian Ministry of Education, Universities and Research) within the PRIN 2015 research project "User-centerd Profiling and Adaptation for Socially Assistive Robotics - UPA4SAR".

References

1. Caccavale, R., Leone, E., Lucignano, L., Rossi, S., Staffa, M., Finzi, A.: Attentional regulations in a situated human-robot dialogue. In: RO-MAN, pp. 844–849. IEEE (2014)
2. Cakmak, M., Srinivasa, S., Lee, M.K., Forlizzi, J., Kiesler, S.: Human preferences for robot-human hand-over configurations. In: IEEE (ed.) IEEE/RSJ International Conference on Intelligent Robots and Systems, September 2011
3. Cavallo, F., Aquilano, M., Carrozza, M., Dario, P.: Robot-era project: the vision of 3D service robotics. Gerontechnology **11**(2), 364 (2012)
4. Conti, D., Cattani, A., Nuovo, S.D., Nuovo, A.D.: A cross-cultural study of acceptance and use of robotics by future psychology practitioners. In: 24th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN), pp. 555–560 (2015)
5. Duncan, B.A., Murphy, R.R.: A preliminary model for comfortable approach distance based on environmental conditions and personal factors. In: Smari, W.W., Fox, G.C. (eds.) CTS, pp. 622–627. IEEE (2012)
6. Hall, E.T.: The Hidden Dimension. Doubleday & Co., Garden City (1966)
7. Huettenrauch, H., Eklundh, K.S., Green, A., Topp, E.A.: Investigating spatial relationships in human-robot interaction. In: IEEE/RSJ International Conference on Intelligent Robots and Systems, pp. 5052–5059, October 2006
8. John, O.P., Srivastava, S.: The big five trait taxonomy: history, measurement, and theoretical perspectives. In: Pervin, L.A., John, O.P. (eds.) Handbook of Personality: Theory and Research, 2nd edn., pp. 102–138. Guilford Press, New York (1999)
9. Obaid, M., Sandoval, E.B., Zotowski, J., Moltchanova, E., Basedow, C.A., Bartneck, C.: Stop! that is close enough. how body postures influence human-robot proximity. In: 25th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN), pp. 354–361, August 2016
10. Rossi, S., Ercolano, G., Staffa, M.: Towards an adaptive user monitoring based on personality and activity recognition. In: Proceedings of the Companion of the 2017 ACM/IEEE International Conference on Human-Robot Interaction, HRI 2017, NY, USA, pp. 269–270. ACM, New York (2017)

11. Rossi, S., Ferland, F., Tapus, A.: User profiling and behavioral adaptation for HRI: a survey. Pattern Recogn. Lett. (2017). doi:10.1016/j.patrec.2017.06.002
12. Sidobre, D., Broqure, X., Mainprice, J., Burattini, E., Finzi, A., Rossi, S., Staffa, M.: Human-robot interaction. In: Siciliano, B. (ed.) Advanced Bimanual Manipulation. STAR, vol. 80, pp. 123–172. Springer, Heidelberg (2012). doi:10.1007/978-3-642-29041-1_3
13. Syrdal, D.S., Dautenhahn, K., Woods, S., Walters, M.L., Koay, K.L.: 'Doing the right thing wrong' - personality and tolerance to uncomfortable robot approaches. In: The 15th IEEE International Symposium on Robot and Human Interactive Communication (ROMAN), pp. 183–188 (2006)
14. Syrdal, D.S., Koay, K.L., Walters, M.L., Dautenhahn, K.: A personalized robot companion - the role of individual differences on spatial preferences in HRI scenarios. In: The 16th IEEE International Symposium on Robot and Human interactive Communication (RO-MAN), pp. 1143–1148 (2007)
15. Takayama, L., Pantofaru, C.: Influences on proxemic behaviors in human-robot interaction. In: 2009 IEEE/RSJ International Conference on Intelligent Robots and Systems, pp. 5495–5502, October 2009
16. Tapus, A., Tăpus, C., Matarić, M.J.: User-robot personality matching and assistive robot behavior adaptation for post-stroke rehabilitation therapy. Intel. Serv. Robot. **1**(2), 169–183 (2008)
17. Walters, M.L., Dautenhahn, K., te Boekhorst, R., Koay, K.L., Woods, S., Nehaniv, C., Lee, D., Werry, I.: The influence of subjects' personality traits on personal spatial zones in a human-robot interaction experiment. In: IEEE International Workshop on Robot and Human Interactive Communication, pp. 347–352, August 2005
18. Walters, M.L., Dautenhahn, K., Woods, S.N., Koay, K.L., Boekhorst, R.T., Lee, D.: Exploratory studies on social spaces between humans and a mechanical-looking robot. Connect. Sci. **18**(4), 429–439 (2006)