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Björn Petrak, Gundula Sopper, Katharina Weitz, Elisabeth André

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Do You Mind if I Pass Through? Studying the Appropriate Robot Behavior when Traversing two Conversing People in a Hallway Setting*

Björn Petrak[1], Gundula Sopper[1], Katharina Weitz[1], and Elisabeth André[1]

***Abstract*— Several works highlight how robots can navigate in a socially-aware manner by respecting and avoiding people's personal spaces. But how should the robot act when there is no way around a group of persons? In this work, we explore this question by comparing three different ways to cross two conversing people in a hallway environment. In an online study with 135 participants, users rated the robot's behavior on several items such as "social adequacy" or how "disturbing" it was. The three versions differ in the type of contact intention, i.e., no contact, nonverbal contact, and a combination of nonverbal and verbal contact. The results show that, on the one hand, users expect social behavior from the robot, so that they can anticipate its behavior, but on the other hand, they want it to be as little disruptive as possible.**

I. Introduction

In recent years, a lot has happened in the field of robotics and a future in which humans and robots live together no longer seems far away, but rather imminent. A lot of work in the field of human-robot interaction shows that we expect robots to follow certain social rules in order to be tolerated and accepted by people [1]. But while we humans grow up with social rules from an early age and learn these rules during the interaction with others, we need to program them into robots, or give the robots the opportunity to learn them, for example by using reinforcement learning [2].

Our social rules influence how we move through the world. They lead us to respect other people's personal spaces and, for example, do not walk between two people who are having a conversation. When we want that robots follow these social rules as well, we have to consider not only purely technical navigation and obstacle avoidance, but also socially-aware navigation. Various works have already investigated how robots can implement this navigation, for example to avoid people which are interacting with other people or objects [3] (a good overview of various works can be found here: [4]). But there may always be situations where avoidance is impossible and the robot will have to violate people's personal space if it is not supposed to stop.

In this work, we investigate how a robot should behave in such situations. As an example, we use a situation in a narrow corridor. Here, two people are standing facing each other and the only possible path for the robot is to pass through them. In an online study, participants were presented with three different videos in which a robot crosses two talking people in different ways (no interaction, nonverbal interaction, and nonverbal and verbal interaction) and were then asked to evaluate the robot's behavior. The robot we use in the videos is a social robot that is being created as part of a research project and is expected to perform appropriate verbal and nonverbal behavior in daily interactions. The robot is able to move autonomously and should therefore also follow spatial social rules and respect the personal space of others.

In the scope of our study, we aim to answer the following research questions:

- **Behavior of the robot:** What influence does the particular behavior of the robot have on the user's perception of the robot in terms of the following attributes: *social adequacy*, *comprehensibility*, *anticipation*, *disturbance*, *whether the behavior facilitates the interaction*, *likeability*, *uncanniness*
- **Impact of human attributes:** How is the perception of robot behavior related to user attributes (i.e., experience with robots, technical affinity, and age)?

II. Background and Related Work

A. Proxemics

Proxemics is a term coined by E. Hall and is used to describe the use of space as a form of nonverbal communication [5]. In his work, Hall describes his observations of how people and animals use space as a form of communication in various situations. As part of these observations, he also reports four different zones around people in which certain social interactions between people typically take place. The four zones are the intimate zone *(0 - 46,cm)*, personal zone *(46 - 122 cm)*, social zone *(122 - 366 cm)*, and public zone *(> 366 cm)*, although the exact values may also vary between different cultures. The names of the zones also describe what interaction typically takes place inside it. For example, a conversation with a stranger would usually take place inside the social zone, while an intrusion of that stranger into the personal zone or even the intimate zone would probably lead to some irritation. Several works highlight that proxemic interactions also play an important role in human-robot interaction (e.g., [6]) and demonstrated that the zones defined by Hall also hold true [7], [8]. Many other works investigate which characteristics of humans and robots influence these distances. Of particular interest for this work are the influence of prior experience with robots [9], as well as the influence of the robot's gaze direction [10]. The aforementioned work addresses proxemics in a direct interaction with the robot, however proxemics also plays a role in how we move around others and respect each other's

*This research has been partially funded by the German Federal Ministry of Education and Research (BMBF) in the project "VIVA" (FKZ 16SV7960)
[1]Human-Centered Artificial Intelligence, Augsburg University, Germany
firstname.lastname@uni-a.de

personal spaces. In the next section, we cover this part of proxemics, which is called socially-aware navigation.

B. Socially-Aware Navigation

There are loads of works dealing with how a robot can navigate in such a way that it respects the personal spaces of people. There are many different approaches to how this can be achieved, most of which are based on Hall's theories. These involves defining zones around people that the robot should avoid. For groups, for example, density functions can be used to compute a zone for the whole group [11] based on the zones of each individual. Other works attempt to learn path planning based on examples of human behavior (e.g., [12]) or let the robot learn the navigation on its own using reinforcement learning [13]. There are also works that make the navigation more dynamic, depending on properties of the people who are navigating around. For example, in the work of Narayanan et al. [14] a person's emotion is detected and taken into account for path planning.

However, there is a gap in the research that we want to fill with this work. Most of the research on socially-aware navigation only focuses on cases when the robot respects the personal space of humans and therefore avoids it. However, as argued in the beginning, it may happen that the robot has to enter this space in order to be able to continue its path, especially in narrow environments such as hallways. There is another work that examines how a robot can best approach a group of people. For example, studies include which direction is best for the robot to approach [15]. There are also concepts that use machine learning to generate an appropriate path for approaching a group [16], [17]. However, this usually considers how the robot can join the group interaction rather than avoiding the interaction if possible. In a work by Pacchierotti et. al [18], the distance a robot should keep when avoiding a person was investigated in a narrow hallway setting. Here, however, only one person was considered and there was enough space for the robot to dodge. The results showed that most of the participants felt more comfortable with a larger lateral distance to the robot. This demonstrates that the question we are addressing is relevant when the large distance cannot be maintained. Nevertheless, to the best of our knowledge, there is no work that addresses the topic of how robots should behave when they need to invade people's personal space in order to continue on their path.

III. Preliminary Study

A. Procedure

To decide which behavioral variants the robot would perform in the main study, we conducted a preliminary study. We investigated how humans would behave in a narrow situation in order to get past two people talking to each other. We were particularly interested in whether and how people would make contact and how the walking person would then pass the talking people. To do this, we created three videos showing three different scenarios. Each shows a first-person perspective of approaching two people in a narrow hallway who are having a conversation and end shortly before the people are reached. The videos differ in how the two people are positioned in the hallway, but they always face each other and talk to each other. In the first video, the two people are each standing on one side of the hallway so that there is space between them. In video two, they stand in the middle of the hallway so that there is not enough space between the people to walk between them. In video three, they stand on one side of the hallway so that there is room on the other side, but not between the people. By varying the positions of the people, we wanted to find out to what extent this had an impact on the behavior of the person walking and their expectations for the behavior of the people standing.

B. Evaluation Methods

In the study, which was conducted as an online survey, participants were presented all the videos in random order and asked questions after each video to which they could respond textually. First, we let the participants describe how they would act in the situation. We then asked more specific questions, namely whether they would make contact and whether they would do so verbally or non-verbally. If they made contact verbally, we additionally asked what they would say. Furthermore, we asked if they would wait for a reaction from the other persons and how their reaction should look like. Finally, we asked to what extent they would adjust their speed when passing.

C. Results

For the sake of clarity, we report only those results that informed the design of the main study. 14 people participated in this preliminary study. 9 of them were male and 5 female between 15 and 56 years old *($M = 24.38$, $SD = 13.39$)*. For the setting in the first video (people standing on the sides of the hallway with space to walk through between them only), participants described very different approaches to how they would act in this situation. Some described that they would simply walk between the persons without making contact in order to disturb the conversation as little as possible. Some also described that they would make contact non-verbally or verbally and reduce speed until they received a signal from the individuals. All who would verbally initiate contact wrote that they would either just say "Excuse me" or "Excuse me, may I get through". Most indicated that they would increase their speed as they walked between the persons. Compared to the other videos, participants indicated an expectation for people to move out of the way (video 2 in which they stand in the way) or simply walk past people on the empty side (video 3 in which they stand on one side).

IV. Main Study

A. Setup

For the main study, we have again created three different videos, all showing the same setting. In the setting, two people are standing in a corridor, each on one side with their backs to the wall, and the robot VIVA can only pass between them. The corridor is about 2 m wide and there is about 1.15 m of space between the persons such that if the robot passes centrally between the persons, it will enter the personal space of both persons (see Fig. 1).

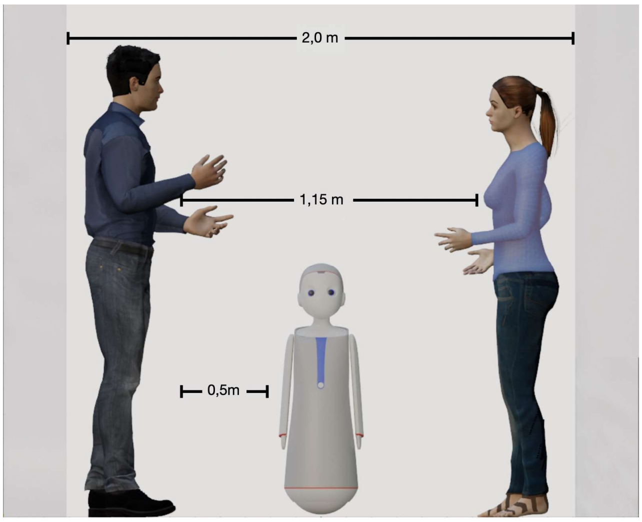

Fig. 1. Overview of the distances in the hallway setting in the videos.

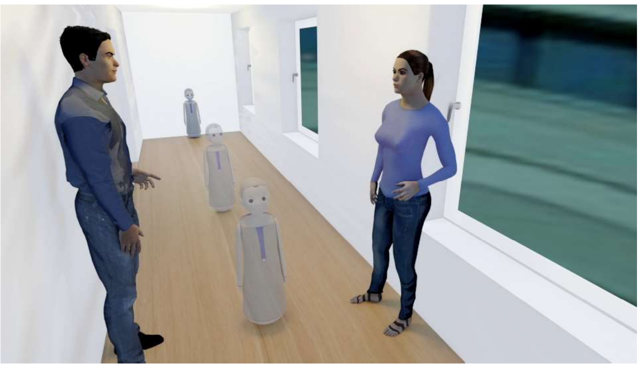

Fig. 2. The image shows the perspective in the videos. The transparent robots show the path that the robot takes between the persons.

The videos differ in what behavior the robot shows to pass between the people. The behaviors are informed by the results of the preliminary study. Here, video a) acts as a baseline, in which the robot simply passes between the people without making contact. In video b) the robot makes contact non-verbally and in video c) it makes contact verbally and waits for a reaction from the persons. The exact behavior sequence of the three variants can be found in Fig. 3. Fig. 2 further shows the camera perspective of the videos and the different stages of the robot's path.

The videos were created and animated the software Blender[1]. The people in the videos were modeled using Make Human[2] software. To reduce gender effects, one person is presented as a man and one as a woman. In this way, most participants would associate themselves with one of the two. The woman is modeled after one of the authors - Gundula Sopper, while the man is a generic male. The size of the persons was chosen according to the average sizes of the respective gender in Germany (163.5 m for women, 177.0 m for men) [19]. A 3D model of the VIVA prototype was used to represent the robot in the videos. The robot is approx. 1 m high.

[1]https://www.blender.org/
[2]http://www.makehumancommunity.org/

B. Evaluation Methods

To answer our research questions, we measured the following variables using different items in our online questionnaire. Unless otherwise specified, all items were assessed on a scale from 1 (not at all) to 7 (very).

Nonverbal and Verbal Behavior: For the following five items, participants were told to base their ratings solely on nonverbal behavior. Subsequently, the five items were asked again for the verbal behavior (or absence of verbal behavior). In other words, participants rated social adequacy, for example, for nonverbal and verbal behavior separately. For each item, participants also had the option of providing textual explanations for their rating. The items were asked after each video.

Social Adequacy: We measured the perceived social adequacy of the robot's behavior using one self-generated item: "How socially appropriate do you find VIVA's behavior in the situation shown in the video?"

Comprehensibility: The question about comprehensibility is modeled after the aspect "Perceived Ease of Use" of the Technology Acceptance Model (TAM) [20]. The question was: "How comprehensible do you find VIVA's behavior in the situation shown in the video?".

Anticipation: The question "How anticipatable do you find VIVA's behavior in the situation shown in the video?" adresses the perceived anthropomorphism of the robot and is modelled after [21].

Disturbance: We measured the disturbance of the robot's behavior using one self-generated item: "How much do you feel disturbed by VIVA's behavior in the situation shown in the video?"

Facilitation: To measure the degree to which the behavior facilitates interaction, we adapted another question from TAM [20]: 'How much does VIVA's behavior in the situation shown in the video facilitate your social interactions with her?"

Likeability: To measure the likeability we used the items of Salem et. al. [22] and Rau et. al [23]: endearing, friendly, likeable, warm-hearted, and approachable. Asked after each video.

Uncanniness: To measure participants' impression of the robot's uncanniness, we used items from [24] asking participants to rate the degree to which they felt uncomfortable, frightened, and insecure. Asked after each video.

Technical Affinity: As the attitude towards the robot plays an important role in reacting to it and accepting different behavior we asked about the general attitude towards technology at the end of the survey. For this we used the *Kurzskala zur Erfassung von Technikbereitschaft* that tests

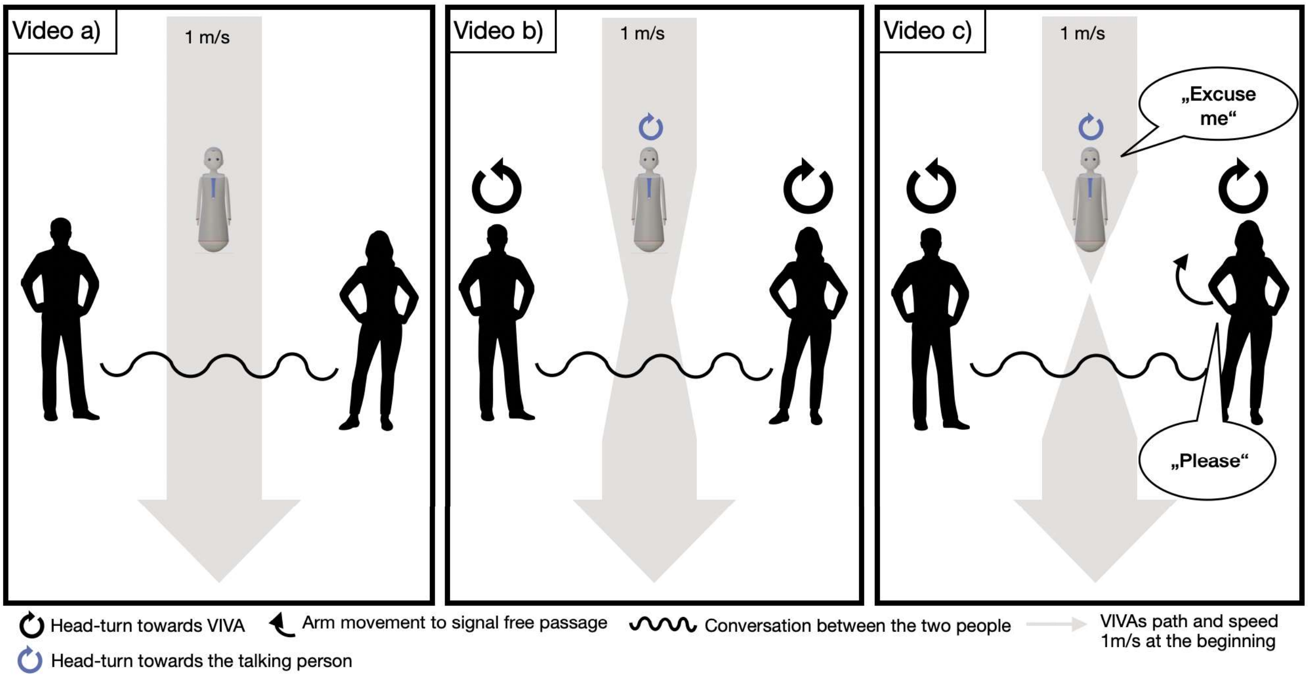

Fig. 3. Overview of the three different forms of interaction used during the online study.

on technology acceptance, technology competence and technology control [25]. The questions we used were: "Modern technology pleases me fast", "Modern technology makes me curious", "I am afraid to not use new technology properly and rather destroy it.", "I find the handling of modern technology difficult", "I like to use the newest technological devices", "When handling modern technology I am afraid to fail.", "I am often overwhelmed when using of new technology", and "If I could, I would use modern technology more often than I do now."

Other: At the end of the survey we further asked whether they ever had contact with a robot before [26]. Finally, we asked about age, gender and the highest level of formal education.

C. Procedure

After providing informed consent, participants were instructed to evaluate the social robots behavior in the videos. We used a within-subject design, so that each participant saw all three videos in random order. Participants watched the human-robot interaction videos and evaluated verbal and nonverbal social adequacy, comprehensibility, anticipation, disturbance, facilitation, and the robots perceived likeability and perceived uncanniness concerning the interaction each time. After evaluating all three scenarios, we asked for their technical affinity, previous robot contact and demographics.

D. Participants

Participants were recruited through personal connection and social media. 135 participants from Germany between 15 and 90 years (M = 32.17, SD = 17.38)took part in the study. 45 of the participants stated that they had already interacted with a robot before, 90 participants did not. 61 of the participants had an academic background, 57 finished high school, 5 participants were still in school, 10 participants had vocational training, and 2 participants did not provide information about their educational background. Participants averaged a score of M = 4.10 (SD = 1.20) on technology affinity (items ranged from 1 to 7).

V. Results

Overall, we found that 18 participants (13.3%) stated that they liked the robot's behavior in video a) most, 54 participants (40%) liked the robot's behavior in video b) most, and 63 participants (46.7%) said that they liked the robot's behavior in video c) most. In a next step, we investigated what influence the robot behavior in the three presented videos had on participants rating of the robot.

A. Impact of the Robot's Behavior User's Perception

To determine the direction of the differences between the three robot videos (a = no interaction, b = nonverbal interaction, c = verbal interaction, see Fig. 3 for details) regarding social adequacy, comprehensibility, anticipation, disturbance, facilitation, likeability, and uncanniness, we used paired t-tests. In Fig. 4 is an overview of the participants' ratings on the measured constructs. Detailed results of the statistics can be found in Table I. To calculate effect-sizes for significant results, we report Cohens' d[3].

When looking at the results, it is immediately noticeable that in most of the categories, video c) was rated best. Regarding the scales social adequacy, comprehensibility, facilitation of interaction, as well as likeability, the ratings

[3]For the interpretation, we use the recommendations from [27]: .10 for small, .20 for medium, and .30 for large effects

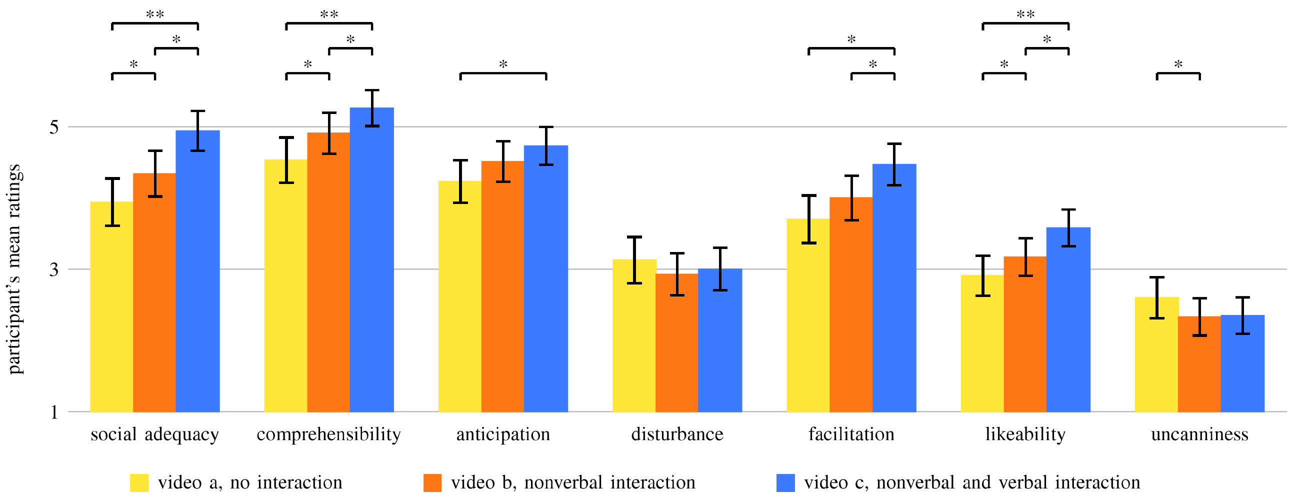

Fig. 4. Overview of mean values for each condition and dependent variable asked during the online survey. Error bars denote 95% confidence intervals. Scale ranges from 1 to 7. Higher rating is better, except for uncanniness. $^{**}p < .001$, $^{*}p < .05$.

are significantly higher than video a) as well as video b). For anticipation, the ratings of video c) are only significantly higher than video a). For disturbance, there are no significant differences between the robot behaviors. For uncanniness (lower is better), only video a) is rated significantly higher than video b), while there are no significant differences between a) and b) and b) and c). Video b) is also rated significantly higher than video a in the scales social adequacy, comprehensibility, and likeability.

B. *Impact of Human Attributes*

To investigate the significant variables of the paired t-tests, we calculated Pearson product-moment correlation coefficients. We examined the dependent variables *social adequacy*, *comprehensibility*, *facilitation*, and *likeability*. These variables were tested with: *age*, *technical affinity*, and *previous experience with robots*.

Social Adequacy: We found a significant negative correlation between age and the social acceptability of video b), $r_p = -.18$, $p = .042$. The older the subjects were, the less socially acceptable they considered the robot to be. No further significant correlations were found for other videos and dependent variables.

Comprehensibility: We found a significant negative correlation for the participants technical affinity and their comprehensibility rating in video c). People with higher scores in technical affinity rate the robot's actions as less comprehensible ($r_p = .20$, $p = .022$). No further significant correlations were found for other videos and dependent variables.

Facilitation and Likeability: We found no significant correlations regarding the likeability and facilitation of the videos b) and c) with technical affinity, age, or previous experiences with robots.

C. *Qualitative Data*

When completing the questionnaire, participants had the opportunity to comment on their rating for each of the scales. Here they could state why they gave this particular rating or what would improve the rating. This provided interesting insights into the thoughts of the participants and added further evidence.

For example, when rating the robot's disturbance in the situations at video c), participants commented that they did not like that VIVA interrupted their conversation. On the other hand, some also felt that they were disturbed by VIVA simply passing by without communicating like the robot's behavior in video a). One participant expressed that the robot should wait until the conversation was over before passing, since a robot is never in a hurry. Some also said that a robot should only contact humans when it needs something specific. However, some also wrote, especially on video a), that the robot could have greeted. Many comments also referred to the size of the robot, in particular that the robot was not disturbing because it was so small, but that this also made it easy to overlook. It was also frequently mentioned that collision could occur if it was not clear that VIVA would choose the path between people or, also due to its size, would not be noticed. Many participants expressed these concerns for video a), few for video b), and for video c) it was mainly mentioned that here, compared to the other videos, a collision was highly unlikely because the robot waits until it gets a signal.

Several comments highlighted how the behavior could be improved, for example, by having VIVA look at the person talking and wait for their verbal response. In contrast, some suggested that VIVA should also be able to read nonverbal responses and also be more gestural or show friendlier facial expressions. Some also mentioned that this extended interaction could make it easier to anticipate that the robot wants to cross the people, making it easier to avoid a collision. A few comments also indicated that there were sometimes problems in understanding the videos. However, overall, the number of problems described is very low.

TABLE I

RESULTS OF THE PAIRED T-TESTS TO COMPARE THE THREE DIFFERENT ROBOT BEHAVIORS IN THE VIDEOS (CONDITIONS). COHENS D EFFECT SIZES ARE REPORTED ONLY FOR SIGNIFICANT RESULTS.

Scale	Condition	$t(134)$	p	Cohens d
social adequacy	a) vs. b)	-2.08	.039*	$.18^s$
	b) vs. c)	-3.16	.002*	$.27^m$
	c) vs. a)	4.49	< .001**	$.39^l$
comprehensibility	a) vs. b)	-2.07	.04*	$.18^s$
	b) vs. c)	-2.12	.036*	$.18^s$
	c) vs. a)	3.62	< .001**	$.31^l$
anticipation	a) vs. b)	-1.54	.126	–
	b) vs. c)	-1.25	.212	–
	c) vs. a)	2.51	.013*	$.22^m$
disturbance	a) vs. b)	-1.08	.283	–
	b) vs. c)	-0.39	.695	–
	c) vs. a)	-0.70	.488	–
facilitation	a) vs. b)	1.45	.149	–
	b) vs. c)	-2.49	.014*	$.21^m$
	c) vs. a)	3.29	.001*	$.28^m$
likeability	a) vs. b)	-2.22	.028*	$.19^s$
	b) vs. c)	-2.84	.005*	$.24^m$
	c) vs. a)	4.40	< .001**	$.38^l$
uncanniness	a) vs. b)	-2.27	.025*	$.19^s$
	b) vs. c)	-0.25	.804	–
	c) vs. a)	-1.97	.051	–

$^{**}p < .001$, $^{*}p < .05$, ^{s} small effect, ^{m} medium effect, ^{l} large effect

VI. DISCUSSION

The results show that video c) (nonverbal and verbal interaction) was rated significantly better than video a) (no interaction) on most scales and than video b) (nonverbal interaction) in some. In addition, the explicit question about which of the behaviors is preferred showed that most people chose video c) here as well. So is the robot behavior in video c) (i.e., stopping and waiting until one gets permission to pass) the best way for a social robot to cross two conversing people? While it seems so at first, a closer look at the ratings and comments gives some evidence that this is not necessarily the case. First of all, it is very interesting that when asked about the preferred behavior, while most selected video c), a large proportion of participants also preferred video b) (63 vs 54), whereas video a) barely was selected. Thus, the difference here is not as large as the significantly different scores on the different scales might suggest. Looking at the comments written by the participants, there are several clues what could be possible causes for this discrepancy.

One thing that is often mentioned in the comments is the risk of collision with the robot if the robot's behavior is not predictable. In the case of the behavior in video c), according to the comments, this collision is prevented because the robot only continues after it has received the permission of the people, i.e., the robot has also been noticed and the people are thus prepared for the crossing. Lower ratings for comprehensibility, anticipation, and facilitation of interaction on the other videos also suggest that the risk of collision is higher in that case, which is also underlined by further comments of the participants. The need for safety seems to play a large role and presumably also leads to the higher ratings for video c). In contrast to the need for safety, is the need to be disturbed as little as possible. While the quantitative data showed no significant differences between the three videos, the qualitative data shows a somewhat different picture. Here, especially variant c) is perceived as disturbing, since the robot interrupts the conversation with its behavior, while in variants a) and b) it hardly disturbs at all and is mainly perceived as disturbing by people who generally find a crossing disturbing. These contrasting needs probably lead to the discrepancy described earlier. In the qualitative data between the videos no significant differences could be found in how much the robot disturbs, whereas in the comments definitely version c) is perceived as very disturbing compared to the other two alternatives.

The perception of many participants that a collision could occur could be due to the fact that none of them have yet experienced an interaction with the VIVA robot and most even not with robots in general. Thus, if humans interact with robots more frequently, the problem could resolve itself if the robot's behavior always is the same and therefore is then easily predictable, as some comments also indicated. Results from Walters et al. support these, showing that more experience with robots resulted in people allowing a lower distance to the robot [9]. Furthermore, the statistical correlations showed that people with higher technical affinity found the behavior of the robot in video c) less comprehensible. These findings are in line with the work of Pacchierotti et al., where people with higher technical affinity found a too wide evasion as exaggerated [18]. The robot's stopping may also have been perceived as exaggerated and thus not comprehensible. This also suggests that more experience with robots could lead to further tendencies toward the behavior in video b). However, minor adjustments in the behavior of video b) or c), or a robot behavior that combines parts of both behaviors, could also lead to a better result. Also, as noted by some participants, enhanced facial expressions and gestures could make the behavior easier to anticipate and thus also reduce the fear of collisions. Which behavior will help specifically needs to be explored in further studies.

A. Limitations and Future Work

Since the study was conducted online, the participants had to put themselves in the situation. Since most of them had never had contact with a robot before, this might have been difficult for some participants. As also pointed out by some of the comments, the size of the robot plays a role in the evaluation, so the results should not be generalized to all robots with different sizes. We also designed the variants of the behaviors based on the results of the preliminary study and the capabilities of the robot prototype VIVA. Therefore, the behaviors are limited to nonverbal communication via orientation, gaze direction, and speed. However, extended facial expressions and gestures could have a further influence on the evaluations of the behaviors.

Future work should take the findings of this work and focus on a variation between the versions in video b) and video c). In particular, an adaptation of the experiment with a real-world setting should be attempted. One possible research question here is how the robot's behavior can be further adapted so that people can clearly anticipate its behavior without the robot disturbing too much and interrupting people's conversation. For example, extended facial expressions and gestures may be utilized for this purpose. In addition, variables that have an impact on the behavior that the robot should show ideally can be investigated. For example, the size, voice, or appearance of the robot.

VII. Conclusion

In this paper, we reported on a study in which we compared three different ways by which a robot traverses two people in conversation in a hallway in an online survey. In doing so, we address a gap in social navigation research, in which mostly only avoidance is an option for the robot. However, situations may arise in which the robot cannot find an alternative path and thus has to traverse, for example, two people. We investigated how three different behaviors affected various constructs such as social adequacy, how much the behavior disturbs, or the robot's likeability. The results show that it is important to the participants that the behavior is as little disruptive as possible, but that the robot's behavior must be anticipatable for the people so that the people are not concerned about a collision. Nonverbal cues play an important role here, as they are less likely to interrupt the subjects' conversation. None of our three variants presented in the videos emerged as a clear favorite, so further studies should be conducted to gain additional insights into how the behavior can be improved in order to satisfy the desired criteria.

References

[1] J. Zlotowski, A. Weiss, and M. Tscheligi, "Navigating in Public Space: Participants' Evaluation of a Robot's Approach Behavior," in *ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, 2012.

[2] H. Ritschel, A. Seiderer, K. Janowski, S. Wagner, and E. André, "Adaptive linguistic style for an assistive robotic health companion based on explicit human feedback," in *Proceedings of the 12th ACM international conference on PErvasive technologies related to assistive environments*, 2019, pp. 247–255.

[3] J. Rios-Martinez, A. Spalanzani, and C. Laugier, "Understanding human interaction for probabilistic autonomous navigation using risk-RRT approach," *IEEE International Conference on Intelligent Robots and Systems*, pp. 2014–2019, 2011.

[4] ——, "From proxemics theory to socially-aware navigation: A survey," *International Journal of Social Robotics*, vol. 7, no. 2, pp. 137–153, 2015.

[5] E. Hall, *The Hidden Dimension*. New York: Anchor Books, 1982.

[6] B. Petrak, K. Weitz, I. Aslan, and E. Andre, "Let Me Show You Your New Home: Studying the Effect of Proxemic-awareness of Robots on Users' First Impressions," in *2019 28th IEEE International Conference on Robot and Human Interactive Communication, RO-MAN 2019*, 2019.

[7] M. L. Walters, M. A. Oskoei, D. S. Syrdal, and K. Dautenhahn, "A long-term Human-Robot Proxemic study," in *Proceedings - IEEE International Workshop on Robot and Human Interactive Communication*, 2011.

[8] D. S. Syrdal, K. L. Koay, M. L. Walters, and K. Dautenhahn, "A personalized robot companion? - The role of individual differences on spatial preferences in HRI scenarios," in *Proceedings - IEEE International Workshop on Robot and Human Interactive Communication*, 2007, pp. 1143–1148.

[9] M. L. Walters, D. S. Syrdal, K. L. Koay, K. Dautenhahn, and R. Te Boekhorst, "Human approach distances to a mechanical-looking robot with different robot voice styles," in *Proceedings of the 17th IEEE International Symposium on Robot and Human Interactive Communication, RO-MAN*, 2008, pp. 707–712.

[10] L. Takayama and C. Pantofaru, "Influences on proxemic behaviors in human-robot interaction," in *2009 IEEE/RSJ International Conference on Intelligent Robots and Systems, IROS 2009*, 2009, pp. 5495–5502.

[11] A. Vega-Magro, L. Manso, P. Bustos, P. Núñez, and D. G. Macharet, "Socially acceptable robot navigation over groups of people," in *2017 26th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*. IEEE, 2017, pp. 1182–1187.

[12] M. Luber, L. Spinello, J. Silva, and K. O. Arras, "Socially-aware robot navigation: A learning approach," in *2012 IEEE/RSJ International Conference on Intelligent Robots and Systems*. IEEE, 2012, pp. 902–907.

[13] T. X. Tung and T. D. Ngo, "Socially aware robot navigation using deep reinforcement learning," in *2018 IEEE Canadian Conference on Electrical & Computer Engineering (CCECE)*. IEEE, 2018, pp. 1–5.

[14] V. Narayanan, B. M. Manoghar, V. S. Dorbala, D. Manocha, and A. Bera, "Proxemo: Gait-based emotion learning and multi-view proxemic fusion for socially-aware robot navigation," *arXiv preprint arXiv:2003.01062*, 2020.

[15] D. Karreman, L. Utama, M. Joosse, M. Lohse, B. van Dijk, and V. Evers, "Robot etiquette: How to approach a pair of people?" in *Proceedings of the 2014 ACM/IEEE international conference on Human-robot interaction*, 2014, pp. 196–197.

[16] Y. Gao, F. Yang, M. Frisk, D. Hemandez, C. Peters, and G. Castellano, "Learning socially appropriate robot approaching behavior toward groups using deep reinforcement learning," in *2019 28th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*. IEEE, 2019, pp. 1–8.

[17] F. Yang and C. Peters, "Appgan: Generative adversarial networks for generating robot approach behaviors into small groups of people," in *2019 28th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*. IEEE, 2019, pp. 1–8.

[18] E. Pacchierotti, H. I. Christensen, and P. Jensfelt, "Evaluation of passing distance for social robots," *Proceedings - IEEE International Workshop on Robot and Human Interactive Communication*, pp. 315–320, 2006.

[19] G. Mensink, A. Schienkiewitz, M. Haftenberger, T. Lampert, T. Ziese, and C. Scheidt-Nave, "Uebergewicht und adipositas in deutschland," *Bundesgesundheitsblatt - Gesundheitsforschung - Gesundheitsschutz*, vol. 5/6, pp. 786–794, 2013.

[20] M. Qingxiong and L. Liping, "The technology acceptance model," *Journal of Organizational and End User Computing*, vol. 16, no. 1, pp. 59–72, Jan-Mar 2004. [Online]. Available: https://doi.org/10.4018/9781591404743.ch006.ch000

[21] J. Heafner and N. Epley, "The mind in the machine: Anthropomorphism increases trust in an autonomous vehicle," *Journal of Experimental Social Psychology*, vol. 52, pp. 113–117, May 2014.

[22] M. Salem, F. Eyssel, K. Rohlfing, S. Kopp, and F. Joublin, "To err is human(-like): Effects of robot gesture on perceived anthropomorphism and likability," *International Journal of Social Robotics*, vol. 5, pp. 313–323, 08 2013.

[23] P. Rau, Y. Li, and D. Li, "Effects of communication style and culture on ability to accept recommendations from robots," *Computers in Human Behavior*, vol. 25, pp. 587–595, 2009.

[24] J. Bernotat and F. Eyssel, "An evaluation study of robot designs for smart environments," in *Proceedings of the Companion of the 2017 ACM/IEEE International Conference on Human-Robot Interaction*, ser. HRI '17. New York, NY, USA: Association for Computing Machinery, 2017, pp. 87–88. [Online]. Available: https://doi.org/10.1145/3029798.3038429

[25] F. Neyer, J. Felber, and C. Gebhardt, "Entwicklung und validierung einer kurzskala zur erfassung von technikbereitschaft," *Diagnostica*, vol. 58, no. 2, pp. 87–99, April 2012.

[26] N. Reich-Stiebert and F. Eyssel, "Learning with educational companion robots? toward attitudes on education robots, predictors of attitudes, and application potentials for education robots," *Int J of Soc Robotics*, vol. 7, pp. 875–888, June 2015.

[27] G. E. Gignac and E. T. Szodorai, "Effect size guidelines for individual differences researchers," *Personality and individual differences*, vol. 102, pp. 74–78, 2016.