Exploring the Perceptions and Challenges of Social Robot Navigation: Two Case Studies in Different Socio-Technical Contexts

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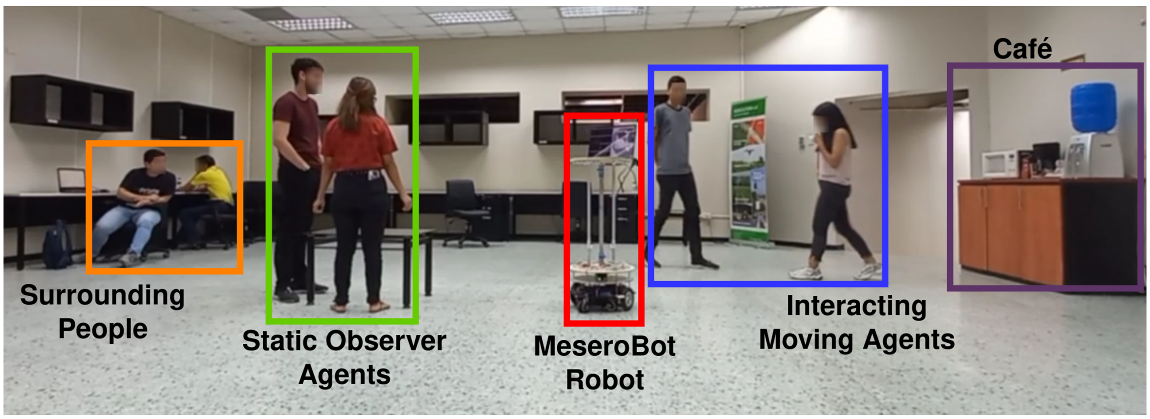

Fig. 1. Experiment with the MeseroBot robot at the office scenario in ESPOL University, Guayaquil, Ecuador.

Service robot applications such as waitering, require robots to move in social spaces while preserving people's comfort, known as social robot navigation (SRN). Prior work has proposed and evaluated several SRN methods mostly using quantitative measures, focusing only on one type of scenario, using one robot, or taking place in one socio-technical context. Yet it is still unclear what makes a moving service robot acceptable in a social environment. In this work, we present two case studies conducting real-life experiments and qualitatively evaluating an SRN approach in two different socio-technical contexts (Ecuador and the UK) with two different robots. Our findings highlight participant's perceptions, experiences and emotional responses towards the acceptance of the navigating robot's capabilities and appearance in indoor social spaces. We discuss how socio-technical factors such as robot's speed and appearance along with the settings spatial constraints, can influence the acceptance and experience of SRN.

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1 Introduction

In social spaces (i.e., spaces shared with people) such as shopping malls, restaurants, hospitals, and museums, service robots are being designed and developed to support leisure and work activities for various purposes [37], for example as a waiter to assist customers [20] or as a museum tour guide [84]. For a service robot to fit and perform well in social spaces, it is important to preserve human physical safety and display socially acceptable behaviours to avoid making people feel uncomfortable [61]. One particular aspect that affects robot acceptance is how service robots move around people [69, 94] and how well they adapt to human behaviours and practices, which may vary depending on the socio-technical context of the experiments [52, 55, 90]. Recent work has highlighted the importance of understanding the socio-technical perspectives of human-robot interactions [9, 12, 72], that influence people's perceptions and acceptance towards robots [55, 57, 82, 92], which are "highly context dependent" [10].

The problem of endowing robots with the capability of moving autonomously around people in a socially acceptable manner is commonly referred to as Social Robot Navigation (SRN) [61, 87]. Several methods have been proposed for SRN [31, 40, 86], mostly quantitatively benchmarked in simulation or evaluated by carrying out real-life experiments that do not resemble realistic scenarios. In particular, Silva et al. [86, 87] proposed SRN frameworks which enable a robot to move in a socially acceptable manner by aiming to preserve nearby people's comfort. One of their frameworks [87] not only outperformed other state-of-the-art approaches for SRN [19, 42, 91] in an extensive quantitative benchmark, but also proved to be feasible in real-word trials. However, they did not include any qualitative analysis to demonstrate people's acceptance to their SRN approach [87]. While previous research has shown positive results regarding the acceptance of the robot appearance and tested SRN methods in real-life experiments [48, 62], many of them focus on one specific scenario, one particular type of robot or take place in a single socio-technical setting (e.g., mostly in developed countries). Therefore, it is necessary to deploy and test SRN methods in more than one robot and in more than one socio-technical setting to be able to adjust to the dynamic changes of real-life environments and match human expectations and routines [90]. In this study we focus on the following research question: *"How is the social acceptance of SRN affected by different socio-technical factors and contexts?"*

Considering that service robots are increasingly being utilised in several service research areas and applications around the world [5, 14, 43, 77], we present two case studies with adults in the UK and Ecuador investigating the user acceptance and experience with the deployment of the SRN approach proposed by [87]. Accounting for the current access and implementation of robotic systems in each study setting, we defined two distinct indoor scenarios (office and hallways) and made use of two local robots to further explore how the socio-technical settings and robot's capabilities influence people's perceptions, and acceptability of robots using the SRN approach in real-life experiments. Our findings uncover how the physical and socio-technical factors influenced the perception of robots' navigation capabilities and the experiences and acceptance of the implemented SRN approach in each study setting. Based on the findings, we discuss how the robot's capabilities in each socio-technical context can hinder or facilitate the social acceptance of SRN and present design considerations (e.g., increasing the robot's speed in Ecuador and moving the robot further away from people in the UK) to enhance the user experience in SRN contexts.

2 Related Work

2.1 Evaluation of SRN Approaches

There are different ways to evaluate SRN approaches, these can be quantitative (e.g., using success rate metrics [37] or distance between the robot and participants [91]) and qualitative, either in simulation or real-life experiments. However, there is limited work qualitatively evaluating SRN approaches.

Bruckschen et al. [15] modified their previous robot navigation approach to include a cost function, which prioritises navigation paths based on robot's social distance compliance, visibility, orientation change and path efficiency [16]. Their modified robot navigation approach was tested in a user study with participants by using virtual reality and a simulated environment. Their SRN approach was evaluated quantitatively by measuring proximity to the user and the visibility of the robot. A limitation of their work is the lack of experiments with a real robot failing to demonstrate how people perceive their approach in practice.

Shahrezaie et al. [83] carried out unstructured interviews to study human-robot interaction where participants were asked about their experiences regarding personal space, robot navigation and recovery behaviours with robots in a museum [83]. Based on the results from the interviews, the authors extended their previous Socially-Aware Navigation (SAN) approach [34] by including some social behaviours (e.g., engaging behaviour to initiate an interaction). Their enhanced SAN was tested in four different simulated scenarios in which the robot would show an engaging, conservative, reserved or stationary behaviour. Despite showing positive results about their enhanced SRN functionality, Shahrezaie et al. [83] did not test their approach in real-life settings.

Most SRN approaches like [16, 66, 83] are developed according to feedback obtained from interviews without involving a real-life SRN experience with robots. Other user studies such as the ones in [74], carry out evaluations using robot navigation simulations or recorded media that fall short in understanding people's perspectives and acceptance of SRN. While some authors have conducted real-life experiments [62], they often lack a comprehensive understanding of human-robot interactions through a qualitative analysis of participants' experiences and perceptions. In addition, Kayukawa et al. [48] investigated the acceptance of robot navigation for people with visual impairments in public buildings. The authors used interviews with facility managers and focus groups with legally blind participants and uncovered privacy and visibility concerns with robot appearance. Despite their work is remarkable for enhancing robot guidance for people with visual impairments (PVI), their study is focused on a very specific socio-technical context and revolves around the robot's instead of the surrounding people. Similarly, Mavrogiannis et al. [60] carried out several experiments in which social agents moved and interacted between surrounding easel pads while a telepresence robot moved between the easel pads. For these experiments, the telepresence robot moved using an approach called Social Momentum (SM). After each trial, their participants were asked to fill a Likert-scale questionnaire about their impressions of the interaction with the robot and one open question regarding the experience of moving and interacting around the robot. The information obtained from the only open question was thematically analysed to obtain insights about the robot's navigation, behaviour, appearance and expressed human emotions. However, they did not consider conducting an in-depth qualitative study which could have provided more in-depth insights on participant's perceptions, challenges and experiences. Although they had a high number of experiments (35), they focused on one scenario (factory setting), with one type of robot (telepresence robot) and in one socio-technical context in USA [60].

2.2 Socio-technical Considerations and Social Robot Acceptance

There is a need to further understand how social robots are introduced and integrated into the broader socio-technical context [72] to uncover the barriers and facilitators for their acceptance, and impact in the environments they are deployed [64, 89]. Here, one major consideration to take into account is proxemics, which refers to the spatial distance that each individual maintains in social and interpersonal situations [78]. Human proxemics towards robots have great influence on the social acceptance of the robot and the used SRN approach.

There are few studies understanding the effect of culture on human-robot proxemics, which indirectly affects SRN [28, 47, 85]. For example, Joosse et al. [47] conducted a robot proximity online survey that was distributed in three different cultural regions: China, Argentina, and the USA. The survey asked about the appropriate position of a robot in proximity when approaching a woman, a man, and a child that were having a conversation, their results showed how Chinese and Argentinian participants were more comfortable with a closer robot approach than USA participants.

Another important consideration is the robot's anthropomorphic appearance and how it influences robot acceptance especially by people with practical experience with similar technology [39]. Anthropomorphism is the tendency of attributing human characteristics, behaviours, and feelings to non-human entities such as robots [27]. There is a tendency to design robots with human-like features to enhance human-robot interaction [30]. Anthropomorphism also affects the user's trust in the robot and user's compliance towards robot's feedback. Natarajan and Gombolay [65] conducted a user study using four different robots with different levels of anthropomorphism to give feedback to participants, and found that the Pepper robot [88] (a human-like robot) would generate more trust than a robotic arm such as Sawyer robot [80]. Similar results were obtained by Chowdhury et al. [21], who conducted a user study in which participants programmed and moved a Franka Panda robot [79] and only 5 out of 22 participants showed compassion due to the robot's anthropomorphism. However, increased levels of human-likeness can also evoke strongly negative responses (e.g., revulsion) according to the "uncanny valley" theory by Mori [63]. In fact, the appearance of a robot is perceived differently according to the specific socio-technical context and application. For example, in search and rescue tasks, users prefer machine-like robots over human-like robots [8], and in hospitals, machine-like mobile robots are perceived in different ways (e.g., an alien, a worker, a machine, a work partner) by different staff groups [56].

Furthermore, user's beliefs, gendered assumptions, expectations and norms also influence the acceptance and potential use of social robots [23, 90, 92]. For example social norms for navigation such as passing on the right, keeping a safe velocity, not invading people's personal space are important to consider in SRN [45]. Mismatched human expectations of the robots (e.g., plug-and-play solution) [90] and the existing constraints of the physical environment (e.g., high traffic, narrow and/or cluttered hallways) can negatively influence people's perception of mobile robots [64]. Thus, it is important to take into account the physical, social and material arrangements of each setting as these are crucial in SRN to detect and correct potentially harmful outcomes (e.g., high intrusion in people's personal space) and mitigate unwanted bias and discrimination during navigation [12, 45]. However, there is limited research directly deploying and evaluating SRN methods in different socio-technical contexts to further understand the factors that can facilitate or hinder the implementation, use and acceptability of SRN.

3 Experimental Setup and Case Studies

To further understand the socio-technical factors that affect the acceptance of SRN to inform the design of socially acceptable robots and robot navigation systems, we carried out two case studies investigating people's perceptions and experiences using controlled in-the-wild (CITW) experiments [22] where the same SRN approach/algorithm was deployed in different robots at two different socio-technical contexts: one in Ecuador and one in the UK. An exploratory case study methodology [97] was chosen as it emphasises the qualitative understanding of people's perceptions, opinions, and experiences in real-life settings [71, 97] and it has been commonly used for evaluation in HCI research [49, 51, 68]. We were interested in understanding the relevant socio-technical factors that facilitate or hinder the introduction and acceptability of SRN in different social contexts by taking advantage of controlled in-the-wild methodologies as a first step towards the subsequent field evaluation of the robots in real life settings (in-the-wild studies) [22]. As robots are highly context dependent [10, 45], we will describe the details of each case study in the following sections, including the robots, participants, and methods used. In both cases, we used two different indoor scenarios in shared spaces (office, hallway) in which common interactions are likely to occur between static/moving humans and robots.

We recruited participants based on a convenience sampling strategy [3] by deliberately inviting participants around the local research settings who were willing to volunteer at the time of the experiments. These participants had no relationship with our project and were asked to share their experiences, opinions, preferences, and suggestions to improve the acceptance of the SRN approach used. Each complete trial of an experiment, i.e., including experiment explanation, robot moving around participants according to one scenario, and the follow-up interview or focus group, lasted around 30 minutes on average[1]. Table 1 shows a summary of the participants per experiment, scenario, and location. In some cases, more than one experiment was conducted with the same participants. For example, in the UK, we conducted three experiments (one for the office scenario and two for the hallway scenario) with five participants and conducted a single focus group. In such cases, the participants rotated between being an observer to interacting with the robot for each experiment. We obtained ethical approval from an ethics committee in the UK for conducting the experiments as there was no local ethics committee in place at the Ecuadorian institution. Participants received a participant information sheet with the explanation of the study and signed an informed consent. The study was conducted in English in the UK and in Spanish in Ecuador.

3.1 SRN Approach Selection and Implementation

Several SRN approaches have been proposed. To choose the most appropriate SRN approach for our user studies, we carried a simulation benchmarking in which we tested six different state-of-the-art approaches such as the Social Force Model (SFM) [42], Proactive Social Motion Model (PSMM) [91], socially aware collision avoidance with deep reinforcement learning (SA-CADRL) [19] and two from Silva et al., [86] and [87]. For reactive SRN approaches such as SFM and PSMM, we tuned their parameters heuristically by test and error. One hundred trials were run for each of the tested SRN approach. For each trial, one of four different simulation scenarios was randomly chosen in which the robot had to navigate from a random start position to a random goal position using that SRN approach.

To evaluate these SRN approaches, we used the most common SRN metrics such as the success rate of the robot to reach the destination, the amount of collisions with the surrounding obstacles and social agents, the appropriate distance between the robot and social agents, and the time required to arrive at the destination. As a result of this benchmarking, it was found that the most appropriate approach was the one proposed by Silva et al. [87][2]. It was the

[1]To get an overview of the simulation trials and the experiments, check the following video: https://youtu.be/dFreXVsIJmc.
[2]Source code of the implemented SRN framework is available at: https://github.com/CardiffUniversityComputationalRobotics/social-multi-fed-nav-stack

Table 1. An overview of participants. Female (f), male (m), E (Ecuador), U (UK), Office (O), Hallway (H), Interview (I), Focus Group (FG) (e.g., UOFG-5 = **U**K **O**ffice scenario **F**ocus **G**roup # **5**).

Location	Scenarios	Participants			Study method	# of experiments
		Observer	Interacting	Observer and Interacting		
ESPOL University Guayaquil Ecuador Case Study 1	Office	9 (7 m, 2 f)	12 (8 m, 4 f)	-	21 I (EO1-21)	6
	Hallway	5 (1 m, 4 f)	5 (2 m, 3 f)	-	10 I (EH1-10)	5
Cardiff University (CU) Cardiff UK Case Study 2	Office	-	10 (7 m, 3 f)	2 (2 male)	1 I (UOI-1) 5 FG (UOFG1-5)	7
	Hallway	-	2 (2 male)	4 (2 m, 2 f)	2 I (UHI1-2) 1 FG (UHFG-1)	4
	Both scenarios	-	-	5 (2 m, 3 f)	1 FG (UOHFG-1)	3 (1 office 2 hallway)

most balanced overall, while maintaining a low amount of collisions on the successful cases, and a low average time to arrive to the destination compared to the other SRN approaches such as PSMM and SA-CADRL that had issues (e.g., robot getting stuck) with surrounding objects and social agents.

A differential wheeled robot was used in each research setting: the *MeseroBot robot* (see Figure 2) in Ecuador, and the *TIAGo robot* [70] (see Figure 5) in the UK. Both robots were set up to detect people and move autonomously by using the selected SRN framework [87]. The framework, including sensors' drivers and interfaces, was implemented using Robot Operating System (ROS). To detect social agents in the real environment, laser sensors were used along with a people tracker [53]. To detect obstacles (e.g., desks and chairs), both robot used an RGB-D camera to build a 3D map using Octomap [44]. Practical constraints had to be considered as both robots did not have a CPU capable of running the whole semi-autonomous navigation system and sensors. We decided to adapt an external laptop to the robots to retrieve the pointcloud from the RGB-D camera and run the selected navigation framework.

3.2 Case Study 1: SRN in Ecuador

Case study 1 was conducted in collaboration with Ecuadorian researchers at ESPOL University in Guayaquil (Ecuador) who design and create their own social robots as that helps reducing development costs while adapting their hardware capabilities to support social interactions [33]. Something important to have in mind is that the access to social robots on the market in Ecuador is quite limited, as they are not affordable for companies or universities [33]. Additionally, the case study was conducted at ESPOL University in Guayaquil, Ecuador.

3.2.1 ***The MeseroBot robot****.* The MeseroBot is in the process of being deployed to support catering applications in environments such as restaurants and social events, where the robot must resemble and work as a mobile waiter. To do so, the MeseroBot has a tray on top to carry objects. To navigate and perceive the surroundings, the MeseroBot is equipped with a RPLIDAR-A1 laser range sensor (360 degree) and an Intel RealSense D435i RGB-D camera. At our

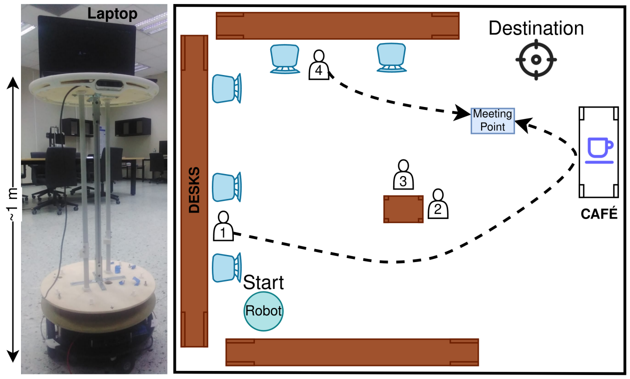

Fig. 2. MeseroBot robot and the office scenario for Case Study 1

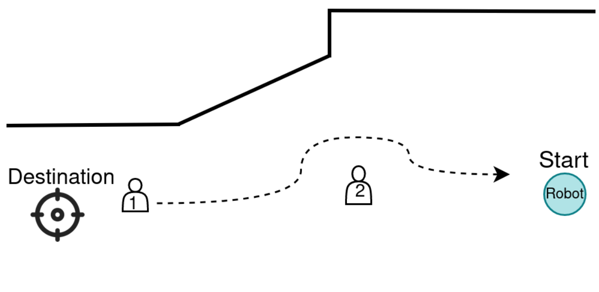

Fig. 3. Hallway scenario for Case Study 1

partner institution, researchers have been implementing the MeseroBot since 2020 and due to its sensor capabilities was able to deploy the selected SRN framework. The MeseroBot's measures are $1.0x0.45$ meter height and diameter.

3.2.2 ***Participants***. At ESPOL, we carried out 11 experiments using both scenarios (office and hallway), combined with 31 semi-structured interviews (25 students, 4 researchers, 2 visiting professionals) to capture their experiences, perceptions and suggestions after interacting with the navigating MeseroBot. Eighteen participants self-identified themselves as men and 13 as female, and 12 participants expressed to have no previous experience with robots. Experiments and interviews took place in a research centre at ESPOL between January and February 2023.

3.2.3 ***Office Scenario:*** This scenario includes a number of desks and chairs, along with four participants who are either making or getting a cup of coffee or chatting with other participants. For this scenario at ESPOL, we had a larger space in an office environment. While two participants (1 and 4) were asked to move as shown by the dashed arrows in Figure 2, the other two participants (2 and 3) were asked to act as if they were standing performing a more static activity, e.g., reading a paper. As illustrated by Figure 2, participant 1 would first pass in front of the robot and walk towards the café area to grab a cup, before meeting with participant 4 in a specified meeting point and start chatting while the robot moves from a start to a destination position. This scenario was designed to evaluate how the participants would perceive the movement of the robot when passing in front of them and when two participants interact stepping in front of the robot's movement trajectory.

3.2.4 ***Hallway Scenario:*** This scenario resembled a *passing by* situation in which two people walk and pass next to each other. For this scenario, as illustrated in Figure 3, the robot moves from a start position to a destination straight in front of the robot. Meanwhile, participant 1 moves from the robot's destination to the start position. Because of the available space, we included participant 2, which remains static in the scenario. This scenario was designed to evaluate how the participants would perceive the movement of the robot when passing by in opposite directions.

3.2.5 ***Procedure:*** At ESPOL, apart from the invited participants there were also some external people who worked in the surrounding offices that passed around during the experiments. These external people were not included on purpose. However, the presence of surrounding people in the experiments aligns with previous research, which suggested that having people standing close to each other in common social spaces can reduce the potential anxiety that a robot might cause [46]. To capture the desired interaction, participants were asked to adjust their walking speed (e.g., to move slower) and behave as they would commonly do in a normal day while following the moving directions and interactions as shown in Figure 2 and Figure 3. Participants received instructions as a script similarly to the experiments carried in [6]. After signing the consent form, the experiment started with the robot moving from a start position to a destination. Despite people feeling comfortable with robots moving at speeds between $0.254m/s$ and $0.381m/s$ [17], the speed of the robot was adjusted to $0.22m/s$ due to the maximum speed of MeseroBot. The robot took two and a half minutes in average to reach the destination in both scenarios.

3.2.6 ***Qualitative Study of SRN.*** After each experiment, we conducted semi-structured interviews looking at the perception and social acceptability of the navigating MeseroBot. We asked: a) *How would you describe your experience around the robot?*, b) *How did you perceive the movement of the robot?*, c) *In terms of comfort and safety, how did you feel around the robot?*, d) *How did you feel that the robot and its movement affected your personal space?*, e) *What potential values do you find in the robot?*, f) *What would you change about the robot to make it more trustable while moving autonomously around you?*.

3.3 Case Study 2: SRN in the UK

In the UK, the case study was conducted at Cardiff University (CU) in Cardiff, Wales, UK.

3.3.1 ***The TIAGo robot.*** The TIAGo is a general service robot for indoor environments, and it has been envisioned for a variety of applications, e.g., sorting bookshelves and transporting objects [70]. The TIAGo uses built-in sensors, such as a SICK laser range-finder (180 degree range) and an Orbbec Astra S RGB-D camera, to create a representation of the surrounding environment. The TIAGo's measures are $1.1x0.54$ meter height and diameter.

3.3.2 ***Participants.*** At CU, we carried out 14 experiments for both scenarios (office and hallway), combined with 3 interviews (2 researchers and 1 student) and 7 focus groups (19 students and 1 researcher) to capture their experiences, perceptions and suggestions after interacting with the TIAGo robot. Thirteen participants self-identified themselves as male and 8 as female, and 4 participants expressed it was their first time interacting with a nearby robot. Experiments, interviews and focus groups took place at location CU in February 2023.

3.3.3 ***Office Scenario:*** At CU, we made some adjustments considering the practical constraints, e.g., having a smaller space available as seen in Figure 4. Experiments were conducted with 2 to 3 participants. When a third participant was involved, this participant was asked to stay seated on a chair while observing the experiment. Participant 1 walks and

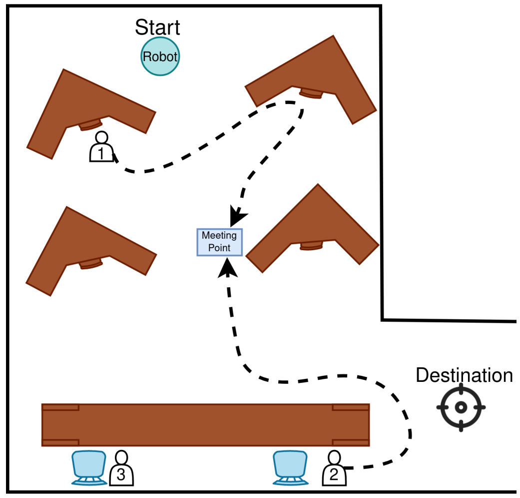

Fig. 4. Office scenario for Case Study 2.

takes some documents from a desk, meanwhile, participant 2 moves and meets participant 1 at a meeting point where they start chatting. As the participants move, the robot moves from the start to the destination position.

3.3.4 ***Hallway Scenario:*** At CU, experiments involved 1 or 2 participants according to the availability of participants, walking across the hallway in opposite direction to the robot as illustrated by Figure 5. When two participants were involved, they were asked to walk together chatting as they knew each other beforehand. Similarly, the robot moves from the start to the destination position.

3.3.5 ***Procedure:*** At CU only the participants were present during the experiments. Similar to case study 1, participants in case study 2 were asked to adjust their walking speed and act as they would commonly do in a normal day while following the directions as shown in Figure 4 and Figure 5. Same instructions were provided similarly to the experiments carried in [6]. After signing the consent, the experiment started with the robot moving from the start location to a final destination, and the participants also started moving as described in each scenario. The robot speed was also adjusted to $0.22m/s$.

3.3.6 ***Qualitative Study of SRN*.** Practical constraints had to be considered due to the short time availability of participants and after the initial interviews we opted for using focus groups. We conducted 3 interviews and 7 focus groups. The focus groups helped exploring participants' perspectives and how they share and compare experiences with other participants after the experiments. We used the same open-ended questions from case study 1 to guide the interviews and focus group discussions.

3.4 Post-Experiments Qualitative Data Analysis

As user experiences are by nature subjective [35], we took a constructivist stance [96] and follow a reflexive approach to analysis rather than following other positivist approaches that rely on quantification of patterns [13]. Qualitative data was thematically analysed using the online collaborative tool Taguette [75], following the step-by-step guide from Maguire et al. [58] to gain insights into the participant's subjective experiences and opinions during the experiments.

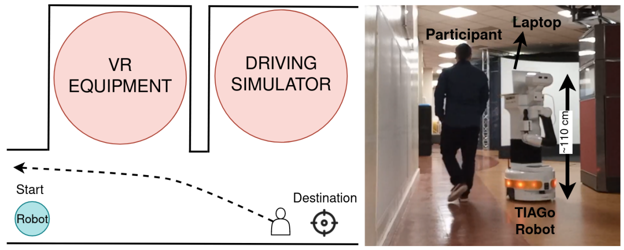

Fig. 5. Hallway scenario for Case Study 2.

Initially, the interview recordings were transcribed and analysed by three researchers (2 of which are native Spanish speakers). Data from ESPOL was primarily analysed in Spanish and translated to English for reporting in section section 4. Data from CU was analysed in English. The researchers read the transcripts multiple times to familiarise themselves with the empirical material, and coded all the transcripts using an inductive approach. Researchers discussed the codes with a fourth researcher to avoid losing information and misunderstandings. Then, Miro[3] was used to collaboratively group codes by themes and sub-themes in a visual form. The codes were grouped separately for each scenario and case study, re-defining and removing themes and sub-themes until the grouping converged into a consensus. It took five iterations within a month to complete the analysis and was finalised while writing this paper.

4 Findings

4.1 User Perceptions, Experiences, and Emotional Responses on Robot's Social Navigation

The case studies revealed how user's perceptions and experiences are highly context dependent. In our case study 1, participants' perceptions and emotional responses were mainly triggered by the navigation capabilities of MeseroBot. Most participants reported *positive* experiences around the navigating robot in both scenarios and in a few cases reported negative opinions. For example, participants expressed positive emotions as they felt *calm* around the navigating robot and *"…very comfortable, in no moment I felt it [MeseroBot] was about to crash with me …"* **(EH-2)**. Nonetheless, some participants reported negative experiences as they felt *uncomfortable* or *unsafe*. One participant in specific felt *"…a bit nervous because I had never been near a robot."* **(EH-7)**.

In case study 2, more than half of participants expressed *positive* experiences with the navigating robot. Several participants described the experience as *exciting* and *enjoyable*. For example, a participant mentioned *"I was quite excited to see what would happen, and I was looking forward to seeing what it [TIAGo] would do."* **(UOFG-1)**. However, some participants also described the experience as *scary* and *uncomfortable*. In particular, few of the participants without prior experience with robots had negative responses such as *fear*. In one of the focus group, a participant commented *"…I have never really interacted with robots like this before, so I do not know what to expect, it kinda freaks me out."* **(UHFG-1)**. Overall, participants' perceptions and emotional responses were triggered by both the navigation capabilities and the physical appearance of the TIAGo's robot.

4.1.1 Robot movement capabilities: Perceptions of robot speed control, navigation trajectory, safety, and potential risks.

MeseroBot robot. In our case study 1, participants frequently commented on the robot's navigation capabilities, while expressing that MeseroBot was aware of the room environment and participant's movement to avoid potential

[3]https://miro.com/index/

collisions. For example, a participant stated *"The robot was like stealthy, like he realised that I was walking, and he was paying attention . . . "* **(EH-10)**. In fact, many participants perceived the navigation trajectory as *safe* and *pleasant* as a participant mentioned *". . . the robot was slow and gives the advantage of being more or less safe . . . it wouldn't hurt a person even if it crashed."* **(EO-15)** and another participant stated *". . . because it is pleasant that it moves slow, with control, that one feels like it [the robot] is not going over an obstacle . . . "* **(EH-8)**. The low speed was associated with safe navigation while safety concerns arise at higher speed since *". . . if the robot had a higher speed or something like that, or if someone was not paying attention, basically it could have crashed . . . "* **(EO-18)**. Additionally, one of the participants mentioned that *". . . it felt like in the future it would be comfortable to live together with a robot."* **(EH-5)**, meaning the robot could fulfil tasks in social spaces where daily interactions with humans occur. Still, some participants from both scenarios categorised their experience as *'normal'*, as the robot was barely noticed. A participant mentioned *". . . I was talking with my friend and like I didn't feel the robot, I forgot the robot was going through there . . . "* **(EO-16)**.

Although, the low navigating speed was perceived as *safe* for many participants, some negative responses describe the navigating robot as *too slow* and *not agile*. Others suggested that it can create *safety risks* to their *personal space* since *"it [MeseroBot] moves slow, therefore . . . it is not like a person walking normally."* **(EO-16)**. While some participants found the navigating robot to be *precise* with *safe* movements, others highlighted *". . . when the robot start moving, it wobbles a bit, but it moves well."* **(EO-20)**. In addition, other participants instead had a negative experience because of how the robot navigated while stopping abruptly as *". . . at some moments the robot took some impulses . . . "* **(EO-1)**. As a consequence, a few participants noticed that the robot wobbled and expressed their concern of the robot falling while starting movement, and that it was indecisive regarding the navigation trajectory, *". . . if the robot had dodged me and gone its own way, maybe I would not have worried about my personal space, but the robot was undecided, I did not know if it would maybe invade my personal space . . . "* **(EH-8)**. Moreover, because of the wobble, a participant felt *'. . . scared that the laptop could fall off."* **(EH-8)**. In particular, two participants commented on the robot navigation trajectory, thinking it was predefined and therefore they felt *comfortable* as they perceived *low risk* of a potential collision. However, another participant felt *confused* as, *". . . I did not know what was the trajectory of the robot . . . thought it could crash with me . . . "* **(EO-17)** increasing the perceived risk of collision.

TIAGo robot. Regarding the navigation trajectory in case study 2, participants gave positive comments such as *". . . yeah, this bit was really impressive, how it was moving up here, around the table . . . "* **(UOFG-5)**, highlighting how the robot adjusted its navigation trajectory to avoid obstacles. Similarly, participants also reported feeling *safe* for how the navigating robot *"was good at avoiding us [the participants]"* **(UOFG-2)**. Likewise, participants from **(UHI-1)** and **(UOHFG-1)** perceived the risk of potential collisions as low, as they felt the robot was *safe* due to its *slow navigation speed*, *"Yeah, I think the slow pace helped that [feeling comfortable]"* **(UHI-1)**.

Participants had mixed opinions in both scenarios on the level of navigation speed. While for some participants that perceived the robot navigation as slow it was associated with safe navigation as *"I didn't feel the danger at any point."*, other participants would have preferred otherwise, *"I wish it was faster."* **(UOHFG-1)**. One participant noticed that the robot's movement and speed did not adjust to the walking speed of the participants since *"When you walk past the person, you both walking much faster than that and you kind of judging each other's [speed], aligning yourself up with each other, kinda thing, and you stop going when if you are about to hit someone . . . "* **(UOFG-4)**. Still, some participants also commented on how the *low speed* enabled them to become aware of the presence of the robot, and change their orientation towards the robot if needed. For example, a participant stated *"It is definitely a bit slow, but I*

Table 2. Summary of the major findings obtained from the interviews and Focus Groups for case studies 1 and 2.

	Case Study 1 (31 participants)	**Case Study 2 (23 participants)**
SRN positive experiences	12 participants expressed it was their first time experiencing with robots.	4 participants expressed it was their first time experiencing with robots.
	21 participants expressed having a positive experience by feeling *"comfortable"* and *"pleasant"*.	13 participants expressed having a positive experience by feeling *"safe"* and *"comfortable"*.
Perceived negative experiences on the used SRN capabilities	**Robot movement**	
	Participants negatively criticised the wobbling and doubtful movement of MeseroBot.	Participants negatively criticised the linear and doubtful movement of TIAGo.
	13 participants expressed MeseroBot was slow.	8 participants expressed TIAGo was slow.
	Personal space	
	7 participants expressed personal space was negatively affected and caused discomfort.	9 participants expressed personal space was negatively affected and caused discomfort.
Robot appearance effect on comfort	MeseroBot's appearance did not significantly affect participant's comfort.	TIAGo's human features positively affected some participants' comfort but also very negatively to others who called it *"creepy"*.
Suggestions to enhance SRN experience	Participants focused on improving MeseroBot's appearance and avoiding the wobble movement.	Participants focused on respecting the personal space and the linear movements of the robot.

guess that gives us an advantage, so that we know there is a robot and then if there is something we can move away from its path." **(UOFG-3)**.

Yet, there were some experiments in which negative experiences arose. In one experiment, the robot moved in front of a participant and stopped, and this participant commented on the robot's inability to detect people from far away as *"He [TIAGo] doesn't know until he kinda gets to the point where I am and then you move like at the last moment."* **(UOFG-4)**. A participant also commented about the perceived *indecision* of the robot when it paused as *"... it [TIAGo] was looking in different ways and then found out the best way ... "* **(UOFG-2)**. Comparably, participants noticed that the robot turning was *not smooth* enough as *"... it is very much like turn, drive one direction, turn, drive, instead of kinda of curved path."* **(UOFG-4)**. In particular, for the hallway scenario, a participant expressed safety concerns in relation to the perceived competence of the robot (or lack thereof), *"because of these abrupt movements, I could not really predict, what he was doing."* **(UHFG-1)** and another participant said the robot *"... was less predictable with other people being very close to it, so it couldn't really say what he will do next time."* **(UHFG-2)**. Some participants still considered the movement *"... a bit weird, how it was walking up to me, even though I was still there ... then it was kind of approaching me a bit weird in a way."* **(UOFG-5)**.

4.1.2 Personal space: Perceptions of robot distance, associated experiences, and perceived risks.

MeseroBot robot. In case study 1, most participants felt comfortable with the distance taken by MeseroBot. A participant mentioned *"to me the robot didn't transmit any discomfort, the robot maintained a safe distance . . . "* **(EO-14)**, as a consequence of the robot's capabilities to navigate while *avoiding collisions* and respecting the participants' *personal space*. Indeed, many participants did not perceive the navigating robot as creating a safety risk as a participant commented *". . . I did not feel the robot was a threat or that it would hit me, I felt calm just that."* **(EO-21)**. Despite having a positive experience, e.g., *"it was cool, it was good, it was interesting"* **(EO-22)**, few participants also felt their personal space was affected negatively *"a bit since when the robot passed it delayed a bit to dodge . . . "* **(EO-22)** and *"in this case yes, because I had to go back for the robot to pass."* **(EO-21)**.

TIAGo robot. In case study 2, almost half of the participants had a *comfortable* experience, because the navigating robot *kept distance* and did *not crash* into any participant. One participant mentioned *"I never felt like it was bothering me or something. It was just moving at one pace."* **(UOFG-1)**. Although *"it [TIAGo] was getting too close sometimes, it never got into our [personal] space"* **(UHI-1)** and *"it was quite, it didn't really get too close to us . . . "* **(UHFG-1)**. Still, some participants expressed that although it was not the robot intention to affect their personal space, *"it [TIAGo] came a bit closer than a normal person would"* **(UOFG-4)** and also *"It [TIAGo] moved quite tightly around me . . . "* **(UOHFG-1)**, making them *uncomfortable*, *scared* and feel *". . . the fear of knocking it [TIAGo and the laptop] over."* **(UOHFG-1)**. In particular, participants reported a *scary* experience when the navigating robot was out of sight and suddenly appeared, as a participant stated *". . . I had an instinct to check what was behind me, at one point it was behind me and it was a bit scary."* **(UOFG-1)**. Another participant **(UOI-1)** stated that people would be *scared* while not having an understanding of a safe distance.

4.1.3 Robot physical characteristics: Perceptions of size, noise levels and appearance.

MeseroBot robot. In case study 1, participants felt *comfortable* not only because of the robot's *navigation speed*, but also because of its *size*, and *noise level* as one participant stated *"very comfortable to be honest, the robot was not spacious, it is not significantly large to present a nuisance when being close, nor is it noisy, nor is it very fast."* **(EO-8)**. Another participant also mentioned that *"[MeseroBot] did not cause any insecurity involving its aspect or materials."* **(EO-16)**. In that sense, MeseroBot's *height and width* contributed to its perceived trust and *social acceptance* in the office scenario. We also noticed how all participants perceived it as a male-gendered robot due to its name and appearance.

TIAGo robot. In case study 2, TIAGo's appearance affected the perceived *trust* of the navigating robot, given that several participants referred to the robot as *polite* with human characteristics and a male name. A participant stated *"I think it is quite trustable as it is, it is not like faceless . . . "* **(UOFG-1)** and others felt *"he [TIAGo] looks quite friendly."* **(UOHFG-1)**. However, few participants expressed some concerns due to its *humanoid* appearance as either the robot *"gotta [have a] full . . . face on it, or make no face at all, it has got like a creepy face at the moment."* **(UOFG-4)**. Another participant expressed negatively that TIAGo has *"In my opinion, it has a lot of stuff to it, if you see what I mean, a lot of shapes, a lot of different textures, colours, patterns, I think if it was more like uniform, like a maybe like an egg shape, it grabs less of your attention . . . So if it grabs less of your attention, you kinda of notice it less. If you don't really want to notice it, right . . . it is not the centre of attention, it is not intended to be the centre of attention . . . "* **(UHFG-2)**.

4.2 Suggestions to Enhance the User Experience of Navigating Robots

MeseroBot robot. In case study 1, participants suggested adjusting the robot's height, weight and speed to make the robot safer and more trustable. Avoiding navigating robots abrupt behaviours (e.g., sudden stops or changes in direction) could be an improvement as a participant mentioned *"Just that it [navigating robot] does not wobble too much because maybe it could flip itself . . . "* **(EO-4)**. Other participants suggested that the robot should adapt and adjust its movement according to the people's speed. A participant commented, *". . . I saw it was too slow, then I think when someone is going to interact with the robot, it should move with our rhythm."* **(EO-17)**.

Most participants suggested the trust could be improved by having a more human-like appearance as *"Maybe the robot could be like a person, that it looks like a person . . . "* **(EH-10)** and by *"covering it [MeseroBot] with something to cover the cables . . . "* **(EH-5)**. Also to enhance its visual interaction, e.g., by adding lights to be aware of its presence and proximity *"for people to pay more visual attention to the robot . . . "* **(EH-2)**. In terms of the structure of the robot, this same participant commented that the robot could be more trustable if it was more visible, e.g., using lights to attract attention: *"Maybe to add a bit more [to increase] attention to the robot, for people to pay more visual attention to the robot, like it can be seen more and that people are more aware that it is near."* **(EH-2)**.

TIAGo robot. In case study 2, participants provided suggestions to enhance the robot's physical structure to make it more trustable, e.g., by adding a rubber stopper around its bottom, to avoid unintended consequences such as having *"some kind of spillage"* **(UOFG-3)**. Some participants suggested enhancing the multimodal interaction of the navigating robot to make people aware of its proximity. For example, a participant suggested adding *"sound, so we would know it is there. Either saying that the robot is here or just to add beeping."* **(UOFG-2)**. However, a participant mentioned the robot should be as simple as possible not to attract too much attention, *"just like for utility purposes, I would make it less colourful, multi-shaped, to be honest."* **(UHFG-2)**.

From the Focus Group **(COHFG-1)** in which mixed experiments were carried, there were not many comments about suggestions to improve the robot, in general they just expressed that they desire the robot to go faster and be more agile: *". . . it probably would be better if it was a bit more faster and like agile. It's kind of hard to get a good balance of that."*

5 Discussion

For mobile robots to be acceptable in shared social environments, they should navigate in a reliable and appropriate manner [83]. In our case studies, we observed that personal space and spatial arrangements (distance and proximity), social awareness, physical appearance (aesthetics and size) and even the robot's movement (speed and movement intentions) played an important role influencing the perceptions and experience of the participants and the social acceptance of the SRN approach in each socio-technical context. All of these socio-technical aspects led to positive and negative responses as several participants, from both research settings and scenarios, felt mostly *safe*, and *comfortable* but at times also *strange* or *nervous*. Social acceptance varies according to each socio-technical context where the robots are introduced including the readiness for use and the actual resources available in early stages of robot development. In this section we discuss the different socio-technical factors that are important to consider when investigating the social acceptance of SRN to inform the design of SRN systems.

5.1 Robot appearance effect on social acceptance

In the case of TIAGo, in spite of its friendly appearance which could have led to trustable experiences as suggested by Walters et al. [94] and evidenced by Natarajan and Gombolay [65], two participants in case study 2 found TIAGo's facial aesthetics features (not having a complete humanoid face) as *creepy*, similar to previous work [93]. Aligned with Antonioni et al. [4], we found that in general TIAGo's medium-level of anthropomorphism (robotic arm and face) was well received by most participants in contrast to previous research on the uncanny valley effects of robot's appearance

[98] which hypothesises that a person would experience revulsion towards a robot that possesses behaviours and appearances too similar to a human [63]. Regardless of TIAGo's friendly aesthetics, participants suggested that as long as the robot would have the minimum capabilities for the intended application in each socio-technical context of use (e.g., office scenario), their expectations would be met, otherwise it would lead to negative responses [32]. Thus, having a robot with an incomplete human-like face at CU did not significantly influence the social acceptance of the navigating robot.

In case study 1, participants did not perceive that the appearance of MeseroBot (i.e., not anthropomorphic physical appearance) greatly influenced the social acceptance of the navigating robot, even though many of the participants had no previous experience with robots, but suggested that MeseroBot could be more trustable with a more human-like appearance. Although Marroquin and Saravia [59] highlight that people from Latin American countries are not generally supportive of robots, they also mentioned that people who are male, single, educated and democratic, have less negative perceptions towards robots. At ESPOL, more than half of the participants were male and all of them belonged to an educational institution where the level of readiness was high as many participants were curious and competent enough to be involved in the experiments.

In addition, we observed how participants in both cases assign a male gender to both robots due to their names, however, their influence in social acceptance was not self-evident and rather perceived as a superficial gender attribution as participants value utility over appearance. The participants in our case studies were from Western countries (UK a highly developed country and Ecuador an upper middle-income country) with easy access to Internet and Education. Even though a few participants in CU have been previously exposed to robots, participants in CU also expressed negative responses (e.g., *uncomfortable*, *unsafe*, etc.). This differs from previous research that has stated that the longer people are exposed to robots the more positive attitudes people have toward robots [81]. One possible explanation, of the low number of negative perceptions towards MeseroBot despite its lacking anthropomorphism could be due to the novelty [67] of robotics in an emerging country like Ecuador, with little development on SRN and limited exposure to social robotics [33]. Actually, when introducing new technology such as robots, a transition period is usually required so that the robot is accepted correctly [73]. However, similar to the participants' experiences from [60], in case study 1 many of the participants were curious to see how the robot would move and react around them, than scared from its behaviour. This could have contributed to participants in ESPOL having a positive attitude (e.g., *pleasant*, *comfortable*) and interest towards the robot and their own *personal space*, even without a human-like physical appearance while having the expectations of the robot met. Indeed, it has been proved that machine-like appearance is preferred in laboratory context [38], and at ESPOL, participants were aware that the location where the experiments were carried was inside an academic institution which could have contributed to the positive reactions.

Our study suggests that, even though SRN research commonly focuses on how the robot moves around people and preserves their psychological and physical safety [78], anthropomorphic characteristics may affect the social acceptance of a moving robot according to each socio-technical context [27] and the expectations of users [11]. The effect on the social acceptance of the navigating robot is highly dependent on the socio-technical context, as for example, Alzahrani et al. [2] showed that Western countries tend to trust robots more than Eastern countries. However, more research is needed to further understand people's initial preconceptions, gender assignment, and expectations and explore how these socio-technical factors influence people's perceptions and experiences with mobile robots. Thus, there is a need to better design tailored SRN approaches to provide meaningful human-robot interactions in shared-environments that can adapt to the practicalities and expectations of each socio-technical context [90], which is crucial especially in early stages of development [24]. Indeed, it is challenging to discuss our work since, to the best of our knowledge, there is no previous research exploring SRN in Global South socio-technical contexts.

5.2 Robot's speed and movement behaviour effect on SRN

Another important feature was the robot's speed, as we observed that, in general, participants from both case studies felt safe due to the low speed. Considering that Shahrezaie et al. [83] and Althaus et al. [1] suggest the robot's speed should be adjusted based on the social setting and the distance to the surrounding people, we set it up lower than previous recommended values [17, 52, 78] to ensure people's comfort and adaptation to social norms for navigation to maintain a safe velocity as suggested by Kirby [50] and Chowdhury et al. [21]. However, participants in both case studies indicated that the moving speed could be faster while adjusting to the participant's speed and the dynamics of the socio-technical environment. A possible reason is that the contexts presented were office related, in which higher velocities are expected than in other contexts such as healthcare places [36]. Particularly, speed perception could be attributed not only to the spatial arrangement, but also to external environmental factors. For example, ESPOL being located in a big city in terms of size and population, in which people may expect a high movement speed for the robot [54]. Indeed, the used SRN approach does not make any consideration into the variation of robot's speed and therefore did not feel appropriate by our participants in some cases. Similarly, in [60] participants expressed the need of adjusting their speed when they had the robot moving past them. In a recent study, Tornbjerg and Kanstrup [90] present a case where "robots drove at a slow pace for safety reasons" resulting in staff becoming frustrated as robots could not adapt to their walking speed.

A similar effect is observed towards the participants' perception of safety according to their *personal space*. Aligned to [28], participants in ESPOL were overall less sensitive to having negative connotations such as being *scared* when a robot moves close. Even when the robot moved directly towards them or near them, participants in case study 1 reacted to the movement of the robot by giving free space and having a positive experience despite their personal space being affected negatively. This is related to testimonies seen in [60] where participants mentioned that although the robot passed very close to their feet, it was just like when you move around a crowd. This can also be attributed to the spatial features (e.g., space, proximity, distance) in each setting. For example, for the experiments in ESPOL, having much bigger spaces for the scenarios in case study 1 than in case study 2, may have increased the confidence of participants to evade the robot and move freely, influencing the social acceptance of the robot and its movement. Eriksen and Bodenhagen [29] describe how a moving robot got stuck in narrow hallways, where staff got frustrated while waiting for the robot to react. Indeed, high traffic and/or cluttered hallways in the trajectory of an autonomous delivery robot can negatively impact the organisational workflow in particular settings (e.g., hospitals) as it gets in the way of more important and crucial work [64]. In addition, most participants in case study 1 expressed that MeseroBot did not affect their personal space and felt *comfortable* or *normal* even when the robot passed close to them. Furthermore, participants in case study 2 that interacted in a much smaller space, showed several concerns about their *personal space*, e.g., whether the robot gets too close or in some cases even felt *creepy*. Nevertheless, non-maleficence is also evident [45], since some participants from both locations expressed the understanding that the intention of the robot was not to cause harm or get close to the participant.

In our case study 1, participant's reactions to the robot wobbling while navigating, and its unnatural movement, were more prominent due to the MeseroBot's physical structure not being as strong as the TIAGo's physical structure. The MeseroBot wobbles due to the inertia while decelerating, and the harsh movement was a known characteristic of the used SRN approach [87]. The wobbly movement of MeseroBot and harsh movements in both robots, negatively affected the legibility, which refers to the capability of the robot to transmit its movement intentions to surrounding people [26]. Aligned with [90], harsh movements caused annoyance and frustration to our participants as especially in case 1 participants thought the robot moved following a predefined trajectory since many participants did not have previous experiences with navigating robots.

Participants in case study 2 highlighted the importance of having the robot in their line-of-sight to predict its navigation intentions, rather than not knowing the robot's position, which was scary for some CU participants. Our findings align with Bungert et al. [16] and Charalampous et al. [18] that have highlighted the importance of human visibility on the moving robot to maintain people's comfort. While case study 2 participants wanted the robot to have a more explicit interaction (e.g., using speech to express its proximity to surrounding people), case study 2 participants mentioned their desire for a more implicit type of communication (e.g., use of lights around the robot). This aligns with previous research that has shown how the use of speech and lights can be used also improve the communication of intents [21, 26]. For example, Hall [41] shows how German participants have less preference for implicit communication and prefer a robot that speaks and makes people aware of its presence [74, 76]. However, it is important to point out that unexpected voice may put participants in uncomfortable situations [28]. Also, previous research such as Baraka and Veloso [7] has presented that using animated lights to express the presence of a moving robot and its movement intentions can enable better collaboration between robots and humans. Our study suggests that SRN systems need to be able to identify nearby social agents and make them aware of the navigating robot's presence and intentions by using either lights or speech, or other source of communication but modulating their intensity to adapt to the user's situation in each socio-technical setting.

5.3 Suggestions to enhance SRN social acceptance

In both cases, participants suggestions were especially oriented to enhance the robots' appearance and navigation style. For instance, many case study 1 participants suggested that MeseroBot's appearance can be improved by putting a cover and a face on it, and with a stronger and stable structure to avoid wobbling. In case study 2, participants suggested the TIAGo could have a smoother navigation and curved paths. Likewise, De Heuvel et al. [25] show how participants preferred curved paths for a robot passing by a human. Since the implemented SRN approach [87] in this study uses a sampling-based technique and does not consider the robot's kinematic constrains, the resultant trajectories tended to be irregular and linear. As a consequence, the used SRN approach generated geometric paths which abruptly changed the direction of the robot and caused a perception of indecision in both cases. Apart from that, the abrupt changes of direction greatly affect robots with weak structures, such as MeseroBot, by causing wobbly movements which generated negative emotions (e.g., feeling *unsafe*) on participants. To increase the social acceptance of the moving robot, the design of SRN approaches not only need to consider kinematic constraints to generate curved paths, but also need to be consistent with the moving trajectory and apply smooth acceleration and deceleration behaviours. Doing so would also avoid wobbling issues, especially for robots with weak structures such as the MeseroBot, that look unstable when attempting to follow geometric paths. In addition, generating curved paths would increase the predictability and legibility of the robot [26], a similar concern also seen in [60], and would also improve the interaction between humans and robots and the anthropomorphic perception of the robots [46].

5.4 Limitations and Future Work

One of the limitations of our study is the use of convenient sampling, since many of our participants in Ecuador were either students or researchers from engineering and computer science, and in the UK, they were students or researchers with a psychology and computer science background, whose exposure to technology in an academic setting could have altered their perception of the experiments [95], and thus we acknowledge that they are not representative of the entire population. Future work should conduct controlled in-the-wild studies with participants beyond academic settings to improve the generalizability of the findings and also consider field studies that capture the natural behaviour of people surrounding the robot. In addition, there were some technical limitation with the people's tracker used which delayed the detection of new approaching people to the robot. Furthermore, due to lack of processing power of the robots' computing capabilities, we placed a laptop on top of both robots to run the SRN approach, which changed the robot's appearance and raised a potential concern of the laptop falling during movement.

Future work should improve the used navigation system to make smoother movements by using curved paths with adjustable speed depending on the situation at hand. Future work should also consider that the physical shape of the robot and its anthropomorphism, have to go according to the user expectations and the practicalities and constraints of each socio-technical context [32]. As highlighted by Tornbjerg and Kanstrup [90], many of the socio-technical factors that influence robot acceptance are not often anticipated before deployment. In addition, future user studies should include quantitative and qualitative data collection methods to complement each other and provide a broader evaluation of the social acceptance of SRN. We encourage the HCI and HRI communities to conduct more qualitative user studies exploring the potential adaptations and acceptance of SRN systems while having in mind the importance of robot's sensitiveness to the situated socio-technical context (e.g., spatial constraints, people's perceptions, expectations, and experiences, etc.) [45, 90].

6 Conclusions

We present two case studies and carried out experiments to evaluate the acceptance of a SRN approach and highlight a number of socio-technical factors that influence navigating robots acceptance in real-life environments. The case studies were conducted in two different socio-technical contexts with two different robots in two different scenarios. Our experiments provide in-depth insights into the user's perceptions, experiences, emotional responses and the robot navigation capabilities and suggestions for improvement that are central determinants of acceptance of navigating robots in each socio-technical setting. Some of these improvements include adjusting the robot's speed and movement to respect the personal space comfort of surrounding people according to the available space in the environment (e.g., higher speed in bigger settings), as well as moving in curved and smooth trajectories regardless of the surrounding in order to match the expectations of people.

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