On Being Guided: How People Follow a Robot-Guided Tour

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Abstract

Being guided from one place to another is a pervasive social practice that connects deeply with socially aware robot navigation. We examine how robots come to feature within the organisation of these established and well-worn leading and following practices, practices which are assembled 'in place' by the efforts of individuals and groups that are using robot guides. We deployed mobile robots in a museum context to provide additional information for visitors around multiple sequential exhibits. Our ethnomethodological video-based analysis of interaction centres on how the social organisation of being guided was practically managed by visitors: in initiation of following, doing following, and finding a place to stop. Our study shows how following and being led is more than just a mechanical activity, and describe the implications for socially aware robot navigation in addressing novel technical challenges that a shift in understanding following-leading phenomena presents.

CCS Concepts

• **Human-centered computing → Empirical studies in collaborative and social computing**; **Field studies**; • **Computer systems organization** → *Robotics*.

Keywords

robot-guided tour, social robot navigation, socially aware robot navigation ethnomethodology, video analysis

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1 Introduction

If there is to be further deployment of service and assistive robots into everyday life, then there is concomitant need for greater integration of socially aware navigation capabilities. These include detecting humans, prioritising their safety and minimising disturbing and discomforting them. At the same time, it is argued that such robots will need to exhibit intentions and behave according to social norms, especially when facing and resolving conflicts [52]. Whilst there have been significant advancements in dynamic obstacle avoidance and human motion prediction for informing robot motion planning, there is still limited understanding of high-granularity human action and its social features beyond commonly accepted considerations such as proxemics (i.e., the idea of personal space) [31, 37]. Additional complications arise as social practices can change depending on the specific contexts in which they take place, consequently affecting the notion of what appropriate (and inappropriate) robot activity entails [17]. Making progress in socially aware navigation thus necessitates we deeply understand social practices in detail; for example, to inform the role of conflict avoidance in social navigation [38].

Our position is that robots that are designed to inhabit human, social worlds will become embroiled in the practical organisation of mundane human practices [45]. These social actions are not only hard to predict and model for (since they are—in our perspective—locally contingent), but may be easily overlooked when designing autonomous mobile robots and their socially aware navigation capabilities. In this paper we select one seemingly trivial yet pervasive social practice that connects deeply with socially aware robot navigation: that of being guided from one place to another. We examine how robots come to feature within the organisation of established and well-worn guiding and following practices, practices which are assembled 'in place' by the efforts of individuals and groups that are following robot guides. We think it possible that guiding and following is considered trivial or perhaps simply invisible to researchers, since we have struggled to find others making much of it within HRI research in such a way that centres *human practices* (as opposed to robot design). The only exception is in the phenomenon of guiding and following as it relates to assistive robots and disability [13, 14].

Further, this activity of being guided by a robot might on its face appear to be a purely linear, mechanical matter, where an optimal path is determined and then follower follows the guide in line with some proxemic rules and dynamic avoidance of intermediate obstacles. But when we look closer (as we will do in this paper), we discover a set of human practices which work to sequentially organise the activity of being guided, into which a guiding robot comes to play a part. This sequential order of guiding can be broken down into three broad phases: *initiating following*, *doing following*, and *stopping following*—each moment of which requires a concerted set actions on the part of the guide and any followers. In places with others around, these sequences may also involve coordinating action with bystanders, onlookers, or passers-by. The video data we present in this paper helps us break down the ways that robot guides are brought into the sequential and moral orders of guiding and following, and detail what the implications are for designers of robots that attempt to accomplish this feat.

We used commercially available Temi robots [49] that find an optimal path around static and dynamic obstacles, but lack more sophisticated features due to the need for a robust and safe system operating without support in a public setting (ensuring safety and avoiding legal challenges of verifying fully autonomous behaviour; [46] describes the robot tour deployment including co-creation with curators and museum management). Despite technical limitations of the robot, we note this type of real-world study is also rare, grounding HRI in emerging challenges observed in-situ. As organisations have increasing access to and deploy these commercially available robots for assisting the public, our findings are valuable to the HRI community, given that "spontaneous, unscripted encounter of humans with navigating robots in the wild features a great amount of unmodeled phenomena" [37, p.27].

Our contributions thus: 1) provide **empirical evidence** of the importance of legible and predictable motion and navigation e.g., [9, 10, 33]; 2) bring **insights into accommodation work** [42] **or invisible work** [32] that users need to do when legibility is absent; and 3) provide a **conceptual vocabulary** for deconstructing the social practice of following (in initiating, doing and stopping) to inform the design of robot guides.

2 Guiding and Following: Robots and Humans

Three main areas relate to our research: 1) past work on the development and evaluation of robot-guided tours; 2) robotics research concerned with the challenge of humans following robots; and 3) sociological work studying how guided tours are conducted.

2.1 Robot-Guided Tours

There is longstanding robot-centric interest from designers in developing robots that can provide guided tours, mostly for museums, as they are the quintessential setting in which guided tours take place [15, 16, 18, 25, 37, 60]. The attraction of museums seems obvious given their potential to act as a controllable yet simultaneously 'real' space. Technical challenges such as those of navigation, human and object detection, collision avoidance, face and emotion recognition, and establishing spatial formations (i.e., F-formation) have been a central part of this realisation [20, 22, 57, 59, 66]. However, as it often occurs with such complex technical problems, much of this work uses lab and experimental settings, occasionally with some form of user study validation [16, 59, 66]. Only a small amount of this work deploys in real-world environments [12, 27, 61].

Other forms of robot guided-tour research have been less concerned with navigation challenges and instead focused on tour content [18, 41, 60]; for instance, by exploring and testing how to maintain visitor engagement [19, 43], which rest on advances to detecting visitors' attention and engagement through techniques such as face, body and gaze detection and tracking [63, 64]. As these robot guides tend to be humanoid (or have some humanoid features), their physical characteristics are used to mimic human guides, e.g., pointing, gesturing, gazing [44]. Where they do concern themselves with navigation challenges, mobile robots have, for example, been deployed to roam and provide timely information to visitors who choose to interact with them [23]. Therefore, research on robot-guided tours typically focuses on tracking and predicting people's movement rather than understanding how they follow robots, moment-by-moment.

2.2 Humans Following Robots

While there is a plethora of research on robots that autonomously follow humans [24], there is little work on its opposite: *humans that follow robots* [15, 39]. Although it is recognised that a robot following and a robot guiding constitute different tasks, they can also be seen as facets of the same challenge, especially for future robots able to swap roles dynamically [15, 17]. Research on robots leading humans has mainly focused on what Reeves et al. term "robot phenomenology" [45], i.e., robot-centric perception, tracking, planning, control, and human-robot communication [39, 54, 58]. This research is far less concerned with the experience and social organisational practices of human followers, except initial perceptions about their encounters with robot guides [26] and comparisons of robot guide modalities (e.g., facing the visitors or the point of interest [28]).

We noted earlier a strong interest in developing robot guides for visually impaired people. Due's work [13] compares instances of real guide dog vs robot guide dog navigation, and shows how the human-dog approach is entirely different to the mechanistic human-robot approach. Notably, the way visually impaired people interact in these robot-guided encounters is inherently specific to their disability, as they rely on guidance by touch and other non-visual methods [47], or what Due conceptualise as "distributed perception" i.e., how the human perceives the environment through the animal and robot guide dogs [13, 14].

Following robots is also relevant in other contexts (e.g., restaurants, streets, care homes) [45, 51, 55]. A review of user-generated Youtube videos of "unguided interactions" with robots in public places reported instances of people following robots, most prominently in airports and shopping malls [40]. The AirStar robot [48], which is explicitly designed for guiding people, has integrated features that show (analogous) 'awareness' of the humans following it (e.g., stopping or waiting for the person, turning the head/face towards the follower). However, Nielsen et al.'s work showed [40] that only a small percentage of people filming the robots actually initiated an interaction with them. In this paper we argue that the mobility aspect, or what is entailed in 'following' and 'being guided' is a topic worth examining empirically so that we can understand its locally-organised character and therefore provide conceptual input to developments in socially aware navigation.

2.3 Human Guided Tours in Museums

Some HRI research takes direct inspiration from human guided tours to inform the technical development and design of the robots and tours [29, 65]. Although our intention in this paper is not to empirically study comparisons between human and robot guided tours, we believe it is important to review findings from sociological studies of human guided tours to ground our own study.

Guided tours involve the provision of information about the exhibition to a group of visitors, answering questions and coordinating group movement and cohesion through the space. These activities have been observed not only as part of the professional services offered by the museums, but also in groups visiting these spaces (e.g., in which parents and teachers take the role of the guide) [56].

Best and Hindmarsh's analysis of guided tours show how guides and visitors configure and reconfigure the groups throughout the tour to ensure that visitors can see and learn about the exhibits, whilst continuously assessing visitor engagement and understanding [2]. It is through the audience recognising, orienting to, and engaging in the space that the guide can co-produce the tour by indicating where and when to move and look. Further, the verbal explanations provided by the guide are calibrated in situ to allow for movement across the space and gathering around the artifact of interest before continuing with the tour [2]. De Stefani and Mondada show how mobile formations can be reoriented not only by the guide but also by the visitors asking questions while moving to the next artifact, sometimes about already seen and explained exhibits, which then may cause a change in tour trajectory and focus [8]. Thus, human guided tours are fundamentally interactionally formulated, calibrated, and personalised depending on the specific visitor group being guided [1]. The approach taken in this range of work—particularly that which centres the organisation of social action—informs our approach for this study.

3 Studying Robot-Guided Tours

We describe the robot tour deployment including a brief overview of the process, and data collection. We then talk about our approach.

3.1 Robot Tour Deployment in the Museum

Our study received ethical approval from the University of Nottingham's School of Computer Science following a Data Protection Impact Assessment (DPIA) to ensure ethics compliance when collecting data in public (e.g., not filming children unless having signed consent by guardians).

The deployment took place at a public gallery for a week, as part of a project on robots in museums [46]. We used the Temi 3 robot [49] (100cm x 35cm x 45cm, 12 Kg), which has a 360° LiDAR, one RGB and two depth cameras, IMU sensor and six time of flight linear sensors for safe autonomous navigation. It also has a touch screen, speakers and directional microphones for multimodal HRI. It uses 2D mapping and localisation for navigation and path planning, and includes person detection and tracking, with obstacle avoidance with adjustable collision avoidance thresholds. Temi allows for mapping a space and setting virtual boundaries within which it can navigate. The robot's management system also allows us to set up 'tours' in that space by arranging a sequence of actions for it to perform in a specific order under certain conditions. That is, we can select a series of locations on the map, the order in which to visit them, the ideal path it should take to get there, the position it should take at each location (i.e., which direction to face), the text, images, speech and videos to be played at each location, and how long to wait before moving to the next location.

Following a collaboration with the gallery's management and the exhibition's curators [46], we used Temi's features to set up a guided tour that would take visitors along certain sections of the gallery to give additional information about the exhibits. Taking approximately 15 minutes, the tour stops at six locations across three rooms (Figure 1). At each location, after displaying a mix of videos, images and text about the exhibit, the robot asks the visitors tap the screen when they are ready to move on (and informs them that it will move on by itself after five minutes if they do not tap it). The space layout consisted of some exhibits in the middle of the rooms and against the walls. The crowd density during data collection varied from empty to roughly 20 people in the current room. Participants were walk-in visitors (general public, adults) who were recruited when passing by the first stop and signed the consent form prior to the tour. They knew the tour was going to be led by a robot and were told to press the touchscreen button to go to the next stop; no further instructions were given.

Data collected includes over 2.5 hours of video recordings of ten different tours (six tours with one participant, one of which was interrupted by children; and four tours with two participants, two of which knew each other, and two in which the participants did not). Recordings were made by using two main moving cameras (one attached to the robot, one carried by a researcher following the participants and the robot) and two static cameras, placed in Rooms 1 and 2. Fieldnotes were collected by two researchers during the 1-week observations, also documenting robot-guided tours not video recorded and the space usage by visitors not interacting with the robot. The first author attended one of four (human) public guided tours offered during the three-month exhibition; two researchers present during deployment observed a private curator-led tour.

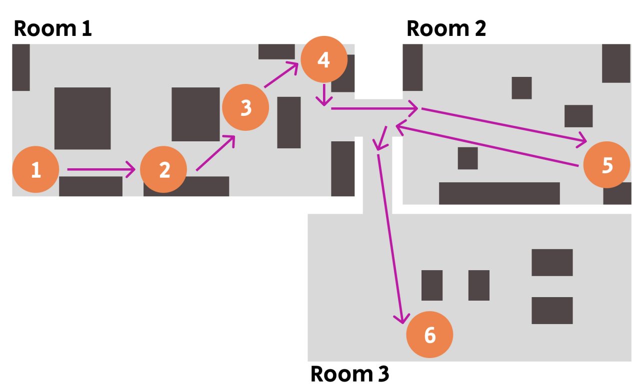

Figure 1: Map of the gallery, tour stops, and flow

3.2 Our Approach

We take an ethnomethodological (EM) perspective [5]. This means we as researchers are concerned with how members of a given setting (in this case a museum gallery), act as 'everyday sociologists'. We centre the conduct of members of the setting, their practical, ongoing *reflexive* [36] social actions, and, correspondingly, the analytic work *they* are doing as they visit the gallery. EM argues that practical activities in everyday life themselves constitute social order, i.e., comprising a sequence of methods or characteristics shared in society, from which some form of 'transferability' (or more accurately, 'family resemblances') can be drawn out regardless of criteria such as the number of observations or sample size [6, 7]. Therefore, our approach, in engaging with HRI research, aims for something akin to this sense of 'transferability' rather than generalisability [11]. We thus conduct in-depth examinations of material practices with what might be classed by others as a 'small participant sample'. Rather than fully rehearse such arguments, we refer readers to prior work (on qualitative research in general, see [6, 50, 53]; on phenomenological research positions on qualitative / quantitative distinctions, see [21]; and for EM studies in HRI specifically, see [4, 13, 14, 42, 45]).

Our approach uses video as a 'reminder' to help us unpack following and guiding—a phenomenon that becomes 'strange' when it is a robot ostensibly doing the 'guiding'. The structure we outline in the next section (initiating, doing, stopping) was the result of reviewing all our video (and, of course, reflecting on our own routine experiences of following others in many mundane circumstances, as well as the observed human guided tours at the museum gallery). We wanted to understand what interactional challenges people face when being guided by a robot. It became particularly interesting to consider beginnings, middles and ends of the tour, and we noticed how these were locally organised by visitors. This also led us to structure our presentation of the phenomenon in this paper as a 'vocabulary' of sorts for deconstructing the social practice of following a robot tour. Our video dataset included 49 different instances of visitors moving from one stop to the next one (5 stops per 10 tours, except one stop that could not be recorded due to the presence of children). There are of course trade-offs for filming people in museums [35]. While visitors are indeed aware of cameras and their activities may be affected, they still follow the tour in the same order as when cameras were absent.

4 Analysis: How to Follow a Robot

We present the phenomenon of following a robot in terms of three key moments in its social organisation. Each component part—*initiating following*, *doing following*, and *stopping following*—involves significant and often subtle coordinative action on multiple levels: visitors managing the robot's machinic actions, coordination between the local group (where there is a pair), and also with copresent others in the gallery. Our strategy in the following sections is to provide examples of the practical realisation of these moments in the gallery and analytic points to draw out of them.

4.1 Initiating Following

To do following, someone (or something) must first initiate it. Following emerges between lead and follower(s) as a concerted activity and as part of the broader sequence of initiation. However, for the guide robot, actually 'initiating following' must first be triggered by a visitor tapping the on-screen "Next Stop" button, whereupon the robot produces a voice utterance "*please follow me to the next stop*". It then begins moving towards the next stop on the tour.

In Figure 2, a visitor is tapping on the screen and immediately stepping away, eventually ending up with their back against the exhibit, perpendicularly oriented to the robot while gazing at it—awaiting the response. After a short pause, the robot then moves off past the visitor while they wait for the right moment to latch on, and follow behind.

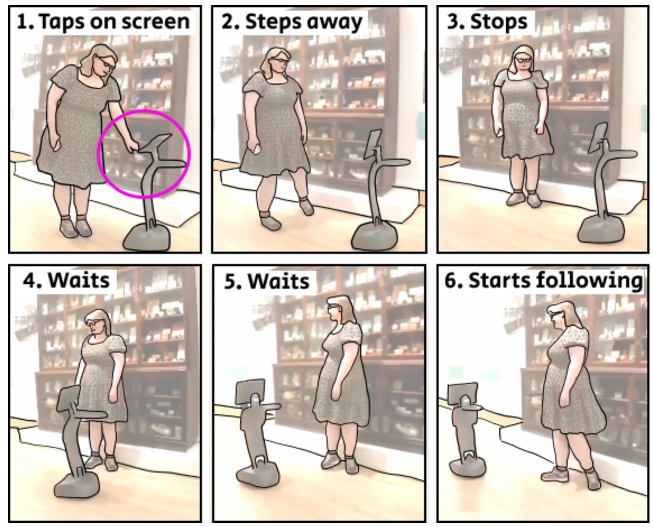

Figure 2: Visitor strategy for initiating the following [Tour 10; moving to stop 3; middle of tour; empty space].

In all observed instances, people make space for the robot in some way or other: it is characteristic of initiating following and is part of visitors acting as *robot analysts* [45, p.18]. The need to tap the screen places visitors in front of the robot's forward direction, which then leads to them physically anticipating an imminent movement and the potential of their body acting as obstruction to its path—thus they step aside. In Figure 2's 'ideal' case, the visitor steps away and, moreover, 'out of the way', by pulling up against the wall of the exhibit behind them. This opens up floor space for the robot to start moving and thus become a follow-able thing. Hence, initiating following involves producing follow-ability. The visitor has, in doing their step away, made a public, bodily analysis about where the robot is likely to go (from their perspective). In this case the visitor is right and the robot moves smoothly past them. Their waiting while the robot begins to move enables the visitor to also observe the robot's unfolding trajectory (which they orient to visibly by turning their head to track the robot as it does this). This in turn creates the possibility for the visitor in locating a relevant (and timely) point to commence walking, which they do, leaving a neat 'Goldilocks' not-to-close, not-too-distant 'following gap' between them and the machine.

Across our data, we found this process of initiation tended to include the same elements: 1) tapping "Next Stop", 2) stepping somewhere else, 3) waiting until the robot trajectory is developed enough, then 4) starting following it. However, as we have indicated, initiating a lead and starting to follow that lead (before we even get to the main mobile part of following practices, next) has several sequentially tied component parts, in which there are many points of potential derailment. And, indeed, we were easily able to locate instances in which initiating following surfaced interactional breakdowns that visitors needed to deal with. Figure 3 offers one such example. After the visitor triggers "Next Stop" on the screen and slightly steps back, the robot rotates clockwise. Partway through this turn, the visitor steps forward as if to start following, however the robot continues to rotate and only then start moving. The robot's trajectory now more closely intersects with the direction the visitor stepped in (i.e., to the right hand side of the robot as it faced away from the visitor). In response the visitor then stops, aligns themselves bodily with the robot's new direction and waits until the robot is slightly ahead, and as with the previous example, latches onto a following position.

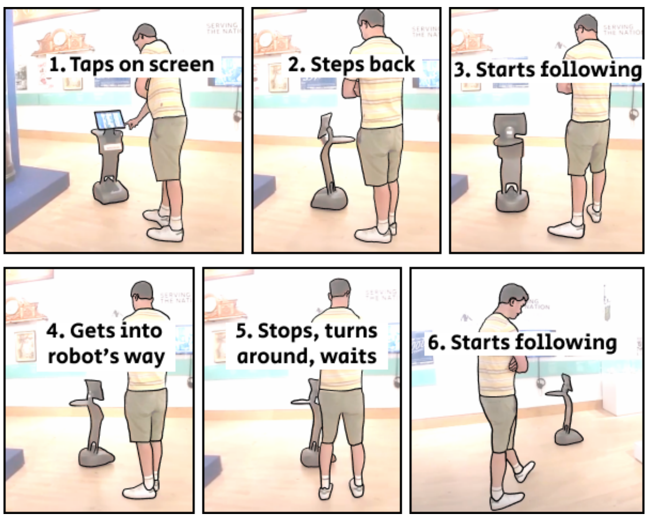

Figure 3: Mismatch between perceived and actual robot trajectory during initiation [Tour 8; moving to stop 4; middle of tour; empty space].

What this fragment shows is the incipiency of initiating following. The problem for any given visitor using the guide robot is coordinating their actions with those of the robot. The visitor is thus searching for potential endpoints of the initiation sequence in which there is a transition to following the robot. In this example the visitor projects a possible point of consilience between robot actions and theirs and they step forward in anticipation of this—but the robot is actually still turning. The visitor thus has to suspend this first attempt, and deal with a new problem, that is, the robot is driving forwards in an unanticipated trajectory, meaning the visitor's own calibration of making enough space and stepping back, coupled with their false start of following, becomes problematic.

Across the data we found examples showing visitors 'getting into' the robot's way by not stepping away in a sufficient manner (e.g. stopping and waiting too close or right on the robot's trajectory), even if they have not started the following yet. Therefore, further adjustments or correcting are needed, having to repeat the rest of the steps all over again (i.e. stepping away, stopping, waiting) until the correct trajectory is identified. This happened more towards the beginning of the tour (at stops 1-3, Figure 1). Perhaps in response to these initial issues, visitors sometimes adopted more unusual methods, such as exaggeratedly getting out of the robot's way by walking several meters away or by immediately positioning themselves fully behind the robot, right after tapping on the screen.

4.2 Following the Robot

Once initiated, the robot leads the way and visitors are intended to follow behind. We are primarily concerned with what visitors, *coordinate with* robot guide actions, are 'up against' in terms of moving through the gallery as followers of the device. We particularly want to draw attention to the ways visitors manage intra-group and group-robot coherency as they navigate the gallery. (Note: an integral part of being led somewhere is whether one knows or can anticipate a prospective stopping place or not; we deal with this problem for visitors in the next section.)

To illustrate following, in Figure 4 we see a couple being led by the guide robot towards the next stop (which involves going through a narrow corridor between Rooms 2 and 3—see Figure 1, stop 5 to 6). A visitor with a rucksack appears in the corridor's archway, then halts, looking at the robot as it turns towards the corridor, with the couple being guided following behind. The rucksack-carrying visitor then steps out of the archway as the robot turns inwards, and circles around the pair; the pair simultaneously move into the archway while the other visitor heads off into the adjoining gallery. The pair being guided follow the robot further, onwards into the connecting room, keeping a short distance away from the robot all times.

Following can involve maintaining group cohesion. The couple work to stay proximate to one another, maintaining their 'groupness'—this means that both visitors are adjusting their pace-work to

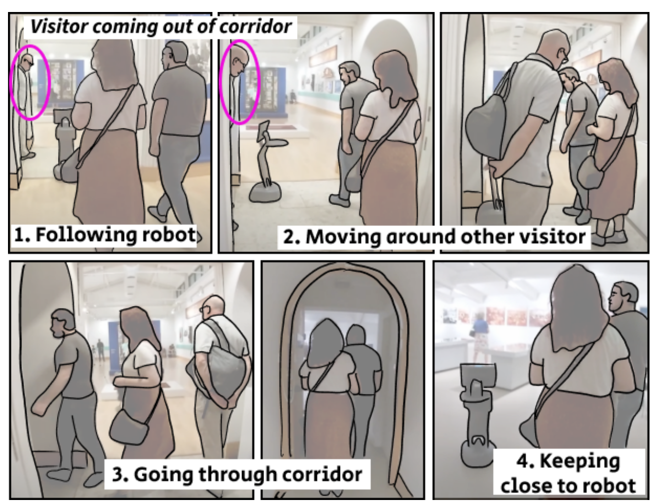

Figure 4: Maintaining cohesion while following the robot [Tour 2; moving to stop 6; end of tour; low crowd density]

establish themselves as a coherent following unit. However, there is a complication, which is that they are also simultaneously working to maintain a consistent distance from the robot as it moves. However, the robot does not do mutual adjustments back to the couple so there is a potential to be left behind, which the pair must make up for with their traversal around the gallery. In this case, the robot acts as a 'scout party' of sorts, enabling them to follow in its wake as other visitors make way for it.

This brings us to another perhaps obvious, but interactionally-significant feature of following: that it happens around co-present 'others' who themselves are also involved in their own in-gallery activities. In our fragment, the visitor in the archway is traversing between rooms as they go through the gallery. But, they abruptly stop on seeing the robot, and then step out as the robot passes, 'offering' it space within the corridor between rooms. The other consequence of co-present others is the observation that following a robot is not *just* the mechanical act of doing so but simultaneously about being categorically implicated with the lead (i.e., visibly available as a follower, following a lead). For co-present others, it may be unclear who the robot is with, so visitors being guided work to present as a 'robot-human cohort' in various ways. In our data they typically did this through (variously) maintaining proximity, looking towards the robot as they followed, acknowledging the unusualness of the activity by exchanging looks or smiles with co-present others, pointing at the robot, commenting about it, and sometimes apologising on its behalf in case disruption was caused.

For example, consider Figure 5, where a pair of visitors are following the guide robot from stop 4 to stop 5. As the robot drives ahead it moves very close to another visitor who is taking a picture of a proximate exhibit. This visitor does not seem to be aware of the robot behind them, but as they turn, one of the following pair points towards the robot, drawing attention to it. As the robot stops and begins its presentation, the pair enter a conversation with the other visitor (oriented towards the robot as a group of three, however the talk was not audible on our recordings).

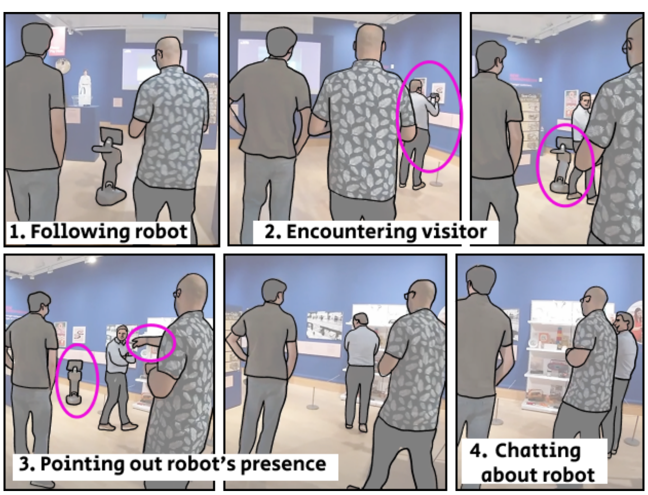

Figure 5: Encountering co-present others while following robot [Tour 1; moving to stop 5; middle of tour; low crowd density]

What we can take from this is that doing following, whether involving a guide robot or not, is best understood as intertwined with many other concurrent activities involving seemingly unrelated co-present others, such as the visitor in Figure 5 who is busy taking photos of the exhibition. This tells us there is also a moral accountability associated with being a robot-follower, as demonstrated through the pair making the co-present other visitor aware of what just drove very close by to them. This sense of what the robot does in the space as potentially becoming embroiled with and relevant to co-present others is an analysis that the followers made quite consistently throughout our video data. Once again, then, following a robot is not just a matter of matching its trajectory through space, but also what potential moral entanglements this opens one up to, as in the case here where the following pair make it clear to a co-present visitor that their photographing activity is beginning to intersect with the activities of the robot. In contrast, one can imagine the absurdity of visitors doing something similar for a human guide; no 'scaffolding' work is required there.

4.3 Stopping Following

All following must come to an end at some point, with lead and followers jointly working to halt in an agreed place. Similarly, at some point during following, the robot comes to a stop and delivers information relevant to the next (hopefully proximate) exhibit on the tour. For visitors the interactional problem is where and how 'stopping together with a robot' is done.

Figure 6 shows a simple example of this, where a couple are reaching the first exhibit (stop 2 in Figure 1). The robot they are following stops, and they stop rapidly after this too. The guide robot has to go to a specific point (stop) to deliver its content. The robot rotates slightly, but its screen remains away from them. During this, the couple remain paused for a moment. They then perform a series of exaggerated side steps (possibly performed for the benefit of the camera operator), arcing around to make the screen of the robot visible to them. During this the robot begins its presentation related to the large medicine case in front of them.

As with initiation, coming to a stop involves fine-grained work on the part of the follower in concert with the actions of the lead. A continuous concern, therefore, for those following the guide robot, is how and where a stop might emerge. The incipiency of potential stops during following means that visitors are often (but not always!) working to place a given robot movement into a broader

Figure 6: Is this stop a tour stop? [Tour 2; moving to stop 2; start of tour; empty space]

trajectory, and subsequent locatable endpoint, where they transition to this final stage in which the robot will deliver the relevant presentation. This fragment—particularly being the very first stop—shows this problem for visitors, and how they come to recognise the robot's activities as being 'the next stop'. The stop performed by the robot is not initially taken up by the visitors as such—instead they wait, then after a short time re-orient to the lack of further movement by the robot as 'the next stop', which we see in their sidestepping around to see the screen.

Stopping following may also take place around co-present others, meaning that even if the projectability of the stop is clear, there is work to do to ensure that the place of the stop is available. If there are obstacles in the way the Temi specifically will get as close as possible, make further attempts to reach the stop from other directions, and eventually 'give up' if the point is still obstructed.

Finally, Figure 7 shows an example where the next exhibit (stop 4) is proximate to a pair of other visitors. Here, a single visitor is participating in the tour and is following the robot which has driven straight ahead. It turns leftwards towards the corner of the room, close to the pair. One of the pair turns, glancing up to the visitor being guided, then back to the exhibit they are looking at. The robot does a series of backwards and forwards movements, seemingly having trouble getting to the 'desired' stopping point which is being obstructed by the pair. One of them glances at the visitor, who in turn points at the robot. The pair step aside, enabling the robot to get closer to the stop, although the visitor is still distant. The robot's presentation starts facing the wall (it has not rotated), attracting the attention of the pair who step in closer and look at it. The visitor being guided looks on from behind, somewhat obstructed.

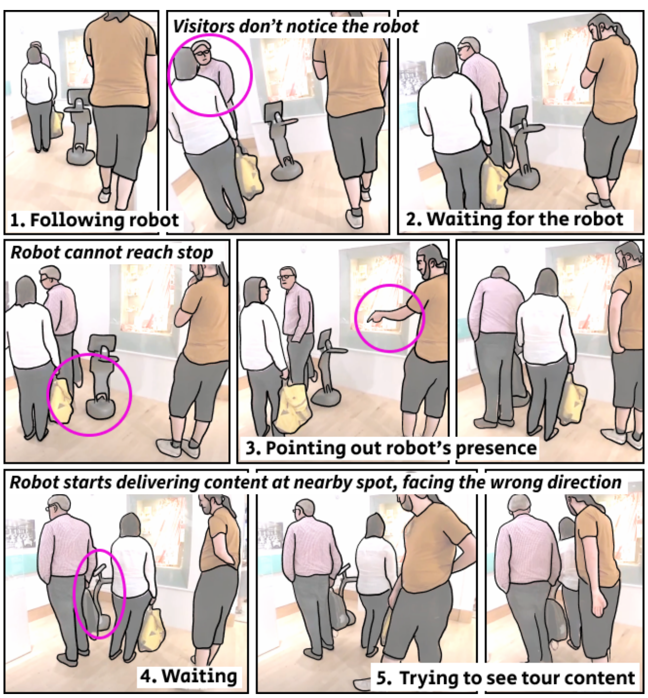

Figure 7: Visitors at the stop, obstructing the tour [Tour 9; moving to stop 4; middle of tour; low crowd density]

Coming to a stop during moments of following is more than just stopping in a specific place. We see this with the fragment—the stopping place is already occupied, meaning that the visitor, in coordination with the co-present pair, work to reconfigure themselves around the need for the robot to get to the right spot and indeed 'come to a stop' in the first place. The visitor points out the robot, leading to the subsequent reconfiguration and attention to the robot as it shifts from motion to delivering its presentation about an adjacent exhibit. Stopping following thus may require coordination between followers and co-present others.

5 Discussion

We have emphasised in detail the variety of ways visitors practically manage being led by a guide robot, and how they build its various machinic behaviours into the social space of the gallery. Echoing prior research [42], this yet again underscores how important it is for HRI to study *settings in practice*. While advances in social robot navigation and related work (e.g. eHMIs) will no doubt improve robot actions around leading human followers around, what we see at present time and time again is the ways people work to accommodate robot actions [42, 45] and envelop them within local situations. Such practices seem unlikely to disappear, because there are always contingencies arising which reside outside anticipated use and technical advancement. HRI research should reflect on how it may be designing a world where people are effectively asked to do *increasing* amounts of accommodation work [42] for robots. This "invisible work" [3, 32] will grow if we are to deploy ever larger numbers of robots into diverse everyday life contexts which require robot mobility. To conclude this paper we restate the conceptual and pragmatic insights from our analysis, that we hope can speak to technical design for HRI in these contexts and beyond.

5.1 A Conceptual Vocabulary for Robot-Guiding

Going beyond the specifics of the existing implementation we studied here, social robot navigation techniques in general will *necessarily become part of socially organised practices in situ*. Our approach in this paper enabled us to find ways of 'pulling apart' social practices of following a robot guide. Doing so offers an empirically-grounded language for HRI and social robot navigation research to conceptualise these: initiating following, doing following, and stopping following. Each component of this language can also generate design considerations for these sequentially organised stages (albeit with some overlap). While it may be that some insights are artifacts of the technical limitations of deployed robots (e.g., human followers guessing robot guide trajectories), some findings will likely be transferrable to other instances of robot-guided tours and broader social robot navigation applications (e.g., the need to manage moral accountability with co-present others).

5.1.1 Designing for ***initiation****.* Our examples show how followers continuously monitored the movements of the robot (as well as *their absence*) to infer and anticipate the direction and trajectory to the next stop. Sometimes robot motions were misleading (see Figure 3). This facet of our study is well-defined and studied problem in HRI research on legible and predictable motion [9, 10, 33]. However, our studies also demonstrate how, despite limited explicit communication from the robot, visitors were mostly able to successfully initiate following (as well as actually do following, and stop following). Visitors themselves filled in the gaps left by the absence of typical bodily and verbal conduct found in human-led guiding. For initiating following, this means that people following a robot may step away and create space for the robot to move, start moving in tandem with the anticipated trajectory, and ultimately stop and repair their own trajectory, in case they see a mismatch.

*5.1.2 Designing for **following**.* Recent HRI work has shown that public spaces in which robots are deployed are already inhabited by people engaged in their own activities which together constitute the broad social organisation of the space [4, 42]. In the case of a museum, there are observable, enduring practices through which individuals and groups move around exhibits and each other, whether they are companions or strangers [35, 56]. Robots deployed in museums will necessarily become part of this web of social practices; in their novelty they may disrupt visitors' expectations and interactions with co-present others, as we observed substantively as visitors were following the robot when such co-present others are more likely to become relevant. Concepts such as designing for an assumed set of 'social norms' within robot navigation such as quantitative metrics of comfort, safety and human preferences (e.g., proxemics, formations, orientations) [17, 52] are limited. For instance, robots will be seen as potentially relevant within the dynamic practices of moral accountability: a robot-follower is implicated in robot activities for better or worse, and may at times be held to account for them. Visitors may resist this or use their categorisation as a robot-follower to gain accommodation from other co-present visitors (to name two possibilities). For this reason, visitors closely monitored what the robot was doing and provided subsequent explanations or apologies when disruption to others in the gallery was perceived or anticipated (see Figure 5). There is burgeoning discourse in HRI about topics such as social responsibility and accountability as they relate to robots [30, 34, 62, 67]. However, we demonstrate how a far more pervasive, *mundane* sense of moral accountability is *also* present as a relevant resource for people in the midst of social interaction around robots.

*5.1.3 Designing for **stopping**.* We have shown how a robot stopping in place benefits from being projectable by followers (see Figure 6), but also, like all stages of the following/guiding phenomenon, coming to a halt has implications for the activities of co-present others. In Figure 7, for instance, other visitors did not see the robot as attempting to get to a specific place, nor did they necessarily even treat it as a 'guide' with potential supervening access to the exhibits. While there are application-specific ways of addressing such problems—e.g., from more simplistic solutions such as pre-defining multiple stop locations, broadening the stop radius, to complex ones like dynamically adapting the tour or interpreting the conduct of people around a target stop—the broader point is that design choices around stopping are specific to actual scenarios of use. This means diverse human presence and a range of naturalistic or unforeseen contextual situations need to be captured, as encouraged by recent social navigation systematic surveys [38, 52].

5.2 Specific Real-World Considerations

Integrations between existing touring approaches and robot-led ones need to be considered carefully. Our experience shows how organisational restrictions (such as budget, time, and number of available guides) led to robot guides acting as an alternative option during these in-between periods for walk-in visitors. This role as complementary service positions robot guides as a distinct experience rather than a replacement for human guides, especially if the curators and human guides are involved in curation of the robot guide system itself (see [46]).

The temporal 'ownership' of the robot came into play during sequences of following. Although we have focussed on deconstructing the organisation of this phenomenon, in some cases visitors left the sequence, abandoning the tour early. This enabled other visitors to join dynamically, piggy-backing on the tour. We found bystanders often approached the robot and 'stole' it (i.e., tapped on the next stop button) on these departures, and in a few cases from a current user with no visible indication of 'being with' the robot. This fluidity is advantageous and clearly desirable for visitors, and in some sense mirrors how one can join or depart a sufficiently large tour led by a human guide.

6 Conclusion and Future Work

We presented an in-depth examination of the social practices involved in following a robot guide deployed in a museum gallery. Through analysing video recorded instances of ten different tours, coupled with our ethnographic observations, we have shown the sequential character of the movement-based practices undertaken by the humans behind the robot i.e., initiating following, following, and stopping following. Being guided by a robot is not as simplistic as it may appear, and will involve more than just walking behind the robot from one point to another. Designing robots that take the role of a guide must account for the reconfigurations imposed onto the human follower and co-present others. This requires investigations in real-world spaces to understand context-specific practices. As this research involved a robot deployment over a short period of time and in only one setting, future work should examine the influence of long-term exposure and deployments in different spaces, as well as interactions with bigger follower groups. Future work could also expand on our initial insights and translate them into more specific technical design guidelines for robot-guided tours and social robot navigation more broadly.

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