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Opening Up Human-Robot Collaboration

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As we see robots being deployed into new places in everyday life, questions arise about what 'human-robot collaboration' (HRC) might look like there. At the same time, HRC researchers are looking to CSCW for better conceptualisations of 'collaboration', and recent work has called for more CSCW-oriented studies of HRC to support this. We address this via an ethnomethodological study of encounters between pedestrians and food delivery robots on public streets. Our analysis—using video recorded fragments of what happens on the streets—demonstrates how passers-by continuously manage walking trajectories in ways that account for robot actions; specifically we articulate how people accomplish practices of *following and overtaking* robots, *passing by* and *crossing paths* with them. We then show that the picture of human-robot collaboration is drawn with distinct asymmetries of action and intelligibility, where humans contribute considerable work to get something that looks like 'collaboration' achieved. This raises fundamental questions for how we talk about concepts of collaboration in HRC from a CSCW perspective, and how such notions can and should be applied to activities which include robots.

CCS Concepts: • **Human-centered computing → Empirical studies in collaborative and social computing**.

Additional Key Words and Phrases: ethnomethodology, public robots, mobility, participation framework, social navigation

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1 Introduction

Human-robot collaboration (HRC) research has developed a relatively narrow articulation of collaboration, grounded in the typical robotic applications envisaged by researchers (e.g., 'Industry 4.0'), and expressed by robot-centric classifications of collaboration (e.g., [3, 22, 40]). The CSCW community, in contrast, has explored computational technology's role in human (social) practices, building a significant conceptual and empirically rich set of understandings about what collaboration is. Remarking on this comparison, Johansen et al. [38]—in a recent review of the ties between CSCW and HRC—question the viability of future commensurabilities between concepts of human-human collaboration and those of human-robot collaboration. In spite of these limitations, they propose CSCW's research programme could nevertheless better contextualise human-robot collaboration for HRC research. Thus, taking up Johansen et al.'s call, we think ethnomethodological examinations

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of robots *as we find them in-the-world* may furnish deeper conceptual linkages between CSCW and HRC, and help explore alternate ways of describing 'collaboration'. This is particularly pressing as CSCW's explorations of collaboration become ever more integrated within HRC research.

Our case centres on a specific variety of public-area mobile robots [26]—autonomous delivery robots (see e.g., [18, 65, 89])—which are operating on the streets of various urban spaces in the UK. There are two incommensurate 'phenomenological worlds' at play: the socio-praxeological contexture [35] of the street produced by and made recognisable as such to its members; and, so to speak, an alternate technical 'phenomenology' of robots and robot infrastructures as constructed and operated by their designers. If we are to take the concept of collaboration seriously it means understanding these wildly disjoint worlds and appreciating the ways they are brought together; i.e., HRC's version of 'collaboration'. As these worlds collide in public places, its solution is founded in and on practical work by ordinary members of the street to accommodate the breach yawning between such radically opposing phenomenologies.

For the most part, our on-street phenomena of interest are the broad swathes of ways people there solve—in a irremediably practical sense—Ryave and Schenkein's "navigational problem" that faces 'any' pedestrian [72]. For them, this problem is the marvel of everyday conduct on the street such that people in the midst of its bustle simply do not tend to bump into each other, and are somehow able to get from one place to another with minimal disruption. In that sense we exploit the double meaning of "navigational problem"—as a technical challenge for robotics and human-robot interaction (HRI) research [51], and as a thoroughly mundane problem for pedestrians and other members of the street.

In presenting fragments of video recorded moments of people *following and overtaking*, *passing by*, and *crossing paths* with on-street robots, we hark back to memorable, formative descriptions of mundane coordinative practices in CSCW which reveal how small, fleeting and seemingly inconsequential actions nevertheless gear into one another as a joint accomplishment of (interactional) projects at play, forming (and enabling) the very possibility of collaboration itself. This is perhaps best epitomised by classic CSCW studies, which described close mutual coordination among London Underground rail line controllers [30] as well as airport operation rooms [24, 80]. Continuing in this vein, we too take an ethnomethodological perspective to scrutinise human-robot collaboration (in public streets).

The contribution of our work has three elements: Firstly, we provide detailed examples drawn from our fieldwork of how encounters between people and robots in public might constitute a certain version of 'human-robot collaboration'. This shows us how that 'collaboration' unfolds on a moment-by moment basis, but we centre on the social and moral organisation of public streets as a key cohering aspect to the practical integrity of these scenes. Secondly, we shed light on phenomenological differences in the ways humans and robots navigate the road. Our choice to follow robots forced us to engage with the robot's perspective, which is radically different from human ways of navigating through public spaces in a manner that constantly is attuned to and simultaneously produces the social life of the urban environment. Thirdly, we inspect the term 'collaboration', demonstrating that collaboration among people who happen to have technology in their places of business, and a notional 'collaboration' among people and robots, are certainly not identical and build on entirely different participation frameworks [23].

2 Collaboration, studies of public places, and HRI

To contextualise our study, we need to review work that examines the details of human-human collaboration (a familiar topic to CSCW, naturally), as well as considering how human-robot collaboration research articulates itself. However, we want to look at all of this through the lens of ethnomethodological studies. Our strategy is to subsequently introduce a body of literature mostly

from ethnomethodological studies of public urban spaces, showcasing the fine coordination work that humans engage in to negotiate movement in public. Finally, we introduce prior work in HRI that has begun to shed light on how people engage with robots in public.

2.1 Human-Human and Human-Robot Collaboration

Although unlikely to be news for readers of this paper, the concept of collaboration is at the very heart of CSCW, which aims to study and design "technologies that support or affect social, cooperative, and collaborative practices"[1]. Implicit within this stated aim is that these "social, cooperative, and collaborative practices" are *people's* practices. We think this implication is easily located, simply because in decades gone past, work in CSCW has quite comprehensively studied human collaboration in a range of different settings, from collocated teams [9, 42, 83, 91], to distributed and remote work [6, 10, 27, 32], to collaboration between strangers in online environments [25, 59, 77]. Interview and observational studies have mapped the complexity of collaboration in many environments and domains, including software development [9, 27] and data science work [61, 94], but also medical contexts [41, 64] as well as crowd and on-demand work [25, 34].

Amongst this huge body of research, we want to spotlight the importance of CSCW's historic interests in mundane and often seemingly insignificant (often fashioned 'micro') forms of collaborative activity around digital technologies in the course of everyday work. As we highlighted before, Heath and Luff [30] studied close collaboration among rail line controllers whose interwoven forms of mutual coordination are highly subtle and yet crucial for the day's work to be successfully brought off. Similarly, Goodwin and Goodwin [24] and Suchman [80] mapped the coordinative coupling of work between airport control room staff, who then reformulate ongoing runway activities via radio announcements to colleagues on the airport tarmac. Using video recordings to study how humans coordinate their activities at the level of deciseconds, such work stimulated discussion in CSCW on how awareness [31], space and place [19, 29] as well as mobility [6, 49] impact collaboration, and how design might respond to this fact.

More recently, and most significantly for the topic of this paper, a body of work in CSCW has started to appropriate and apply the concept of 'collaboration' to artificial intelligence systems [15, 37, 58, 87], for example, pointing out that people expect human-level skills of their artificial 'teammates' [95]. Similarly, robots have also become an object of investigation in their capacity as a 'collaborator' [16, 74]. Given this growing adoption, Johansen et al. [38] observe that in the emerging field of HRC, CSCW principles such as awareness and communication modalities are often drawn upon. They call for more CSCW work that can speak (critically) to what human-robot collaboration actually looks like in practice and how this 'collaboration' compares to CSCW's established understandings of human collaboration (and by implication, whether concepts of 'collaboration' make sense with respect to HRC or discussions of human-AI collaboration more broadly). We aim to contribute to such work by looking at collaboration between people who are not primary users or (co-)workers, but rather are 'strangers'[2], who engage in brief moments of something that might appear to some as 'collaboration' with robots on urban streets.

[1] https://cscw.acm.org/2025/index.php/submit-papers/

[2] Although we use this term here, we recognise that it is an inadequate gloss; see the following comment from Lee and Watson: "To us, the most odd and obscure analytic position is to assume that public spaces comprise a 'world of strangers' tout court. This is far from being the case: many categories other than that of 'stranger' pertain in public space. [...] [The use of 'stranger'] privileges the membership categorisation 'stranger' above other categorisations which are routinely available in (for instance) public space" [46, p. 2/10]

2.2 The Phenomena(l Organisation) of Urban Streets

We take an ethnomethodological perspective to investigate coordination of action, which typically happens in an unremarked upon, 'unnoteworthy' manner. Similar to jazz pianists who learn to develop "ways of the hand" [82] and become fluent players without having to articulate every choice, we want to draw attention to what we refer to as *the ways of the feet*, i.e., how pedestrians skilfully navigate without colliding into each other. As we mentioned previously, people on dense streets constantly engage in solving this—i.e., Ryave and Schenkein's "navigational problem". But such conduct is not merely mechanical action; rather, it is conduct that is fundamentally geared into members' ongoing analysis and simultaneous production of the street's social organisation [46].

Ethnomethodological (EM) studies shed light on the social formation of life in public places. To this end, work has explored how people coordinate their walking trajectories when approaching strangers [57, 78], or how they accomplish walking to a shop, passing by other people on the way as part of making sense of the streets' deep visual, categorical order [33]. Studying how social order in urban places is practically achieved, ethnomethodology examines how people produce their activities so that they are formulated as recognisable categories of action, such as being "normal" vs. "loitering" [52] and "crossing" vs. "waiting" [53]. Thus, EM studies seek to recover, from the perspective of members of the street, just how people can produce and distinguish, say, "normal" walking speed [33] from running [2, 76], or how pedestrians may conduct themselves and be seen as walking together with someone else, or alternatively as walking alone [72]. Finally, ethnomethodological work also has had particular interest in technologised mobility and thereby intersects with work in human-computer interaction, with studies ranging from e-scootering [85] to driving autonomous vehicles [11].

While such an interest in the public life of the city and urban environments is nothing new in terms of the broader context of fields like urban studies and human geography, ethnomethodological research like this connects with calls to focus on "the mundane and the 'familiar'" [36] in studies of urban mobilities. That said (and as detailed in the next section), EM resists the application of theoretical frameworks being 'read into' members' actions [14]. Instead it asks what those actions are *for members of public scenes themselves*.

2.3 Collaboration Between Humans and Robots in Public?

Robots in public spaces have been studied primarily in the field of HRI. Many early studies focussed on the deployment of robot prototypes in airports, museums and train stations [4, 39, 90, 93]. This work has demonstrated that besides the envisioned users, robots may encounter myriad others, who may be co-present as, say, bystanders or passers-by. Such work is typically focused on broader behaviour, paying particular attention to supportive and inhibitive actions, such as helping or blocking robots [4, 13, 18, 90]. In recent years, ethnographic studies have examined delivery robots [18, 65, 89], beginning to document forms of interaction specifically with fleets of robots in places within the USA and Europe.

While the majority of work in HRI traces an intellectual heritage from engineering or psychological disciplines, and tends to be primarily interested in problems of *acceptance* of robots in public spaces, ethnomethodological and conversation analytic (EMCA) studies of robots have instead begun to show how robots come to be encased within social organisation itself [70]. Initially such work was concerned with humanoid robots, typically in settings where users are not interacting alone, but in groups leading to dynamic participation [1, 66, 71, 86]. More recently, EMCA work has studied the organisation of social interaction around robots deployed in public spaces, such as with trash barrel robots in a public plaza [12] or pedestrians' and cyclists' interactions with autonomous shuttle buses [55, 62]. This work uncovers the intricate ways humans accommodate and scaffold

robots [54], based on and continuing foundational work by Suchman [79], who demonstrated the contrast between assumptions of *planned* behaviour in the design of photocopying machines that modelled users, and the emergence of contingent, *situated* actions in actual interaction with users. Building on this, we raise the question of whether we can and should apply the concept of 'collaboration'—in the rich sense in which it has been described in CSCW—to robots.

To sum up, recent work has called us to closer inspect the concept of 'collaboration' in HRC from a CSCW perspective. As ethnomethodological work has uncovered, interaction on the road is a setting in which collaboration among strangers happens constantly, and technology plays an important role. Many robots are purposefully designed to be 'collaborators', taking the role of an interactant or agent in the interaction. This role becomes particularly salient when robots are increasingly autonomous and unaccompanied by operators, such as during deployments in public, where they encounter a range of people who are not the primary users of the technology. We think it is clear that such settings offer a premier opportunity to directly inspect 'human-robot collaboration'.

3 Approach: Studying robots as we find them in public

Our approach is ethnomethodological in character. It sits within a frame already established by prior work that is EMCA-informed in that it tries to describe the phenomenon of social order in urban places as *autochthonous*, i.e., as produced in and as the place we find it, and as having its sense inextricably intertwined with the scene of its production. Another way of saying this is that the kind of sociality we find in urban settings is 'native' to its site of production; it is not beneficial to impose order from outside, such as counting crowd activity [50] or learning about mobility from looking down at crowds of people [48]—instead we need to be 'in the thick of it', seeing as members of the street do. To this end, we are interested in understanding how 'the street'—as an exquisitely organised yet simultaneously deeply mundane and familiar place—treats the presence and machinic actions of robots that provide delivery services. Our approach does not seek to disentangle robots from the street scenes they are embedded within; instead we approach the street, its members and their practices, as a gestalt [35, 60] into which robots are engulfed. And we (as investigators, and likely you too as readers) understand people's ways of being on the street, of street happenings and activities, of at-a-glance apprehensions of states of play, because we also *are* creatures of the urban streets that we study.

Practically, we focus on what happens between two points of delivery enacted by Starship food delivery robots; between vendor and customer, as robots progress through the streets to their destination. This reveals many fleeting, momentary, and overall subtle points of encounter that become lodged within the fundamental, socially organised character of robot-inhabited streets. We focussed on Starship Technologies' robots as these exist in the form of various fleets in UK locations, having been in operation since 2018 in Milton Keynes (a city that is home to one of the authors). At the time of writing, this service has extended to various further places in the UK: Wakefield (Leeds), Trafford (Manchester), Northampton, Bedford and Cambourne (Cambridge). At the time of data collection (2022-2023), we focussed on the two most long-established locations: Milton Keynes and Northampton (operating since 2020 [17]).

What we present in this paper is drawn from three days of video data collection (approx. 6 hours in total) in these locations between August 2022 and March 2023. Ethics approval for this study was granted by the University of Nottingham Computer Science Research Ethics Committee (ref. CS-202-R58). Although filming in public in the UK is generally legally permissible, we established various policies for video data collection that were specified to and approved by our ethics committee. Since the locus of our capture was the robots themselves, we adopted a policy during fieldwork of avoiding recording people unnecessarily (i.e., if they were not nearby a given robot). We were

also particularly cautious to avoid capturing children where possible. If we were following a robot order made by people other than ourselves, we always stopped recording before the delivery was received by a customer. During fieldwork, we went in pairs (at least) for safety reasons, and we carried information sheets and identification, should we be queried by anyone during fieldwork, or if we felt it appropriate to provide clear disclosure on the basis of some on-street interaction. Post-processing of data (as presented in video stills here) added extra layers of privacy through the use of anonymising filters which seek to balance clarity of the fragment being presented against protection of the identity of people on the street (including faces, clothing and location). However, as with any ethical consideration for research practices, we note the need for a continuous adjustment and reflection by fieldworkers to exercise judgement both during and after the fact. Hence, we present specific fragments in this paper on the basis of that ongoing consideration.

Our investigation was broadly ethnographic in style, albeit ethnomethodologically-oriented, sitting in a well established tradition of EM-informed video-based studies of interaction common within CSCW (e.g., see [30, 67]). Two investigators (Reeves and Cantarutti) conducted fieldwork at our research sites, collecting video recordings from two different cameras (see Figure 1), as well as ethnographic notes during and after the visits. Given that our interest lay in the gap between delivery despatch and receipt, we worked both opportunistically and purposively in tracking the robots. For the former, we stayed near 'hubs' (i.e., concentrated areas where robots were parked in a characteristic fleet) and spontaneously encountered robots on delivery as we did so. For the latter method, we created orders ourselves so that we could capture robots' journeys through the streets from start to end.

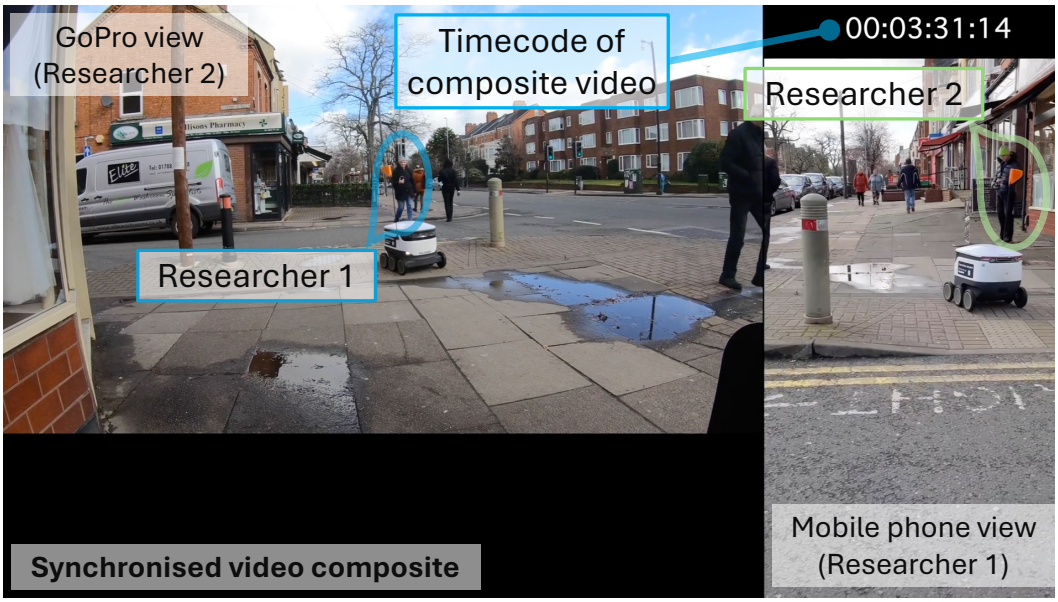

Fig. 1. Our approach to data collection. We employed two video cameras (one per researcher) to document our fieldwork. This provided us with a wider angle shot via GoPro (left), and a more focussed perspective via mobile phone (right). The videos were then synchronised, composited and timestamped as per the still presented here. These recordings provided us with an aide memoir for our reflections on the ways that delivery robots are embedded in the midst of social order on-the-streets.

Our video recordings represent something akin to helpful reminders [20, p. 38] of on-street phenomena we witnessed in-person, and of course simultaneously providing—as in this paper—'exhibits' of such phenomena, arranged in such a way that they provide lucid descriptions which help us reflect together on 'human-robot collaboration' set against living practice. Video fragments presented here thus were selected on the basis of illuminating these topics for the reader. Given that our focus is on 'collaboration' we selected for presentation parts of our video data where there are the most clear (but often fleeting) moments of proximity and interaction between people on the streets and robots.

There is further ethnomethodological significance to our fieldwork practices. The act of video recording itself surfaced key phenomena for us as investigators. For instance, our attempts to follow and record video of the robots taught us much about their mobility. Our practices led us to experience moments of exasperation, surprise, joy, amusement, concern and boredom, to name a few. We better understood the social relevancies of publicly videoing the robots, and how this appeared to others on the street, as well as how it provided grounds for occasional conversations with others on the scene about the robots. In our interactions as investigators with people present on the streets (in almost all cases, exchanging comments about the object of our recordings, the robots), the 'recordability' of the robots and indeed our recording of them was treated immediately as an entirely normal matter—we simply did not need to explain why we were recording. Our video recordings also enabled us incidentally to capture conversation between investigators as our fieldwork was taking place, which had the purpose of topicalising salient matters that—while evident at the time of us experiencing them unfolding—nevertheless sometimes turned out to be far less obvious or even available on video after the event.

Finally, we note that our fieldwork and data collection necessarily has its various limitations and constraints. Firstly, we cannot know how frequently members of a given street scene have been around such robots before; whether this is their first time encountering them or their one hundredth time is not necessarily evident. This may well play a role in how they treated the robots, yet such practices which manifest these prior experiences are nevertheless as accessible or available to us as investigators as to 'anyone' on the street. That said, we feel more confident in saying that, by and large in our fieldwork, the delivery robots in locations we visited were overwhelmingly *not* attended to in any marked, noticeable way (although in our data fragments we will unpick this in detail as the assertion is itself problematic—in fact there is a vast range of quite subtle ways people on the street *do* conduct actions related to robots).

A second limitation lies in our choice to follow individual robot units. Looking at the street-side alone does necessarily hide important infrastructures and organisational features which sustain and underpin the 'surface' of robot activity that is encountered on the street. This behind-the-scenes aspect is often hidden as with many AI-driven applications [63], having the effect of eliding or obscuring systemic accountabilities. However, in choosing to centre the perspective of members of the public out on the streets, we also wish to take that perspective seriously, in that such people likely know or care little about robot operations behind-the-scenes. We as investigators out in the field sometimes speculated on the observable moments robots *could* have been running more or less 'autonomously', or handed over to a human operator, yet we too were ultimately as unsure as anyone else might be. And besides, our professional interest was in studying robot behaviour rather than passing through, shopping, cleaning windows or running a restaurant, so our observations were probably more keen than the 'typical' person on the street.

Thirdly, we also recognise our limitations as investigators with a certain set of bodily and mobile capabilities. Neither of the fieldworkers is disabled physically or has any visual or aural impairments. This shapes our understanding and experiences as investigators, and thus some of our insights on

pedestrian experience with and around delivery robots in public. Further investigations need to be conducted that better centre such members of public places [8].

4 Walking trajectories in robot encounters on the streets

Our examples focus particularly on "walking trajectories" [57] and how such trajectories are made and remade with respect to this new class of mobile entity in public. Although such trajectories are massively, routinely and pervasively conducted, they hold within their mundanity some hints at what we might mean by 'human-robot collaboration'. Thus, looking at how people treat robots in various different circumstances and configurations in public lets us glimpse the great depth and subtleties of on-street action that enfolds public robots in actual practice. Our selection of video fragments represents (at a small scale, owing to the space available) a much wider range of ways people on the street encounter and deal with public robots, as a daily, routine and deeply mundane occurrence.

Our strategy here is to present three distinct sorts of walking trajectories, and how public robots become entangled with them. In line with prior EM research [33, 46, 57, 72, 76, 88] we highlight bodies' work *as a method of reasoning about public space*: both in terms of how bodies are "displayed in space" [46, p. 11], what people's bodily actions are, and how those actions simultaneously act as analyses of local scenes (i.e., an ethnomethodological sense of the reflexivity of social actions [21]).

Firstly we look at what it means to be **following and overtaking** robots. This provides a basic lesson on machine mobilities and their trajectories. Secondly we explore **passing by** robots. Here we introduce issues around the moral ordering of the street. Thirdly and finally our data fragments highlight moments of **crossing paths** with robots. This draws our focus onto what it means to deal in machinic 'negotiation' with robots.

4.1 Following and Overtaking Robots

A pedestrian (P1) holding a shopping bag is walking a few metres behind a robot travelling in the same direction as them along the pavement (sidewalk), see Figure 2 A. P1's lateral position is to the left of the robot's B. For a period of time (around 12 seconds) the distance between P1 and the robot is maintained. Then, the robot's speed reduces significantly and it drifts leftwards, slightly speeds up, and drifts rightwards a little. The overall effect is to reduce the distance between P1 and the robot rapidly C. The robot's ongoing weaving trajectory is as if avoiding objects. Some candidate causes seem to be things like lamp posts or bins that are on the right hand side of the pavement (although it is difficult to fully account for). The net result is that the robot's lateral position is now more to the left side of the pavement (compare relative positions in B and C). P1, in response to this, has also moved further leftwards. The robot is now very close to P1 *and* more directly in line with P1. Next, the robot conducts an 'emergency stop', braking so hard its rear wheels lift in the air D. P1 now stops too, left arm swinging out to steady against the momentum shift of the action E, then immediately turns slightly and sidesteps leftwards as if starting to overtake the now stationary robot F. However, the robot starts rolling forwards again, and P1 continues walking towards the right hand side of the robot G, finally overtaking it as they both approach a road crossing H. P1 subsequently crosses the road while the robot waits for a much longer period before doing its own crossing.

The most immediate analytic point to draw from this is the significant amount of continuous adjustments made by P1 in response to the movement of the robot. Following a robot like this one involves judicious management of distance as well as dealing with the specific character of its mobility. We can see how the various movements of the robot—its wandering position on the pavement, variable speed, as well as its sudden stop—need to be dealt with by P1. P1's actions, such

Fig. 2. **Following and Overtaking**. A pedestrian (P1) is following a delivery robot (A). The delivery robot drives in a somewhat meandering way, gradually arriving at a more leftwards position laterally on the pavement and having slowed somewhat, closing the distance between the pedestrian and the robot (B, C). The robot brakes abruptly (D), causing the pedestrian to also stop immediately (E), which then leads to them sidestepping (F), perhaps to get around the now-stopped robot. However the robot starts driving again (G) while the pedestrian moves rightwards to overtake the robot, heading towards the road crossing (H).

as adjusting lateral position, rapidly halting mid-step, rotating their body towards potential gaps either side of the robot, present us with two things: one is that there are emerging (and foreclosing) saliences in the potential spaces opening to overtake the robot [47, ch. 1], which is troublesome to follow; and second that P1's bodily analyses suggest some significant challenges in anticipating what the next actions of the robot might be. Our analytic points here rely heavily upon the ways that P1's bodily accounts very much reflect our own as investigators when we too attempt to follow or sometimes overtake robots.

Now, problems like this—of following and overtaking others on-street—are not somehow entirely alien to people in the midst of 'any' street scene; in reality there is a distinct set of moral and categorical orders to such routine events. Watson's description of pedestrian movement on train station concourses comments on the local production of "flow-files", i.e., moving queues of unrelated persons who—immediately recognisably to others—manage their distance in space as they traverse a busy concourse:

> In the main hall of the station in Lausanne, relatively sparsely occupied, a flow-file of four people walk diagonally across the hall. The file is of four single people, one following the other, with the first person's gaze fixed on the far corner of the hall, where there was a wide corridor leading to an exit. The file appeared to be the only connection between these people: they exchanged no talk or other movement. Single persons or two or more persons accompanying each other and coming in the opposite

> direction, veered (if necessary) out of the way of the approaching file. The leader of the file set the pace and the other three followed at, perhaps, somewhat more than an arm's length. There was plenty of room for those people to walk individually had they so elected. Each individual kept his/her place in the file: there was no promotion or demotion in turn order. [88, p. 206]

At the same time, following also has its own familiar troubles. As Hester and Francis describe in their account of the availability of visual categorical order in public streets:

> occasionally the local circumstances are such that one's pace cannot be sustained. [...] Although much of the time persons walk at what is recognizably 'normal walking pace', some users of the street may move at a pace that is noticeably 'slow' or 'fast' relative to this. In such circumstances particular navigational problems may be created. [33, p. 43]

Following is inherently connected with overtaking. Mondada and Tekin [57] show how on-street "coordination supposes and relies on the intelligibility and projectability of incoming and upcoming movement trajectories of walkers and bikers, through which mobile persons secure their accountable co-presence in public space" [57, p. 7]—in other words, there is a moral order of followers and followees that forms street scenes just like this one.

In contrast, in our fragment the sense of 'collaboration' is troubled precisely because of the absence of mutuality. This is not to say that P1 does not ultimately accomplish their own walking and overtaking trajectories successfully, but rather that the actions of the robot appear quite unintelligible with respect to any potential for *mutual coordination*. Conduct on the street is accountable, that is, people search for as well as produce bodily, verbal, etc. actions that are oriented to their recognisability as such to other street users. As we see from the wandering and variable speed of the robot's trajectory, core elements from this natural accountability are missing in action-design. Instead the robot acts as a kind of mobile obstacle.

However, in spite of this absence of reciprocal coordination and difficulties in seeing the robot's trajectory *as a walking trajectory*, P1 nevertheless gets by relatively unimpeded in this case, and the robot too carries on its journey. In other cases, pedestrians may not be so lucky.

4.2 Passing By Robots

At the extremes, passing by others in public spaces is a signature example of mass bodily collaboration amongst a crowd of complete strangers, such as in the famous Shibuya pedestrian crossing in Tokyo or in pretty much any other busy crossing around the world [48, ch. 6] (also see [47, 92]). Yet, as we have argued already, resolving Ryave and Schenkein's navigational problem is a constant feature of any urban environment, even ones with relatively a small number of people present who happen to be passing through. The way space features as a resource in passing by is critical, as Hester and Francis point out:

> As co-occupants, the users of the pavement have the practical problem of negotiating their way past one another with minimal interference and disruption. It is this that makes the assessment of the usable space for accomplishing 'passing by' an observable-reportable matter. [33, p. 44]

Here we look at a series of short but varied exhibits of pedestrians methodically dealing with passing by robots; i.e., both they and the robots are moving against one another. As before we will be preoccupied with bodies, space, and distance. It is in passing by others that matters of moral order and normative 'rights' on the street also become more apparent, building on the previous section. Our strategy here, though, is to examine moments of ever increasing proximity and ultimately bodily troubles that (for the most part) people on scene work to resolve.

Our first fragment shows a cohort of three pedestrians encountering a robot head-on (see Figure 3, A through to E). This particular robot is en route for a delivery (having just been loaded by a shop worker moments before). The pavement space here is significant: as we can see in Figure 3 A, it is wide. The pedestrians (P2-4) work as a cohort to adopt a bulging or bubble-like spatial formation as the robot drives towards them, and as they walk towards the robot. In B there is a clearly visible "walking-together" [72] that is made immediately available at-a-glance: i.e., these three people are maintaining group coherence [84] via proximity, looks, and bodily shifts. Next, as the robot heads towards them, the group disperse slightly, moving into a gentle arc that describes a consistent radius away from the robot as its centre. At this point the robot also abruptly stops C. The group continues, as does the robot albeit more slowly this time. The leftmost[3] person (P2) is slowing to swap the bag in their hands D (shaking their now free hand out on release). P2 plays catch-up with P3 and P4 who continue arcing further around, as if reverting to their original walking trajectory like nothing happened, E and F. A quick glance back at the robot by P4 E, some reconfiguration of the group formation F, and both they and the robot continue in their respective ways.

Fig. 3. **Using a 'Bulge' to Pass By**. A group of three pedestrians (P2, P3, P4) are walking towards a robot that is also turning towards them on a wide pavement in front of a grocery shop (A). As the pedestrians continue their walking trajectory, the robot is headed in their direction (B). As their paths intersect, the robot brakes abruptly (C) while the group arcs around the robot (C-F) with P2 lagging slightly behind the others. During this arc, the robot continues on its way (E-F).

Our second fragment in this section features two pedestrians approaching a robot on a much narrower pavement. There is space for two abreast and no more (see Figure 4 B). Again, there is a clear togethering of these pedestrians: they act as a pair. As they approach a metal post, the robot in this scene is also heading towards them A. P6 (on the right of image B in Figure 4) begins moving in front of P5, producing a line or flow-file [88] type formation as we described earlier. Soon the robot is passing the post and stops momentarily C, then continues to move as P5 and

[3]Leftmost as viewed from the robot's perspective.

P6 squeeze around the post D, with P5 and P6 walking on the 'tightrope' of the kerb that runs between the post and the road surface.

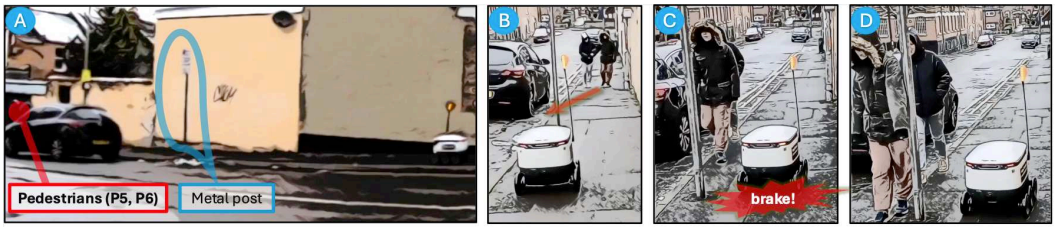

Fig. 4. **Reconfiguration by Squeezing Past a Post**. A pair of pedestrians (P5, P6) are walking towards a robot that is also heading along the same pavement (A). The pedestrian on the wall side of the pavement, P6, walks ahead of P5 towards the kerb, forming a line or "flow-file" / moving queue (B) in anticipation of the upcoming squeeze past the post (C-D). During this, the robot brakes (C) and then continues on its way.

We can now reflect on what these two fragments show us. Much like our description of following and overtaking in subsection 4.1, there is clearly a vast set of continual bodily adjustments made here that enables passing by any given robot, both as an individual and group activity. We can only hint at the sheer detail of these adjustments in our brief descriptive sketches and video stills. Nevertheless, common across all our fragments here is that members must work on and work out how to do passing by others, and how close for any given passing. Members' concern for this is perhaps best illustrated by the ways proximity is managed around people attempting to approach others in the street such as in marketing, sales or charity representatives [56]. Pedestrians, therefore, are acutely concerned with the way spatial configuration is dealt with, how they appear visible as a group (or not), as well as what its moral implications are (e.g., being rude, polite, or unaware).

The relevance and availability of categories like walking-together is highly important in the way they bring with them the concerns of situated moral order. As Ryave and Schenkein note, "for the culture we are describing, it is expected, it is proper, for the lone walker to do walking-around those decidedly doing walking-together" [72, pp. 267-268]. For the group in Figure 3 in spite of the wide pavement, the robot is driving directly towards them without deviation from this path. Ultimately it is this group that reconfigures itself, while retaining coherence and recognisability both from within the group and without as being 'together'. The robot response here is collision detection (braking) rather than something that looks more like detecting the formation of 'togethering' up ahead. Similarly, the pair in Figure 4 give way to the robot in their path, even to the extent that they too visibly anticipate the upcoming need to yield space on the pavement and project the consequent squeeze their walking trajectory will entail past the metal post (see [72, p.270]) by forming a moving queue. Their bodily actions thus present—very early on—an analysis of the robot itself, and of the upcoming passing by; specifically, that it is *they* who will have to do the work to avoid the robot rather than the other way around. Their very bodies therefore offer a striking account of mundane on-street reasoning about expected robot capabilities and the potential for 'collaboration'.

The third fragment we will now look at closes the spatial gap further between pedestrians and robots (Figure 5). While the footpath here is much wider than the first fragment in this section, a pedestrian and the robot are heading directly into one another's path A. As the gap is closed between P7 and the robot, the robot brakes hard, with rear wheels visibly lifting B. P7 on the other hand deviates only slightly from their original walking trajectory and—almost at the last moment—rapidly swings around the left side of the robot and clears the space C. The brief moment

of closeness over, the robot subsequently performs a turn rightwards (as if belatedly responding to the detection of an obstacle, although one now long gone) and starts driving again, arriving shortly at the road crossing.

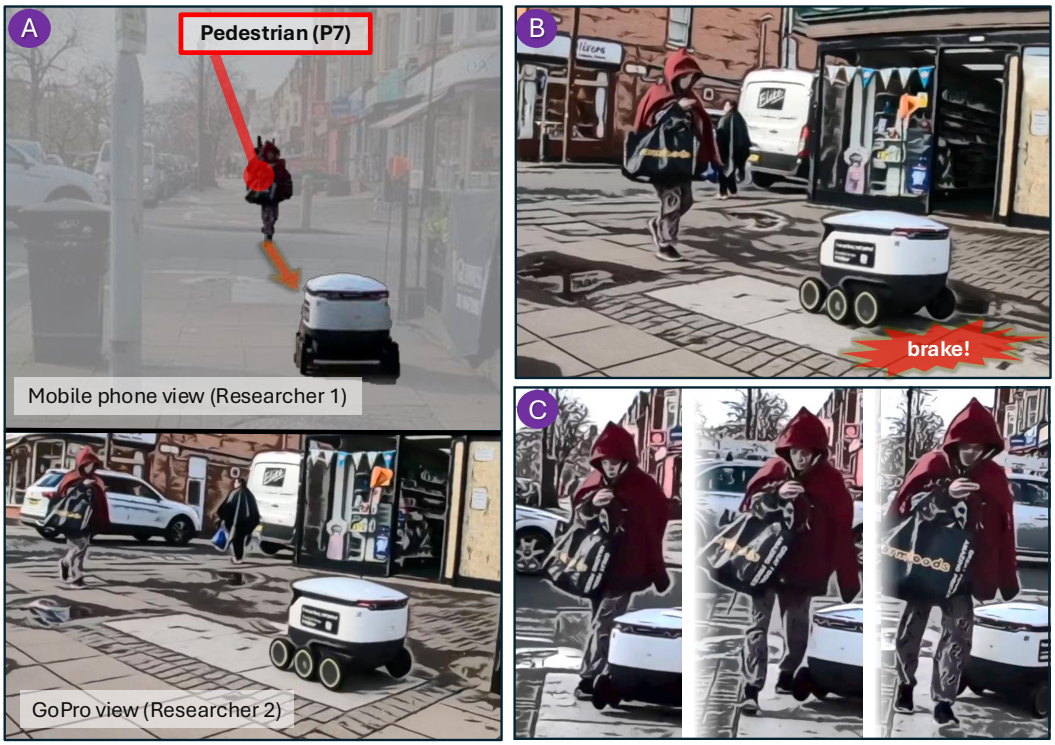

Fig. 5. **A Close Scrape**. Crossing a road, a pedestrian (P7) and a delivery robot are on identical but opposite trajectories across the pavement (A). As distance between the pedestrian and the robot is reduced, the robot brakes suddenly (B), while P7 continues rapidly walking towards the robot, swinging close and almost touching it as they avoid the obstacle in their way (C). During this encounter the robot turns and continues driving onwards at an angle.

In contrast with the prior two fragments, this is perhaps the most minimal possible version of passing a robot by. Yet it involves P7 nevertheless making way for the now-stationary robot with a quick deviation from their existing walking trajectory. The response from the robot is to brake hard, and then to deviate from its prior trajectory in a way that takes place well after the very fact of the passing by has taken place, when all is largely done and dusted and really no longer relevant. We might contrast this with the Shibuya pedestrian crossing where hundreds of people perform many 'close scrapes' just like these at just the right time, just the right place. To do so mutually requires competence in managing—collaboratively—factors like "direction, pace, and body attitude" which are then "all mobilized to ensure that the moment when the passer [is] in precise physical co-presence with the one [they were] passing would only be a fleeting one" [72, p. 273]. In this sense too, managing proximity is a moral matter, i.e., that such fleeting proximity is designedly integral to the normative organisation of doing passing by.

Our final fragment in this section contrasts with the others in that it involves a pedestrian—this time pushing a buggy—stopping rather than passing by. We have already seen members of the street

yielding space for robots in one way or another in passing by, such as: creating distance between them and the robot, reconfiguring their local cohort, or performing swift bodily redirections. But here it reaches a maximum. As shown in Figure 6, the robot's trajectory on the pavement diverts it around a bin that has several extra bin bags placed against it A; as a result the robot is driving towards the centre of the pavement space while a buggy-pushing pedestrian (P8) also approaches from the opposite direction. P8 seems to anticipate a projectable moment of passing by moving the buggy (and their walking trajectory) to the hug the shop fronts A. The robot—reaching the middle of the pavement now—continues, however, driving further towards the shop front side of the pavement B. P8 moves even closer to the shop front edge and then stops to avoid a possible collision. The robot straightens, drives immediately forward C, then steers leftwards slightly D, during which time the buggy-pushing pedestrian then visibly blows out their cheeks in an exasperated manner (not visible in Figure 6, but clear on video and highly noticeable in person). P8 then begins pushing the buggy once the robot is clear.

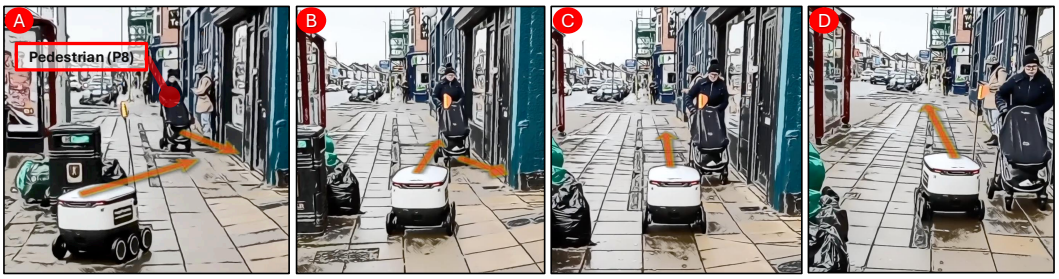

Fig. 6. **Fully Yielding**. A robot is driving along the pavement, but turns in a rightwards direction as its path is obstructed by a bin and some excess bin bags placed next to this bin (A). At the same time, a pedestrian pushing a buggy (P8) is heading in the opposite direction, steering the buggy towards the shop fronts (A). Although clearing the bin, the robot continues to drive towards the shop front side of the pavement; P8 pulls the buggy even closer to the shop front but has to stop entirely (B). The robot straightens and continues driving forwards (C-D) while the pedestrian remains stationary, visibly blowing out their cheeks in an exasperated expression (D).

Like the other examples in this section, the buggy-pusher visibly anticipates the need for managing space, making way for the robot and reconfiguring their use of the pavement as a kind of 'proffer' for how passing by could proceed. Yet, this ultimately does not work and P8 ends up in a turn-taking type environment with the robot where someone must go first (a result of the robot's lateral position on the pavement). While the robot seems to optimise pavement position on the basis of obstacles, the clear need here is for acknowledgement of the moral order of passing someone pushing a buggy as a feature of how turn-taking may be done on the street. For the culture we are investigating, a buggy-pusher is a visual category that normatively would be seen to have rights to go first in many circumstances where space is tight. Yet here it is *they* who yield for the robot. And, most interestingly, they subsequently provide a bodily account (blowing out their cheeks) of the (social) objectivity of this norm in doing so. Simultaneously this perhaps also points to an expressive recognition on their part that such categories and their associated moral implications are simply irrelevant to robots.

4.3 Crossing Paths with Robots

Our final section of analysis turns to the other possibility with walking trajectories: intersecting or crossing paths. We have seen how people following and overtaking robots must deal with

alternate (machine) mobilities as a fundamental shift to managing walking trajectories, and we have developed this by looking at the ways moral order and visual categories infuse the circumstances in which people pass by robots. Here we extend the last example (Figure 6) by looking at how turn-taking unfolds with a robot, and how that turn-taking exists within a potential framework of multiple interconnected projects in play for members of the street.

Here we join a robot as it moves towards the entrance of a shopping centre, see Figure 7 **A**. There are three pedestrians moving with separate and different walking trajectories towards this entrance; we are primarily concerned with P9 **B** and P10 **C** who are moving orthogonally to the robot's direction of travel. As the robot continues to approach and cross the entrance, P9 is walking rapidly across its future path (see **B** and **C**), likely leading to the robot braking hard **C**. At the same time as this particular intersection happens, another, different intersection is simultaneously unfolding between P10 and the robot. Just prior to the robot braking, P10 is also walking towards the entrance, albeit slower than P9, and is looking towards the robot. P10's trajectory is coming to a stop, yielding for the robot as it continues to move. On braking **C**, P10 has already stopped, still looking at the robot. After a momentary hesitation, P10 takes the initiative and begins walking **D**, however, the robot starts moving again shortly after, turning leftwards slightly **E**-1 and driving forwards to P10's trajectory **E**-2. P10 is moving fast, and clears the area **F** while the robot continues driving further ahead.

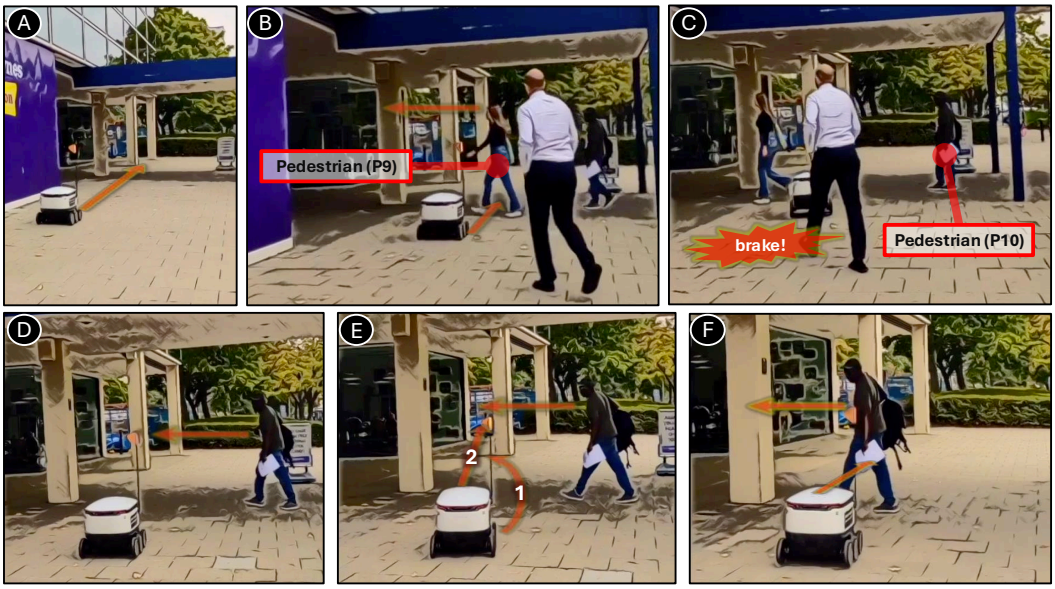

Fig. 7. **Dealing with an Intersection**. A robot crosses an entrance to a shopping centre (A) while three pedestrians approach the entrance from different directions. P9 and P10 have trajectories that are orthogonal to the robot's (B-C); P9 crosses the path of the robot (B) and the robot brakes forcefully just after the intersection of paths (C). Just before the robot brakes, P10 pauses momentarily while looking towards it. After brief hesitation, P10 then makes a move towards the entrance (D). Shortly after, the robot turns (E-1) and then begins to drive towards the emerging trajectory of P10 (E-2). P10 clears the space while the robot continues its driving (F).

There are several points to surface here. As a case of intersection, we can point to the availability of the particular space here being a potential crossing point. This is not a formal crossing in the same

sense of a road crossing with a kerb, change of surface, road markings, signs, etc., but it nevertheless is visible as a possible point at which intersection is likely, being an entrance to a building. Going this way thus holds the potential for encounters where coordination between pedestrians via turn-taking could be on the cards. It is what Liberman [47] describes as heterogenous phenomenal fields of emerging possibilities which involve everyday street practices of looking and recognising, negotiation, and the competence to see specific emerging saliences (e.g., openings to "skate through" [47, ch.1], or in our case here, a moment to seize passage). So, although it might just appear as another linear path to a robot, we must foreground that these rich potentialities are nevertheless present, there to apprehend, for 'anyone'.

There is another interesting aspect of how the robot and pedestrians intersect one another. The braking of the robot as a result of P9's trajectory has the additional effect of also being treated by P10 as a yield of 'turn' in the shopping centre's entrance space. The interactional and moral order of the street is formed in and as such matters—reciprocal treatment of one anothers' actions as morally accountable, and as recognisable in their mobility [28]; for instance, slowing or waiting to give way to others, recipients of the yield speeding up to pass through quickly, glancing and smiling in recognition, and so on. The matter at issue here is how the machinic action of the robot in response to one on-street event (with P9) *may* lead to a relevancy for other local, ongoing activities. In this case, P10 treats the brake as something different to 'braking for P9'; instead it forms emerging salience or opportunity for P10 to act upon. The problem is that the apparent 'turn' offered by the robot quickly gets rescinded as it continues on its way. While pedestrians make judgements about what is happening as a matter of the social organisation of the local circumstances of the street, robot activities must be brought into that order and made at home. In this example, therefore, we see how this 'domestication' took place amidst normative orders of managing turn-taking at intersections between orthogonal walking trajectories.

5 Discussion

Our analysis has purposefully sought out encounters between members of the street and delivery robots as a method of exploring what 'human-robot collaboration' might be, concretely, for mundane and everyday circumstances. Instead of focussing on more obvious moments where, say, people explicitly help or hinder robots [4, 18], we have highlighted those that appear to be far more numerous albeit brief encounters, forming a much wider field of potential 'collaborations' between people and robots. In a future anticipated by some, such robots will be more common, and therefore these seemingly minor situations in which pedestrian walking trajectories become entangled with robots' machinic trajectories have the potential to gain a much larger significance. To this end we have centred our analysis on three ways that walking trajectories may intersect with normal robot activities. By looking at *following and overtaking* (subsection 4.1), *passing by* (subsection 4.2), and *crossing paths* (subsection 4.3) with robots, we learn more about the potential complexities of these small, momentary, yet highly frequent interactions. This focus also highlights the potential resonances with classic CSCW concerns around examining collaborative action in detail. We use this discussion to reflect on some ongoing concerns we might have within CSCW about HRC's awkward relationship to it, concerns which should be addressed if we are to move forwards productively.

5.1 Situated Action, Again, But With Robots

The intellectual resonance of some of CSCW's earliest and most influential studies seems clear to us and worthy of reminding ourselves of their continuing importance, particularly in their relevance for HRC and its concomitant connections to CSCW. We singled out work by Heath and Luff [30], Goodwin and Goodwin [24], and Suchman [80] as exemplars of CSCW's initial ways of tackling the expansion of interest in the sociality of technology use [5, 44]. This approach focussed

branches of CSCW's development on the 'guts' of interaction and their potential significance for designing collaborative technologies. A big chunk of this work in CSCW was informed by ethnomethodological and conversation analytic forms of investigation (although certainly not all). And, for its EM-informed elements at least was (and is) certainly broader in potential than simply 'informing design' [19], including conceptual respecification and critique [68], as evidenced for example by Suchman's rewritten account of *Plans and Situated Actions* [81]. Jumping ahead to the present day, we think there is a significant opportunity for this form of research—which, following Suchman, often (erroneously) gets called a "situated action" approach [79]—to pay close attention to the material, moment-by-moment practical action that people engage in around robots, which we believe forms a central element to burgeoning interests in human-robot collaboration. Our studies are initial forays into the opportunities in this space, as are those of Alač et al. [1], Brown et al. [12], Pelikan et al. [65], Pitsch [66], Rudaz and Licoppe [71], Tuncer et al. [86], to name a few. To fulfil the challenges identified by Johansen et al. [38], and to clarify the wider discussion on 'human-AI collaboration', it is an ideal moment for CSCW's rich heritage in unpacking situated action to be drawn upon once again.

5.2 Human-Robot Collaboration is Not Collaborative?

Taking a CSCW perspective on encounters between people and robots—particularly one that roots us in historic ethnomethodological traditions within CSCW—reveals that there are distinct differences in what we might possibly mean by 'human-robot collaboration'. In our view, CSCW's original formulation of 'collaboration' centres people's collaborative actions, in which technology just so happens to feature as part of any given scene. And it seems fair to draw the conclusion from our analyses that there are some significant conceptual problems to unreservedly appropriating this notion of 'collaboration' from CSCW and blandly applying it to such human-robot encounters on the streets (concurring with conclusions from Johansen et al. who argue that such mappings between HRC and CSCW may be problematic at times). It also seems likely that this is indicative of a wider problem facing CSCW itself, in which we see arguments for ceding of ground from people to machines, as in a related but broader discussion developing on "human-AI collaboration" [58]. This move could well be a significant mistake for CSCW that misunderstands collaborative action.

So, rather than attributing this all to a concept like 'collaboration' we find that such public encounters may sometimes end up placing a heavy burden on the human to manage the on-street scene, whether this is adjusting distances when following (Figure 2), making space for robots in varied ways when passing by (Figure 3 to Figure 5), or slotting robot actions into ways of taking turns in crossing paths (Figure 6 and Figure 7). These moments of "stop-gap labor" [45] look far more like people *accommodating* robots [65] than cooperating or collaborating with another 'equal'. At root this is grounded in various asymmetries of action between members of the street scene and robots deployed there (see subsection 5.3 for further discussion). The concept of collaboration in HRC should account for these fundamental differences to avoid being misleading. While this might seem a potentially pedantic distinction, we think that such conceptual respecifications offer worthwhile reminders or even correctives particularly for designers when contemplating scenarios in which 'collaborative robots' are imagined as possible solutions. Such concepts—if they are to be part of a material practice of robot design—can thus enact huge influence on forms of designerly reasoning. A more clear-eyed view of what imagined 'collaboration' looks like for all practical purposes may lead us to rethink if it is reasonable to traffic in such loaded terms in the first place, especially a notion invested with a significant intellectual heritage by CSCW's programme. So, here we want to assess different options that become open to us.

The *first option* would be to do away with the notion of (human-robot) collaboration entirely owing to its obvious problems. However, this seems practically unlikely without clear alternative

offerings. Two possible reasons researchers might both grasp for and aspire to develop 'collaboration' between humans and robots are that firstly the analogy is ready to hand (although rarely recognised as analogy!), and secondly that it presents an aspirational, future trajectory along which to travel (cf. [73]). A *second option* for us is to constantly bracket 'collaboration', perhaps as *collaboration** or similar, so as to act as a reminder, specifically that we are dealing with a different sense of collaboration than that prevalent in much of the CSCW literature. While this indeed presents an alternative, it is not necessarily a practical one; instead it may just appear technical and obtuse. A *third option* is to locate different approaches by actively talking about ways of being around robots that emphatically position human social practices at the centre, i.e., rendering what is often background "invisible work", visible [43]. For instance, we previously referred to the ways people do "accommodation work" [65] to manage robot actions and embed them into the life of the street. Thus, we do not say the pedestrians are *collaborating with* robots in following, passing by or crossing paths, but rather that human accommodation of robots takes machinic actions—e.g., braking, turning, moving ahead—and relies on human reasoning and ultimately practical work to make such machine actions *meaningful* with respect to the unfolding situation; this machinic aspect of robot actions is therefore always set within complex *socially collaborative* fabrics or contextures [35]. For example, in following a robot (Figure 2), a pedestrian's pace-work transforms the somewhat erratic motions of the robot into something like a flow-file [88], or moving queue. In our example of a group of people co-producing a 'bulge' around a robot (Figure 3), the cohort takes the unwavering path of the robot and instead yields pavement space in a way that does accommodation by reversing the norms of passing by [72]. In a moment of crossing paths with a robot (Figure 7) one of the pedestrians is able to repurpose the robot's braking within an emerging order of turn-taking sited at the entrance to the shopping centre. At other times the kinds of actions people are doing around such systems may instead look more like "regulating" [69], i.e., controlling or containing robot actions to fit with desired outcomes. And there are many alternatives we have no doubt missed. The broader point is that rich descriptions prioritising the nature and meaning of human social action in situ have a greater chance of cutting through the conceptual muddle that is 'human-robot collaboration'. So it is not necessarily that we must studiously avoid saying people might be 'collaborating' with robots, but rather to promote a continued dissatisfaction with such glosses so as to search for more meaningful descriptions that are true to the social settings we throw robots into. (As a solution this has the added benefit of aligning with prior conceptual developments in CSCW, such as that of "articulation work" [75].)

5.3 Robot Phenomenology

As a result of our choice to conduct fieldwork and to think ethnomethodologically about that experience—that is, about members' methodical production of the scenes we came upon (and our role within them)—coupled with the practices we developed of following the robots, and our growing awareness of their various qualities of response to human action, we were particularly confronted by a *robotic way of being* on the streets, most notably a kind of machinic mobility which is radically different from how most people tend to get by in public places. Thus, in following the robot, we had to engage with robot perspectives. These experiences lead us to an analytic contrast we have had to grapple with continuously. On the one hand we are necessarily members of street scenes in certain ways, seeing and co-producing the social circumstances of local cohorts in public places (e.g., being in flow of pedestrians). Yet on the other hand we are also analysts of robot actions, attempting to make sense of what robots are doing in these scenes from a machinic perspective. For example, in trying to keep up with robots to video capture them, the conflict between their machinic paths and our 'ways of the feet' became particularly evident. As creatures of social urban life we are highly conversant in deeply mundane matters of what 'normal' walking pace might be

[33], while at the same time identifying the ways that robots cannot participate and recognise such matters, instead relying on a sensor-based, algorithmic rendering of the street to get by.

This conflict between the phenomenology of the pedestrian (which we have largely focussed on), and what we could term *the phenomenology of the robot*, are both irremediably different and often in conflict. Much of the time this clash of phenomenologies may not actually matter. People work on their own projects whatever they may be (going to a grocers, finding a café, etc.), and the robots perform their deliveries to completion. Yet the contrast between these different phenomenologies is sometimes hugely significant, as they can be in friction or direct opposition at critical moments. For designers, taking such gaps into account within design presents immense challenges that lie well beyond what is perhaps conceived of within current conceptions of HRC. The problem is that fundamentally every social encounter is different, or as Garfinkel would say, every time is "another first time" [20, p. 9]. Members must work to find their way through this. Collaborative action is thus an achievement of members' wide repertoire of practical methods they bring to bear on the specific, unique circumstances at hand. And when there is trouble, people respond to breakdowns in meaning with coping strategies that almost relentlessly attempt to locate the sense and 'reasonableness' of what is happening, typically by attributing intentionalities to hitherto senseless actions, e.g., that someone suddenly stopped moving in the street because they may have dropped a possession, or perhaps that they need to consult a to-do list to determine if they should visit the shop they are walking past, etc. We suggest that this way of thinking could be a valuable consideration for robot designers, particularly in attending to where the gaps might be between robot and pedestrian phenomenological perspectives, and how consequential the very existence of those gaps might be at any given moment. Thinking in this way will need frequent gestalt switches between sensibilities, considering simultaneously what is expected, senseable, and desired by robotic systems designers [7], and the potential gulf between this and how such actions are experienced within the phenomenology of pedestrian perspectives. We can also ask further, connected questions: what capabilities does a designer need to furnish a robot and its infrastructure with so as to be sufficient in moments that are quite specifically not possible to be pre-planned or prepared for, that are always "another first time" for people on the scene? When considering this, we must always remember it is people who end up picking up the pieces of such phenomenological gaps.

6 Conclusion

While CSCW work has traditionally studied how technology mediates human activities, we increasingly see technology being encountered in a role of an unaccompanied agent, with no co-present human at all. In these scenarios, it is easy to gloss the robot as a collaborator or teammate. By sensitising ourselves to the problematics of 'collaboration', we encourage designers to seriously ask whether what they are designing can and should equal human collaboration, or whether we should strive for other forms of human-machine interactions, which potentially would also be better calibrated with human expectations [95]. Designers need to consider what their scope of action actually is and what parts of interaction they are designing for; in this sense, if there is one design takeaway from this paper, then it is to seriously rethink assumptions that robots might somehow be designed to 'collaborate' with people.

With its long history in studying collaboration and scrutinising how technology impacts human collaborative practices, CSCW is particularly well equipped to describe how humans weave robots into the social organisation of everyday action. We hope that future work in CSCW can develop a rich conceptual language for describing encounters between people and robots, which can then support designers in picking relevant and feasible design problems, as well as establishing a rigorous tradition of critique, reflection, and conceptual respecification.

Methodologically, phenomenological approaches may be particularly suitable for pinpointing differences in human and robot perspectives. This will require designers to thoroughly engage with how they make sense of and engage in collaborative work, and how this differs for machines. Suchman [79] made this distinction explicit by listing in a table format the "actions available to the machine" and the "actions available to the user". Taking this distinction seriously may mean that one needs to inspect what collaboration means for humans in a certain setting *before* adapting the technological possibilities that robots offer to fit into the specific collaborative setting. This may ultimately lead to robot and infrastructure designs that better support the collaboration practices in these spaces rather than disrupt them. Or they might motivate decisions to actually avoid robotic intervention in the first place, to choose not to design or deploy.

Acknowledgments

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