Making Sense of the Felt Experience of Controlling Autonomous Systems

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Abstract

Methods for understanding the felt and situated experience of controlling autonomous systems are crucial for designing systems that are adjusted to the complexity of human interaction. Prior work has tended to overlook the bodily and experiential dimensions of monitoring systems at a distance, particularly in moments of losing control. We combined two approaches, ethnomethodology and conversation analysis, and soma design, to explore a case where a semi-autonomous system crashed when controlled by an inexperienced operator, captured in video ethnographic fieldwork. We report on our methodological approach, combining *sequential video analysis* of the unfolding sequence and *interviews inspired by microphenomenology* to unpack the operator's experience of losing control. We contribute methodological considerations for interaction designers seeking to explore the felt experience of having and losing control of autonomous systems and discuss how insights gained through this combination of methods, rooted in phenomenology, support a designerly appreciation of safety operators' work.

DIS '26, Singapore, Singapore

ACM ISBN 979-8-4007-2563-0/2026/06
https://doi.org/10.1145/3800645.3812868

CCS Concepts

• **Human-centered computing → Empirical studies in HCI**; • **Computer systems organization → Robotics**.

Keywords

Ethnomethodology, Conversation Analysis, Soma Design, Robot Autonomy, Operator, Control, Lived Experience

ACM Reference Format:
Hannah Pelikan, Airi Lampinen, Rachael Garrett, Emily Hofstetter, Amanda Hoskins, Hannah Kuehn, Iolanda Leite, Donald McMillan, Sergio Passero, Katie Winkle, Mathias Broth, Barry Brown, and Kristina Höök. 2026. Making Sense of the Felt Experience of Controlling Autonomous Systems. In *Designing Interactive Systems Conference (DIS '26), June 13–17, 2026, Singapore, Singapore.* ACM, New York, NY, USA, 16 pages. https://doi.org/10.1145/3800645.3812868

1 Introduction

Robots are commonly portrayed as being able to perform tasks autonomously, with human operators soon to disappear once tasks are fully automated. Recent studies on human-robot interaction paint a more complex picture, demonstrating that while robots can be used to automate some parts of human labor, other necessary tasks emerge that humans must do to maintain and support the robot's 'automated' performance [65, 112]. Throughout the history of artificial intelligence, human work has often been overlooked and subsequently made precarious [45]. There is a risk that, due to limited understanding, we overlook and fail to design for the work required to make robots work. The design of robot control interfaces is typically focused on task efficiency, situation awareness, and mapping of controller inputs to robot behavior [1, 2, 17], all metrics that treat human operators as mechanical bodies that look at screens and press buttons, implicitly grounded in the idea of impending automation. In the robotics literature, however, the term *autonomy* is used carefully, and robots are typically discussed as *semi-autonomous*: doing things by themselves, but also requiring a human operator, i.e., a form of *shared control* [122].

Approaches that empirically explore the experience of shared control as a *felt* and *situated* accomplishment are currently lacking, despite broader traditions within Interaction Design to embrace research practices that help unpack how interaction sequences unfold from one moment to the next [109] and facilitate the granular articulation of felt experiences [54]. While such phenomenological approaches have been used to study the relationships that people have with robots (see, e.g. [41, 62, 64, 81]), we currently do not have methods to study and document the *felt experience of controlling* a robot. We contribute a novel way to generate such empirical understanding by combining practices from two methodological traditions: *ethnomethodology and conversation analysis (EMCA)* and *soma design*. It is rare to combine these two approaches, in part due to different methodological commitments, yet our exploration shows how bringing them together can generate rich analysis that directs attention to both the moment-by-moment unfolding of complex activity and the felt experience of using technology, supporting an understanding of temporality in felt interaction and facilitating design for lived, bodily experience.

We conducted video ethnographic fieldwork to understand the human labor around robots in a research arena where autonomous systems for land, sea and air are developed and demonstrated. An emerging observation from this fieldwork was that, although the studied systems are being glossed as 'autonomous', they are only autonomous during specific stretches of time. People in designated roles were always on standby to take over control, working as safety drivers, pilots or operators. We take as our starting point the first author's experiences of conducting ethnographic fieldwork with these professionals, who highlighted operating (semi-)autonomous systems as a challenge where even a small distraction can become disastrous. Yet, for a lay observer, their work may be easy to miss, since it may look as if "not much is going on". Taking this discrepancy seriously, we work toward a phenomenological understanding of the work of operators by analyzing a crash in which the first author, while test-driving a robotic system during her fieldwork, lost control. Using video of the crash as sensitizing material, we explored this instance of losing control through interdisciplinary workshops, using our two approaches. EMCA studies observable interaction, and soma design focuses on subjective, felt experience. Despite their shared roots in phenomenology, combining these approaches in this way has seldom been attempted. Bringing experts in both approaches together in two workshops allowed us to ground the findings presented below in both our multidisciplinary expertise and methodological experiments, shared during the workshops.

Our findings are focused on the body and interaction: we 1) unpack the *interactional sequence* of losing control and 2) articulate the first-hand *felt experiences* of controlling different robots. We reflect on how methodological experiments can bridge and broker between different objects of study: observable interaction and the social order, on the one hand, and knowledge embodied in subjective, felt experience, on the other. Reflecting on the potential of novel methodological combinations, we discuss how phenomenological insights can support a critical designerly appreciation of safety operator work, contributing to emerging studies of the "work to make robots work". We also discuss how our unique combination of methods enabled novel and deeper engagement with the operators upon the first author's return to the field site, facilitating an articulation of the responsibility that operators carry. In addition to offering a deeper appreciation for the responsibility that operators shoulder in balancing shared control, we contribute methodological considerations for interaction designers seeking to explore the felt experience of having and losing control of autonomous systems.

2 Related Work

We position our research at the intersections of Interaction Design, Human-Computer Interaction (HCI), and Human-Robot Interaction (HRI). After introducing methods for studying the lived experience of engaging with systems, we briefly present an overview of how robot autonomy and human operators are examined in robotics communities and review the vast and diverse HCI literature on controlling robots.

2.1 Research practices for engaging with the lived experience of using a robot

Influenced by approaches that highlight the situated [109], embodied [25] and felt [54] nature of interaction, the Designing Interactive Systems (DIS) community has long embraced methods for engaging with the lived experience of using interactive systems.

Ethnographic methods gained particular relevance in the shift to studying the context in which systems are used [21, 91, 92], enabling designers to study interaction with systems in everyday life including workplaces [48], homes [89] and outdoor settings [14]. Much of this ethnographic work was informed by ethnomethodology [38], an approach that focuses on how social order is accomplished through practical actions, often using video recordings to document interactions. Multimodal conversation analysis [53] is often combined, using detailed transcription to understand how sequences of interaction unfold from one moment to the next. The combined approach is nowadays referred to as ethnomethodology and conversation analysis (EMCA), which although clunky, captures the underlying fields and methods more accurately than umbrella terms such as ethnography or interaction analysis.

EMCA methodologically requires adapting recording and analysis to suit the activity, in order to be sufficiently accurate to actual emergent, lived behaviors. The emergence of mobile phone technologies [20], for instance, required developing methods for capturing people who are on the move and simultaneously looking at small screens. Similarly, the emergence of autonomous systems calls for the adaptation of existing research practice to new associated complexities [84]. While EMCA has historically emphasized the importance of participant knowledge and experience for understanding their choices and actions [12], recent emphasis on video analysis has often prioritized analyzing solely what leaves traces in video recordings, that is, the visual and aural [73], and not the felt experiences accompanying action.

More recently, there has been another shift in studying everyday experience in HCI to embracing the felt experience of engaging with interactive systems – the somatic turn. Soma design is an approach to interaction design that foregrounds the lived, felt experience of the body as a central material and site of meaning-making and change for design [54]. Rooted in somaesthetics by pragmatist Richard Shusterman [101], it emphasizes first-person bodily awareness, movement [100], sensation, and affect. Through practices such as somatic exploration, bodily attunement, and experiential prototyping, soma design seeks to create interactive systems that engage users at the level of perception and experience, supporting reflection, transformation, and aesthetic appreciation.

Soma design has been applied to wearable soft robotics, drones and robots. Examples of soft robotics include: a breathing garment strapped around the body, built with soft robotic shape-changing elements, that supports awareness and training through changing its shape [58]; the Corsetto system that lets audiences feel reminiscents of a singer's bodily movements while singing through running 'haptic scores' enabled in the Corsetto's worn by the audience [60]; a shape-changing car seat that engages drivers in autonomous contexts [7]; and the Pelvic Chair for engaging pelvic floor muscles by pushing at the muscles in pre-selected patterns [108].

Closer to the topic at hand, there are soma designs for interaction with robots and drones. Examples include: the drones for the Opera Stage by Unander-Scharin et al. [34]; La Delfa et al.'s Drone Chi exploring Tai Chi–inspired interaction [61]; and later their work that lets drones change in interaction with their pilots [62, 64]. Robot interaction has been explored in, for example: Benford et al.'s somatic conceptions of safety and collisions in HRI [9, 10]; while Sondoquah et al. showed how somatic engagement can scaffold learning in micro-robotics [104]. These directions have led to the emergence of "somabotics", a term describing the intersection of soma design and novel human-robot interaction [130]. Soma design has also shaped ethical discussions in human–robot interaction, using somatic methods to engage with the complexities of semi-autonomous systems [33, 40–42].

While ethnography in general has informed interactive system design and both EMCA and soma design approaches, EMCA researchers and interaction designers have often struggled to build common ground, especially when it comes to moving from formulating interesting observations to practical insights that can inform design [16, 26, 127]. In this paper, we combine an observational ethnographic approach, rooted in EMCA, with a designerly approach, rooted in soma design, exploring how a dialogue can enable new insights and contribute to bridging different ways of knowing.

2.2 Sharing control between humans and robots

From a robotics perspective, control is often shared between a robot and a human. The concept of *shared autonomy* is commonly used to describe how humans and autonomous robots work together to achieve a shared goal [8]. The way in which this control is shared between the robot(s) and human(s) can then be configured in different ways.

Some approaches within shared autonomy consider scenarios where robots mostly act autonomously, but sometimes need assistance or human intervention. Reducing the amount of assistance needed is seen as desirable, particularly in the case of multi-agent systems where multiple operators control multiple robots [17]. In these works, it is mostly the robot or the whole system that decides who is in control, at what point in time, and under which circumstances. In the context of driver assistance systems and autonomous vehicles, for instance, the driving system can assist the human by keeping the distance to the next car, or it can switch the driving control between the human and an autonomous driving system [122]. In physical HRI, systems like robotic arms or drones can, similarly, adapt their level of autonomy [98]. Some systems can adapt to different operators, requesting assistance based on the operator's proficiency [19].

Other approaches model the interaction between a controller and a robot, where the controller has an intent for what the robot should do and the robot system tries to fulfill this intent while reducing the cognitive load of the human and adding robustness [1, 129]. For example, Cui et al. [22] present language-guided control, where users can correct the robot during its task execution. To avoid user frustration when the robot does not follow a user's intent, Zolotas and Demiris [131] introduce explainable shared control, where the robot provides information feedback that helps the user understand the robot's behavior. While robots are being designed to dynamically interact with the controller, robotics literature typically does not pay attention to how controllers experience these interactions.

As this body of work highlights, in many robotic systems humans take some form of control. Yet, their lived and felt experience of controlling is rarely taken into account in the design process. Instead, operators are often described as performing abstract, high-level roles. An area that has begun to put more emphasis on the individual operators is assistive robotics, where the controller is often also the main user of a robotic system [11, 75, 79, 128]. While much can be learnt from specific case studies in this area, it remains difficult for designers to gain access to the felt experience of control.

2.3 How to control a robot

Apart from a conceptual understanding of control as shared between autonomous systems and their operators, there is also a material and interactional aspect of control.

Typically, robots are controlled through interfaces that are separate from them, such as joysticks that enable the control of parameters like torque, movement direction, and/or speed. This means that the robot can be in a different spatial location than the operator who controls it from a distance through teleoperation. This remote control enables operators to take action in locations they cannot physically access, such as in keyhole surgery [5], search and rescue [15] or firefighting with drones [13]. Robot teleoperation is also used to collect large-scale datasets to train new robot behaviors, especially when it comes to dexterity or physical tasks [80]. Increasingly then, robots are no longer fully teleoperated but use machine learning techniques to perform previously learned tasks or to learn new tasks as they are being teleoperated by experts [125].

Interaction designers, recognizing the limitations posed by handheld joysticks, have started to explore alternative mechanisms for controlling robots, particularly for drone flying. Large buttons, gestures, or facial recognition can make control more accessible [37, 71, 115]. Examples include exploring remote interactions where controls are placed on the hands to let the drone respond to and learn dance movements [63, 64], or recognizing movements of opera singers and fellow drones on stage, acting autonomously within the boundaries this space offers as all actors move [34].

In contrast, user studies in teleoperation settings tend to take a human factors perspective that is focused on cognitive concepts such as situation awareness and information load (see, e.g. [2, 15]). A small body of ethnographic work led by Pelikan has started to draw attention to the operator experience, documenting the affective impact of teleoperation work on collaboration in surgical teams [83] and unpacking the skilled collaboration between two operators who are driving robotic trash barrels in a public plaza [82]. Ljungblad et al. [67] analyzed drone pilots' self-reports, highlighting the straining experience of maintaining extreme focus, even when using semi-autonomous functions. Recently, researchers in Human-Robot Interaction have started investigating operators' sense of control [18] and drawing attention to the lived experience of operating robots for research studies [116].

Our aim with this paper is to shed further light on the situated, embodied and felt experience of what it is like to operate a robot to inform the design of control in shared autonomy settings.

3 Research Approach: Methods and Theoretical Underpinnings

We aim to better understand the experience of robot safety operators, who are tasked with observing a robot as it drives in autonomous mode, as well as occasionally manually controlling it. Our work is grounded in a longer period of video ethnographic fieldwork of robot operators in a large research arena where robotic systems for use on the ground, in water, and in the air are developed. Additionally, we ran two interdisciplinary two-day workshops that brought together experts in Interaction Design, HCI, HRI, Human-Human Interaction, and Robotics. Combining elements from two theoretical traditions, ethnomethodology and conversation analysis (EMCA), on the one hand, and soma design, on the other, we explored how combining these different perspectives could help us gain a deeper understanding of the operator experience.

3.1 Video ethnographic fieldwork

We draw upon two years of video ethnographic fieldwork conducted by the first author in a large research arena in a Nordic country where different robotic systems with a range of levels of autonomy are deployed in real-world scenarios. In the field site, human operators always keep a line of sight for safety reasons, and since the systems that are being tested are often prototypes that are not (fully) commercial, the safety operators regularly have to take over control. While the goal was to observe and study the safety operators, it turned out to be difficult to learn about their experience. Being fully focused on their task, similar to drone pilots [67], the operators tended to be rather silent and withdrew from interactions with the researcher.

A moment in which the fieldworker had the opportunity to operate a robot used for training students became crucial. Early in the fieldwork, the researcher was invited to test drive one of the semi-autonomous robots. After receiving compliments on their driving, the fieldworker moved the robot to a more challenging area. This ended with an accidental crash into an antenna placed in the area by another group (see Figure 1). The incident sparked discussion with other co-present operators, during which an experienced operator, who had not engaged with the researcher very much up to that point, approached and suggested "So now you can describe your behavior when it started happening. What were you thinking?". The fieldworker described how they briefly got distracted by something the instructor had said, and when they realized that things were going wrong, it took a moment to figure out which button to press. The operator summarized this as "too late", chuckled, and said no more.

The operator's prompt for the fieldworker to describe their experience came as a surprise, and we decided that it deserved further exploration. Taking the approach of ethnomethodological ethnography, we had a general interest in the embodied presence of the fieldworker as an (in)competent participant in the activity we were studying [87]. From an ethnomethodological perspective, the crash is interesting as a moment of trouble, in which the social order is breached and thereby can be studied [106]. We extracted a 30-second snippet from our data, showcasing the moments before and after the crash. The video is included in the supplement to this paper. Using this video snippet as a sensitizing material to further explore the first-hand lived experience that was made relevant by the professional operator in this setting, we brought it to our interdisciplinary workshops.

3.2 Methodological experiments

The analysis we present in this paper draws upon a series of methodological experiments that took place in the scope of two two-day interdisciplinary workshops – with a thematic focus on autonomy – organized by the two main authors, with support from their research group members. It is complemented by an additional interview with the first author, who conducted the fieldwork we build upon, after the second workshop.

The workshops took place in December 2024 and March 2025. They were attended by 14 and 11 people, respectively, mostly from our author team, bringing together strands of work from EMCA and soma design that individuals in the participating research groups have worked on separately over a number of years. The workshop group comprises experts in EMCA, soma design, as well as robotics and critical HCI/HRI. The workshops were attended by senior and junior researchers, each bringing a unique perspective and interdisciplinary background. All researchers had experience in cross-disciplinary research and/or teaching. The majority of the group knew each other beforehand, and some had collaborated on past projects, but not with the full group as assembled in the workshops.

The workshops included a focus on fostering common experiences of operating semi-autonomous systems, with a practical focus on consumer robots. They built on activities inspired by a range of methodological traditions. We partook in hands-on activities with

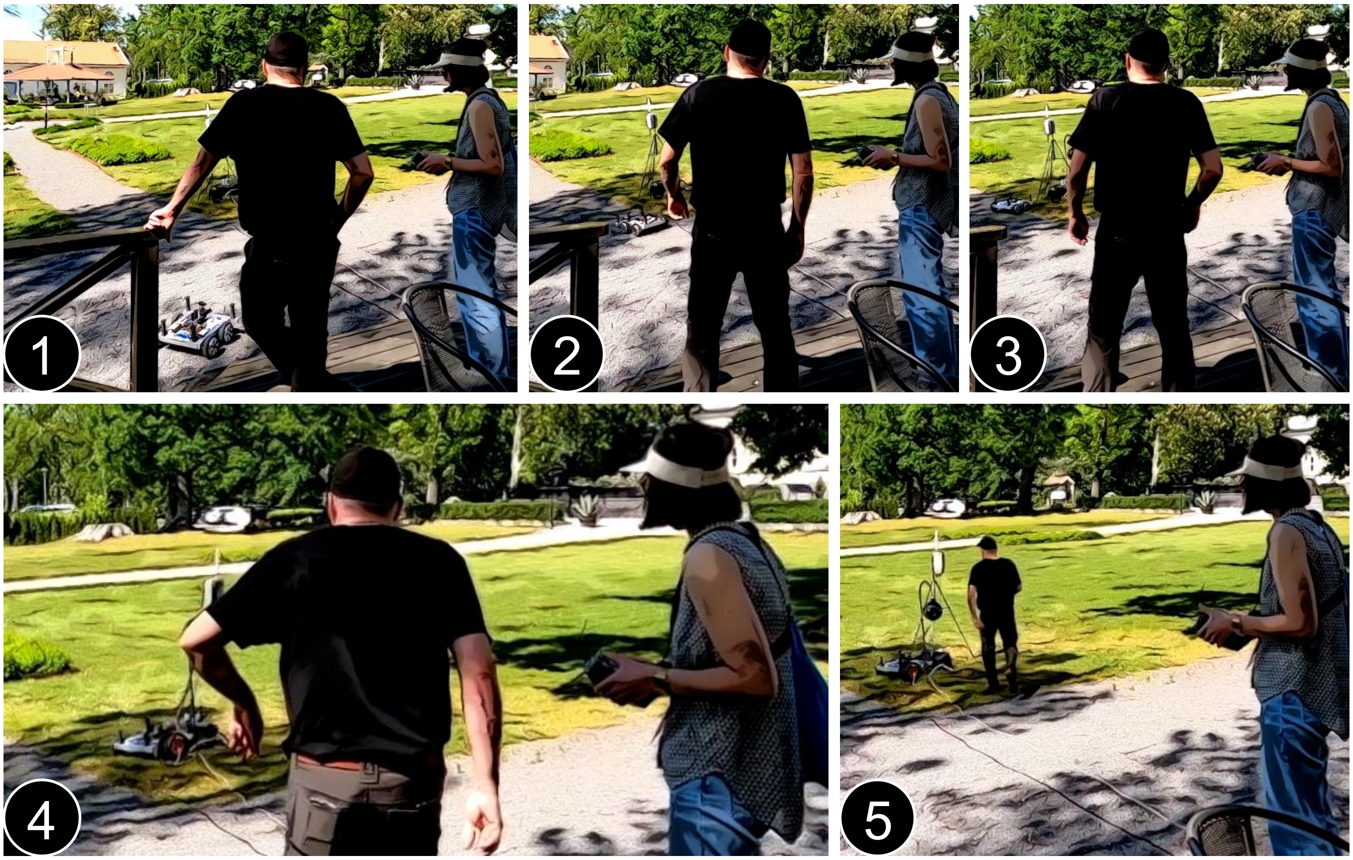

Figure 1: The crash sequence. Researcher on the right, operating the robot on the ground through a hand-held control interface. Instructor on the left. 1: Turning the robot towards the antenna. 2: Moving straight again. 3: Heading for the antenna. 4: Robot pushes into the antenna, operator raises shoulders, instructor starts running. 5: Robot stopped, instructor continues towards the antenna.

two different drones and a robot (TELLO[1], DJI Neo[2], and Cozmo[3]) to ensure that all workshop participants could gain some level of first-hand operating experience.

To explore the moment of losing control, we drew on a range of methods: Taking an EMCA approach, we chose to familiarize ourselves with the video clip by playing the video on loop and discussing what we saw in the clip (see subsection 4.1). In turn, taking a soma design approach, we engaged in joint soma exercises, exploring control as a somatic experience. Subsequently, adopting a more active method for video analysis that we saw as suitable to build bridges towards design, we performed a number of re-enactments [105] of the video clip, exploring the experience from multiple viewpoints. Finally, adopting a more analytic method for exploring somatic experiences, one of the authors conducted a micro-phenomenologically-inspired interview with the first author (who also conducted the fieldwork) to explore the details of the experiential phenomena during the crash shown in the video. Discovering that this was valuable, we conducted another, more in-depth micro-phenomenologically inspired interview after the second workshop (see subsection 4.2) to produce verbal accounts of what the first author felt during the crash that the clip captures.

[1]https://www.ryzerobotics.com/tello
[2]https://www.dji.com/se/neo
[3]https://anki.bot/products/cozmo-robot

3.3 A note on reflexivity

This study focuses on a single case of 'failure' to control. Single-case analysis is foundational for EMCA, because "expressions and actions are irremediably 'indexical', that is, essentially dependent on their local contexts" [77, p. 466] and any order, however broadly it can be seen across social interaction, is actively accomplished locally. Single-case analysis can discover more general patterns, because they must also occur in any and every case. Such analyses are well-established methodologically in EMCA, and have enabled the discovery of new practices (e.g. [93]) and the reorganization of how we understand syntactic organization (e.g. [44]). The most common use for single-case analysis remains examining deviant or breaching cases for their potential to inform about taken-for-granted order (e.g. [38, 68, 123]).

While the video snippet shows the first author operating a robot, the analysis relies on extensive ethnographic participant observation of the specific setting for testing mobile, semi-autonomous robots. Without this ethnographic grounding, there would be no data available on the nature of the activities in which the incident occurred, the concerns and actions of the participants, and the broader development of the controls for the remote robots. The workshops were deliberately designed to depart from the first author's perspective and to enrich the analysis with the contributions of workshop participants and their understandings of control both through analytic and practical engagement.

Examining the first author's experience simultaneously challenges separate roles of participant and analyst in user studies. In design practice, the role of participant and analyst are not necessarily considered separate. For example, Schön [96] has long demonstrated how reflection can be understood as an active part of practice, rather than a detached pre- or post-hoc mode of analysis [99]. In design, it is rare to consider "thinking" and "doing" as separate, and they are often treated as entwined modes of engagement that improve knowledge, methods, and the design of artifacts. Rather than seeing this difference as an impediment to the combination of these methods, we found it deepened our understanding of each other's professional disciplines, examining how reflection-in-action and modes of post-hoc analysis can be complementary in deepening our collective understanding of the experience of operating robotic systems.

3.4 Theoretical approach

In order to examine the experience of operating robots, our work draws on two separate veins of scholarship. EMCA and soma design have historically been seen as incompatible, given EMCA's commitment to attending to observable action – movement, speech, interactions with technology – and soma design's focus on inner bodily experiences of those acts. Here, we bring the two approaches into conversation for the pragmatic purpose of studying the experience of control. More broadly, we are curious how different approaches and experiences in studying and designing interaction can create opportunities for knowledge permeation between different disciplines [cf. 69], contributing to the interdisciplinary nature of HRI.

3.4.1 Ethnomethodology and conversation analysis (EMCA). To understand how EMCA speaks to soma design, it is helpful to understand its origins, challenging dominant streams in sociology and linguistics that focus on broader social structures, and instead foregrounding the role of moment-to-moment actions and interaction in producing and organizing the world we live in and how we understand it [106]. From this perspective, everything a person does (e.g., displays, claims) is made sense of by other participants, regardless of whether the original agent intended the meanings to which others arrive [30–32]. Participants can, at any time, require others to explain their actions (or explain their own actions), though most often, participants' actions are in line with expectations and so are understandable without explanation. However, especially when something unexpected occurs, the agent can be required to produce an 'account' for what occurred. All participants are accountable, inescapably, and with "no time out" [39]; design is no exception. Each action (and any given design or feature) displays an understanding of what is happening, and subsequent actions (i.e. responses) display what understanding has been received [94].

Methodologically, EMCA combines ethnography and video analysis by using deep understandings of activities, cultures, and communities of practice to inform and reflexively question video recordings of those activities [23, 70, 103]. A sufficiently competent understanding of the activity at hand is called 'unique adequacy' [39, 103], where one is recognized as competent by other proficient participants (e.g., professional operators and designers). Novice understandings and probings are also useful in both developing unique adequacy and in uncovering taken-for-granted understandings embedded in the activity context [4, 50, 66, 74]. Purposefully experimenting with, reenacting, and 'breaching' the activity is a useful technique for producing informative interaction recordings [12, 28, 105, 110, 111].

Our approach in this paper demonstrates one pathway for developing unique adequacy through deepening reflection and harnessing the insights available through multidisciplinary, embodied, and sometimes novice, probing. Our process can inform EMCA methods with the embodied and experiential contributions inspired by soma design, and improving the ability of all participants in data sessions to contribute more informed analysis. Including iterative reflection and experience into EMCA work has been considered with respect to data collection [56], but our work develops this procedure for analytic purposes.

3.4.2 Somaesthetics and soma design. To understand how soma design speaks to EMCA and ethnography more broadly, we similarly revisit its origins. In HCI, soma design is a design stance that centers the living, moving body as a resource to explore and imagine interactive experiences [54]. It arose in response to increasingly physical technologies – such as robots – that demand more embodied modes of interaction. Rather than treating "body" and "mind" as separate, soma design adopts a non-dualistic view of the *soma*: body, thought, emotion, and subjectivity as one [52]. Drawing on *somaesthetics* [102], it emphasizes cultivating bodily sensitivity as a way of expanding our experiential repertoire and aesthetic richness [101].

To achieve bodily sensitivity, soma design methods focus on engaging deeply through all the senses both with the design materials and to develop aesthetic skills. Detailed articulation of bodily sensations and emotions is required to come to viable design [54]. Approaches include first-person design [24], autobiographical processes [76], and carefully documented material explorations [118]. Designers typically begin with somatic activities or bodywork, often guided by a somatic connoisseur [95]. Articulation tools such as body maps [3] help share experiences, while expert-led methods like focusing [78] or micro-phenomenological interviews [49, 90] may be used for deeper analysis. Significant experiential features are then identified and translated into design qualities [51]. In short, soma design treats the lived body as an active design material, both for the designer and, eventually, for future users of the resulting designs.

One strong influence on soma design is micro-phenomenology, which builds on philosopher and neuroscientist Francisco Varela's theories. Varela argues that the study of the human mind, body, and psyche cannot rely solely on third-person approaches or physiological measurements [120]. Instead, it must also include accounts of *lived experience*. We draw on microphenomenology-inspired interviews as a method to produce verbal accounts of bodily, felt experience.

3.4.3 Combining EMCA and soma design. While both approaches have proven useful in HCI, combining them is not straightforward. There are clear incommensurabilities that prevent full methodological fusion. In terms of data, EMCA and soma design have fundamentally different assumptions about the relationship between accounts and action. As video analysis has become prominent in EMCA, visual social acts come into focus. Yet, for somaesthetics [101] it is key to (somehow) observe inner acts, building on Varela [121]. In turn, the two approaches consider design very differently; it is central to Soma Design [54] that we can creatively change what is possible to experience, we can change our own bodies and extend what we experience. Theoretically, there is a contrast between constructivist versus Wittgensteinian [126] understandings of meaning. Although addressing these issues goes beyond the scope of this paper, they often surfaced in different ways in our workshops and related discussions.

This all said, both approaches do of course share much of their approach to the body and how the individual and social are conceptualized. Schütz [97] and Gurwitsch [46] had a strong influence on Garfinkel [38]; and in its early years ethnomethodology was often conceptualized as a form of phenomenological sociology (see e.g., discussion in [27, 35, 119]). Somatic approaches and EMCA both attempt to escape dualist and cognitivist accounts, and explore perception as active bodily action. In our work here (as is perhaps often the case in interdisciplinary work), a focus on the material – robot control – worked to productively bracket potential disputes.

4 Findings: Experiencing the Loss of Control

Control is made most obvious at the point at which it disappears. Our methodological explorations therefore focus on an instance of a crash recorded during the first author's fieldwork. We present our sense-making from both approaches, starting with a multimodal sequential analysis typical for EMCA (see subsection 4.1). We then demonstrate how we explored that same sequence from a soma design approach, through interviews that dive into the first-person felt experience, inspired by microphenomenology (see subsection 4.2). Finally, we bring both approaches together, demonstrating what we learned from combining them (see subsection 4.3).

Figure 1 illustrates how the crash emerged in a sequence of images, showcasing the fieldworker on the right, instructed by a person on the left. The robot has a square-shaped form about as large as the seat of a chair, and is driving with the help of two hoverboards. The fieldworker is holding a joystick controller, which translates the movement of the levers to robot motion. In the following, we dive deeper into the experience of this crash. The anonymized video recording is included in the supplemental material.

4.1 Sequential analysis of the crash video

Let us first turn to the analysis of the events leading up to the crash. We chose to start the first workshop by showing the video-recorded crash, following an ethnomethodological interest in when "things go wrong", studying moments of interactional trouble or friction as a way to better understand social organization. Ethnomethodologists see experimenting with breaches of the expected sequence of events as a way to articulate insights about human sociality [106].

4.1.1 Methods for engaging with the video-recorded crash sequence. We engaged with the clip in the format of a conversation analytic data session [113], a meeting during which a group repeatedly watches the clip. Typically, a transcription of verbal and embodied actions is provided at some point during a data session to read and make annotations on the sequence of events. After first showing the clip, we started with an open round of clarification questions to get a joint understanding of the context in which the clip was recorded. Showing the clip stimulated a somewhat unexpected discussion around 'why are you showing this to us', with the engineers on the team asking whether the fieldworker was not embarrassed about her bad performance. In robotics, video recordings are typically used as demonstrations of the ideal, showcasing moments when systems finally work. A soma design exercise conducted before the data session was helpful in reminding the group that the workshop was a safe space, encouraging us to remain with this troubled experience and to further probe and explore it. In the ensuing discussion, we could clarify what control and autonomy meant to the different members of the interdisciplinary group.

While the data session served as a way to start talking about the video, it was difficult for the larger group to really engage with how it unfolded on a moment-by-moment basis and to contribute observations equally. We therefore further explored the sequence through re-enacting it in the second workshop, with different people acting out the researcher, the instructor and the robot and a narrator who read out the transcript. Re-enactments are sometimes used by ethnomethodologists to engage with the sequence of events more thoroughly, especially in interaction with artificial intelligence and robots where one may not have a common-sense of what is happening [105]. While the soma design participants strongly highlighted that re-enacting a sequence does not give insight into how the operator actually felt, the ethnomethodologists found that the group as a whole gained a more thorough understanding of the unfolding sequence and could point more readily to how the crash emerged gradually. Having to re-enact the control interface also stimulated further discussion of how the researcher who was operating the robot had actually controlled the robot.

4.1.2 Analytic observations emerging from the joint video analysis sessions. We present our sequence analysis of the crash with the help of a multimodal conversation analytic transcript. Following established transcription conventions for verbal and embodied actions we can demonstrate how the event in focus emerged in real-time, step by step. Table 1 presents the transcription symbols we use for transcribing speech, following Jefferson's [55] conventions for marking timing and prosody and Mondada's [72] transcription conventions for transcribing movements, gestures and other visual behavior with respect to ongoing talk. In such transcripts, the sequence of actions can be read from top to bottom, with line numbers marking the flow of time. The left hand column indicates who does what action. Capital letters indicate verbal utterances (OPR for the fieldworker-operator and INS for the instructor). Lowercase letters in gray mark lines with embodied behavior relative to talk and pauses. We use a star symbol for the operator and a plus sign for the

Table 1: Transcription symbols used in the right hand column of the transcript in Figure 2.

Symbol	Meaning
((text))	Transcriber's comments for providing context
[text]	Speech in brackets is overlapping
(0.5)	Silence measured in seconds
text.	Full stop indicates falling intonation
text,	Comma indicates continued intonation
text?	Question mark shows rising intonation
tex-	A dash indicates that speech is cut off
text	Underlining shows prosodic emphasis
TEXT	Capitals mark speech louder than surrounding talk
>text<	Increased speaking rate (speeding up)
te:xt	Colon indicates that preceding syllable is stretched
(hh)	Laughter/breathiness
.hh	Audible inbreath
text	Timing of visible behavior with respect to talk
*-->	Action continues across lines
-->*	until the same symbol is reached
#	Hashtag marks where a screenshot was taken

robot, marking the beginning and end of the described visual action. Double parentheses mark comments by the transcriber, which we use to provide more general descriptions of what happens at that moment in the video. Simultaneous, overlapping speech is marked with square brackets, and respective lines are marked with separate numbers for precise reference.

Figure 2 presents a transcript of the crash sequence. The fieldworker is driving a semi-autonomous mobile platform. She has steered the robot from the grass to the gravel and shared some of her experience of controlling the robot. The transcript starts a few minutes into the recording, when the fieldworker-operator moves the robot in different directions and notices "it's pretty good" (line 03 in the transcript). This moment is also shown in Figure 1.1. When the robot is positioned in the direction of an antenna, the instructor warns not to go into the antennas (l. 06). The fieldworker adjusts the driving angle of the robot and the instructor continues to provide an explanation about the robot, which is built from two hoverboards (l. 07, Figure 1.2). The operator acknowledges this while further adjusting the driving angle and then pulls the switch to increase the speed, to which the instructor immediately responds by cutting off his speech and producing a long repetition of non-lexical vocalizations, of the kind which can often be heard when parents warn their children not to step into the road (l. 10, 12, Figure 1.3). The operator joins in with two hearable inbreaths (l. 11, l. 14), interspersed with "ah" (l. 13), and then utters "no" (l. 14). While this is happening, the instructor starts running towards the antenna, repeating "no" with a falling intonation curve (l. 15, Figure 1.4). Finally, the instructor produces a verbal instruction "back, back" (l. 17). Meanwhile, the operator hits the disarm switch, which makes the robot stop (l. 17-18, Figure 1.5). The instructor pushes the robot back and adjusts the antenna. The operator apologizes, also walking towards the antennas, providing a verbal account that "multitasking is difficult" (l. 23).

In our joint explorations of the crash sequence, we became particularly interested in the bodily conduct of the researcher who is operating the robot. On a verbal level, the moment of the crash primarily becomes noticeable due to an interruption of the ongoing conversation about the system, and a switch to a set of repeated non-lexical vocalizations, which can be classified as "response cries" [43], fast reactions to events that are often tied to the body. Repeated response cries are especially used in moments where it is difficult to react quickly enough with verbal description but necessary nonetheless to vocally display ongoing awareness or attention towards the urgent and unfolding event [59].

We found a focus point in the fieldworker-operator's gasp, shown in the transcription as a hearable inbreath transcribed as ".HH" (l. 14). As the soma design experts paid particular attention to the visible conduct of the body, they pointed out that the operator's shoulders were rising and their body was visibly tensing up (see Figure 1.3-Figure 1.4). In a zoomed-in recording of the hands and the controller, we also discovered the operator's flailing thumb before getting hold of the emergency stop switch (see Figure 4). The movement of the thumb was not initially transcribed because it seemed less relevant to the interaction between the operator and the instructor. We further explored the gasp, the raised shoulders, and the flailing thumb in the microphenomenologically-inspired interviews below.

4.2 Micro-phenomenological interviews

We conducted two microphenomenologically inspired interviews [120] to further unpack the experience of crashing. The interviews were carried out by a soma design expert, trained in the microphenomenological interview technique. She interviewed the fieldworker who operated the robot in the video clip. While such interviews are typically conducted immediately after an activity, memories may also be elicited through prompts such as video playback, as we did here.

We want to emphasize that we do not claim the microphenomenological interview provides a complete account of the in situ felt experience of the operator, nor do we suggest that we can know exactly how expert operators feel. Rather, the method is best understood here as a guided form of self-reflection, aimed at mapping a detailed, moment-by-moment sensory, cognitive, and emotional account of a subjective experience [85, 86]. From a design perspective, such interviews can sensitize designers to otherwise unnoticed experiential nuances—for example, how to anticipate and design for moments of freezing.

4.2.1 Methods for engaging with the felt experience during the crash. During our workshops, we engaged in body exercises to become familiar with articulating our felt experiences verbally. The relative inexperience of most workshop participants in operating robots – both generally and in relation to the specific video clip used for sensitization – could be contrasted with the experience of the fieldworker. To mitigate this, we engaged in robot operating exercises as well as an exercise to pay particular attention to the felt experience of crashing. This helped the team to build common ground, but we felt that we ultimately needed to engage with the specific experience of the researcher who was operating the robot during the video recorded crash.

```
01        ((OPR pushes speed lever forward))
02        ((robot drives forward))
03 OPR uh #[it's pretty good.   ]
04 INS     [but it's really stro]ng,
   img    #Figure 1.1
05 OPR cause *you know-            * ((robot moves towards antenna))
   opr       *pulls speed lever back*
06 INS *don't        go        +in*to      the      antennas.+ ((points to antenna))
   opr *pushes angle lever to left*
   rob                          +turns left, continues forward+
07 INS *(hh)s  (0.4) it is,*# +two *hover+boards, you +know hoverboards? ((points to robot))
   opr *touches angle lever*      *pushes angle lever to right-->
   rob                         +turns left+           +turns right-->
   img                       #Figure 1.2
08 OPR yah* yah y+ah. ((nods))
   opr -->*
   rob        -->+
09 INS *#you see the-
   opr *pushes speed lever forward-->
   img  #Figure 4.A
10 INS #bap bap bap*#[ba ] ((robot heads for the antenna tripod))
11 OPR              [.hh]
   opr          -->*
   img #Figure 1.3  #Figure 4.B
12 INS  >ba ba [ba]< bap ((robot drives into antenna tripod))
13 OPR         [ah]
14 OPR .HH #no:. ((antenna tripod starts tipping))
   img     #Figure 1.4
15 INS no no >no no #no<. ((running towards antennas))
   img              #Figure 4.C
16        (0.4)#*         (0.3)           *
   opr       *pulls emergency stop lever*
   img      #Figure 4.D
17 INS *           ba#ck,          * back,
   opr *pushes emergency stop lever*
   img               #Figure 4.E
18        (0.4)+#
   rob      +robot stops moving-->>
   img       #Figure 1.5
19        (1.5) ((INS reaches antenna tripod and repositions it))
20 OPR .h sorry. ((starts walking towards antennas))
21        (2.3) ((INS pushes robot off the grass))
22 OPR sorry, ((INS readjusts antenna tripod))
23 OPR the multitasking is difficult. ((reaches antennas))
24 INS e(h)e
25 INS it's okay, it's their stuff.
```

Figure 2: Multimodal transcript of the sequence of the crash. Line numbers on the left indicate the sequence of actions. Abbreviations in the middle column indicate who does what, capital letters mark verbal utterances `OPR`: fieldworker-operator, `INS`: instructor, and lowercase letters in gray mark visible actions (`opr`: fieldworker-operator, `rob`: robot). Lines marked with `img` indicate exact moments when images shown in Figure 1 and Figure 4 were taken.

The first microphenomenological interview was conducted in front of the entire team, included as a 30-minute session during our second workshop. Discovering that it helped us to empathize with the experience of the operator in a different way than just looking at the video, we decided to do a second, more extensive, 90-minute interview over Zoom to dive deeper into the experience of losing control. In the second interview, only the interviewer and interviewee were present.

During both interviews, the soma design expert encouraged the fieldworker to produce iterative descriptions of where the fieldworker had felt something in their body, articulating bodily experiences into words, expressions, gestures and facial expressions. The interviewer first asked the fieldworker to recount the unfolding of events, before zooming in, closer and closer, on the micro-moments leading up to the crash. The interviewer carefully framed questions to avoid biasing recollection, instead using neutral phenomenological prompts such as "at this moment, do you hear anything?" to help the interviewee reinhabit the memory. Cues such as facial expression, slowed speech, or eye gaze are monitored to assess when the interviewee seems "back in" the memory, at which point the interviewer gently probes for further detail. At intervals, the interviewer mirrored what has been said, reusing the interviewee's own words, body language, and expressions to support the introspective process.

4.2.2 Analytic observations emerging from the interviews. A recurring topic in the interview was how to put words on familiar sensations of 'messing up' and 'freezing' that could be sensed as nervousness or powerlessness and were described as "a cut in my own body" by the fieldworker-operator during the first interview, referring to air being cut off from the lungs (see Figure 3). During the

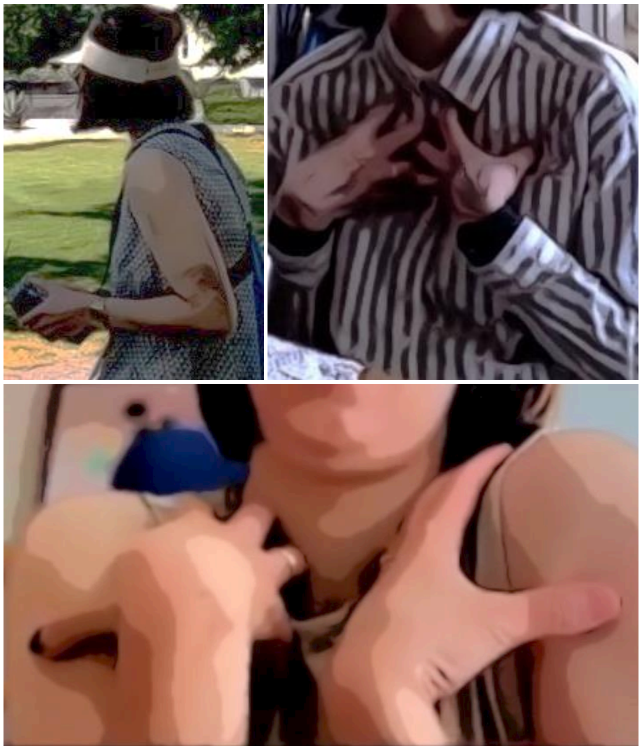

Figure 3: Experiencing the freeze as a sense of losing control. Top left: Raised shoulders from original material. Top right: Gesturing the location of of the freeze in the first interview. Bottom: Demonstrating the location of the blockage in the second interview.

second interview, we went deeper into exploring that experience, and the fieldworker managed to articulate a micro-moment of freezing, which she then had to recover from quickly. The fieldworker formulated this in the metaphor of two arrows moving in opposite directions: a metaphorical arrow moving downwards as a sense of suddenly missing a step, turning blank, the heart dropping, and all blood rushing to the feet, as well as having no air in the lungs in the moment of realizing the robot was crashing. Just after this dip, there was a phase of recovery during which a metaphorical second arrow was moving upwards, as the fieldworker was trying to regain control over their fingers. The freeze was then articulated as some kind of blockage in the upper chest, cut-off air in the lungs, and locked shoulders that the upward-moving sensation needed to overcome, in order to regain control over the flailing thumb and to stop the robot.

With a new appreciation for the freeze, we could reach a deeper understanding of the sequence of events, where the control interface suddenly became an obstacle to control, not letting the operator-fieldworker reach the emergency stop lever. She described the experience during the interview in this way:

> [going from] holding it (the controller) in a confident way to then feeling like suddenly this thing is slippery, whatever I do. And I feel like I made one attempt to fix it, and I realize it's completely, like, not working because suddenly this ((pinches finger as if holding)) lever is like ((gestures wiggly movement with one hand)) you know, moving wildly. But then also, desperately trying to find the other button [emergency stop lever]. And watching the robot, but also figuring out where to hold and where this button was that I faintly remembered that he had told me about because he very quickly went through all the levers.

After the microphenomenological interview, when the interviewer stepped out of the interviewer-role, she argued that she had gained a new appreciation of the video, seeing the flailing left thumb that first looked like "flapping around, not knowing what to do, pressing in the wrong direction" in a new light, as the moment of *the freeze*. In reflecting on the interview the two had just conducted, the interviewer noted: "I realize that you were actually first doing it in the wrong way, increasing the speed (...) and understanding that, [before] letting go of that and then looking for the stop button. (...) And it was not clear to me that why this was so difficult ... [but it] was because you froze and that was a very short freezing." This new appreciation, in which both the interviewer and interviewee had gained new insights through spending time discussing the experience of the crash, also enabled us to make some new observations in the video.

4.3 Bringing both approaches into reflections on the video: Towards new insights

Through our previous joint workshops, we had already become comfortable in quickly moving between EMCA and soma design perspectives, making a return to the video a natural subsequent step. Immediately after completing the second microphenomenologically inspired interview, the interviewer and interviewee returned to the original video clip and compared their new understanding to the video footage of the crash. Bringing together our sequential video analysis and the new understanding of the felt experience gained through the soma design approach, we could make a lot more sense of the researcher's interaction with the control interface, leading to deepened analytic insights about what was going on in the moment when the researcher lost control of the robot and it crashed.

Figure 4 shows a close up of the control interface during the crash. We noticed how the researcher operating the robot was moving the left speed lever in the wrong direction (Figure 4.A) and quickly let it go (Figure 4.B) upon realizing it was wrong. We could make sense of the flailing thumb (Figure 4.C) as searching for the right button during the freeze. We also noticed how the researcher was glancing down, searching for the emergency stop lever on the controller (Figure 4.D), eventually identifying and pushing it and gazing back to the robot at this point (Figure 4.E) to observe the effect of pushing the lever. The movement of the fingers occurs in a very short time frame, between lines 09-17 in the transcript that we previously presented in Figure 2. Articulating the felt experience of the researcher during this sequence helped us to see and appreciate what was happening in that brief moment.

Revisiting the experience of losing control together with the verbal transcript of the sequence, we observed that the researcher in fact did not entirely follow the instructors' suggestion. He had not

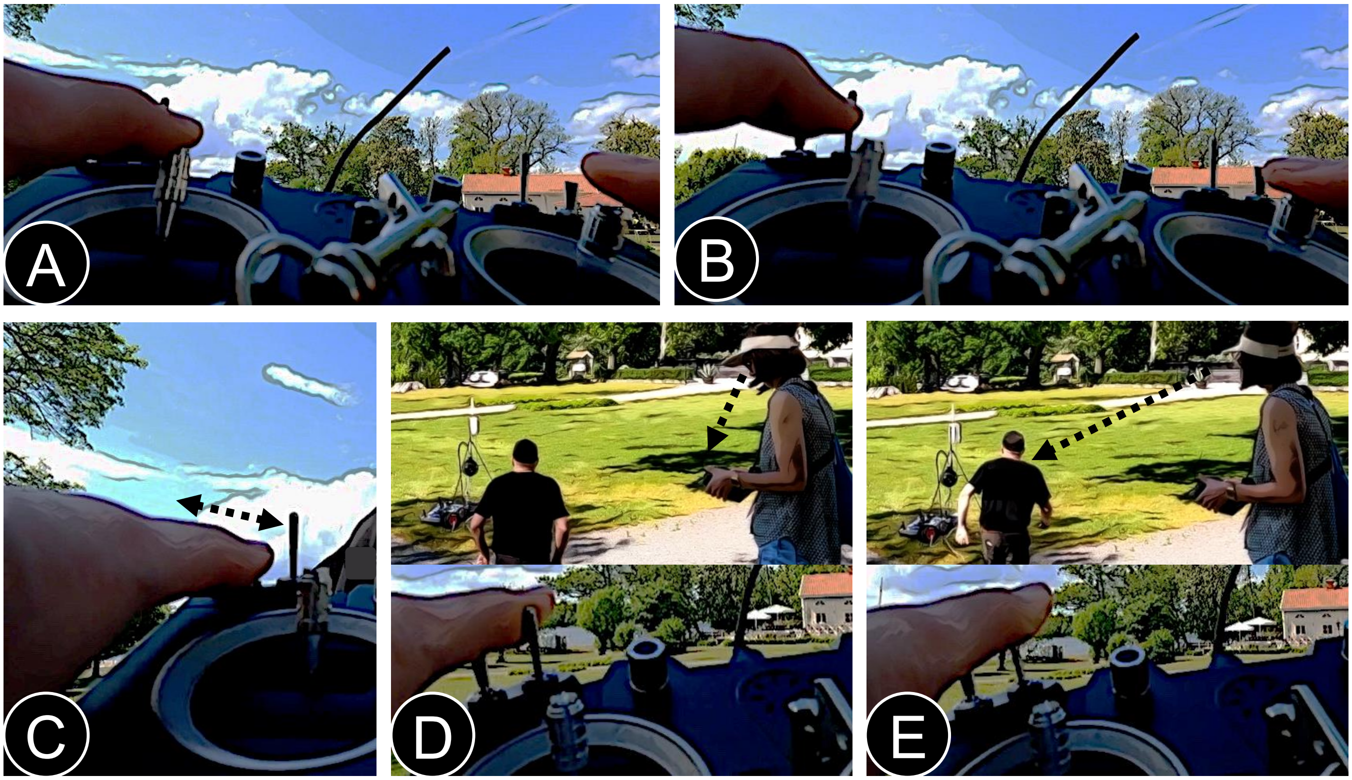

Figure 4: A: Increasing the speed by pushing the speed lever. B: Suddenly letting go off the speed lever. C: The flailing thumb in the moment of the crash. D: Looking down and moving the finger to the emergency stop lever. E: Looking at the robot and pushing the emergency stop lever.

suggested to use the emergency stop. Instead, his instruction was to move "back" (see Figure 2, line 17 in the transcript), indicating a way to keep the robot *moving*. Through the micro-phenomenological interview, we noticed that this instruction was in contrast with what the fieldworker felt like doing: dropping everything, breathing, and taking a moment of rest and reflection. It struck us that for many professional operators who are far from their system, hitting the emergency stop to turn off the robot is not a preferred option, since it could leave a robot in a position from which it cannot be retrieved, or, in the case of drones, make them fall out of the sky.

Further exploring the operator's wish to rest, we gained a new sense of the responsibility that the operators take: Controlling a semi-autonomous system often means pushing the autonomous parts of the system to its limits, while being ready to step in with a cool head when things go wrong. In our workshops, we had explored physically crashing, noticing how one then wanted to briefly rest and reassemble. The operators controlling a robot at a distance cannot rest. Since the robot is still moving, they need to act. During the second micro-phenomenological interview, the fieldworker-operator articulated how the moment of the crash was challenging because it featured both an impulse to act abruptly, letting go and dropping the controls, but also a sense, in response to this urge, that one must act responsibly to fix the situation. Through our methodological explorations, the fieldworker could gain a deeper understanding of what the struggle between losing and retaining control may feel like and how little time there is to prevent a crash.

We took this appreciation for the moments when a crash starts happening as providing the description that was encouraged by the professional operator, who asked the fieldworker to "describe your behavior when it started happening". Grounded in a recording of a moment in which the fieldworker-operator lost control, we closely analyzed the sequence of actions that led to the crash and articulated the fieldworker's own operating experience. Through our methodological explorations, the team gained a sense of what the experience of this moment was like: realizing that things were going wrong and reacting "too late" as summarized by the professional operator, but eventually overcoming the shock and taking back control. We became more appreciative of the work operators do when controlling (semi-)autonomous systems, where they cannot afford to let the feeling of having messed up take over, as that might have severe consequences.

5 Discussion

Exploring the experience of controlling a (semi-)autonomous robot, we brought together two approaches, EMCA, which uses video to study how people make sense of each other on a moment-by-moment basis, and soma design, which explores inner, felt experiences to design in a holistic way with and for the body. Our paper points to generative starting points for interdisciplinary engagement between soma design and EMCA, highlighting both the complimentary and contrasting spaces where practitioners can work together towards the design of robotic control systems.

5.1 Engaging in methodological experiments

This paper can be read as a methodological experiment, exploring if and how EMCA and soma design, approaches that are interested in the lived experience, can be combined. EMCA is rooted in social scientific *analysis*, typically of video recordings, while soma design ultimately aims at *building* interactive technology. Although both approaches originate in phenomenological research traditions and, therefore, should not be fundamentally at odds, we were curious to test how they would complement and rub against each other. By organizing workshops, we could practically probe each other's methods, exploring what kind of insights could emerge when engaging in soma design methods before turning to video analysis and vice versa. The differences between the two approaches are too complex to be bridged by a single method pipeline. Instead, want to present aspects we identified through our workshops that can facilitate interdisciplinary collaboration.

First, working on a **concrete case**, the video recorded crash sequence, was crucial for succeeding in this work. Ethnomethodology is interested in how facts are practically accomplished, meaning they are not taken for granted, but rather should be probed through different methods of inquiry [47, 106]. Similarly, soma design encourages exploring the nuance of a felt experience, developing a language for articulating sensations that would otherwise remain tacit [54]. Both approaches encourage iteratively revisiting emerging observations. Discussing the same instance from multiple different perspectives proved most insightful for us. We engaged in other activities in the joint workshops that we held, such as experiencing robot control ourselves and engaging in bodily exercises. These were important icebreakers and helped to understand each other's perspectives, but ultimately, they did not provide the kind of novel insights that we wanted to reach here, ones that could tell us something about the experience of control.

Second, we noted how EMCA and soma design align in their strong focus on **temporality**, exploring how action sequences evolve and how somatic experiences change over time. EMCA highlights that time is constantly running [39] and the timing of an action in an interaction sequence can determine how it is made sense of [94]. The temporal dimension also became very salient when we did bodily exercises. One of the soma designers brought up a diagram, a so-called *soma trajectory*, where experiences unfolding over time can be mapped, demonstrating how they emerge and fluctuate over time [114]. In discussing the loss of control, the joint interest in how control can evolve from one moment to the next proved to be very productive, leading to the insight that the moment in which control is lost occurs in the context of preceding actions and felt experiences and has consequences for what happens next.

Third, relying on methods that can be facilitated through **dialogical group sessions** has been key in bringing people together, sharing their expertise and building common ground for diving into deeper joint analysis. Further methodological bridges can be built on this work. For instance, besides gaining an analytic understanding of how the activity of operating can change from one moment to the next, which was primarily helpful for the fieldworker and the interviewer to understand what happened, we would want to engage the entire team in gaining a deeper, *felt* understanding of what had happened, for instance by jointly rewatching the interview and further engaging with that reflection in the group.

Rather than seeking to resolve the incommensurability between perspectives, we see the dialogue between them as an opportunity. Each theoretical lens – whether ethnomethodological or somatic – both opens and bounds the possibilities of analysis. By deliberately stepping outside of these boundaries and starting a conversation, our analysis aims to open new ground, expanding the space for analysis and design. We argue that embracing this pluralism is not a weakness, but a productive stance; one that can generate fresh insights and even feed back into the original traditions. What is needed is not reconciliation, but active exploration: tracing how these approaches have historically evolved, identifying their shared ideas, and cultivating methods that move across them.

5.2 Towards critical designerly HRI

Our work can be seen as a demonstration of how DIS approaches could inform critical designerly HRI. Rather than evaluating "end results", such as robot task performance and theoretical promises of human-robot teaming under perfect conditions, HCI approaches developed in the DIS community can provide inspiration in particular through strands of work that focus on lived experience. In our example, the ethnomethodological focus on work-in-practice in design ethnography [16, 21] encourages perspective taking, starting a study from the participants' own concerns, in this case professional robot operators. Soma design embraces both body and mind in a holistic, non-dualistic way, rather than designing for disembodied brains [54]. By exploring how these approaches together can speak to the emerging field of human-robot interaction, we provide a starting point for studying and designing for the different forms of labor involved in "making the robot work" in ways thus far unconsidered by the HRI and robotics communities at DIS and beyond.

We specifically see our work as contributing to the continued development of praxis for Feminist HRI [124], which calls for increased attention to *all* social actors around the robot, *especially* those whose labor is crucial to their operation. As this often requires interdisciplinary collaboration, we want to reflect more broadly about aspects that fostered our encounters.

5.2.1 Orienting to artefacts. As with many practitioners who become deeply familiar with their methods, we sometimes took our foundational assumptions for granted and needed to actively articulate them. We found it productive for physical and digital artefacts to serve as reference or boundary objects [107] to articulate our different assumptions, for example, the video footage in our workshop served simultaneously as "data" and a "sensitising artefact" allowing for different orientations to be articulated and discussed.

5.2.2 Establishing shared commitments. The two approaches we brought together come with different methodological commitments, one towards grounding analysis in what is visible in the video footage and another towards what is revealed through felt experience. Rather than trying to sort out theoretical tensions, we found it productive to reframe our differences in terms of shared practical commitments, focusing on the concrete case and shared concerns around responsibility, labor and visibility [45].

5.2.3 Creating mutual spaces. Engaging with methods that focus deeply on lived and felt experiences might be either very familiar or extremely novel territory for practitioners, depending on their backgrounds. This will inevitably create different vulnerabilities or discomforts in the research space as people move in and out of their professional comfort zones. Rather than trying to avoid this, we sought out pragmatic ways of facilitating these explorations, for example, approaching each other's experiences with care, being attentive to the emotional dynamics of the group, and allowing for withdrawal if needed [88].

5.3 Centering the operator experience

Our exploration of the lived experience of operators contribute to recent efforts by DIS researchers to shed light on the human labor that makes robots and AI work [29, 57, 117]. The EMCA video analysis and the unpacking with microphenomenology-inspired interviews allowed us to make sense of the labor of robot operation, closely studying robot operators and inspecting the practical reality of shared control. Since the operators work with the interface and the robot (alone), their work is hard to access through talk: it is embodied, and arguably, lacking the first-hand experience makes it impossible to properly grasp this experience. In addition, since operators are not supposed to lose control, coming across such moments can be tricky even in extensive fieldwork. The process of articulating the experience of losing control and discussing it with professionals may enable a deeper discussion regarding both the emotional labor [6] and the ethical sensibilities of their work [42].

Returning to the field with the new appreciation for what crashing a robot feels like, the fieldworker was able to articulate to the safety operators *their own* experience, the terrible feeling of losing control. This served as a way to open new conversations with the professionals who do not often seem to talk about their experiences [36]. The safety operators suddenly talked about the difficult decisions that they have to make and the responsibility that they carry: balancing the fine line between letting the system run autonomously (exploring what it can do) versus taking over control and making sure everything is safe, and that any physical collisions are prevented. Since we do not have a good language to talk about these experiences, finding one way to articulate them as a researcher can facilitate conversations with professionals. Some operators then demonstrated their strategies to make the control interface feel less slippery — they gain more nuanced control by holding the levers between two pinched fingers. The researcher's articulation of a felt experience can help to legitimize talking about tacit understandings, opening the door for deeper investigation.

We demonstrate the complexity of operator work, something HRI designers ought to empathize with and actively design for, rather than write off as a temporary stop gap [65]. A starting point for designing for operator experience would be to **design specifically for, and *with*, the experience of freezing or losing control**. Such situations are too often dismissed (and hence unconsidered) as being temporary, "one off", or outside the designer's scope. The ways in which automation has not yet seemingly reduced labor, only shaped, shifted and muddied who does what, would caution against such assumptions [45]. Additionally, freeze or loss of control might be a particular blind spot for HRI designers who are overly-familiar with their robot platforms. By studying the embodied experience in detail, we could show how the moment of losing control becomes evident both on a verbal level, but also how the specific movements of the lungs, larynx, shoulders, arms, and fingers may be implicated in such moments. Here, our work with re-enactments of the interaction sequence and with soma exercises that put the designer in a position of vulnerability [88] can be a starting point for cultivating more empathetic design.

6 Conclusion

Exploring the lived experience of operators, we brought together two methodological approaches, EMCA, which uses video to study how people make sense of each other on a moment-by-moment basis, and soma design, which explores inner, felt experiences to design in a holistic way with and for the body. Through this novel methodological configuration geared to explore the experience of control, we contribute to the critical study of human-robot interaction and provide a phenomenological perspective on 'work that makes robots work'. Our work offers a deeper appreciation for the felt experience of operating a robot and the responsibility that operators take when balancing between shared autonomy and manual control, especially in situations where losing control of the moving robot can have dramatic consequences. Our interdisciplinary research process demonstrates the novel insights that can be gained by combining methods that are rooted in a similar research philosophy, and showcases how a dialogue between an analytic and a design approach can be opened and practically facilitated.

Acknowledgments

This work was funded by Riksbankens Jubileumsfond (PF25-0001), the Swedish Research Council (Vetenskapsrådet, 2023-04032, 2024-05867), the Wallenberg AI, Autonomous Systems and Software Program — Humanity and Society (WASP-HS, Project No. 676 and 808, MMW 2019.0228 and 2020.0086), and the Engineering and Physical Sciences Research Council (EPSRC UKRI Turing AI World Leading Researcher Fellowship EP/Z534808/1). We thank the associate chairs and the external reviewers for their comments that helped us to improve the paper.

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