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Editor's Note
Special Issue: Sensor-Mediated Communication

Sensors as media and sensor-mediated communication: an introduction to the special issue

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Abstract

This special issue examines mediated communication through the rise of sensors. Sensors are increasingly in the phones we carry, in the cars we drive, and throughout the homes and communities in which we live. In this introduction to the special issue, we define sensor-mediated communication (SMC) and argue the embedded, automatic, and datafied nature of sensors belie the glitches and biases in sensor mechanisms, networks, and infrastructure. The collection of articles in this issue explores SMC across a variety of contexts and cases, including municipal infrastructure, community, health, industry, and the domestic. They represent studies of voice assistants, self-tracking apps, self-driving cars, fitness games, home health care, as well as municipal sensor networks in urban, indigenous, and rural communities. Across them all we see the different ways through which mediated communication is initiated, transformed, and maintained by sensing technologies. Together they represent an important evolution in the study of computer-mediated communication.

Keywords: sensors, media, sensor-mediated communication, technology adoption, ubiquitous computing

Sensors are everywhere. They monitor environments and measure a multitude of environmental characteristics such as air quality, temperature, noise, humidity, and radiation (Gabrys, 2019; Starosielski, 2021). They communicate what they measure to other sensors, networked technologies, and humans. They are increasingly embedded in urban infrastructures, offices, objects, and homes. With our smartphones and watches, we also carry sensors with us or on us. Many smartphones are equipped with proximity sensors, ambient light sensors, accelerometers, gyroscopes, barometers, biometric sensors, face or fingerprint scanners, heart rate monitors, and sensor receivers like the Global Positioning System and Global Navigation Satellite System. These sensors collect and process data and mediate many physical and virtual interactions in public and private spaces. Sensors offer ambient detection and communication opportunities, operating in the background of routine as well as involuntary activities; their size, sensitivity, as well as their always-on monitoring capabilities mean that they are often worn or carried on bodies or integrated into devices in practically invisible ways. As a result, communication practices and exchanges initiated, transformed, and/or maintained by sensing technologies have become routinely integrated into our daily lives.

How can we understand sensors in the context of computer-mediated communication (CMC)? In a special issue editorial in this journal, Mike Yao and Rich Ling ask, "what should constitute a 'computer' in digitally-mediated communication research?" (2020, p. 6). In framing this question, they provide a list of the sorts of "digital devices with which we communicate today." Their list includes:

> personal computers, smartphones, smartwatches, digital assistants (e.g., Alexa, Siri, Echo, etc.), home appliances (e.g., smart thermostats, security cameras, refrigerators, etc.), and even robots. Increasingly (at least in the Global North), people are living in smart homes controlled by computers and driving autonomous vehicles that essentially are computers that people carry around (Yao & Ling, 2020, pp. 5–6).

What is noteworthy about this list in relation to this special issue is that every item contains and is powered (or in some way facilitated) by embedded sensors. These routine computing technologies and the opportunities they provide for connection, communication, and exchange all rely (in part) on audio, visual, environmental, and/or biological sensing technologies and affordances in order to function.

Although sensing systems are widespread and foundational to current and emerging computing trends, sensor-mediated communication (SMC) has not been the primary focus of studies in CMC. Instead, sensors and SMC have been subsumed within broader conversations about the Internet of Things (IoT), smart cities, surveillance studies, and data-driven decision-making and governance. A focus on sensors in studies of communication technologies recognizes new understandings of agency and bias; misinformation and miscommunication; and how we negotiate and manage computational data, machine vision, and surveillance systems.

Bunz and Meikle define sensors as "*media of communication*" (original emphasis) in that "they create and communicate data about the world and those in it" (2018, p. 11). We build on their understanding of "sensors as media" and expand it with a focus on the *communication* processes that take place with, through, and among sensors. We define SMC as any communicative exchange that is initiated,

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transformed, and/or maintained by sensors. SMC takes place between sensors, between sensors and other computing or digital devices [e.g., between a sensor and a central processing unit (CPU)], between sensors and humans, as well as between humans through the use of sensors. These multi-layered and multi-directional lines of communication among, with, and through sensors share characteristics common to other CMC and human–machine communication (HMC) systems, but also present definitional qualities that differentiate them in their design, use, and integration into everyday life. In the following section, we suggest that there are several attributes that uniquely define SMC and constitute SMC as an increasingly significant and compelling area of research.

First, sensing, and using our senses, is increasingly outsourced to machines, and SMC relies on automated detection as the impetus for communication. People partially or wholly delegate the task of collecting information about users, environments, and actions to devices that are programmed to sense instances and occurrences, survey, and track repeated or continuous activity as well as deviations from repeated activities. Within SMC, the initial recognition and interpretation of a stimulus or communicative act such as speech, gesture, or movement is outsourced to sensors. The recognition and interpretation of presence and copresence, ambient conditions, and the contexts for communication may be outsourced to sensors as well—for example, the distance between objects, weather conditions, air quality, or sonic atmosphere. Instead of uniquely relying on human sensory facilities such as touch, hearing, and vision to identify signs and signals and interface with the world around us, sensor systems become central actors in the initiation, production, and transmission of messages and meaning. Beyond the choice of implementing the sensor or turning it on, communication is initiated and structured by machine detection.

Second, sensors datafy our senses and delimit what is sensed. Similar to other "smart technologies," sensors translate communicative and ambient information into machine-readable code and searchable data. As is the case with surveillance technologies such as CCTV cameras and searchlights for example, sensors work to "see" and monitor surroundings through a type of "vision" that is presumably enhanced or more accurate than human sight. The datafication of our senses is evident in the output communicated through the use of sensors, where sensors communicate sensory information in computable formats. In addition, they are also programmed to delimit "signal" from "noise" or calibrated to detect particular frequencies, rhythms, feedback, but not others. In this way, sensors are limited to signals which can be sensed or "picked up" computationally. For example, a sensor network could measure whether someone's heart rate increases when in co-proximity with a specific other person, but sensors cannot measure whether someone is in love. By doing so, sensors may privilege information about processes and practices that can be measured and made visible or knowable through automatically acquired data.

Third, sensors "make sense" or make meaning of information inputs. They filter what can be recognized as input or data and are programmed to categorize the objects, conditions, and activities they encounter. Sensors co-produce knowledge about our bodies, environments, and interactions with particular biases where some people and occurrences are never detected, recognized, or known (Benjamin, 2020; Noble, 2018). The knowledge produced through sensor systems can be significantly different from how humans sense and co-produce knowledge. This bias stems from the technical issues and moral assumptions (Kitchin et al., 2015; Safransky, 2020), the normativity of data, and the bias in training datasets that are used in automated communication and decision-making systems. Additionally, they can be distributed and positioned unevenly both locally and globally (Enlund et al., 2022). Certain areas throughout a home or city, certain activities, or particular bodies may be more integrated into, privileged by, or harmed through SMC practices than others. That being the case, the information and communication co-produced by and with sensors is significantly influenced by existing inequities in ways that amplify them. Issues related to digital literacy and access persist in SMC. Populations with routine access to smartphones and wearables may be more familiar with and literate in SMC than populations where sensors are not ubiquitous. Biased or exclusionary perceptions of human versus machine vision and knowledge production arise as well. As is analyzed in several articles in this special issue, seemingly "objective" computational sensing is often juxtaposed against human knowledge to verify or contest it, sometimes in ways that exclude or devalue the experiences of marginalized communities.

Relatedly, the information produced by sensors as well as the human processes involved in producing SMC are anything but streamlined and seamless. Instead, SMC demands contradictory ways of thinking about knowledge production and may create friction or tensions between humans and machines when integrated into everyday life. As Sun-ha Hong suggests, accessing computational data about ourselves and our environments may lead us to question whether our own "knowing" or sensing of our bodies and environments are accurate (Hong, 2020). Furthermore, sensors and SMC can introduce discomfort or disruption as they become integrated into daily routines. As Forlano (2023) explains, the act of calibrating her sensor-based insulin pump according to manufacturer instructions literally kept her up at night. Although the sensor-based system promised to more accurately and effortlessly capture and communicate health information, the effort involved in supporting SMC negatively affected her health, quality of life, and wellbeing. Several articles in this special issue draw attention to the various forms of material and immaterial labor and negotiations involved in sensor-based communication and human–sensor interaction, interrogating the many ways in which people work to make sensors make sense.

In some cases, however, sensors don't always make sense. This is to say that these processes are not always free of "sensing errors" and can be subject to "glitches," such as noise, drifts, miscalibration or calibration biases, missing or incomplete data, technological limitations and sensitivities, or poor signal quality (Benjamin, 2020). Detecting these errors and correcting them are increasingly automated and rely on self-learning models and neural networks (de Oliveira et al., 2021; Sinha & Das, 2023). Yet, as is the case with other computational systems, what constitutes a sensing "error" may be up to the interpretation of humans rather than machines. Therefore, as in any mediated communication practice, in SMC there can be communication and there can also be miscommunication. This has significant implications, especially for automated processes, where human agency is also delegated to an external agent.

From self-tracking apps to self-driving cars, sensing technologies power automated decision-making systems and influence social practices around health and wellbeing, parenting and family dynamics, navigation and transportation, climate and energy use, labor, commerce and consumption, sociality and engagement, stewardship in natural and built environments, and urban governance. People utilize sensors in personal, wearable, and "smart" devices to track, archive, and articulate movements, experiences, shared knowledge, and flows of information in ways that complicate preexisting understandings of what "counts" as data, how we manage and make meaning of sensor-produced data, and how we live with sensing technologies.

Despite the growing prevalence of sensors and citizen-sensing projects (Gabrys, 2016), and the value placed on the data acquired through their use, academic interest in researching their societal, behavioral, and ethical implications is only recently gaining momentum. Even with key contributions that define contemporary societies as "sensor societies" (Andrejevic & Burdon, 2015), and as attributes of the "quantified self" (Neff & Nafus, 2016) become foundational to an increasing number of everyday interactions, SMC has remained a relatively under-researched topic. With current crises of mobilities such as climate change, pandemics, and mass migrations and deportations, mobile forms of sensing and SMC have gained salience as smartphones, IoT devices, and technologies for "always-on," passive data collection are increasingly utilized to control and govern communities, societies, and populations. We believe this is a critical time to reflect on and empirically analyze SMC practices and their societal and ethical implications. As a central provocation, we ask researchers to consider: What is the role of sensing technologies in "redefining and reshaping fundamental social and communicative processes" (Yao & Ling, 2020, p. 6)?

Collectively, the articles in this issue dive into this provocation. The contributions highlight significant implications of SMC and address questions integral to studies of SMC such as: What does it mean to think about sensing technologies and practices as CMC? How does SMC foreground investigations of sensing technologies to reveal emerging organizational, cultural, and structural mechanisms at work? Following Guzman and Lewis' (2020) framework for studies of HMC, what are the unique functional, relational, and metaphyscial dimensions of SMC, and through what interactions are these dynamics experienced and imagined?

Although the Covid-19 pandemic with its increased uncertainty and anxiety around public health and contagion has created new urgency around sensors and the ways in which they mediate communication and interaction practices, this special issue focuses on issues of ethics, surveillance, technology design, and use that precede the pandemic yet contextualize current discourses and decisions around sensing technologies and sensor data. Our focus includes not only the commonplace use of smart(phone) sensors, such as apps for parents to track their children, or apps for care for the elderly and disabled, but also (and most importantly) the broader uses of sensors and scanners in cities, by platforms and governments, in robotics, drones, and satellites, and through other forms of mobile and remote sensing.

The papers in this issue address emerging debates regarding sensors and SMC, sensor data practices, and their social implications for measuring, seeing, and knowing bodies, mobilities, environments, the data they produce, and information they communicate. In particular, the subsequent studies empirically analyze how we live with and integrate sensors into our everyday lives, how we understand their work and value, how we manage misinformation and missing sensor-data, and the socio-technical and political impacts of these integrations and negotiations. The range of topics investigated in this issue illustrates the ways that sensors have been integrated into everyday life: to track and visualize locations and mobilities of bodies and vehicles, communicate biological data to caregivers and medical professionals, and monitor environmental conditions. These studies highlight emerging issues and forms of CMC related to the communication practices, processes, power, and ethics specific to SMC. The papers collected here also highlight the range of methodologies that can be used to study SMC in new and meaningful ways.

The special issue contains eight papers. These papers address practices of SMC and sensor technologies in three overarching respects: the labor associated with and politics of these practices, including automation of communication and decision-making; the sensing of mobile bodies and objects in space and time; and the politics and cultural geographies of the sensors that collect, process, and transmit data. Each piece offers a unique social and technological context within which SMC reconfigures human–computer interaction, predictive analytics, automated data collection, and decision-making, and governs the somatic and spatial relationships with our environments.

Three articles prioritize the study of labor and agency associated with SMC in regard to municipal governance, healthcare, and domestic labor. In "Digital governance with smart sensors: exploring grid administration in Zhejiang's 'future community,'" Zhao seeks to understand the role of smart sensors in Chinese urban governance initiatives. Zhao argues that, in the Chinese context, local governance unfolds in the complicated interplay between manual labor and automation and datafication. In this article, Zhao seeks to understand how local grid members negotiate these tensions, suggesting there are three different modes of engagement. Zhao's argument is that the agency of grid members "remains critically important in mediating the means and meaning of e-government."

Taking a sociology of infrastructure approach, Hine et al. examine the use of in-home sensor systems supported by machine learning to enhance communication between those living with long-term conditions like dementia, and the carers and health care professionals supporting them. In their article, "Negotiating the capacities and limitations of sensor-mediated care in the home," the researchers look at the labor and human decision-making involved in managing the production of sensor data, and interpreting and responding to sensor data. Their contention is that SMC carries "multiple and diverse ethical connotations" that have implications for how service users should best respond to data-informed care.

Echoing the theme of labor and agency in managing and maintaining SMC, Özkan's article on domestic labor and wearable sensors focuses on sensing objects and bodies at home. Her article, "Sensing productivity at home: self-tracking technologies, gender, and labor in Turkey" explores the "revelatory" role of personal sensor data and how wearables can work to translate embodied knowledge into quantified data. The paper details how a group of women in Turkey share self-tracking data, such as step counts or calorie scores, on Instagram to render visible the productivity of their (otherwise often invisible) domestic labor.

Three other articles critique the sensing and tracking of objects and bodies in space and time through SMC. Focusing on generational and relational identities, Baldwin et al examine the production and use of data in SMC about activities related to fitness. In "Mediating social support through sensor-based technologies for children s health behavior change," Baldwin et al. tested the long-term effectiveness of sensor-based technologies, such as Fitbits, to support children's behavior change and amplify the effectiveness of social network support.

In "Sensing technologies, digital inclusion and disability diversity," Nectoux et al. examine how sensing technologies—ambient home systems (e.g., Google Home), sensory interfaces (e.g., voice activation), and sensory devices (e.g., iPads)—are understood and experienced by those within racially and ethnically diverse disabled communities from socio-economically disadvantaged areas of Sydney, Australia. The authors argue for the need for greater inclusion of disabled peoples from diverse backgrounds in the design of sensory technology systems and supporting infrastructures.

Özkan, Nectoux et al., and Baldwin et al.'s articles focus on the sensing of bodies as they move through space and time alongside the intersection of identity and differential mobilities within SMC. In contrast, Hind identifies aspects of SMC within the sensing and mobility of vehicles, rather than human bodies, in space and time. In "Sensor work: enabling the interoperation of autonomous vehicles," Hind takes an operational analysis approach to examining the SMC that occurs by and between various internal sensor systems that are incorporated into autonomous vehicles. Hind's aim is to develop a detailed account of the "sensor work" undertaken by autonomous vehicles, and how much of this work revolves around "the knotty question of 'interoperability'" or how different computer systems can be conversant or exchange information with one another. His article reveals how communication processes change and become more integrated with sensor data preparation processes when shifting from a reliance on human vision to machine vision in autonomous vehicles.

Although all of the articles in this special issue focus on specific social and spatial contexts, two articles investigate SMC in direct relationship to particular cultural geographies and situated knowledge. "Nalaquq (it is found): a knowledge co-production framework for environmental sensing and communication in indigenous Arctic communities," Gleason et al. introduce a framework for combining custom sensor networks with Yup'ik knowledge to study land and weather, and the present and future impacts of climate change in the Yukon-Kuskokwim Delta, Alaska. The article presents a series of case studies revealing collaborative approaches to utilizing SMC and concludes by posing significant questions for communication scholars working with sensor data and First Nations communities. Namely, how should we make sense of quantifiable sensor data "within the context of Indigenous lands and heritage" and knowledge systems? And, how should we use sensors and SMC as "emancipatory tools" to communicate traditional knowledge in ways that strengthen the sovereignty of First Nations peoples?

In "Communication about sensors and communication through sensors: localizing the Internet of Things in rural communities," Butkowski et al. present a mixed methods study of the use of long-range wide area network sensors within rural community contexts. The article finds that in designing rural sensor networks, stakeholders must be able to explain and talk about what sensors are and how they work to foster municipal and community buy-in. This is an important first step before sensor networks can be established to do the work of monitoring energy use, lake levels or road conditions, which are then communicated back to the community.

Together, these articles demonstrate a variety of technologies and contexts in which SMC is at work and integrated into everyday lives. Butkowski et al. and Gleason et al. both demonstrate ways that sensor networks help rural and indigenous communities meet local needs in ways that have been overlooked within commercially-driven technological development. Baldwin et al. and Hine et al. reinforce the importance of sensors in health contexts, but also demonstrate the limitations and constraints of such technologies. Similarly, both Özkan and Nectoux et al. reveal how sensor technologies within the home can help people become more agentic in the everyday environments in which they live. Hind, Zhao, and Hine et al. reveal the complexities between infrastructures of automated sensing systems and the people who have to use, respond, and manage such technological systems. SMC reveals the human elements, practices, and processes within, around, and in response to a sensor society.

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