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Communicating behind the scenes: A primer on radio frequency identification (RFID)

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Abstract
Mobile media researchers have increasingly focused on smartphones as locative media. However, our field has not devoted as much attention to another mobile technology used to track far more people and things than smartphones: radio frequency identification (RFID) tags. RFID tags are used to track products and people, and they are an increasingly important part of the infrastructure of the Internet of Things. This article argues that mobile media scholars have much to contribute to scholarly analyses of RFID. I make that argument by first giving background on RFID as a mobile technology. I then identify and discuss four areas of research related to RFID tags—Big Data, surveillance, space and place, and nonhuman agency—that are particularly relevant to mobile media scholars.

Keywords
Agency, Big Data, locative media, RFID, space and place, surveillance

Mobile media scholarship has increasingly focused on how mobile technologies are used to locate individuals. Much of this research has focused on smartphones as locative media and has explored different ways people use location to reconfigure their relationship with surrounding space (Frith, 2014; Ozkul, 2013). However, while smartphones may be the most visible form of locative media, they are far from the most common. Instead, another mobile technology has been deployed in the billions to track people and things: radio frequency identification (RFID) tags.

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RFID tags play an important role in the mobility of things and people. They are a key part of the global supply chain logistics that are crucial to our global economy (Ayoade, 2011). They both enable and record human mobility through biometric passports, toll tags, keyless cars, and in some cases, tags embedded under the skin (Bhuptani & Moradpour, 2006; Crandall, 2010). The number of RFID tags dwarfs the number of smartphones, and yet the technology has received little attention in mobile media scholarship, despite the fact that as Crang and Graham (2007) point out, locative media artists and activists have already begun to weave together "mobile devices, GPS, GIS, RFID, mobile databases, ubiquitous computing, and urban architectures in new ways" (Sheller, 2013, p. 314).[1] In part, the lack of attention in mobile communication scholarship can be explained by Horst's (2013) argument that mobile media scholarship has often ignored the role of infrastructure. As she writes, "mobile media scholarship should look to the changes in the technical, social, political, regulatory and other forms of infrastructures that the first two waves' focus upon novel uses and consumers often rendered invisible" (p. 147). The goal of this article is to make the case that mobile media scholars should pay attention to the role RFID plays as a mobile technology in the often invisible infrastructures that operate in the background of our interactions with space.

The field of mobile media studies has a great deal to contribute to the understanding of RFID, and our scholarship will be increasingly important as billions of these technologies become essential to future Big Data approaches and the networking of objects in the Internet of Things. RFID tags are certainly different from the technologies typically focused on by mobile media scholars. They are not primarily designed for interpersonal communication, nor are they often interacted with in an intentional manner by human actors. Instead, as I detail later, they are a mobile technology that plays an important role in shaping what Thrift (2004b) calls the "technological unconscious" that operates beneath the level of human perception. Consequently, building on Horst (2013), it makes sense to think of RFID systems as both mobile infrastructure and locative media, shaping logistics and the tracking of people and objects, but in a mobile rather than fixed way.

To make my case that the study of RFID tags has a place in mobile media scholarship, I begin by giving background on RFID as a mobile technology. I then discuss four areas of research relevant to our field that are impacted by RFID: (a) Big Data, (b) surveillance, (c) space and place, and (d) nonhuman agency. Because the goal of this article is to identify areas of overlap between our field and the study of RFID tags, I focus more on breadth than depth in each of these sections, though I do link each topic to relevant literature. I conclude by posing questions to suggest ways in which our field can contribute to the scholarly understanding of RFID tags. RFID has been identified as a supposedly "revolutionary" technology with the potential to reconfigure our environment and revolutionize the tracking of people and goods (Albrecht & McIntyre, 2006). While claims of "revolution" are common with new technologies, if enough people believe RFID will have a significant impact on our contemporary world, then as mobile media scholars we should have something to say about it.

Background on RFID

One of the more understudied mobile technologies of our time may be the barcode (Thrift, 2004b). The barcode was first patented in 1952 but was not widely adopted until

the 1970s when laser scanners became widely available. By 1982, the U.S. postal service included a barcode on every piece of mail that went through the system, and barcodes have only become more ubiquitous since then. For a technology that has been mostly unremarked upon in research on mobile technologies, few technological developments have become more pervasive in everyday life than the barcode. The codes enabled manufacturers to embed Universal Product Code (UPC) information on products, and barcodes played a crucial role in shaping the modern economy (Thrift, 2004b). They enabled products to be cataloged and tracked across great distances, reshaping the accuracy and effectiveness of supply chain logistics.

Barcodes have now been in use for more than 40 years, and they are still found on countless products in stores around the world. However, beginning in the late 1990s and early 2000s, they began to be replaced in some cases by RFID tags (Landt, 2005). RFID tags can do everything barcodes can do and more, and they can do so more efficiently and quickly (Chan, 2011). However, as Albrecht and McIntyre (2006) point out, they are not just an updated, more advanced form of product tracking, and they have already been used in far more contexts than the humble barcode.

To understand why RFID tags are more than just updated bar codes, it helps to provide a brief description of how the technology works. There are three types of RFID tags: passive, semipassive, and active (Bhuptani & Moradpour, 2006). Passive tags are the cheapest and most popular form of RFID. These tags can cost less than US$ 0.10 and have no internal power source. Information is embedded in tags and when the tags pass within range of an RFID reader,[2] they are activated and the reader can access their information. These tags can be as small as a grain of rice and can be embedded in a living organism or as a label on a product. Passive tags also, like semipassive and active tags, come in three different forms: read only, write once/read many (WORM), and read/write. Read-only tags can only have information written to them once; WORM tags can be written over multiple times, but information cannot be deleted; read/write tags are the most advanced and can be written over multiple times, and in some cases, respond to changes in the environment using sensors to change their internal information.

Both semipassive and active RFID tags have an internal power source so they can broadcast information over a longer distance. The difference between the two is that semipassive tags still rely on the RFID reader as a power source. The reader must activate the tag, just as with the passive variety. Active tags, on the other hand, have an internal battery powerful enough to send out the signal without the aid of an external reader. Data can be accessed at much larger distances from active tags, and active tags can include more data than the typical 96 bit limit found in passive tags.[3] Unsurprisingly, active tags cost much more than passive tags, ranging in price from US$10.00 to $50.00.

While different types of tags have different uses and costs, they all work in fundamentally the same way. A full RFID system involves the tag as mobile technology, a reader to activate or access the tag, and a host computer to host the data (Haller, 2010). The reader accesses the tag through microwave waves, and different tags and readers transmit at different frequencies. The use of microwave signals rather than the optical scanners used to read barcodes means that RFID tags do not require the clear line-of-sight between reader and tag necessary for bar codes. In other words, a human being does not need to actively manipulate a reader to access the tag, and a reader can access multiple tags at

once. RFID tags also use the Electronic Product Code (EPC) rather than the UPC numbers found in bar codes. UPC numbers are assigned to categories of products, so different packs of Diet Coke would have the same UPC number. EPC, on the other hand, uses a 96-bit code (a series of 96 0s and 1s giving 2^{96} unique options) to assign an individual number to *every single* RFID tag (Landt, 2005).

There are now billions of RFID tags in circulation, and that number increases every year. Walmart—the world's largest retailer—now requires its 100 top suppliers to track products with RFID tags. The U.S. Department of Defense also requires major suppliers to use RFID tags to combat waste (Ayoade, 2011). And RFID has been identified as one of the key technologies in the infrastructure of the growing "Internet of Things" because the tags can assign unique identifiers to objects and let them communicate with other objects in a networked manner (Haller, 2010). For example, the oft-cited example of the "smart fridge" would be able to read RFID tags on products and then inform the owner when a product was about to expire or if the owner needs to buy more of a product. Similar models have already been deployed on "smart shelves" that inform retailers when a product needs to be restocked (Syrjälä, 2012).

Of course, RFID is used for more than the tracking and networking of consumer products. RFID tags are embedded in pets so veterinarians can scan them to access contact information. Most new passports issued by the United States and the European Union include RFID chips that contain biometric data. Pharmaceutical drugs contain RFID chips to help combat piracy (Ayoade, 2011). Keyless cars rely on RFID tags to recognize that the car owner is in the driver seat. Babies in newborn wards are tracked through RFID bracelets. Some people even embed RFID tags in their skin so they can gain access to clubs and secure work sites (Losowsky, 2004) and so on. For all the research on smartphones as locative media, RFID tags are being used to track more things through the physical world than GPS and Wi-Fi location, and they will become more popular as prices decrease and more RFID readers are deployed. Like with many other types of infrastructure that go unnoticed by most people (Horst, 2013), RFID has already begun to impact people's lives, often without their knowledge. The rest of this article builds upon this discussion of RFID and suggests four possible research areas of interest to the mobile communication community.

RFID and future research

The four areas I cover in the rest of this article are (a) Big Data, (b) surveillance, (c) space and place, and (d) nonhuman agency. As I stated in the introduction, the goal of this article is to begin a discussion about RFID technology and suggest trajectories for future research in the mobile communication field. For that reason and because of space constraints, I am concerned more with exploring a variety of research areas than focusing too deeply on any single one. I also chose four areas based on particularly relevant topics for the mobile communication field rather than addressing the bulk of RFID literature, which mostly focuses on technical details and the use of RFID tags in supply chain logistics. After linking RFID to each one of these research areas, I conclude the article with a set of questions designed to provoke future RFID research from mobile media scholars.

RFID and Big Data

Big Data is possibly *the* dominant current buzzword in some parts of the social sciences. Big Data is a research paradigm that relies on large datasets and the computational power to analyze the data. Once the data is collected into various databases, data scientists run algorithms to identify correlations in the data. Searching for correlations by itself is not a new practice. What shifts with Big Data approaches is that correlation and not causation is the end goal of the research: "society will need to shed some of its obsession for causality in exchange for simple correlations: not knowing why but only what" (Mayer-Schönberger & Cukier, 2013, p. 7). Equally importantly, Big Data is in many ways opposed to central tenets of the scientific method because, at its core, Big Data has little interest in explanatory power or scientific precision (Mayer-Schönberger & Cukier, 2013). Instead, theories that guide the research are supposedly abandoned and Big Data approaches are not interested in explaining the correlations they find. In addition, because Big Data is more interested in correlations and gigantic datasets, the types of precision typically associated with quantitative sampling become less important. The goal is the manipulation of huge datasets rather than maintaining the "rigid exactitude" of the scientific method (Mayer-Schönberger & Cukier, 2013, p. 13).

Big Data is still in its relative infancy. Only recently, with the growth of the Internet, mobile technology, and sensor technology has the world begun to produce enough analyzable data for successful Big Data approaches. And Big Data has had its successes, many of which are detailed by Mayer-Schönberger and Cukier (2013). However, Big Data also has its detractors and has been criticized for not working as advertised (Harford, 2014), for endangering users' privacy (boyd & Crawford, 2012), and for ignoring groups of people in its data analysis (boyd & Crawford, 2012). These criticisms are important, and we are still at a point at which Big Data may be more hype than reality. But for now at least the hype is real, and urban planners have already adopted Big Data to guide infrastructure projects and urban development (Mayer-Schönberger & Cukier, 2013).

So what does Big Data have to do with RFID tags? Big Data requires the collection of massive amounts of data, and those data have to come from somewhere. In many cases the deployment of RFID tags as mobile infrastructure contributes to massive new forms of data collection. Describing this phenomenon, Hayles (interviewed in Gane, Venn, & Hand, 2007) argues that "If the relational databases are the brains of the system, RFID tags are the legs" (p. 349). RFID tags embedded in products, cars, mobile phones, and so on, become a form of networked, mobile infrastructure, transmitting data when accessed by RFID readers, and tags can also be embedded with sensor technology so they can transmit sensor readings. A few examples of how Big Data and RFID are related can be found in the management of urban transportation. Many subways now use cards that feature RFID chips, meaning data about passenger volume is recorded and can be analyzed to manage train schedules. Many toll roads, such as the EZ Pass system in the United States, also rely on RFID technology to capture automobility data, and those data can be used to respond to traffic patterns and address congestion. In these ways, RFID helps make data collection mobile in new ways, which is an essential element to Big Data approaches that want to analyze certain types of correlations.

In effect, in a Big Data paradigm RFID tags operate as a pervasive form of locative media that moves past the collection of human-centric smartphone location data and makes products, things, and people trackable all over the world. Mobile carriers have already begun to experiment with Big Data tracking and marketing from smartphone data (examples include Verizon's precision marketing and Telefonica's Big Data push), and one of the goals of RFID manufacturers is to make almost all things trackable at all times (Albrecht & McIntyre, 2006). In a sense, this tracking and data contribute to what Bleeker (2006) suggested in his concept of the "blogject" as an object that blogs about its own state and shares its own mobility and status with various databases. To return to the Hayles quote mentioned earlier, RFID tags are one of the legs in the march towards Big Data.

RFID and Big Data also have consequences for another shift identified in Hayles's (1999) earlier work: the shift from presence/absence to pattern/randomness. As RFID tags are used to track bodies in many different walks of life, it will be patterns of data, specific configurations of bodies, that matter more than any individual embodiment. Big Data, in effect, focuses on finding patterns in the randomness of large bodies of data, and RFID data collection turns movement of people and things into the data that helps comprise the posthuman shift towards pattern/randomness as the governing code for our contemporary age. Of course, as the next section examines in more detail, this data collection also raises concerns about surveillance that may be particularly relevant for mobile communication scholars.

RFID and surveillance

The journal *Surveillance and Society* recently featured a theme issue on Big Data that examined the close links between the types of data collection discussed in the previous section and concerns about surveillance.[4] As Klauser and Albrechtslund's (2014) article in that issue discussed, surveillance is often enacted through infrastructure that includes CCTV cameras, smart buildings, and RFID. The authors also point out that one of the major pushes of Big Data is the desire to "optimize urban infrastructure through smart technologies" (p. 273), and RFID tags are one of the prime technologies in this plan. RFID embedded in subway cards and toll tags track individuals' movement, and the data collected can be used to optimize infrastructure. That data, however, is tied to the individual through credit card purchases and individual toll accounts. So while the goal to improve transportation may be laudatory, Klauser and Albrechtslund show that this data collection may take surveillance to a new level.

And urban planning is only one way in which data is collected through RFID. Possibly the most detailed account of how RFID tags may lead to a more extensive surveillance system comes in the book *Spy Chips.* The book is written by Katherine Albrecht and Liz McIntyre (2006), who are representatives of the advocacy group Consumers Against Supermarket Privacy Invasion and Numbering (CASPIAN). Albrecht and McIntyre are two of the leading critics of the RFID movement, and their book paints a dystopian picture of RFID as a Big Brother, total surveillance technology. While the book occasionally overstates concerns about RFID, *Spy Chips* is important reading for anyone interested in how RFID may enable new forms of tracking.

Albrecht and McIntyre (2006) are not alone in their concerns about RFID. Research has shown that consumers have significant concerns about surveillance when companies begin tracking products through RFID (Weis, 2004), and multiple theorists have pointed to the surveillance potential of RFID (Crandall, 2010; Crang & Graham, 2007; Hayles interviewed in Gane et al., 2007; Hayles, 2009). As Hayles (2009) succinctly states, "Surveillance remains one of the principal concerns raised by RFID technology" (p. 48). Consequently, mobile communication scholars who already have examined surveillance through the lens of locational privacy have much to add to the debates about RFID (de Souza e Silva & Frith, 2012; Farman, 2014). Of course, it helps to understand *why* RFID tags are so important from a surveillance perspective.

To understand why RFID can be used to enact new forms of surveillance, we can return to the earlier description of how RFID works. Two fundamental shifts from bar codes are the move away from line-of-sight optical scanning and the move towards unique EPC numbers. Bar codes required the scanner to have a clear path to the code, meaning the person must actively position the product in relation to the scanner. RFID readers, on the other hand, send out a signal using radio waves that activates passive tags, and the signal can move through walls and does not require any active participation from someone scanning the RFID tag. The adoption of EPC is the other major shift because unlike UPC (the barcode standard), EPC allows for individual products to be tagged with a unique identifier. The use of EPC means that all products can then be tracked comprehensively, and because passive tags do not have internal power sources, they work in practical perpetuity.

If RFID are eventually widely deployed on products, then when someone buys a product with an RFID tag with a credit card, that product can then be traced specifically to them. The product can then be scanned without the consumer's knowledge because RFID readers can access tags by using radio waves that do not require any active participation from the consumer (Albrecht & McIntyre, 2006). Some retailers have already implemented marketing plans and have patented processes that scan when a specific consumer picks up a product and then uses RFID readers located throughout the store to track their path using that product's EPC. The end goal, just as it is with targeted location-based advertising on smartphones or targeted advertising online (de Souza e Silva & Frith, 2012; Turow, 2012), is to build a profile of the user and provide targeted advertising. For all the attention paid in academic literature to how people are tracked online and through their mobile phones (de Souza e Silva & Frith, 2012; Turow, 2012), the RFID patent applications reviewed by Albrecht and McIntyre (2006) suggest that RFID may take corporate surveillance to a new level.

The tracking of people through the tracking of products only touches on one of the surveillance concerns about RFID. RFID tags have already been embedded in Alzheimer patients to track movement and provide contact information, and many cars already include RFID tags that are read whenever the car passes through a toll, raising its own set of locational privacy concerns (Monmonier, 2002). And RFID tags do more than reveal location or product information. They can be written with personal information as well. For example, biometric passports contain RFID tags that reveal the passport user's identification numbers and biometric information, and some driver licenses in the United States now include RFID tags. In addition, Dennis and Urry (2009) predict that RFID may be used to track people's mobilities to limit car travel in the near future.

Before moving on, I want to conclude this overview of the surveillance concerns related to RFID tags with an important point: RFID tags are not always visible on products or in other materials. They can be embedded inside skin, sown into the fabric of clothes, placed underneath clothing tags, located in the soles of shoes, embedded in driver's licenses, and included in between layers of cardboard on boxes (Albrecht & McIntyre, 2006). One of the most interesting explorations of the invisibility of the technology was Nancy Nisbet's (2004) art project *Pop! Goes the Weasel*. For the project, Nisbet injected RFID tags into her skin and explored how issues of surveillance could be tied to the body through microchip tracking. The project focused on how data captured through the chips raised questions of identity and what the data meant as it traveled from an embodied actor to a database, and her work suggests pathways for future research from mobile media scholars who can examine how behaviors are enabled and constrained through RFID surveillance, how people negotiate the new surveillant assemblage of RFID, and how data is collected to add to our already detailed data profiles.

RFID and space and place

Mobile media scholars have long studied how mobile technologies can affect how people experience physical space. Du Gay, Hall, Janes, Mackay, and Negus (1997) and Bull (2000) wrote about the Walkman and the "privatization" of space; Ling (2004), Humphreys (2005), and many others discussed how mobile phone use impacts how spaces are experienced; and locative media researchers have analyzed how location-awareness and location-based digital information can impact the social construction of physical space (de Souza e Silva & Frith, 2012; Farman, 2012). As technologies that can potentially be deployed everywhere and make the world more calculable and trackable, RFID tags pose interesting questions about the role mobile technologies play in constructing space and place. I want to discuss two concepts that may be particularly useful for future spatial analyses of RFID technology: Thrift's (2004b) technological unconscious and Kitchin and Dodge's (2011) code/space.

Thrift's (2004b) concept of the technological unconscious examines how various technologies have made space more calculable and addressable. This technological unconscious "is the bending of bodies-with-environments to a specific set of addresses without the benefit of any cognitive inputs" (p. 177), and the goal of the technologies he examines is the "standardisation of space" (p. 177). He discusses various technologies, ranging from mechanical time keeping to the development of a physical address system, but in his examination of different innovations that have contributed to spatial standardization, he writes that "The fourth innovation, and perhaps in the end the one likely to prove the most powerful, is the RFID (Radio Frequency Identification) tag" (p. 185). RFID tags standardize space in new ways, potentially making millions of products and people locatable. They are a prime example of the "unconscious" that operates beneath the level of human cognition, transmitting information in the background of our everyday interactions with space. They also represent an important technology in the forms of "qualculation" Thrift (2004a) examined in other work. Qualculation is "an activity arising out of the construction of new generative microworlds which allow many millions of calculations continually to be made in the background of any encounter" (p. 584), and

the tracking of RFID tags and the transmission of the data to databases are examples of the qualculation occurring invisibly in our interactions with space.

Thrift's (2004a, 2004b) writings on technology and space were important to the concept of code/space developed by Kitchin and Dodge (2011). Their work focuses on the crucial role software plays in the production and the constant state of becoming of contemporary spaces. As they argue, many of our contemporary spaces cannot function as intended without software. For example, a passport area of an airport will not function if the software used to scan passports does not work. The space of a car does not function for automobility if it has a keyless car system and the active RFID tag does not work. These are all code/spaces and they are differentiated from coded spaces, which are spaces augmented by software, but that do not require software to function.

Kitchin and Dodge's analysis of code/space and coded space extends to far more than RFID tags, but RFID is one of the increasingly important pieces of the technological infrastructure that helps construct code/spaces. Tolls use software to read tags, supermarkets use readers to control merchandise, and software combined with RFID tags is altering the ways in which the global flows of products and people are tracked and calculated. Even an RFID key fob to an office can form a code/space when the tag fails to work and the space stops working as an office because no one can enter. In addition, the idea of code/space can also be used to show how RFID can be crucially important from mobilities perspective. As mobilities researchers have argued, technologies play a crucial role in mobility practices and can lead to new forms of mobility/immobility amongst certain groups (Cresswell, 2010). For example, unequal access to transportation technologies can contribute to differential mobility and lack of access to certain mobile media can contribute to new forms of "splintered space" (Frith, 2012). RFID may contribute to new forms of differential mobility in which people without the right tags (e.g., an EZ Pass for private highways [Graham, 2005]) may not be allowed access to certain forms of mobility. Studying RFID from a mobilities perspective will obviously require much more detail than I can provide here, but it is important to note that, just as RFID can help produce space differently through code/spaces, these tags may also contribute to new mobility practices.

The analysis of RFID tags from a spatial perspective will be different from the more common analyses of popular locative media such as smartphones. The locative media analyzed in mobile communication literature is typically human-centered; location-based applications are designed so that human users can "read" their spaces differently by accessing spatial information (de Souza e Silva & Frith, 2012). RFID tags can also impact how spaces are produced, but they do so at a level of cognition beneath the intentional use of typical locative media. RFID tracking, the mobilities produced through toll tags and key fobs, and the possible networks of the Internet of Things operate in the background, working as infrastructure beneath the level typically perceived in our day-to-day interactions with space (Aztori, Iera, & Morabito, 2010). For that reason, concepts such as the technological unconscious and code/space that move away from human intentionality to understand how spaces are understood and produced can be a useful addition to the already strong understanding of spatiality in mobile communication scholarship. The technological unconscious also has implications on a more theoretical level for the meaning of nonhuman agency, which I detail in the next section.

RFID and nonhuman agency

RFID technology is an excellent example of why technological determinism cannot account for the role people play in shaping how technology is used and deployed. Based on Albrecht and McIntyre's (2006) reading of patent applications and industry literature, we would likely already live in a world dominated by RFID tags if it were entirely up to the designers of RFID technologies and the corporations that adopt them. However, RFID implementation has come in fits and starts, in large part because of protests from consumer groups. For example, in Germany people protested against a plan for "Next Generation" supermarkets that would incorporate RFID tags in all products. In the UK, consumer groups protested when Gillette and supermarket chain Tesco implemented a plan to use RFID tags to activate cameras to photograph consumers (Albrecht & McIntyre, 2006); privacy groups in California likely played a role in getting the state to drop plans to include RFID chips in state driver licenses (Kravets, 2013). Clearly, human actors have exerted agency over how RFID tags are used; however, RFID raises interesting questions about machinic agency that should be the topic of future studies by mobile communication scholars.

While not the dominant theories in our field, approaches such as actor–network theory and nonrepresentational theory have been adopted in some mobile media scholarship for understanding the agency of mobile technologies (Tosoni & Tarantino, 2013). These theories, along with others—including object-oriented ontology (Bogost, 2012) and phenomenology (Dourish, 2001)—move away from a focus solely on human agency and can potentially be valuable theoretical frameworks from which mobile communication scholars can analyze the role RFID tags play as active agents in our environment.

Understanding machinic agency will be important because RFID tags are a key element in what is called machine-to-machine (M2M) communication, which is an important part of the growing Internet of Things (Aztori et al., 2010). M2M communication refers to devices' ability to communicate information to another device without direct human intervention. For example, sensors may communicate information about energy use to a city's smart grid, which can then activate stand-by generators. Or a smart shelf could read RFID tags on food and send a message to the warehouse that a product needs to be restocked. The Internet of Things is expected to include more than 25 billion devices by 2020 that can communicate with one another ("Gartner says the Internet of Things' installed," 2013), and RFID tags are an important part of this system (Aztori et al., 2010).

Arguing that these machines communicate with each other does not mean they are autonomous. M2M communication is created by humans, deployed by humans, and built on code and algorithms written by humans. However, much of the communication that goes on between these machines, including through RFID tags and RFID readers, does not in any functional way require human intervention or human perception. When RFID tags are read by stationary readers and the information is transmitted to databases, most of the time no human will ever see the individual pieces of data. In some cases, the machines will automatically change state, by for example changing the thermostat in a house or adjusting energy in a smart grid. In other cases, the data will be transmitted to relational databases where it will be analyzed for correlations using various Big Data

techniques. In that case, the only data human actors will directly interact with is the overall correlations found in the data, not the individual data collected by the RFID readers. Once these tags and machines are deployed in the environment, they act and communicate information with only occasional intentional human action.

Hayles (2009) has been one of the few thinkers to engage with the question of the agency of RFID tags. She writes that one of the central theoretical concerns about the technology "are the effects of RFID in creating an animate environment with agential and communicative powers" (p. 48). She argues that RFID tags are changing the human environment by making it interactive in new ways, but she does not go as far as others such as Latour (2005) in arguing that RFID and similar technologies are equal actors in the environment. Instead, she argues that with these tags, readers, and related technologies, "A framework is needed capable of building bridges between human agency and an RFID world without collapsing distinctions between them. Such a framework would allow us to shed the misconception that humans alone are capable of cognition" (Hayles, 2009, p. 66).

The issue of agency examined by Hayles points to an important future area of research for mobile communication scholars and also closely relates to the previous section on spatial perspectives to the study of RFID. Key to the concept of code/space developed by Kitchin and Dodge is the role software plays in the transduction of space. Transduction refers to "the constant making anew of a domain in reiterative and transformative practice" (2011, p. 16), and "space from this perspective is an event or a doing" (p. 16) rather than an ontologically fixed site of action. Space is always contingent and based upon certain, never fully fixed, constellations of people, practices, and technology. In these code/spaces, as discussed before, software has an agentic function that plays a significant role in how spaces are transduced by allowing or disallowing certain sociotechnical practices. RFID are a major technology that comprises code/space, so mobile media scholars will be able to provide close analyses of how these technologies exert agency in how spaces are made anew through the hybrid constellation of people and the software they interact with in everyday life.

As media studies scholars, we have explored issues of human and nonhuman agencies, and we can also contribute and critique existing models of M2M communication so central to the growing Internet of Things. I explore these issues in more detail in the concluding section of this article in which I pose a set of questions about RFID tags that will hopefully encourage future engagement from the mobile media community.

Questions and conclusion

Our world is filled with billions of RFID tags on shipping containers, in our pets, on our cars, in our wallets, and on our key chains (Bhuptani & Moradpour, 2006). I want to conclude here with a set of questions meant as a provocation for future research on RFID. By no means are these questions meant to be all encompassing, and these are only a few of the important research questions raised by the deployment of RFID as mobile technologies. Instead, the goal of this final section is to spur future research and make a final case that the field of mobile communication has valuable insight to contribute to the understanding of how RFID technology may impact society.

- **What are the strengths of Big Data approaches that analyze RFID data? How representative of the population is the data?** RFID tags already play a key role in collecting data on transportation patterns, supply chain logistics, and transnational mobility; however, as researchers have warned (boyd & Crawford, 2012; Crawford, 2013), Big Data methodologies raise concerns about privacy and sampling. Mobile communication scholars can adopt Big Data approaches and critique existing approaches that use RFID technologies while also attending to sampling issues associated with more established social scientific approaches.
- **How can mobilities and mobile media scholars use RFID in research designs?** Locative media art projects, such as the Milk Project (Polak & Auzina, 2004), have used GPS to visualize the mobility of products across Europe. As Allen-Robertson and Beer (2010) point out, RFID tags and the constant tracking of goods provide opportunities for scholars interested in mobilities to use mobile technologies to better analyze and visualize how goods flow in the global economy.
- **How are RFID technologies discursively positioned by manufacturers and other corporations?** Kitchin and Dodge (2011) argue that the software that composes code/space is often justified using discourses of security and convenience. RFID tags have been rationalized using discourses of security by various governments and convenience and cost by corporations (Ayoade, 2011). Mobile media scholars have analyzed the discourses surrounding earlier mobile technologies such as the mobile phone (Ling, 2004), and they are all well suited to contribute to the scholarly understanding of the rhetorical construction of RFID.
- **How can RFID be understood from a spatial perspective?** Mobile communication literature has a long history of analyzing how technology interacts with space and place. That tradition has become more developed with the recent growth in locative media research, which has closely attended to the interrelationship between space and mobile technologies (Farman, 2012). Consequently, our field has much to contribute to the work of Thrift (2004b), Kitchin and Dodge (2011), and others who have analyzed the role RFID plays as hidden infrastructure that standardizes and socially constructs contemporary spatiality.
- **How will the deployment of RFID be used to *surveille* individuals?** Mobile communication literature has exhibited an intricate understanding of the locational privacy issues associated with new types of surveillance (de Souza e Silva & Frith, 2012; Dourish & Bell, 2011; Shklovski, Vertesi, Troshynski, & Dourish, 2009). We now have the opportunity to extend these analyses to the spread of RFID tags to better understand the surveillance capabilities of this relatively new mobile technology.
- **How can mobile communication scholars help develop a framework to understand the different types of machinic agency of RFID systems?** As I stated earlier, mobile media research has used theories of nonhuman agency—such as actor–network theory and nonrepresentational theory—to understand the relationship between people and various technologies. Hayles (2009) argues that RFID helps create new animate environments and that scholars need to develop frameworks for understanding the active role RFID as mobile infrastructure plays

in our environment without conflating human and machinic agency. As experts in studying the interactions between people and technologies, mobile media scholars can help develop those frameworks and situate RFID tags in larger discussions of machinic agency.

These are a few of the many research questions raised by RFID. As I hope to have shown throughout this article, RFID tags are an important mobile technology that should become an object of analysis in our field. While they differ from mobile media such as the iPod and the mobile phone, RFID tags raise many of the same questions of spatiality, surveillance, and communication, though they often do so in a more invisible way. RFID tags will likely be embedded in more and more objects and used to track mobility in new ways; consequently, they represent an important trajectory for future research in our field, and mobile media scholars should be able to contribute valuable analyses of this important, though often ignored, mobile technology.

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Notes

1. Multiple locative media artists have begun including RFID in their projects. A few examples of these projects are Zapped! (Kumao, 2005) and Exchange: Drifting Between (Nisbet, 2006).
2. The distance at which a passive tag can be read can range from a few inches to 20 m, depending on the tag and reader's antenna, environmental condition, and frequency being used (Bhuptani & Moradpour, 2006).
3. RFID tags have also been used for electronic article surveillance (EAS), which typically involves a simple 1-bit tag that alerts when it comes within a distance of a reader. EAS is often used to combat shoplifting.
4. I chose to focus on surveillance in this section rather than privacy because privacy is an immensely complicated term. Different people understand the concept differently, and as some scholars have argued, privacy may not be an analytically useful concept for understanding the tracking of people and things in our contemporary media environment (Dourish & Bell, 2011; Shklovski et al., 2009).

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