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Computer Guts and Swallowed Sensors: Making Ingestibles Palatable in an era of Embodied Computing

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Introduction to Ingestibles

Picture the following three scenarios. You have an elderly uncle named Buck. Given his advanced age, on rare occasions Uncle Buck forgets to take his lifesaving medication. Stephanie, your best friend's niece, requires risky surgery to dislodge a foreign object that has become stuck somewhere in her gastrointestinal tract. A company, Visceral Data, produces a smart pill that sends your biodata to their proprietary app, allowing you to make decisions about your body (perhaps that you should slow down your run, or adjust a prescribed dosage of thiamazole). Currently, numerous partners and organizations in academia, government, and the private sector are building ingestible computational technologies that would feature prominently in each of the above scenarios, including the policy frameworks that govern them.[1] As Google executive chairman Eric Schmidt recently stated, "You will - voluntarily, I might add - take a pill, which you think of as a pill but is in fact a microscopic robot, which will monitor your systems" and share information about what is happening in your body (Bilton 2013).

[1] See the FABRIC archive for various examples: https://www.fabricofdigitallife.com/

This chapter discusses ingestible computing, or what are sometimes called "ingestibles"—that is, embodied computing technologies that enter the mouth and, in most cases, eventually travel through (and out of) a user's body. Estimates put the global smart pills market size to be worth roughly $3.0 billion by 2025 (Grand View 2017). Though the technology may seem new, speculative fictional portrayals of ingestible technology began half a century ago with films like the 1966 sci-fi classic *Fantastic Voyage* and then later with films like the 1987 sci-fi comedy *Innerspace* (technically the object is injected but the general idea is the same) and the 2011 nootropic thriller *Limitless*. Today, several dozen companies and research teams are producing ingestible computational technologies and products that are already hitting the market, yet there is relatively little social scientific research on these emerging developments. In this chapter, I untangle some of the theoretical implications of ingestibles and their relation to embodied computing and discuss some of the emerging people, places, and practices in the ingestibles market, before ending with a few of the developing political and ethical issues that are at stake in ingestible computing for their users and manufacturers.

While ingestibles may be the least established form of embodied computing, companies like Proteus Digital Health – which began research and development before 2008 and is one of the most visible ingestibles manufactures on the market – continue to design and deliver products that include ingestible sensors, small wearable sensor patches, and applications on mobile devices that are connected to provider portals.[2] There is some obvious anticipated resistance to ingestibles—people have trouble visualizing and accepting that they would *swallow* a sensor or a computer. Yet the evidence shows that, before long, ingestibles will become palatable to users in the same way wearable technologies have. They will be commonplace as patients adopt ingestibles as part of their long-term health strategies at the behest of insurance companies, as users begin to track biodata over time to regulate their bodies, and unique applications develop, such as using ingestibles for things like gaming and security. As such, it is necessary to consider the sociotechnical affordances and constraints of ingestible technology, along with the tradeoffs that users make when interacting with them. Central to these concerns will be our relationship to our biodata, and who controls it. We can start by addressing how media and communication researchers have theorized computing and embodiment, before contextualizing ways that media and communication policy is currently handling new technological developments in ingestible computing. After, I highlight several areas of emerging ingestible media centered on visceral data, smart pills, and microbots, and end by considering the social implications of these technologies, including potential ethical concerns.

[2] Proteus website: https://www.proteus.com/

Theoretical Precursors: Embodied Interaction, Ubiquitous Computing, Biomedia

Theorizing embodied forms of computation has a long history in literature on communication and media technologies. Long ago, the cyberneticist Norbert Wiener proclaimed, "information is information, not matter or energy" (1965: 132). There was a tendency in Wiener's early information theory to think of information as being distinct from the material world—bodies and relationships could ultimately be reduced to information systems. Of course, information and energy are a couple and compose materiality, but thinkers such as Wiener privileged the notion of foregrounding informational processes to organize and understand reality. Hayles (1999) provided a famous corrective to Wiener's account by instead asking, "When and where did information get constructed as a disembodied medium?" (50). Hayles asks us to "recall the embodied processes that resist" the "separation between information and materiality" (20). Information here must be understood as embodied in material forms, and there is a certain degree to which it is acceptable to think of our data as being literally a part of ourselves. How could those data be generated if not for the existence of our own material bodies? The body has a fundamental role to play in the production and manipulation of information, and today ethics researchers interested in developing frameworks for understanding embodiment and data ownership are returning to contextualizing the body's privileged relationship to the data that it generates. Particularly in the context of health services, why should we give up sensitive data about our bodies to large companies who might then manipulate users through various mechanisms like incentives and noncompliance?

There is an undeniably social dimension to our interactions with embodied information and computation. Using a combination of Heideggerian philosophy that privileges a bodily, situated being-in-the-world with diversified forms of material computing, Dourish (2004) highlights the notion of embodiment and interaction in social computing. Dourish's philosophical approach foregrounds embodied interaction over abstract reasoning to "understand the contributions and opportunities emerging from dynamic new forms of technological practice" (ix). Embodied interaction describes a new way of interacting with computer systems that is sensitive to the environment where interaction takes place. The main thesis that Dourish presents in the book is that embodied interaction can provide a common basis for understanding tangible and social computing, and that we should understand computation in terms of phenomenological presence and action. Going further, Dourish and Bell (2011) provide a rich ethnographic and historical account of the emergence of the ubiquitous computing industry, including its many key actors and products. They situate ubiquitous computing (ubicomp) as unique compared to other areas of technical computing, since ubicomp is as much an idea as it is a technical product—much like the way 'big data', 'cloud computing', and 'internet of things' function today. Ubicomp "encompasses a wide range of disparate technological areas brought together by a common vision of computational resources deployed in real-time, real-world environments" (61). By emphasizing that "the domain of technology and that of everyday experience cannot be separated from each other; they are mutually constitutive" (73), Dourish and Bell show how computing permeates social life and that cognition is wrapped up in our everyday interactions with the world in "embodied practice" (101). Such frameworks are useful for thinking about our embodied interactions with newer forms of ubiquitous computing like ingestibles because they highlight the embodied nature of these technologies.

Perhaps most importantly, data, too, play a crucial role in our conceptualizations of bodies and entangle computational and biological embodiment. Looking past the phenomenological situating of bodies as embodied interfaces with the world as well as past ubiquitous computing, the types of biodata generated by embodied computing technologies like wearables, implantables, embeddables, and ingestibles collapse these two notions of embodiment into what Thacker has termed 'biomedia' (2004). Biomedia are the product of bioinformatics technologies enhancing biological materiality. Thacker notes that that the body situates itself between the phenomenological concept of embodiment and techno-scientific frameworks, and it is here where he proposes thinking of the body-as-media (10). Today, one can push this notion even further, as Cheney-Lippold (2017) has, by seeing ourselves reflected in and determined by the data structures and algorithms that process biological information about us. Drawing on Foucault's notion of biopolitics and Deleuze's concept of modularity, Cheney-Lippold situates the body as a corporeal entity managed by institutions that remain at a distance, governing our embodied selves through datafication.

Embodied Computing, Bodily Negotiations, Data Ontologies

Building on and extending theoretical work on embodied interaction, ubiquitous computing, and biomedia, literature on new and emerging forms of wearables, ingestibles, implantables, and embeddables complicate our relationships to perception and action as the necessary and sufficient conditions for understanding tangible and social computing. Here, the notion of embodied computing that I associate with such technologies should be understood as a double articulation where computing is at once embodied through computational materiality and passively embodied in the user's enhanced body, rather than as an embodiment of how we come to understand biomateriality or the user's external interaction with computers. The interactive environment where embodying takes place is in this case not the exterior world but rather the enhanced activity of the user's body—the user does not necessarily interact with the environment but becomes the environment. Meaningful engagement with the world defines embodied interaction, but what happens when internal activity produces meaning for understanding bodily capabilities, rather than external activity between user and tool in their environment? If embodied interaction and ubiquitous computing are about the intentional manipulation of external artifacts, and biomedia concern a clearer picture of what happens inside the human body, the concept of embodied computing signals what happens when computational artifacts are manipulating us from the inside, enhancing our bodies, while they share information about ourselves with external forces.

The literature on embodied interaction stresses intentionality, as far as the computer products we use typically require representations. Of course, it is not a black and white distinction, but what happens with ingestible technology, where the user does not necessarily interact with the produced representations based on the internal processes that are taking place? Here, I am thinking of things like data collection, surgery, etc. If embodied interaction is about how we intentionally act on and through technology (Dourish, 2004, 154), then embodied computing might be how computing acts on and through us, producing new power asymmetries with external regulators and administrators who have privileged access to data generated by embodied computing devices. Where embodied interaction amplifies our external activities, embedded in a set of social practices, embodied computing sees devices extending our enhanced bodily activities and practices alongside new relationships of governmentality based on access to privileged information.

Following Mol's (2002) anthropological work on the ontology of the body in medical practice, I understand embodied computing as the site where negotiations about the human body take place and where data and governmental frameworks deploy new ontologies of bodies-in-the-making. My intention in drawing attention to bodily negotiations and the ontologies they introduce is to circumvent received knowledge of technologies like wearables and to highlight ways in which governing frameworks associated with embodied computing devices like ingestibles cast user's bodies in specific contexts. Embodied computing aligns here with biopolitics and theoretical traditions that do not separate the social body from the technological or political apparatuses. This approach also draws on Haraway's (1991) conceptualization of organisms as hybrid, intertwined with technology. Haraway notes that the concepts of nature and experience are not innocent or self-evident aspects of culture and embodiment, and embodied computing highlights this distinction. More specifically, Lupton (2017) theorizes the ontologies of personal digital data through embodied computing technologies like ingestibles. Drawing on the work of Haraway and Mol, Lupton (2016) theorizes what happens when we literally eat data and become digital data–human assemblages, writing that "the human subject may be conceptualised as both data-ingesting and data-emitting in an endless cycle of generating data, bringing the data into the self, generating yet more data" (4). Ingestibles and embodied computing devices are engaged in bodily negotiations and their data ontologies are the new frontiers where such negotiations will take place.

Shifts in Governmentality, Privacy, Policy

New bodily ontologies are being constructed by governments that facilitate policy shifts to new conceptualizations of the body. Pedersen (2013) has described embodied computing in terms of reality shifting along a continuum of embodiment, and movements in policy orientations about ingestibles show how such changes occur. Today, governments are debating the policy implications of these shifts. The US Food and Drug Administration (FDA) has product classifications for an ingestible event marker which they describe as a system "composed of an ingestible microsensor, a data recorder in the form of a skin patch, and software" and an ingestible telemetric gastrointestinal capsule imaging system "used for visualization" (FDA 2018a, 2018b). In 2001, he FDA approved ingestibles for assisting with gastrointestinal visualization and listed several risks, including biocompatibility, electrical and mechanical safety, radio-frequency radiated power and electromagnetic compatibility including interference, functional reliability, and misinterpretation (FDA 2018c). Yet, while the FDA lists many safety controls on ingestible cameras, privacy and user data does not appear on the guidance document. One may chalk this up to less concern about private data in 2001, yet today the datafication of health is a primary issue in embodied computing (Ruckenstein & Schüll, 2017). Government attention is purposefully redirected away from such concerns to make room for boosting the innovations and efficiencies promised by technologies like ingestibles to make them more palatable to the consumer market.

The FDA recently approved the first ingestible in 2017. The product was Abilify MyCite, a pill with sensor that digitally tracks if patients have ingested their medication (FDA 2018d). In the FDA's press release, Mitchell Mathis, director of the Division of Psychiatry Products in the FDA's Center for Drug Evaluation and Research states, "Being able to track ingestion of medications prescribed for mental illness may be useful for some patients". While true, the press release about the Abilify MyCite approval did not mention privacy or user's data, and the product website contains limited information about data retention.[3] Abilify MyCite's parent company is Proteus, in partnership with Otsuka Pharmaceutical Co. Ltd. (Proteus 2018). On Proteus' own press release, Andrew Thompson, president and chief executive officer of Proteus said, "The time is right for the category of Digital Medicines to be available […] Consumers already manage important tasks like banking, shopping, and communicating with friends and family by using their smart phones, as they go about their daily lives." The language interestingly frames ingestibles next to activities like shopping, even though they transmit sensitive biodata. But such framing is in the interest of Proteus, who would prefer to be seen as providing choice and freedom rather than

[3] See: https://www.abilifymycite.com/

collecting vast troves of valuable private information. There is no indication of what happens to user's health data, or how access to such data may affect insurance premiums, coverage, privacy, or retention.

Among several other mandates – including the wildly unpopular Restoring Internet Freedom initiative that sought to repeal Obama-era net neutrality regulations – the US Federal Communications Commission (FCC) has put forward a task force to advance health care technologies and create interest about them, including ingestibles. Titled Connect2HealthFCC, the proposal explores "the intersection of broadband, advanced technology and health" (FCC 2016a). Among the projects that lay under the purview of Connect2HealthFCC is a mandate to boost health care technology and knowledge in the form of ingestibles, wearables, and embeddables (FCC 2016b). The FCC innocuously frames Connect2HealthFCC in terms of convenience and efficiency, pointing to embodied computing devices as enhancing routine tests, appointments, and results waiting periods. They describe internet-enhanced technologies like wearables and radio-frequency identification (RFID) chips as offering the potential of "more convenient, ultimately less-costly – and less-invasive – solutions", pointing to examples like smart clothing and smart tattoos.

Speaking specifically to ingestibles, the FCC describes the new technology as "digital tools that we actually 'eat'" and include examples such as smart pills that use RFID to monitor physiological reactions to medicine. They invoke smart pills that might track blood or dosage levels and describe tiny pill cameras used during surgeries or checkups. The FCC also describes wearables and embeddables but implantables are curiously absent. In any event, documents like this show that governing bodies like the FCC are paying attention to ingestibles and are currently laying down policy frameworks for how ingestibles are regulated and conceptualized. Connect2HealthFCC focuses almost exclusively on the efficiency improvements and innovation benefits of ingestibles, without providing much content about their potential harms and negative consequences.

Lacking content on the historical development and potential ethical implications of these technologies, there is a need to understand the historical emergence of ingestibles and their sociotechnical status and ethical frameworks. How are current inventors and industry leaders framing and using ingestibles? Where the FDA lacks information about ingestibles and privacy, as a communication regulating body, the FCC should conceivable pick up some of that slack. More generally, there is a need to understand the people, products, and practices in the ingestibles industry and tease out ethical concerns. Articles in the popular press have mischaracterized ingestibles as wearables (Jervis, 2016) and there is a need to track the emergence of ingestible tech and other forms of embodied computing. The FABRIC database is one such approach and contains information about a wide variety of embodied computing products, including ingestibles (www.fabricofdigitallife.com). Below are some of the primary contexts in which ingestibles are being developed and used on the market. Some are FDA/FCC approved, while others remain in the prototyping stage.

Inside Out: Ingestibles as Visualization-Enhancing Technologies

One of the primary and earliest aims of ingestibles was to act as literal cameras inside the human body. Currently, there are three main companies involved in the production of ingestible cameras in the form of smart pills approved by the FDA. Given Imaging is an Israeli medical technology company that manufactures and markets the PillCam SB 3, while Olympus America Inc., based in Pennsylvania, produces the EndoCapsule. The Intromedic Company out of Korea produce the MicroCam, and there is a fourth company based out of China called Jianshan Science and Technology Group Co. Ltd. that develops a product called the OMOM capsule, but this last product has not been approved by the FDA (Van de Bruaene, De Looze, & Hindryckx, 2015). PillCam SB 3 is the most known among the wearable cameras and if used for detecting illnesses like Crohn's disease.

Technologies like the ones listed above will generate vast amounts of visual data about our guts. It reasonable to question what the production of such internal visualizations will mean for our future interactions, much in the same way that facial recognition technologies are currently introducing unique social problems. Facial recognition is being used for dubious purposes like determining individuals' race, sexuality, and gender. How might future algorithmic recognition technologies frame and contextualize authority's perceptions of our bodies once access to vast amounts of internal images are made available? For example, might such phenomena as internal stereotyping of bodies occur, creating new biases and problematic epistemologies? Such questions should be asked by critical technology scholars in advance of ingestibles' wide use on the market.

Visceral Data: Ingestibles as Data-Enhancing Technologies

Privacy is becoming a huge concern in ingestible computing, specifically around user data and monitoring (Bilton 2013). HQ Inc.'s CorTemp (Ingestible Core Body Temperature Sensor) transmits biodata as it travels through the digestive tract of the user (HQ Inc 2018). Proteus' digital pill system tracks patients' health with an ingestible sensor made with magnesium and copper that interacts with stomach acid, a sensor patch, and a smartphone application. The pill notifies physicians when patients have taken their medicine and can track dosage accuracy. Further, researchers at MIT found that they could record the acoustic wave of the gastrointestinal tract and measure heart and repertory rates (Traverso et al., 2015). There are also pseudo-ingestibles like the 'pill on a string' developed by researchers at the University of Cambridge, which could help doctors detect esophageal cancer by providing data on a regular basis (Ross-Innes et al 2015). Even smart bottles such as those produced by AdhereTech produce data about our bodies—they emit colors when it is time to take a pill and signal if you have missed a dose, tracking the event; Vitality's GlowCap also offers such a service (Silverman 2017). Embodied computing devices may also include visceral dataenabling technologies that promote sensations, including "data that we see, hear, feel, breathe and even ingest" (Stark 2014).

It would be useful to consider the future forms of visceral data generated by ingestibles and to unpack the ways in which those data may be operationalized against the best interests of the users to whom those data belong. What would it mean if a private health care company had permanent access to your internal biodata on an everyday basis? What types of new power and regulatory frameworks would be enforced that disadvantage individuals who may not understand or comply with directions related to ingestibles? There would be potential privacy problems related to the collection of metadata about user's geolocation, as well as the potential to increase insurance premiums if noncompliance is discovered. The main point is that, much in the same way that we care about our privacy in environments like those provided by social media sites and platforms, similarly we should be attentive to the privacy implications of mass distributed biodata produced by ingestibles.

Nootropics: Ingestibles as Intelligence-Enhancing Technologies

Nootropics are cognitive enhancing smart drugs that are supposed to improve intelligence and memory, including even creativity and motivation. While nootropics are not embodied computing devices per se, they are sometimes included in the category of ingestibles. HVMN, previously known as Nootrobox, is an American company that manufactures and sells nootropics products.[4] There are many nootropics on the market, including Aniracetam, Oxiracetam, Noopept Phenibut, Vinpocetine, Huperzine-A, 5-HTP GABA, Alpha GPC, among others. There are few long-term studies of nootropics and more research must be conducted to determine the exact effects (if any) of these drugs. Some nootropics are prescription only and are developed by big pharmaceutical companies (Modafinal being a popular example, used to increase alertness). Nootropics are often grouped into natural and synthetic varieties, and the FDA has approved few nootropics for non-medical purposes.

Depending on the legitimacy of nootropics, which can only be established after more long-term studies, it will be useful to consider what the use of nootropics would mean in terms of advantaging certain users while disadvantaging others. There are obvious fairness problems involved when someone who can afford highly expensive nootropics uses them to perform better (perhaps gaining them admission to college after a successful test or interview) while those who cannot afford nootropics remain at a disadvantage. How would such technologies be regulated and what best practices would be put in place by authorities who must ensure fairness? Would nootropics be banned in certain

[4] See: https://hvmn.com/

intellectual pursuits in the same way that performance enhancing drugs like steroids are in sports?

Microbots: Ingestibles as Surgery-Enhancing Technologies

Ingestibles can also take the form of tiny, sometimes molecular robots that are used for performing surgery inside your body. Researchers at MIT, the University of Sheffield, and the Tokyo Institute of Technology have recently shown that a tiny origami robot can unfold itself inside the human body – once the user swallows it in pill form – and can be manipulated by an external magnetic field to move inside the body and potentially remove foreign objects from stomach lining, such as a button battery, or to patch a wound (Hardesty 2016). Researchers in Germany have created a robot that resembles a tiny piece of rubber that can move, run, jump, crawl, and swim, and can be used to perform non-invasive surgery on patients (Gorman 2018). Such microbots can also be used to deliver drugs into a patient's system, sometimes in slow-release stages, in order to accurately track prescription dosage—tests have already been conducted on mice and have been shown to "have cured bacterial infections in the stomachs of mice, using bubbles to power the transport of antibiotics" (Revell 2017). Such devices may be able to even swim in your veins or bloodstream (Crane 2017).

The introduction of autonomous foreign artificial agents inside of our human bodies might be the most saliently problematic aspect of ingestibles. Today, we worry about internet of things connected devices and the potential ability of hackers to gain access to these technologies for nefarious ends. Our internet connected cars, fridges, home security systems, even city grids are open to exploitation on the network. What would happen if similar problems occur around internet connected devices in our bodies? There is already evidence that pacemakers can be hacked, and such problems would only be exacerbated in a context where even greater amounts of autonomous foreign artificial agents were inserted into our bodies. Potential problems are not limited to a directed attack. Accidents happen regularly, and there is higher degree at which life-threatening accidents may occur if such ingestible technologies are working inside us.

Other Uses for Ingestibles

There are many other unique areas where ingestibles can be used and their applications are almost limitless. For example, researchers have developed an ingestible for games where users swallow a digital sensor to play (Li et al 2017). The researchers designed a game called Guts Game to investigate ingestible game design and "ultimately help designers to create a wider range of future play experiences". Ingestibles will also someday be produced at home. Google has patented the 3D printing of ingestible shells for medicine (Google 2017) and Intel has also patented ingestible tech (Intel 2016). Ingestibles have also been shown to assist with things like security and tasks like storing passwords inside our bodies (Bilton 2013)—a natural extension of biosecurity. Perhaps more humorously, ingestibles can also track gas development inside the body to let users know when it might be time to visit the bathroom (Mole 2018).

Innovators in the technology industry clearly spend time thinking about researching and developing ingestibles in a wide variety of cases and contexts, often at the expense of thinking about potential harms. It is incumbent on critical technology researches to similarly engage in speculative design practices to remain apace these inventions and to think about the various sociotechnical affordances, constraints, and tradeoffs that would occur once technologies like ingestibles are widely adopted. It is clear that federal regulating bodies are mostly interested in assisting with developing the market of embodied computing devices than in the privacy of users.

Conclusion: Let's Attend to the What Ifs of Ingestibles

While there are seemingly limitless applications of ingestible technologies, there is also the potential for ingestibles to produce harm and negative effects that are not only related to health and medical safety. Many developers of ingestibles will argue that non-adherence to ingestibles can result in health care problems once ingestibles are in wide use on the market. They can be used for things like tracking your medicine intake, reminding you to take drugs, repairing your guts, and tracking data about your body over time. This will reduce visits to the doctor and, in some cases, potentially save people's lives. All of this is true, yet few ingestibles developers pay any considerable attention to privacy issues regarding user health data, or the ways in which ingestibles may be used to produce harm for users. For example, through a content meta-analysis, Mittelstadt and Floridi (2016) analyze five major ethical themes that have emerged from the literature on biomedical big data, including informed consent, privacy, ownership, epistemology, and the big data divide. Products like ingestibles may create future problems if customers do not provide adequate consent. Customers may be nudged or forced to use ingestibles and give up valuable data about themselves that can later be sold, traded, or used against their wishes, often in ways that are unimaginable by them when they sign up to use the technology. User privacy is at stake when ingestibles are used to save data in the form of images, sounds, and biodata about things like heart rate, body temperature, and movement. Such data can be used against people, for example, as when insurance providers require users to successfully track themselves to receive lower insurance premiums. Such problems are also associated with ownership. What happens when individuals cannot afford ingestibles or when they do not have the means to track themselves? Who owns the data when successful tracking does occur, or when it occurs through rented or free technologies?

Ingestibles act as new forms of surveillance and stand to monitor users in unknown ways (Schlaefli 2016). *The New York Times* wonders if the first digital pill will create a biomedical Big Brother (Belluck 2017). There are new epistemologies of the body that will be created by ingestibles and their various uses in the market and these will change our conceptions of the body and what it means to interact with it. Otsuka and Proteus state that their Abilify MyCite system "records medication ingestion and communicates it to the patient and healthcare provider" and that "it can collect data on activity level, as well as self-reported rest and mood which, with patient consent, can be shared with the healthcare provider and selected members of the family and care team"—yet there is little information about what will happen with this data (Proteus 2018). Brandom (2015) states that patients' "best protections are medical privacy laws like HIPAA, which prevent medical data from being shared with anyone outside the hospital system." Such protections, Brandom states, prevent employers or authorities from using products like those developed by Proteus to track you, yet they do not "keep data out of the hands of healthcare providers"—ingestibles can be used to enforce compliance, or insurers can increase co-pays if there is evidence of noncompliance. Cloud-connected medical devices save lives, but also raise questions about privacy, security, and oversight (Alexander 2018).

As we move into a new era of embodied computing devices, ingestibles are one of the least studied forms of such computing. Much talk and research has focused on the innovative and efficient outcomes of ingestibles, but more time should be spent, particularly by media and commination researchers, on investing the what ifs of ingestibles and how they will affect users in the future. Embodied computing is here, and we should be proactive to the problems generated by ingestibles, not reactive. Only then will ingestibles truly become palatable.

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