Original Article

Fabricated data bodies: Reflections on 3D printed digital body objects in medical and health domains

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Abstract The advent of 3D printing technologies has generated new ways of representing and conceptualising health and illness, medical practice and the body. There are many social, cultural and political implications of 3D printing, but a critical sociology of 3D printing is only beginning to emerge. In this article I seek to contribute to this nascent literature by addressing some of the ways in which 3D printing technologies are being used to convert digital data collected on human bodies and fabricate them into tangible forms that can be touched and held. I focus in particular on the use of 3D printing to manufacture non-organic replicas of individuals' bodies, body parts or bodily functions and activities. The article is also a reflection on a specific set of digital data practices and the meaning of such data to individuals. In analysing these new forms of human bodies, I draw on sociomaterialist perspectives as well as the recent work of scholars who have sought to theorise selfhood, embodiment, place and space in digital society and the nature of people's interactions with digital data. I argue that these objects incite intriguing ways of thinking about the ways in digital data on embodiment, health and illnesses are interpreted and used across a range of contexts. The article ends with some speculations about where these technologies may be headed and outlining future research directions.
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Introduction

The advent of 3D printing technologies has generated new ways of representing and conceptualising health and illness, medical practice and the body. There are many social, cultural and political implications of 3D printing, but a critical sociology of 3D printing is only beginning to emerge. In this article I seek to contribute to this nascent literature by addressing some of the ways in which 3D printing technologies are being used to convert digital data collected on human bodies and fabricate them into tangible forms that can be touched and held. I focus in particular on the use of 3D printing to manufacture non-organic replicas of individuals' bodies, body parts or bodily functions and activities.

The article is also a reflection on a specific set of digital data practices and the meaning of such data to individuals. Data – and particularly digital data – have become a key word for our times. As social life, social institutions and spaces are increasingly digitally monitored and configured by digital technologies that document and record data, the meanings and uses of these data have become important topics of enquiry. Given the current prevalence of digital data surveillance and monitoring of people by both voluntary and involuntary activities, data practices, data assemblages and data objects have all become phenomena for critical social and cultural investigation. Such a perspective devotes attention to the wider social, cultural and political elements of people's data practices and understandings (Kitchin and Lauriault, 2014; Lupton, 2014a, 2015).

In the ensuring discussion I use the term 'digital body objects' to denote the phenomena that are generated from the use of digital technologies as they are applied to gathering data on human bodies and using these data to represent bodies in certain ways. 3D fabrications of human bodies are one form of digital body objects among a vast array. They incite intriguing ways of thinking about the ways in digital data on embodiment, health and illnesses are interpreted and used across a range of contexts.

3D printing (or in technical terms, additive manufacturing or additive fabrication) has been used for more than two decades in manufacturing (Petrick and Simpson, 2013). The technology is a development of ink-jet or laser printing. It brings together digital technologies (design software) with manufacturing devices that can 'print out' or construct three-dimensional objects. A digital model of the object to be built is developed using software programs, which then direct the printing process using 'build paths' (Petrick and Simpson, 2013). At present 3D printing operates at the level of the small-scale making of objects, as it is quite a slow process compared with large-scale industrial manufacturing processes. 3D printing works by using a technique that involves the layering of 2-dimensional materials sequentially, layer by layer, through a series of cross-sectional slices. Nozzles containing the materials used to make the object extrude the materials in a sequence that is controlled by the software.

3D printing initially developed as a way of quickly generating prototypes, but is being taken up in an increasing number of social and commercial institutions (Berman, 2012; Petrick and Simpson, 2013).

The materials used in 3D printing processes are usually plastics, plaster or metal powders. However, some companies and researchers are beginning to experiment with organic materials, such as edible substances to produce 3D-printed foodstuffs, plant nutrients and human bodily products such as living cells. Many artists, designers and makers are taking up 3D printing in creative and artistic endeavours (Nascimento, 2014). Marketing and events promotion companies are also beginning to employ 3D printing for product and event promoting purposes; for example, by providing facilities by which people attending an event can undergo a 3D body scan, which is then fabricated into a 3D self-replica figure that they can take home (Lupton, 2014c).

Medical applications of 3D printing are rapidly developing. When used for specifically medical or health-related purposes, 3D printing technologies may be viewed as one of the latest devices that contribute to digital health technologies (Lupton, 2014b). Writers in the medical literature have discussed the current uses and potential for using 3D printing technologies. These include for medical training and education, diagnosis, surgery, the fabrication of medical devices, patient education and medical research (Rengier *et al*, 2010; Sher, 2014). There are two types of 3D fabricated bodies in medicine: those that are organic (using human biological material) and those that are non-organic (using materials such as metals, resins and plastics). The use of human biological material is called ‘bioprinting’, with which researchers have experimented for over a decade (Mironov *et al*, 2006). Bioprinting creates biomaterial that mimics human body tissue. It involves the use of ‘bioink’, or living cells that have been cultured in a cell growth medium. The bioink is loaded into a cartridge, inserted into the bioprinter and layers of this material are laid down on sterile surfaces with the guidance of software to form new biological materials. Depending on what is being fabricated, a form of scaffolding may be used to help shape the object (Murphy and Atala, 2014).

One ultimate aim of bioprinting is to generate new human tissues and organs, such as hearts, livers and kidneys, for use in transplants and grafts, but at present this is at the experimental stage only (Collins, 2014). Current uses of bioprinting include the production of biomaterial such as brain matter for medical education. This material allows students to cut through or dissect the tissue as part of their surgical training (Chavez, 2014). Researchers are working on bioprinting human tissue that will be capable of developing full biological functions for use in testing dangerous or experimental drugs (Collins, 2014; Murphy and Atala, 2014; Grunewald, 2014a). Some of these developments offer a further step towards ‘personalised medicine’ that began with genetic testing and the customisation of medical treatment based on a patient’s genetic makeup (Swan, 2012). For example, it has been speculated that 3D printed biomatter could be created, which is a genetic match to individual patients and could then be used to test treatments before using them directly on patients themselves (Grunewald, 2014a).

Digital Medical and Health Data and Fabricated Bodies

There is much more that could be discussed about bioprinting and its implications for medicine, but I want to focus for the remainder of this article on the types of digital data objects that create non-organic fabricated bodies or body parts. These technologies are part of a diverse array of devices and software that are currently employed to represent human bodies using digital data; that is, to configure digital body objects. The human body is digitised in many ways, including not only voluntary self-representations on social media (including the 'selfie' image) for purely social encounters, but more specifically for medical and health-related purposes. Digital health technologies that are used to generate detailed digital data on human bodies related to their functions, health and physical activities include such devices as smartphone medical, health and fitness apps, wearable self-tracking devices and wireless patient self-care technologies. Other technologies that produce digital body objects in the medical realm include scanning technologies such as ultrasound, computer tomography and magnetic resonance imaging, digital photography and videos and the use of virtual reality in medical education and training.

Social media sites also facilitate the configuration of digital body objects for health or medical-related purposes. Many types of bodies and body parts can now be viewed on the internet, from the 'thinspiration' and 'pro ana' images that celebrate extreme thinness to the images of fat bodies that are uploaded and circulated by those seeking to support fat activism and fat pride sentiments. A large array of medicalised images are also available online, including videos and photographs of surgical operations and post-surgical bodies and of people living with any number of medical conditions, and websites and apps that provide detailed medical anatomical images of human embodiment from conception onwards (often with the use of three-dimensional imaging technologies). All these digital body objects are contributing to lay knowledges, discourses and practices about embodiment, health, medicine and selfhood (Lupton, 2012, 2014b, 2015).

As noted above, 3D self-replicas of people's bodies can now be generated as part of leisure and marketing activities. Medical imaging technologies are also being used to create products for the commercial market as novelties. One company offers a service by which MRI scans are turned into full-scale replicas of an individual's own brain for display as an ornamental object (Grunewald, 2014b). 3D ultrasound imaging is now being used to produce life-sized figurines of human foetuses for their expectant parents to hold and display. A Californian company calling itself '3D Babies' provides this service, as well as fabricating newborn infant replicas using photographs supplied by the parents. These replicas are marketed on the company's site as offering an 'artistic sculpture for your display case', 'memorabilia for baby's room', 'centrepiece for baby shower', a way to 'share the news of your pregnancy' or to use at a 'gender reveal' party (3D Babies, 2014).

Non-organic materials are used in a variety of ways to fabricate body parts. They have been employed to produce customised 3D printed prosthetics and implants that are inexpensive to manufacture. Prosthetic limbs, dental crowns, and cranial, bone, joint and heart valve implants have been used successfully in patients (Collins, 2014). The use of what has been dubbed 'patient-specific 3D printed organ replicas' (models of patients' organs using data from MRI, ultrasound and CT scans) in surgery, medical training and doctor–patient communication is also beginning to be discussed and researched in the medical literature (Moody, 2014). Such replicas can be manufactured in separate parts to demonstrate the internal as well as external view of an organ or other body part, and they can be made transparent to allow a better view inside it. They allow surgeons to look closely at the body part's structure and plan or practice surgical interventions before cutting into the patient's body. These anatomical models can also be employed as diagnostic tools. One example is the use of a 3D printed anatomical replica of a diseased infant's brain and part of its skull by a surgeon in Brazil. The surgeon used the replica to visualise the condition for diagnosis, plan the complicated surgery that was required and as a reference during surgery (Krassenstein, 2014a). Another intriguing case is provided on a 3D printing blog of a man who was not medically trained but expert in 3D imaging and printing, and thus was able to use the CT scans that had been made of his spine to produce a fabrication of it. Having done so he was able to finally identify a long-term condition for which his doctors had failed to find a diagnosis (Krassenstein, 2014b).

3D organ replicas are increasingly employed as part of educational practices, both for medical students or surgical trainees and for patients. Researchers are working on fabricating models of human body parts for teaching anatomy to medical students in lieu of cadavers (West, 2014). Patient-specific 3D printed organ replicas are employed in some hospitals to communicate information to patients about their conditions and assist doctors in obtaining informed consent for procedures (Sher, 2014). The replicas are made and shown to patients so that they can not only see but also touch them and their doctors can point to features on the replica to explain the problem and how they intend to treat it. It is contended that such replicas offer more explanatory power to doctors when explaining complex medical matters to their patients than do 2D representations or simply verbal communication (Moody, 2014; Sher, 2014).

An example of how such a replica may be used is provided in a short promotional video demonstrating the case of Bradley White, an American 16-year-old boy who was born with a heart tumour (Materialise, 2014). The video was made and used as a promotional tool by Materialise, the 3D tech company that had made a replica of the heart. The video begins with Bradley's grandmother holding the model like a ball, casually stroking and tapping it while she talks about her grandson's damaged heart and the medical treatments he has endured in his short life (including several open-heart surgeries). We see Bradley and his grandparents conversing with his cardiologist while the latter brandishes the model, and other surgeons conferring while they simultaneously examine images of the heart on a computer screen and handle the model. Holding up the model of his heart, Bradley comments that 'I always thought that my tumour was, like, the size of quarter, but when they showed me the model, it's about the size of a golf ball'. As he gazes on the model he remarks: 'It's probably one of the coolest things that I've seen, by far. But I want to show my friends and everything, like, show them that a heart doesn't really look like on Valentine's Day'. His surgeon remarks in the video that viewing the model helped him and his team to understand the best way to remove the tumour. He also observed that using such models when talking to patients about their surgery helps to make them feel more 'comfortable' about what is going to happen.

3D fabrication may also be employed to represent more abstract features of human bodies. Human–computer interaction researchers have been experimenting with ways of using 3D digital body objects as an educational tool for assisting people in understanding the personal digital data that they collect from self-tracking efforts. For example Khot and colleagues (Khot *et al*, 2013; Khot *et al*, 2014) have investigated producing 3D printed artefacts that represent an individual's heart rate during physical exertion, as tracked by a wearable digital device. The idea of such artefacts is to encourage people to achieve greater awareness of their personal bodily data and to engage in self-reflection upon being confronted with the material representation of these data. Khot and colleagues argue that as physical activity is a material, embodied practice, material representations of the data related to this activity that can be handled and touched help people in making sense of their data. The design principles followed by the team included the following: the material should not only reflect the aspects of physical activity but also be aesthetically pleasing; users should be able to use them publicly without concern that the objects revealed their personal data that the users may not have wanted to share in a public space; each artefact should be unique; and the artefacts should act as a positive reinforcement for physical activity.

These researchers tested their system, entitled SweatAtoms, with six households using five different material manifestations of their physical activity. These artefacts included a 3D graph of heart rate data, a flower shape where the length and width of the petals represent heart rate duration and intensity, a frog shape that changed in size according to the amount of physical activity carried out that day, a die representing the six zones of heart beat data and a ring displaying the number of active hours in a day. The participants were supplied with a digital heart rate monitor, an iPod Touch installed with an app to collect the data and a 3D printer for their homes to print out the artefacts from their data.

In a similar experiment, Stusak and colleagues (Stusak *et al*, 2014) developed what they entitled 'data sculptures' from participants' running activity data. In a 3-week field study they investigated the impact of four different types of sculptures on the participants' running activity, the personal and social behaviours that the sculptures generated and their reactions to receiving the physical tokens of the runs. The digital data that the participants generated from each of their runs over this period were individually rendered via 3D printing into a discrete unique component that could be added with other components produced in the study to make a larger sculpture. The idea of this was to incite interest and enthusiasm from the participants as they sought to build their own customised sculpture with each piece and to encourage them to reflect on their data.

As 3D printing technologies become more widespread and less expensive and move into the home, it is likely that these types of manifestations of self-tracked bodily data will become more commonly used as part of people's data practices. Some commentators have speculated that digital data could inform such practices as the 3D printing of food, in which a person's physical activity or body weight data dictate what type of food is printed for them. This idea was put forward by Lipson and Kurman in their book *Fabricated: the New World of 3D* Printing (2013, pp. 142–144), which outlines many scenarios for how 3D printing may be used. They write about the possibility of people using a digitally controlled food printer that is continuously updated with the biometric data that people collect on themselves as part of their self-tracking practices. The printer would be programmed to respond to these data, and to print out food that was accordingly adjusted for nutrient level. If a person with diabetes sent through data that demonstrated high blood sugar levels, for example, the printer would make food that regulated the sugar content. If someone did not engage in high-enough levels of exercise that day, the printer would make low-energy food for them. Here the printer is acting as a disciplinary device in its responsiveness to biometric data and its subsequent modification of the food that is delivered to the user. As Lipson and Kurman (2013, p. 143) suggest: 'A dedicated 3D printer chef could be a stern disciplinarian. A couch potato who skipped his morning jog would be denied his request for two pieces of printed pizza. After reading his biometrics, his printer would instead print him a fresh Caesar salad and a piece of whole wheat bread'. The spectre of our personalised 3D printing machines coming to dictate how we should live our lives is here represented as potentially enhancing of human well-being, if not of human agency.

Theorising Digital Body Objects

How might these new material forms of digital body objects be entering into knowledges and practices related to medicine and health? What are their broader social and cultural resonances? I would argue that a good starting point for theorising the phenomenon of 3D fabricated bodies is the perspectives that are offered from sociomaterialism and 'the new materialism'. These approaches seek to build on anthropological understandings of material practices and engagements with things to explore the entanglements of physical objects, humans and other non-human actors. They go beyond a focus on the discursive that has tended to characterise poststructuralist theorising of subjectivity and embodiment to emphasising the role played by material artefacts in social relations and the construction and negotiation of meaning. This perspective acknowledges that bodies/selves are dynamic assemblages of flesh, affect, others' bodies, objects and space/place. It draws attention to the interdependence and physicality of this relationship, and like actor-network theory, accords agency to material artefacts. Objects are represented as participating in specific sets of relations, including those with other artefacts as well as people (Coole and Frost, 2010; Marres and Lezaun, 2011; Harvey and Knox, 2014).

Sociomaterialism and new materialism also acknowledge the wider contexts in which object–subject relations are configured, such as geographical location, the age, gender, ethnicity and socioeconomic status of consumers, and the influence of these relations upon contexts. The notion of code/space, as articulated in the work of Kitchin and Dodge (Dodge and Kitchin, 2009; Kitchin and Dodge, 2011; Kitchin, 2013, 2014), emphasises the entanglements of human bodies, software and everyday life in domestic and public spaces. As this concept suggests, human bodies and behaviours, as well as knowledges of these bodies and behaviours, are increasingly mediated via software codes. In a 'sensor society' (Andrejevic and Burdon, 2015), in which an increasing number of spaces and places and the movements of human bodies within them are monitored by sensors and 'smart' objects collecting digital data, it has become difficult, if not impossible, to avoid becoming digitised. The 3D material rendering of the human body or parts thereof represents a specific type of code/space; a fabricated bodily form of digital data that may be a miniaturised version (as in 3D self-replica figurines), life-sized (as in the customised anatomical replicas used in medicine) or a non-body shape (as in the data artefacts and sculptures generated from physical activity tracking in the experiments described above).

The 2D representation of digital data is an important element in contemporary data practices. Much emphasis is placed on the aesthetic quality of data visualisations as well as their ability to convey information in easy-to-understand forms. The choices that are made about which data to select and how to represent these data structure the meaning of the subsequent visualisation (McCosker and Wilken, 2014). In writing specifically about digital visual images, Pink (2011) has argued for the importance of re-thinking the image through a phenomenology of the senses, movement and a theory of place. Such an approach avoids the dominance of the visual sense for acknowledging the ways in which images are produced and consumed using multiple senses working together and the contribution of location in space and place in generating the meaning of the visual.

I emphasise this aspect of sociomaterialism here because current theorising on digital data often tends to represent these phenomena as immaterial invisible signals emitting from digital devices and circulating in virtual spaces such as the computing cloud. Yet, as some critics have pointed out, digital data must be viewed as material objects. They are generated by, transmitted, circulated by and stored in tangible things. A hardware device is required to generate digital data in the first instance, and these data are then transmitted and stored by material technologies. They generate a significant amount of material waste when discarded. Further, even though the digital signals themselves are electronic, and therefore 'non-solids', they are created by and embedded in human and non-human material actors (Gabrys, 2011; Parikka, 2012).

The materiality of digital data about bodies and selves is also expressed in the ways in which these data can have physical effects on people. It is increasingly the case that the digital data that are collected on people are shaping their life chances and opportunities via the use of analytical and predictive algorithms, further entrenching already established social discrimination against minority groups. For example, whether people are offered jobs, insurance, credit or entry into a country is now often determined by the calculations of these algorithms (Crawford and Schultz, 2014).

Furthermore, it is important to recognise that digital data have important material effects on other material things, including human bodies. The concept of data doubles has emerged as key in theorising the mutable and ever-changing data assemblages that are configured when humans interact with digital technologies that generate digital data. Data doubles configure a certain representation of a person by the bringing together of a specific set of data (Haggerty and Ericson, 2000). They have their own social lives and materiality, quite apart from the fleshy bodies from which they are developed. Data doubles representing aspects of the body and self are continually re-enacted and reconfigured. The physical activity tracking device produces some forms of data that may or may not be acted on by the user, as does the productivity app or the mood tracker, for example. Each configures a different and constantly changing data double of the user (Ruckenstein, 2014; Lupton, 2014d).

Central to the process of digitising bodies, therefore, is the concept of change. Data doubles never stand still. As soon as they are generated they are subject to change when more data are added. Data doubles are constantly open to reconfiguration and hence re-interpretation. Data doubles are also recursive and reflexive. People may reflect upon their data and seek to make sense of them. Data doubles, therefore, are both constituted by the body and self and in turn serve to re-constitute the body and self. When they are used to record bodily data that are then fed back to the person who generated these data, they may incite changes in behaviour or in the ways that people think about their bodies and everyday activities. Thus, for example, self-trackers commonly use the personal data that they collect to inform decisions about their lives in the quest to optimise the self. This may include making changes to their diet, their exercise routines, their drinking or smoking habits, their sleep practices and so on (Li *et al*, 2011; Lupton, 2012, 2013a). These changes in turn produce new sets of data doubles that again may have a role in influencing the configuration of future data doubles.

People often respond emotionally to their personal data when they view the visualisations that are produced from the data. A study of Finnish people using digital self-monitoring devices for physical activity and heart rate tracking (Pantzar and Ruckenstein, 2015; Ruckenstein, 2014) revealed that participants found the visualisations that were generated from their data meaningful and motivational, generating feelings of pride, accomplishment and satisfaction. The data visualisations were viewed as more credible and accurate by the participants than the 'subjective' assessments of their bodily sensations; indeed they expressed the desire for more data about their bodies to add to those already collected, so as to provide further insights. Several participants commented that the visualisations revealed aspects of their lives that they may have suspected (such as the stressful nature of their work) but the data served to prove these impressions, while others found that the data demonstrated findings that they did not anticipate (they were more physically active than they thought). A new kind of value was therefore given to some everyday activities and interactions.

Digital data as they are rendered into 3D digital data objects can be agential in this way. They can work to shape medical knowledges and practices in relation to a patient's body, configure a patient's own bodily knowledge and change people's behaviours in relation to their physical exercise habits. Indeed some researchers have contended that the 3D materialisation of personal data can be even more compelling and motivating than two-dimensional imaging because they engage more of the senses. In their 'Sweat Atoms' research, for example, Khot and colleagues found that among their research participants, viewing and handling the material artefacts that were generated from their personal body data helped people gain a sense of their data and illustrated different levels of engagement with the data. Their participants felt affectionate about some of their digital body objects (in particularly the frog artefacts, which were the favourite of the five shapes that were generated from their data) or found them aesthetically pleasing. Several participants commented that the 3D materialisation of their data rendered these data more persistent and memorable, facilitating deeper engagement with this information (Khot *et al*, 2013).

What is particularly intriguing about 3D printed body objects is that they represent the re-materialisation of digital data as solid, tangible object extruded from a 3D printer. 3D body fabrications, like any form of data visualisation (such as graphs or other two-dimensional portrayals), constitute an attempt to fix these data doubles at a certain point in time in a specific context. Data visualisations, therefore, may be conceptualised as solidified data. The physical assemblages that are configured of the human body via 3D printing techniques are material manifestations, or coming together, of human and non-human actors. These include the human flesh that is rendered into a different form via digitisation and fabrication, but also the human actors who operate and use the technologies that produce this object and the range of non-human actors that bring the object into being, including digital software, the materials that are used to form the shapes and the machinery that extrudes and lays down the materials to form the object.

3D fabricated data bodies share the properties of other anatomical models from previous eras of medical training. Owing to the contribution of personalised digital data, however, they differ significantly from these traditional models in terms of the extent to which they can be customised and personalised. The individuality and wide variation of human anatomy is lost when standard anatomical models (including virtual reality training materials) are relied upon (Prentice, 2013). However, when students, health-care professionals or patients handle a patient-specific 3D organ replica, they are interacting with a unique digital artefact produced from a unique human body at a specific moment in time.

We can see in the fabricated body in medicine and health a return to the haptic, or the sensation of touch, as part of representing and understanding human bodies. There has long been a bias towards visual responses to phenomena in western cultures that is reflected in contemporary medicine (Duden, 1993; Waldby, 2000; Prentice, 2013). Such biases tend to discount or ignore the major role played by affective responses and senses other than vision in people's embodied experiences, including those related to medical practices and knowledges and the phenomenology of health, illness and medical care. The emphasis on the visual often works to erase other ways of knowing about the body and render fleshly human bodies into informatic body objects. This tendency has been intensified by the introduction of new digitised ways of monitoring and representing bodies, illness and disease (Waldby, 2000; Nettleton *et al*, 2004; Lupton, 2012, 2013b; Prentice, 2013).

There are limits to the sensory affordances of the non-organic 3D digital body object, however. Non-organic anatomical replicas, of course, do not provide the types of haptic and other sensual cues that organic human flesh and bone does. Unlike the organic objects that are fabricated using 3D bioprinting techniques, while these objects may be touched and held, they are still cold and stiff, lacking the tactile and olfactory properties of human flesh and bone. Interestingly, some of the supporting argument for why such models are superior to cadavers for medical training is the fact that they combine the anatomical accuracy (as in detailed replicas of human organs) and physical materiality (students can handle them) of human flesh, without what is represented as the repugnant features of dead bodies such as their smell, tendency to deteriorate and cultural or religious distastes or prohibitions against using dead bodies for medical training (Monash University, 2014).

When I use the term 'data made solid' in describing the manifestation of digital data in a 3D printed artefact, I do not imply that the meanings and purposes of this object are fixed and immutable. As we can see from the examples I provided above, material objects are not necessarily stable in their meanings and uses, and these change depending on the context in which the objects are appropriated. For instance, the video describing the 3D printed model of the diseased heart of Bradley White demonstrated that the model was used by various actors for their own purposes. For the company that funded and made the video, the heart model was a symbol of their success in developing anatomical 3D printing technologies for medical use. For Bradley's cardiologist, it was a communicative tool, providing him with a way of discussing possible surgical options to Bradley and his grandparents in a mode that they could readily understand. For his cardiac surgeon the model was a professional decision-making aid, which he could use to address and reflect on the different options he had for surgical intervention. For Bradley's grandparents, the model was the focal point of emotion, a stimulus for remembering all the operations he had had to endure and a symbol of his fortitude. For Bradley himself, the model of his heart was 'the coolest thing' he had ever seen. He was able to reflect on the size and appearance of his heart by looking at and touching it. He viewed the model as both a novelty to show his friends and a teaching tool so that they too could understand what human hearts looked like. The model, therefore, is invested with affective, commercial, functional and pedagogical value in the respective viewpoints of these diverse human actors. It operates as an intermediary between the life worlds of the technology developers, medical doctors and the lay people who are interacting with it.

Conclusion

Sociocultural theory and research related to medicine and health has yet to fully explore the ways in which people are using digital technologies for health and medical purposes, including analysing and understanding how the digital data on human bodies that these devices generate are being used and interpreted. As I have argued in this article, 3D printed digital body objects offer a novel mode of materialising and conceptualising human embodiment in medical and health domains. What is particularly interesting about 3D objects of the human body, or parts of it, is that they allow the fleshly body to interact with the digitised physical materialisation of that same body. Flesh and bone are rendered into another material form (usually made of some kind of plastic) that can then be viewed, picked up and handled by the body from which the object is derived.

3D printing technologies offer the possibility of producing fabricated forms of embodiment that are uniquely customised. Patients can not only see but touch and handle a plastic model of their own organs; self-trackers can grasp an object that is a tangible representation of their bodily activities, movements or functions. A circuit of making, meaning and representation, of digital fragmentation of the body and subsequent solidification of these data, is created whereby human bodies emit digital data, which may then be used to construct 2D digital models for 3D printers to turn back into material digital body objects. People who handle these fabricated objects may then change their behaviours accordingly, thus generating a different set of digital data that may produce different objects and so on. The agency of the non-human actor on which writers who adopt a sociomaterial perspective insist is all-too obvious in this circuit.

In a context in which digital data are increasingly used to configure digital data assemblages or data doubles on people that are subject to constant revising and reconfiguring, the 3D printed fabrication of a human body or body part represents a moment of stillness by materialising these lively data that are used to generate it. We know very little about how a 3D digital body object is responded to by the people whose bodily data generated this object. What are the affective investments in these objects? How are they incorporated or appropriated into everyday lives? What knowledges of the body, health and medicine do they reproduce or reconfigure? How might senses other than vision and touch be employed to assist people make sense of and engage with material representations of their bodies? Will the use of fabricated bodies as teaching tools become a further element of the digitally engaged patient ideal (Lupton, 2013b)? Future uses of customised 3D digital body objects may include various ways to track an individual's physical changes over time: children's growth, body builders displaying their progress, people attempting weight loss or even adults making regular self-figurines to document their ageing processes all come to mind as possible uses. People may choose to collect figurines of family members, lovers or friends as a means of remembering relationships. As these objects become more common in medical practice, they could even be used by patients as mementos of their illness and medical treatment and recovery – or by their family members if treatment is unsuccessful and the patient succumbs to their condition.

The further developments and expansion of these technologies raises a further series of issues and questions. Given the emergent artist, maker or tinker movement around 3D printing (Nascimento, 2014), how will people begin to tinker with fabrications of their bodily data? Will people not only start to print out full-body replicas at home, but also use their medical scans or self-tracked health and fitness data to generate their own artefacts or 'data sculptures' (Stusak *et al*, 2014)? What will they do with these artefacts? How might these affect medical dominance and the power relations inherent in the doctor–patient relationship? What social inequities might emerge in relation to access to and use of 3D printing technologies? Addressing these questions requires social theory as it is applied to health and medicine to begin to engage with some aspects of embodied experience that have hitherto been little explored. These include data practices and representations, the affective dimensions of digital data objects representing the body, visual cultures and sensory experience in medicine and health care and the interactions of code and space.

About the Author

Deborah Lupton researches the social and cultural aspects of medicine and public health; embodiment; risk; pregnancy and parenting cultures; and digital technologies. Her latest books are *Medicine as Culture*, 3rd edition (2012), *Risk*, 2nd edition (2013), *Fat* (2013), *The Social Worlds of the Unborn* (2013), *The Unborn Human* (edited, 2013) and *Digital Sociology* (2015). She is currently completing a book on the quantified self and self-tracking cultures.

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