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Unpacking Digital Material Mediation

Heather Wiltse

Abstract: Digital technologies mediate engagement with the world by making activities visible. The automaticity and physicality of the ways in which they do this suggest that it could be productive to view them as responsive digital materials. This paper explores the structure and function of responsive materials in order to develop a conceptualization of responsive *digital materials*. It then begins to unpack the complexities of *digital material mediation* through both drawing on and extending existing postphenomenological theory.

Key words: postphenomenology, experience, mediation, digital material, digital theory

1. Introduction

Digital technologies mediate engagement with the world by making activities visible. There are many ways in which they do this. This happens, for instance, every time text shows up on a screen after keys are pressed, a number on a widget reflects distant (or not-so-distant) weather conditions, or a place is tagged in a social network post through a GPS-enabled check-in. It is also the basis of the many online activities that are made 'social' through revealing human presence and activity (such as, for example, people sharing a particular article via Twitter). Although they are often associated with intentionally-created media or messages, the function and significance of these digital traces are different. They implicitly claim to mediate reality, with the basis of this claim ultimately resting in the physicality of input mechanisms that are part of digital substrates designed to automatically respond to certain types of activities in certain ways. These qualities point to a way of conceptualizing and analyzing digital technologies as *responsive digital materials* that both constitute and reveal our reality.

Heather Wiltse, Umeå Institute of Design, Umeå University, SE-901 87 UMEÅ, Sweden; tel +46 (0) 90 786 69 96; http://heatherwiltse.me/; heather.wiltse@dh.umu.se

Further, and taking for now a common sense understanding of mediation as a going-between, it is possible to think of digital materials as mediating a person's engagement with the world. In the middle position between person and world, the material relates to both the world on the one hand and to the perceiving person on the other. The nature of its relation to the world—its sensors, in more practical terms—determine how it reveals the slice of reality to which it is oriented; while the outward-facing surface—its display—can make the traces it records visible such that they can come into specific relations with perceiving people. This structure of relations consisting of perceiving person, digital material, and world can be conceptualized as *digital material mediation*.

In this paper I will explore and conceptualize the role of digital materials in revealing information about the world, and begin to unpack the complexities of *digital material mediation* by both applying and extending existing postphenomenological theory. I will begin by conceptualizing digital technologies as responsive materials, and look at the basic structure and function of responsive materials with respect to making activities visible. I will then outline a conception of *responsive digital materials* and develop the related structure of *digital material mediation*. Finally, I will begin to unpack the complexities of digital material mediation along the dimensions of functional, perceptual, and temporal uncoupling.

2. Mediating Reality

The digital and online have since their beginnings been commonly thought of as constituting another virtual world, less real than the physical world. This was especially true when, in its early days, cyberspace was thought to be a "sad, lonely world" (Harmon 1998). But this belied the everyday experience of most people who use digital networked technologies, for whom digitally-enabled activities are very much of the real world, and not separate from it. More contemporary research and popular writing has generally caught up with this state of affairs, yet distinctions between the virtual and the real are still frequently made in discussions of digital technologies and interactions with and through them.

When digital technologies make activities visible, that process and the resulting traces are not just status information, system feedback, messages, or media content: it is some part of the world being 'caught in the act' by technologies that have been designed to do the catching in particular ways.[1] The fact that these technologies are all around us, and that we live in and through them, means that we are living in a world that is becoming increasingly attuned to our activities, and that these activities are producing traces that can appear, travel, and endure

in ways that most physical traces never do.[2] Further, because activities and the substrates that respond to them are rooted in material, digital traces have a claim to represent reality that is unique with respect to other types of digital content. They are distinct from things such as messages, posts, and other media, even as they are often associated with them. Also, when technology is discussed in terms of experience (particularly aesthetic experience), the technology is typically seen as the focal point of attention even as it gathers together around it multiple aspects of lived experience and meanings. In the case of mediation, however, it is the world experienced *through* the technology that is the ultimate focal point of attention.

Perceiving and experiencing traces as legitimately reflecting some aspect of reality entails a certain kind of relation among a perceiving person, (digital material) technology, and world. This relation can be described as one of *mediation*, in which the technology allows a person to experience and engage with the world. It is a less than straightforward type of mediation, though, and it is to this issue that I turn next.

3. Technological Mediation

Mediation is a flexible and evocative concept that has been developed in a number of ways in order to convey precise and nuanced meanings. Activity theory, for example, emphasizes the role of sign systems and tools (including computational ones) in mediating human experience and daily activities (Nardi 1996; Bødker 1997; Bødker and Andersen 2005). Service mediation has been conceptualized as a broad spectrum of activities that enable clients to access and use technologies and service programs (Dombrowski, Voida, Hayes, and Mazmanian 2012). Technologies can also be thought of as mediating relationships and intimacy through the communicative capabilities of things such as the telephone or Internet (e.g., Vetere et al. 2005; Coleman 2011). Information and the underlying technologies used to produce, process, and represent it can be seen as mediating reality (Kallinikos 2011). Several kinds of technical mediation also figure prominently in Latour's (1999) description of collectives of humans and nonhumans and the processes that constitute them.

All of these senses of mediation can potentially be brought to bear when considering digital material mediation. There are, however, two more specific things required for the present analysis.

First, I wish to foreground and explore the qualities of mediation itself, specifically in relation to digital material. Although mediation is a commonly used concept, Van Den Eede argues that technological mediation, while present in a

wide variety of phenomena studied and theorized, has not yet received the focused attention it warrants. As he states in summarizing this situation:

> The features of a void start to show out: philosophical theories about technology but no special focus on technology as an 'inter-human component'; empirical and sociological accounts of mediated interaction but not of mediated being-with-each-other *an sich*; and a body of theory on relationships but not so much on their technological mediation. Whence this imbalance? Do we not need a more general, and at the same time more focused notion of technological mediation *an sich*? (Van Den Eede 2011, 140)

He goes on to state:

> So on the one hand, too much attention is given to the odd (e.g., the new), while on the other hand too little is proffered to the obvious—the ubiquitous. The general condition of 'being technologically mediated' falls through the cracks of theoretical bricklaying and lived experience alike. (Van Den Eede 2011, 141)

Although my analysis here deals with the specifics of digital material mediation and not technological mediation in general, it is 'obvious' and 'ubiquitous' mediations that I want to bring into focus and unpack.

Second, activities are often made visible because technologies are being used to mediate some action or communication. However, when traces of activities are *perceived* and taken as evidence of some kind of real-world happening or situation, this is a rather different kind of mediation that involves one's experience in and of the world, and raises questions regarding the structure of that experience. This is the kind of territory dealt with by postphenomenology, and for this reason it serves as the starting point for my analysis.

The main insights and conceptual tools from postphenomenological research that I would like to draw on and develop concern technological mediation: specifically, its hermeneutic dimension that foregrounds the role of technologies in mediating access to the world. While I will not here provide a complete overview of postphenomenology, it is worth emphasizing a few key points in the present context.

Although postphenomenology has its roots in phenomenology proper, it does not make the same claims for being a method that could be used to truly describe reality (Verbeek 2005). Rather, in transitioning to *post*phenomenology, Ihde emphasized the referential and relational aspects of experience, building on the insight from phenomenology that experience is always referential because it is

always the experience *of something*. There is no such thing as 'plain' experience without any content, because in order to be aware of one's being as a conscious self there must be something presented to consciousness of which it is aware. There is always an *intentionality*, a directedness of consciousness toward something that is its object. This means that it is possible to describe the *structure* of experience and to give an account of these relations between perceiving subject and what it is that is perceived. This also entails a relativistic ontology that is not relativism, but rather an account of relations. Ihde states that this type of an account is "rigorously relativistic" in taking "as its primitive the relationality of the human experiencer to the field of experience" (Ihde 1990, 25). In line with this approach, when considering how digital materials mediate experience of reality, I understand this to be reality *as constituted for an experiencing person*.

Verbeek (2005) takes this a step further in seeing subjects and objects as *mutually constituting* each other. While the world is always a world *for* an experiencing subject, a person's subjectivity is also constituted in particular ways when coming into particular relations with the world. One example that he develops extensively to illustrate this point is that of obstetric ultrasound (Verbeek 2008b, 2011). When an unborn fetus is made visible on a screen by means of ultrasound technology, it is constituted in a specific way and thereby brought into a number of specific relations. For instance, the highly magnified image shown on the screen as isolated and separate from the mother's body constitutes the unborn fetus as an individual person. It also constitutes the fetus as a patient, thereby transforming pregnancy into a medical process involving a good deal of monitoring. The mother is also no longer the one with privileged knowledge about her baby, as that role is transferred to medical professionals and she becomes instead the environment in which the fetus develops (which may also be considered a hazardous environment, depending on her lifestyle). Significantly, since tests can be done to detect congenital defects, obstetric ultrasound also constitutes the expectant parents as decision-makers: because such tests exist the parents can choose to have them done or not, and then if a birth defect is discovered they are put in a position where they also must decide whether to continue with the pregnancy given that knowledge. In sum, in this and in other instances, subjectivity and objectivity are mutually constituted in particular ways, and when mediating technologies are involved they can shape the character of that constitution.

Finally, postphenomenology emphasizes materiality. As Ihde (1990, 25) says: "I wish to retain the sense of materiality which technologies imply. This materiality correlates with our bodily materiality, the experience we have as being our bodies in an environment." Verbeek (2005) similarly references the materiality

of mediating artifacts. Although materiality with respect to digital technologies is somewhat complex, this emphasis accords with both the conception of digital material and bodily perception that I want to develop.

4. The Materiality of Activities

Activities that are made visible by technologies are necessarily physical and material. There must be physical contact between something in the world and an input device designed to process certain kinds of contact in certain ways. Even in the case of various imaging technologies that can be used to produce an image of a face or bones or brain waves, the technology responds to phenomena in the physical world—even if those phenomena are as ephemeral as waves of light.

The technologies that respond to activities must have a material component that is the interface between the physical phenomenon and its captured digital representation. In the case of typing activity being registered on a screen, the physical interface is the keyboard.[3] A message is sent when the 'send' button is pressed, which is accomplished by a physical interaction with a mouse or touch screen. A post is 'liked' through a similar interaction. A 'check-in' is accomplished through physical interaction with a device, and that device's interaction with the physical components of the GPS infrastructure that determine the device's location. A current temperature reading shows up on a weather widget because there are somewhere in the world physical sensors that respond to conditions in the surrounding atmosphere such as heat, wind speed, and humidity.

In many cases, especially with online activities, there is also content involved. This content is what might commonly be thought of as media: texts, images, videos, and the like. There is, however, a difference between content and the *activity of posting content* that is made visible through the post itself and the associated information provided by the device and platform being used (such as account identity, time stamp, or location). The act of posting content registers a body interacting with a device, a specific online platform and space, and specific content at a certain point in time. There is also a difference between the types of implicit claims made in online profiles and posts, and those made by the online platform in which they appear: the former are made by people, while the latter are attested to by the technological platform and other parts of digital infrastructure. This is the difference between a social media post stating 'I am at the Eiffel Tower,' and a GPS-enabled check-in at the Eiffel Tower.

Online platforms that allow for posting of content are designed to enable and register certain types of activities (such as posting and commenting), and these ac-

tivities are made visible as the content of the site. This also means, conversely, that when a post or comment appears it is (at least typically) the result of intentional activity. For example, posting vacation photos on Facebook is one way in which people can make their activities visible to others; but the fact that they were using a device with the Facebook application or website at a particular time and chose to share the photos is made visible by the underlying technologies.

Some such traces of activities are created intentionally (such as photos posted on Facebook or the text of a message), while others are created unintentionally or as the byproduct of activity. These include things such as time stamps, automatically tagged locations, identification of devices used to produce content, 'read' receipts or notifications, and general metadata.

There is thus a level of automaticity to making activities visible, in which there is in place a digital infrastructure that is designed to automatically respond to certain types of activities in certain ways. This infrastructure basically 'sits there' until a particular kind of activity happens, at which point it is activated and responds in whatever way it was programmed to respond. This response implies a change in system status. This is often represented somehow in the interface, but sometimes it is not. Tracking people's activities in some way without their awareness is an instance in which system status changes without that change being made visible in the interface with which people interact, even as it is made visible in the interface that faces those doing the tracking. Online tracking and discreet sensors in the physical environment, such as those often used in ubiquitous computing applications, are examples of this type of configuration.

The automaticity and physicality of technologies that make activities visible, along with the fact that they are increasingly part of and constitute our environments, suggest that it might be productive to view them as *digital materials*. The physical materials around us also respond 'automatically' to activities in ways that change their 'status' and appearance. Moreover, they do this in ways that allow us to understand the activities to which a specific material's condition speaks, and thus help us in making sense of our environments.

One very basic and common example is that of a 'desire path' worn through grass. Here the material of grass is worn away and eventually disappears along the line traced by many people walking that trajectory over a period of time. The path appears because of the way that the materials of grass and dirt respond to the activity of repeated walking. The overall status of a grass lawn is changed when it becomes marked by a desire path, and in a way that reflects the activities that caused it. When seeing a path like this one also in a way sees the many people who have traversed

it and thereby registered their presence in that space. This dynamic is obvious to us because of our understanding of how grass works as a material, and because of the direct physical, temporal, and visual connection between activity and material.

There are many other similar examples from the physical world. A heavily-stapled post by a major pedestrian route on a college campus bears witness to the many flyers that have been posted there over time. The markings carved into a wooden school desk register the presence of previous generations of bored and obstreperous students, and the degree of their wear marks the passage of time. The same can be said of initials engraved in a tree, graffiti sprayed on the side of a building, or footprints left in wet concrete. A fresh blanket of snow can reveal the typically unseen nocturnal ramblings of animals by means of the tracks that they leave behind. Even air, as the carrier of smells, can reveal activities such as baking bread or other (perhaps less savory) things.

While materiality seems to be a promising lens for looking at how activities are made visible in our environments, viewing digital things in material terms poses some challenges and requires some new theoretical developments. For one thing, physical materials respond to activities (or not) according to their inherent material qualities, but digital materials respond to activities according to how they were designed and programmed. Once a system is up and running it may at that point function and respond to activities automatically, but *how* it does this is determined during its design. This means that digital materials can respond to activities in infinitely more complex ways than physical materials can, and in ways that are not transparent or standard. There is also the more theoretical question of what kind of materiality digital things can have, when so much of their constitution seems to be immaterial.

In spite of these challenges, 'materiality' has recently become something of a buzzword in academic circles concerned with digital technologies, experience and social life (e.g., Orlikowski 2007; Leonardi and Barley 2008; Orlikowski 2010; Robles and Wiberg 2010; Sundström and Höök 2010; Wiberg and Robles 2010; Ishii, Lakatos, Bonanni, and Labrune 2012; Fernaeus and Sundström 2012; Jung and Stolterman 2012; Wiberg et al. 2013; Gross, Bardzell, and Bardzell 2013; Wiberg 2013; Leonardi, Nardi, and Kallinikos 2013). Although it is outside the scope of this paper to undertake a more thorough review of various approaches to digital materiality, it should be noted that the conception of digital materials presented here both builds on and diverges from them: it builds on the perspective of viewing technologies in terms of their materiality, but takes a different approach in considering how digital technologies *function* as responsive materials (rather than considering their material*ity* more generally).

It should also be noted that, although the main concern of this paper is digital material, this analysis of the structure and function of materials with respect to making activities visible is by no means limited to the digital. We can see this responsiveness to activities in all forms of materials, whether they are natural or technological, digital or analog. Moreover, the conceptualization of responsive materials developed here is intended to be broad enough to work across a range of hybrid compositions of the digital and physical, even as it calls attention to some of the particular complexities of the digital.

5. Responsive Materials

Physical materials respond to different types of activities in different ways because of their character, and this response is registered as a change in their state. This can be seen in examples like the grass path, where grass responds to the activity of walking by bending over and eventually dying and being worn away. Snow responds dramatically and immediately to walking by becoming compressed in a way that leaves an imprint of the shoe (or foot, paw, hoof) that stepped on it. Stones, on the other hand, hardly respond at all to being walked on, and show evidence of wear only after many years. The specific qualities of the material thus determine how the material responds to activities and over what timeframe, and what that response looks like when it is registered in the material itself.

In these and other examples from the physical world, there is a common structure of a material *substrate* that responds to an *activity* in such a way that the substrate is inscribed with a *trace* of that activity. I will next further develop a conceptualization of this structure and its elements that can then be extended to digital materials and the ways in which they also make activities visible.

5.1 Substrates and Traces

Substrates I define simply as *materials that respond to activities*. While all materials conceivably respond in some way to some type of activity, the respective types of activities that can elicit responses and the nature of those responses vary widely. Getting a response out of granite, for example, requires explosives or powerful equipment, whereas mud is rather more pliable. A smoke detector is an example of a technology that, like granite, requires a quite powerful and specific activity in order to respond. The nature of the substrate determines the types of traces that can be left behind by certain activities.

Traces[4] I define as *perceptible changes in substrates that are brought about by specific actions*. Traces can also potentially reflect actions over time, and thus

reveal a substrate's history. This is what happens with the grass path: a path through grass that is just beginning to be traced may be barely perceptible, whereas one that has been there for a long time is quite clearly marked out.

Whenever activities are made visible it is possible to identify specific substrates, activities, and traces that are involved in the process. For example, the activity of *walking* on the substrate of *grass* results in the trace of the *path*. Semi trucks stopping at a light by an interstate exit for a truck stop leave a trace of ruts in the substrate of asphalt. Graffiti on a wall is a trace of the activity of spraying paint.[5] The substrate of air can carry scents that are the traces of activities like baking or mowing grass.

There is also a *direct causal relation between activity, substrate, and trace*.[6] Activities cause traces. The types of traces that can be made, and how they must be made, are determined by the character of various substrates. So asphalt, especially when warm during the summer, responds to the weight of heavy semi trucks by becoming compressed, because that is the nature of asphalt as a substrate. It is also due to its nature that it is much more difficult, if even possible at all, to create a trace in asphalt with one's feet and body weight. To take another example, initials etched into wood can (at least barring suspicious alien activity) be caused only by the activity of people carving with a sharp instrument. This is thus a trace that gives evidence of intentional human activity. The trace of carved initials is also possible because of the nature of wood as a substrate. It might be possible to 'carve' initials in mud or water or ice cream, but they will not be registered as traces because of the nature of those materials as substrates. And while carved initials may be intentional, a tree can also bear other traces that are unintentional, such as those that are the byproduct of a well-used swing or rope ladder hung from a branch.

While the relations among some activities, substrates, and traces, such as those discussed above, are fairly clear and transparent, others are more complex and opaque. Articulating this basic structure at least provides a way in, however, for teasing apart these various elements when analyzing specific cases, and makes it possible to articulate questions about their function. It also provides a way in for thinking about how digital technologies make activities visible.

5.2 Responsive Digital Materials

Although digital technologies function in ways that are less obvious and more opaque than those of substrates like grass or wood, when they make activities visible we can still see a similar structure of relations among substrates, traces, and activities. To start with a simple example, when this text first showed up on my computer

screen it was the result of my fingers pressing keys on the keyboard. Typing was the activity, and text was the trace. The substrate, though, is a little more complicated and difficult to pin down. The keyboard is obviously part of the substrate, since it is the interface between my physical action of typing and the computer that registers that activity. But it also just as clearly takes more than the keyboard to create the trace of text: there is also a digital component. This includes the operating system that enables the computer to process input from the keyboard, as well as the application that accepts that input and makes letters show up on the screen that correspond to the keys I press. Also, while this is the immediate evident result of my pressing the keys, there are also other traces registered by the digital substrate that show up as the part of the file metadata which indicates when I last modified the file.

Other examples of digital technologies making activities visible get even more complex. For example, there can be many different traces of different activities by many different people contained in even a single Facebook post. The original post makes visible typing activity and also the activity of posting, while the time indicator registers the time at which the posting activity took place. The icon next to the post also shows the privacy settings selected by the poster which determines who can see the post. The list of people who 'like' the post makes visible these people's activity of clicking the like button, but it also makes *them* visible as other people who have viewed the post in the time since it was posted. The 'share' icon with the number beside it serves a similar function of showing how many people shared the post within their own accounts. Comments and 'likes' of the comments provide another layer that registers people's presence and activities in relation to the original post.

Activity does not need to be intended to produce traces in order to do so. For example, when the social functionality of Spotify[7] is enabled, people's listening activity is automatically made visible to their followers in what seems to be real time. Most people probably do not listen to music on Spotify so that their activity will show up in their friends' feeds (although maybe some do); but because Spotify functions as a substrate in this regard, people's use of Spotify and their specific listening activities can be made visible to each other. A similar example is Pandora.[8] Pandora also displays music listening activities, although, while Spotify makes visible specific tracks to which people listen, Pandora shows stations listened to instead. The temporal granularity of Pandora also seems to be at the level of hours or days, as opposed to Spotify's minutes or "a moment ago." This difference illustrates the flexibility of digital material substrates and traces. Both music services have a record of the specific tracks people play, and the times at

which they play them. In this way the substrates are similar with respect to the activities to which they respond. However, the ways in which they then make these activities visible as traces are different.

Another example where this dynamic can be seen is in social media sharing buttons. A Twitter sharing button with a counter displays the number of people who have shared a particular article via Twitter. Here the substrate includes the web page, the Twitter API, and individual users' devices; and the trace is the number displayed by the counter. It is also possible to embed on a web page a Twitter button that does not have a counter that makes sharing activity visible. However, Twitter still counts the number of times a link has been shared, even when this is not made visible.[9]

Also, just as some purely physical substrates respond to some activities but not to others, some activities are registered by some digital substrates but not others. Going back to the text entry example, the text shows up on my screen because the word processing application is active. If another application, say one for playing media, is active instead, letters I type will not show up on the screen. However, typing certain combinations of keys corresponding to the keyboard shortcuts of the application will result in the corresponding commands being executed. The applications are different kinds of substrates, and they respond to different types of activities.

In sum, there must be causal links between activity, substrate and trace in order for activities to be made visible, and the nature of those links determines what activities are captured and how they are made visible. In other words, activities are made visible by and in materials that respond to them according to their character.

I thus conceive of *responsive digital materials* as *compositions*[10] *of physical devices and digital code that function as substrates that can register activities and make them visible as traces*. They are constituted by sometimes many layers of digital applications, devices, and digital infrastructure components, and anchored on some level by physical input and display devices that allow them to both respond to activities in the world and to make them visible. This is how they can function as material substrates that make 'real' activities visible. They also do this automatically, responding to activities according to the 'nature' they were programmed to have. Traces of activities are registered in digital materials as a change in their system status that is often (but not always) made visible in the digital material (interface) itself.

It should be noted that this conception of digital material is related to, but not the same as, digital applications, devices, and the like. Instead of taking these more well-defined entities as the unit of analysis, digital material points to the many different digital substrates that exist within and across them. As these can provide a sort of window onto pieces of a mediated reality, they are significant in their own right and can thereby serve purposes not immediately related to their core designed functionality.

This distinction between an application as a unit of analysis and that of digital substrates is similar in a way to de Certeau's (1984) distinction between strategies and tactics. The 'strategy' of an application includes its intended use cases and is decided from the top down by its designers; while the 'tactics' employed by actual users are based on the actions that an application either affords or constrains, and that are carried out in relation to their own goals. Digital substrates afford visibility of activities, and this is something that can potentially be highly useful outside the specific contexts of use for which they were intended.

Digital materials are highly flexible and changeable, making the interpretation of digital material traces a potentially more vexing proposition than the interpretation of their more reliable purely physical counterparts. However, digital traces are commonly taken as reflecting reality, making digital technologies of all kinds increasingly important means by which the many people who use them both find out what is going on in the world around them and are themselves made visible.

6. Digital Material Mediation

When traces in digital material are interpreted in order to understand the activities that caused them, they can be seen as mediating a relation with the world. Specifically, this is a *hermeneutic relation* (Ihde 1990) in which some aspect of the world is transformed into a 'text' (in the broad sense) that is then read.[11] This 'reading' can happen with varying levels of consciousness and critical reflection, and the kinds of traces that are quite familiar and ordinary may seem in a way transparent. However, traces cannot enable a truly transparent *embodiment relation*, as is possible with something like eyeglasses or a telescope, in which the technology withdraws and becomes part of bodily perception during use. Even with something like a video chat, which may seem in many ways like a transparent 'window' into another space, the original scene is translated[12] into bits that are then reassembled in order to create the video image that is perceived. 'Interpretation' of the image may not require much effort, and it may even be subjectively experienced

as a transparent embodiment relation.[13] There is, however, a series of substantive transformations that have taken place in order to produce the video.

Considering how digital technologies 'actually' function in contrast to how they are experienced might in a way seem to be problematic within a postphenomenological framework, since postphenomenology does not see technologies as having an independent existence in themselves outside of the relations within which they are constituted. Yet in order to really look at 'what things do,' particularly digital things, there is in many cases a need to consider both how they relate to humans within praxis but *also* how it is possible to relate to them in a way that discloses their properties and functionality more clearly and completely. This is especially true, as I will attempt to show, in the case of digital technologies, which may be in a way transparent in use but are by no means transparent with respect to their operation. Although it is outside the scope of this paper to lay out this argument in more detail, this alternate perspective might be thought of as the designer's perspective or even a common sense perspective that users themselves might take when critically reflecting on and investigating the technologies they use. This is the perspective I take when considering digital materials and the mediations they can enable.

There are many different specific configurations of responsive digital materials, but for the sake of clarity and simplicity it will be helpful to work with a simple model of material mediation involving its basic structure and main components of *substrates* and *traces*. As a starting point I will follow Ihde's (1990) schema, where the general intentionality relation is:

I–technology–world

This indicates a subject perceiving the world through the mediation of a technology. The more specific hermeneutic relation can be formalized as:

I→(technology–world)

Here there is a clear intentional orientation toward the technology, which is seen as outside of oneself and part of the world to which it also relates, and about which it provides information. This can be modified to reflect digital material more specifically:

I→(digital material–world)

However, digital material mediation entails a few more complexities that require a few more modifications of the schema.

First, the fact that different material substrates respond to different types of activities and in different ways means that, in terms of its capacity to register traces, digital material has its own sort of intentionality toward the world. *Technological intentionality* is a concept that Ihde (1990) develops in a couple of ways; the most relevant here refers to the directedness of a technology's sensing apparatus that is configured to pick up and process input in certain ways. Verbeek (2008a) also further extends the concept of technological intentionality through using the idea of the *cyborg*, and looking at the hybrid intentionalities that arise when technologies actually merge with humans in order to form new entities.

A substrate has a kind of intentionality toward the world, and specifically activities in the world, which is determined by its character as a material. Materials respond to some activities while not responding at all to others, and materials that respond to the same activity may respond in different ways. To return to the simple example of the grass path, the grass responds to the activity of walking, so it can be thought of as in a way 'directed' toward that activity. It does not respond to other activities like, say, talking, whereas a telephone does respond to that activity (but not to walking).

While physical materials are 'naturally' directed toward certain types of activities because their specific qualities determine if and how they respond, digital materials are programmed to have certain intentionalities. For example, a word processing application is directed toward receiving text input through a keyboard but not (at least usually) voice input. It is possible to say anything you want around a word processing application without fear that it will register what you are saying, but the same is not true for audio recording equipment that is directed toward sound.

Materials, then, have their own intentionality with respect to the world, and the diagram can be modified further to reflect this:

I→ (digital material→world)

This constitutes what Verbeek (2008a) calls *composite intentionality*, in which a human is directed toward a technology and also at the way in which the technology is directed toward the world.

However, this still does not fully account for the structure of digital material, because it is really the *substrate* that is oriented toward the world, while its *traces* face the perceiving subject. With physical materials these are tightly coupled together: the grass path is both the site of the activity of walking and its trace. However, with digital materials this relation between substrate and trace can be,

and generally is, significantly more complex and uncoupled. In fact, this is true anytime something is posted on the Internet: the point at which the activity of posting content occurs (i.e., the device used) is separated from where it shows up (i.e., a website or application displayed on the same or another device) by many layers of digital infrastructure that include the devices' operating systems, applications, online platforms, and the underlying technologies and protocols of the Internet and world wide web. Or, in another type of scenario, activities may be registered by digital materials that do not let on at all that they are acting as substrates and registering activity. This is what happens when online activity is tracked, or when sensors embedded in a road register passing traffic. A more simple (if unusual) example would be a program that could accept keyboard input without making it visible or acknowledging it in any way. This would be a terrible design, but a situation like this is at least possible (and perhaps even likely in the case of programming novices writing their first programs).

This state of affairs requires splitting up digital material into these two component parts, with substrates directed toward the world and traces being what a person can actually perceive. These parts also have their own relation to each other that determines how 'input' received by the substrate is made visible as the 'output' of traces, even as they together function as a unified composition. The schema can be updated to reflect this *digital material mediation*:

I→ ([trace | substrate] →world)

Here digital material is represented as [trace | substrate], with the trace facing the perceiving person and the substrate facing the world.

It should be noted that this structure represents a person perceiving traces in order to gather information about the world. This is distinct but in practice very closely related to acting through technologies, and one's actions that involve perceiving traces may even be recorded as traces themselves (as in the case of a 'read' receipt for a message). From this perspective that focuses on technological mediation of perception, activities are part of the 'world' that is perceived. However, even though the 'I' in the schema is in the perceiving position, a person will in turn also be in the position of 'world' that is made visible for others to perceive.

While this schema represents the general structure of digital material mediation, in terms of functionality it seems to have a higher level of complexity than more straightforward and non-digital kinds of technological mediation. Classic examples of the hermeneutic relation are the thermometer and various kinds of scientific instruments. In these cases the general operation of the technologies is

fairly focused and clear; they are used deliberately in order to find out about some specific aspect of the world; and there is generally little if any lag between that aspect of the world being registered by the technology and being made visible to the person using it. Digital materials, in contrast, function in a wide variety of ways that are often far from transparent; they are often encountered incidentally; and there can be a good deal of time that goes by between when traces are registered by digital material and when they are perceived. Thus, even within the general structure of the hermeneutic relation there is a wide range of specific sociotechnical configurations.

7. The 'Uncoupling' of Digital Material Mediation

In order to try to tease apart some of the complexities of digital materials, it seems potentially productive to consider ways in which their function and use is 'uncoupled'[14] with respect to more simple and strictly mechanical technologies and materials. Specifically, it is possible to identify dimensions of *functional*, *perceptual*, and *temporal* uncoupling. There are, however, no strict dichotomies between 'simple' and 'complex,' 'mechanical' and 'digital,' 'coupled' and 'uncoupled.' Each specific sociotechnical configuration has its own unique characteristics, and ways in which it is both simple and complex. This is why I consider *dimensions* along which specific configurations can be uncoupled in varying degrees, and which can be used to articulate their specific qualities.

7.1 Functional

A mercury thermometer 'captures' and 'displays' the temperature quite naturally and simply. As mercury expands and contracts with the temperature, its level in the tube rises and falls. The substrate of mercury is also the trace: it is both the material that responds to the world (specifically, to the heat in the world) and the material that is visible and can be read. Capture and display of information are accomplished in a single, unified function and in a single material. More modern thermometers, however, separate (and generally hide) the material that responds to heat and the display, which may be an analog dial or a digital screen. There may still be a clear correspondence between the device's physical apparatus and its display, but these are two distinct functions. This distinction becomes even clearer in the case of a digital weather widget or website, which can give weather conditions for locations on the opposite side of the world or right outside the door. In either case, the physical devices that register weather conditions are clearly separate from the digital devices that display them. Rather than being unified as in the mercury thermometer,

they are *functionally uncoupled*. Sensing and displaying the temperature are two separate functions, even though they work together in a unified way during use.

This functional uncoupling of input and display is characteristic of digital material. Even in the case of something like a drawing app on a tablet device, where the trace of drawing is registered in the same location and at roughly the same time as the activity, there are separate functions for handling input and output. This is even more clear when the Internet is involved as one of the underlying infrastructures of a substrate, since when it registers an activity it can conceivably make it visible on any device connected to the Internet. This is what happens with every web page update and social media post.

The uncoupling of the functions of capture and display, substrates and traces, is a basic and characteristic aspect of digital materials, and it is what enables *perceptual* and *temporal* uncoupling.

7.2 Perceptual

When viewing digital traces of activities, understanding something of both capture and display functions is key to their interpretation, even if this is usually done without a second thought. This is how a social network post viewed on a computer can be understood as reflecting the activity of a distant friend rather than the output of a local computer program. However, it also contributes to *perceptual uncoupling* in digital material mediation.

When using a thermometer or more sophisticated scientific instruments, there is a clear directedness in use toward some specific aspect of the world. The technology is set up and configured so as to be directed toward this area or phenomenon by someone familiar with both it and the technical apparatus, such that she can understand its output in terms of how the apparatus is set up to relate to the world. One example of this can be seen in Vertesi's account of the Mars Exploration Rover Mission, in which she describes how the team members operating the Rovers come to have an embodied relationship with them. The "humans on the mission learn, imitate, and demonstrate what it is like to be a Rover on Mars" (Vertesi 2008, 2525). They learn to 'see like a Rover.' The bodily connection that Vertesi describes between the team members and the Rover does not constitute an embodiment relation in a postphenomenological sense. It is rather a hermeneutic relation in which the operators are so familiar with the technologies involved that the latter become in a way transparent during skilled operation, even though the camera images the operators use often involve distortions of some kind (such as those produced by the Hazard Avoidance Camera with 'fish-eye' optics).

In another perspective on working with images of Mars, Rosenberger (2008, 2013) explores the role of hermeneutic strategies in relation to scientific images, particularly how rival strategies play out in scientific controversies. A hermeneutic strategy "contains an account of the *technological transformations* which have been brought by the imaging process" (Rosenberger 2008, 66). This is the kind of transformation that can render a three-dimensional world as a static, two-dimensional, single-perspective image, or can make things that are invisible to the human eye visible in an image or other form of data. Images must be read not only in terms of their content, but also in terms of the processes by which an imaging technology generated that content. Interpreting data in terms of how they were produced by certain technologies is thus a fundamental part of scientific practices (and one which Rosenberger argues deserves more explicit attention). This also implies that scientists are generally *able* to understand something of how the technologies they use function, including their orientation toward some specific part of the world, sensing apparatus, processing capabilities and settings, and the relation between captured input and displayed output.

In contrast, perceiving the world through more everyday digital materials is often an incidental, post-hoc affair in which one cannot be entirely sure how traces are created. Although the means by which traces are created often seem self-evident, it is usually not possible to see the entire digital material 'apparatus' involved in producing them, or the nature of the apparatus's directedness toward its object. It is also not as possible to play around with its settings in order to explore the effects that different configurations can have on the traces produced, as is perhaps more typical in the case of scientific instruments, and which could also aid in better understanding the effects of particular configurations of mediating technologies.[15]

For example, an image posted online generally does not contain any explicit evidence of how it was produced. It is possible that it is a relatively straightforward snapshot of reality, of the kind captured by a classic film camera. But even if that is the case, a printed photo that is scanned into digital format can still present mysteries. For instance, is a blurry corner of the photo due to a raindrop on the camera lens at the time the photo was taken, or is it due to a smudge on the glass of the scanner? And does a photo of a friend at the Eiffel Tower provide proof that he was really there, or does it rather provide proof of his skill with a green screen and image compositing? Was the sky really that blue, or was a post-processing filter used to intensify the colors? Was the original frame posted, or has a now-ex-girlfriend been cropped out? There are definitely clues in a photo that can provide informa-

tion to a skilled reader about all of these potential ancillary activities regarding the creation of a photo, but such digital forensics can also be quite challenging and inconclusive (especially for non-experts). Or, they may not be undertaken at all, when a person simply accepts an image (or other traces) at face value.

Another way of putting this is that the *means* of producing traces are separated from the *ends* of the traces themselves. This separation of means and ends is something that Borgmann (1984) argues is characteristic of modern technologies. The famous example that he uses to illustrate this is central heating, which generally hides the means of its functioning while delivering the end (warm air) as an effortless commodity. Although Borgmann's concern is generally with a loss of engagement with the world, this concealment of technologies' interior workings has implications for mediated perception as well. If the kinds of traces that are produced are determined by the nature of the substrate, then it follows that interpretation of traces relies on an understanding of the nature of the substrate. Put more simply: a person needs to know how a trace got there in order to know what it means.

When seeing a desire path that has been worn through grass, there would be little reason to believe that it has been (or even could be) caused by anything other than a number of people walking the same trajectory over a period of time. There is a fairly transparent relation between substrate, activity and trace. Crop circles, on the other hand, are more difficult to interpret! They can also be seen as traces, but their cause is not as immediately apparent. There is not a clear relation between activity and substrate—they are mysterious because of what one knows about the kinds of activities that would normally be required to leave those kinds of traces in the substrates of a field.

With digital material there is a tremendous flexibility in the possible relations between activity, trace, and perception. One example in which the same trace can be caused by two distinct activities is the 'away' status in an instant messaging client. The away status can be set intentionally, just like setting the status to 'available' or 'busy' or something else; and it can be set automatically after a period of inactivity. A person's status might indicate that he is 'away,' even when he is not. When interpreting this status it is not possible to know if the activity that caused it was the person leaving his computer, thus triggering the automatic change, or if it was the person setting it so as to make it *appear* that he is away. Understanding this distinction that follows from the nature of the instant messaging substrate, and the traces that can be actively constructed and those that cannot, can lead to subtle differences in interpretation on the part of someone looking at another's status (and can figure into the performative setting of one's own status).

A more fanciful example is the classic stunt of the ingenious crime show villains who replace live surveillance camera feeds with a pre-recorded video loop. In this case the hapless security personnel are duped by what they naturally consider to be a straightforward relation between camera, reality and displayed video, but which is actually a lie that plays on assumptions of how the technological apparatus normally functions. A similar example is the email time stamp. It is commonly assumed to be objectively captured by the substrate of the email architecture. Thus, barring any server snafus, it can be seen as a fairly reliable indicator of when the sender of an email was sitting at a computer (or using another networked device) and clicked the send button. But on the other hand, there can also be a lawyer who has the sending of his email delayed until the early hours of the morning to give his client the impression that he is up late working on the case. In this scenario he is playing on the common understanding of the relation between the substrate of the email system and the trace of the time stamp in order to mislead the email recipient. More commonly, many social media platforms now enable scheduling of posts, so that the time at which something is posted reflects this scheduling activity rather than the actual moment at which a person created the post (although this likely reflects the needs of corporate marketing managers more than those of devious lawyers).

Another somewhat amusing example is CouchCachet, a web-based service that "finds the coolest parties in your neighborhood, and automatically checks you in on Foursquare so all your friends can be super jealous of how awesome you are."[16] This is a "tongue-in-cheek app," but since the concept is actually feasible it still makes a good case. The idea is that instead of actually going to cool restaurants, concerts, and the like, a person can relax at home while CouchCachet produces the kinds of traces that would ordinarily reflect actually doing these things. What makes this concept work is that Foursquare is used as the substrate. If the service were to just automatically generate Tweets or Facebook posts consisting of text stating the person was doing the same things, this would still constitute a kind of performance of self that would be an illusion. But what makes this so compelling is that a Foursquare check-in requires using a GPS-enabled smart phone while actually being at the location at which one is checking in. It thus provides a confirmation of what a person is doing beyond what can be achieved in a text-only social media update in which one simply attests to being at a specific location (although many social media services, like Facebook, now integrate check-ins as well). Understanding how Foursquare works in this regard enables mediated perception of a person actually being at a certain location when seeing the trace of

a check-in. CouchCachet subverts this dynamic by changing the behavior of the Foursquare substrate, without letting on that this has been done. A person who perceives traces created by CouchCachet would ostensibly not be able to differentiate these inauthentic ones from those that are genuine.

The scenarios in the above examples are possible because of the uncoupling of digital material mediation: the *functions* of substrates and traces are separate, and it is not possible to *perceive* how the substrates function and what the relations are among activities, substrates and traces. Most ordinary interactions with digital materials probably do not involve quite the levels of intentional deception and obfuscation of CouchCachet. However, these extreme examples do point to the fact that digital material mediation is less than transparent; and when one sees only the traces that are the end products of activities without seeing the means by which they were produced, interpretation becomes more challenging and uncertain.

7.3 Temporal

Whenever digital traces are created there is some degree of lag between the time at which the activity takes place and the time at which the trace is made visible. This time delay may be infinitesimal, it may be months or years, or anywhere in between. One small example where this time delay was made explicit was in the web cam that was part of the *New York Times'* online coverage of Hurricane Sandy in November 2012. During the time that the storm hit New York City there was a web cam that provided an almost-realtime view looking out over the city from the *New York Times* building. This enabled mediated perception of the at times scary and surreal scene, including the power outages that were quite noticeable at night, even by people in another part of the country or world. It was not quite realtime though, but was rather updated once a minute, with a timer that counted down the number of seconds to the next image. After the storm passed the web page that showed current images was updated to show a four-and-a-half minute time-lapse video of the storm.[17] This video takes advantage of the temporal flexibility of digital traces in another way, while its viewing several months or years after the images were captured entails an even greater temporal uncoupling than the original 60-second delay.

Another way that temporal uncoupling can be seen is when traces are viewed as a historical record, and potentially processed and made visible in new ways. One example of this is a visualization of three months of Foursquare check-ins worldwide.[18] When the check-in locations are represented in a sort of heat map the resulting image forms a clearly recognizable map of the world, while also making

visible where the 'hot spots' are. This mediates a certain kind of perception of the world in and of itself, even though it is quite removed from the original traces in terms of both time and level of processing.

Traces in digital material are also increasingly being used as evidence in legal cases and related investigations. One particularly striking example of this was in the uncovering of digital evidence of the affair between former CIA director General David Petraeus and his biographer Paula Broadwell in 2012. In addition to tracking IP addresses to physical locations, investigators uncovered draft messages in a Gmail account that the two shared (Ward 2012). Leaving draft messages in this shared account rather than actually sending messages between accounts is a standard way to thwart surveillance. However, once this account was uncovered the messages were taken as traces of these people's activities, and thus as legitimate documentation of their affair. This is a case where the materiality of digital materials can be clearly seen: the digital traces were traced back to real people, and the IP addresses used were followed to real physical locations.[19] Moreover, these digital traces were described as "a trail of digital fingerprints" (Ward 2012), a comparison to one of the most incriminating types of material evidence that connects a site of criminal action back to the physical body that created the prints. Given the complex and non-transparent nature of digital substrates and the number of places they now exist—not to mention the staggering scope and scale of ongoing digital surveillance (Greenwald and MacAskill 2013)—this type of use of digital traces should give us pause.

8. Conclusion

Digital materials that make activities visible can also in turn mediate perception of the world, specifically the activities registered by and in the materials. These digital traces, like Latour's circulating references (Latour 1999), can be traced back through a series of transformations to the particular actions that caused them. These traces are both marks and connections, the visible results of a chain of actions that begin in the physical world and are propagated through the various layers and processes of digital substrates.

In this paper I have explored the ways in which digital technologies mediate engagement with the world by making activities visible. Noting the physicality and automaticity of this process, I have used the logic of materials as a starting point in conceptualizing how they can function as substrates and make activities visible as traces. I have defined and used these concepts of *substrates* and *traces* in order to articulate the structure and function of responsive materials, and extended this in developing a conceptualization of responsive *digital materials*. I have then considered how existing

postphenomenological theory needs to be developed and extended in order to account for the complexities of *digital material mediation*. Finally, I have articulated some of these complexities in terms of functional, perceptual, and temporal uncoupling.

In this analysis I have not attempted to provide a complete or conclusive account of the digital, but rather to open up and begin to define a problem space for further inquiry. While many theoretical approaches in philosophy of technology remain highly relevant, the analysis presented here also shows that the digital does have some distinctive characteristics that require new theoretical developments and approaches. However, it will not do to simply treat the digital as a separate 'virtual' realm, since digital technologies—and the mediations they enable—are firmly and very materially anchored in the real in both experience and practice. The digital is always on some level inescapably material and is also becoming increasingly embedded in the world around us. It is because of this close material and functional interweaving of physical and digital that I have worked with a broad conceptualization of material and developed concepts that can be used to articulate the structure of a range of hybrid compositions with respect to the ways in which they respond to and make activities visible. Indeed, the flexible and highly malleable character of the digital requires such theoretical and analytic sensitivity to specific configurations.

Digital technologies have come to be pervasive in everyday life, mediating interaction and engagement in an increasing variety of ways. Understanding their role and character is thus an important challenge for philosophy of technology. For we now live in a digital material world: one in which digital technologies participate in both constituting and revealing our reality.

Notes

1. This conception of technologies 'catching in the act' has been informed by the realist tendency in film, which similarly emphasized the mechanical nature of the camera as validation of the resulting image as reflection of reality (Bazin 2009a, 2009b; Kracauer 2009). I do not, however, make the same claim that technologies represent reality, and instead try to find ways to articulate specific relations among certain technological configurations and reality in specific situations.

2. This attunement of digital materials to human activities, and the capture, storage, merging, compiling, analysis, retrieval, and use of digital traces warrant further attention and consideration, particularly since the number and persistence of these digital traces seems to increase faster than theoretical, practical, and legal frameworks for dealing with them.

3. Input to digital devices works differently when using assistive technologies designed for people with physical impairment, but it still involves physical interaction with the devices. I here refer to the most common types of interaction while acknowledging that these other variations exist.

4. 'Trace' is a rich and evocative term that has been appropriated and developed in many ways, perhaps most famously by Derrida (1967). However, in my use here I draw on a more common understanding of the term and its reference to marks left by activities, or the act of making such marks.

5. This is one of many examples in which some kind of tool or equipment is needed in order to create traces. In the case of graffiti the necessary 'tool' is a spray can full of paint. Considering this additional level of complexity is outside the scope of the current project, but is something that could be productively explored in the future.

6. Speaking of a 'direct causal relation' is of course problematic in a philosophical sense, and even in the context of contemporary physics. However, our ordinary experience is that of a world in which these consistent causal relations obtain. I here base my analysis on this common experience, while acknowledging that these common sense explanations of phenomena may not square with the underlying reality as understood from more sophisticated and technically accurate perspectives.

7. https://www.spotify.com.

8. http://www.pandora.com.

9. Twitter's link counting API is described in more detail at https://dev.twitter.com/docs/tweet-button/faq#count-api.

10. In referring to "compositions" of the digital and physical, I draw on Robles and Wiberg (2010) and Wiberg and Robles (2010), and also on the more general concept of design as composition developed by Nelson and Stolterman (2012).

11. It should be noted that the kind of hermeneutics referenced here, and particularly in my extension of the concept, is a different type of activity than the textual interpretation indicated by its classic meaning. 'Reading' a mediating technology involves interpreting not only the 'content' or readout itself but also the means by which it was produced. The focal point of the activity is ultimately the aspect of reality disclosed by the technology, not the output of the technology as a stand-alone text.

12. Ihde (1990) mentions this function of digital 'translation technologies,' even though digital technologies do not feature prominently in his analysis.

13. Ihde (1990) mentions this tendency to desire total transparency and embodiment of technology, such that the transformations the technology brings about are ignored. 'Immediacy' in this sense is also one of the 'logics of remediation' articulated by Bolter and Grusin (2000).

14. It is difficult to find a word that is exactly right for indicating the dynamics I wish to explore, but what I like about 'uncoupling' is that it suggests not an absolute separation in practice, but rather an undoing or lack of the thing that *compels* things

to hang together. The elements in question may drift apart, or they may actually stay close together. The key point is that there is no mechanism requiring that they be joined together.

15. Although outside the scope of the present project, the various means by which people can come to understand the function of specific mediating technologies is another significant issue that warrants further investigation.

16. The service's website and a post about it on the official Foursquare blog are no longer active as of this writing in 2014, but a Google search still leads to related media coverage. CouchCachet is also documented in more detail (including screen shots) in Wiltse (2013).

17. http://www.nytimes.com/interactive/2012/10/28/nyregion/nyt-webcam.html?hp&_r=0.

18. https://foursquare.com/infographics/500million.

19. This example points to what can perhaps be considered another kind of 'uncoupling,' which is the uncoupling between people's intentions and awareness in using the technologies and the ways in which traces of their activities can actually show up and be used. Digital traces may travel far beyond the contextual, spatial, and/or temporal scope intended by those who created them, and even without their knowledge. I have here been concerned with digital traces as the object of perception, but the other side of this issue that also warrants exploration is that of how people understand the ways in which their activities are made visible and the level of control (or lack thereof) that they have over this visibility.

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