35. Robert Darnton, *Censors at Work: How States Shaped Literature* (New York: W. W. Norton, 2014), 29.
36. The centering of whiteness in cyberpunk operated in tandem with a simultaneous fascination with, and othering of, Asian culture that historians have described, aptly, as "techno-Orientalism." See, for example, David Roh, Betsy Huang, and Greta Niu, eds., *Techno-Orientalism: Imagining Asia in Speculative Fiction, History, and Media* (New Brunswick, NJ: Rutgers University Press, 2015).
37. Pfaffenberger, "The Social Meaning of the Personal Computer," 39–41.
38. Pfaffenberger, 44. See also Emily Chang, *Brotopia: Breaking Up the Boys' Club of Silicon Valley* (New York: Penguin Random House, 2019); Cynthia Cockburn, *Brothers: Male Dominance and Technological Change* (London: Pluto Press, 1983); Cynthia Cockburn, *Machinery of Dominance: Men, Women, and Technological Know-How* (London: Pluto Press, 1985); Kendall, *Hanging Out in the Virtual Pub;* and Sherry Turkle, *The Second Self: Computers and the Human Spirit* (New York: Simon and Schuster, [1984] 2005).
39. Liz E. Borden, "Sexism and the Computer Underground," *Computer Underground Digest* 3, no. 3.00 (January 6, 1991).
40. See Elyse Graham, "Boundary Maintenance and the Origins of Trolling," *New Media and Society* 21, no. 1 (2019).
41. Thiel quoted in Taplin, *Move Fast and Break Things*, 70.
42. Michael Harry, *The Computer Underground: Computer Hacking, Crashing, Pirating, and Phreaking* (Port Townsend, WA: Loompanics Unlimited, 1985).
43. Harry, *The Computer Underground*, 4–5.
44. Sherry Turkle, *The Second Self* (Cambridge, MA: MIT Press, 1984), 25.
45. Harry, *The Computer Underground*, 4.
46. Stewart Brand, "Purpose," *Whole Earth Catalog* (September 1968), 3. Quoted in Taplin, *Move Fast and Break Things*, 52. Emphasis in the original.
47. Reprinted in von Bitter et al., *Mondo 2000: A User's Guide*, 11.
48. Hebdige, *Subculture*, 61; Langdon Winner, "Peter Pan in Cyberspace," *Educause Review* 30, no. 3 (May/June 1995).
49. Graham, "Boundary Maintenance and the Origins of Trolling."

CHAPTER 19

The Computer as Prosthesis?

Embodiment, Augmentation, and Disability

Elizabeth Petrick

The computer is an intellectual prosthesis; an information prosthesis; a communication prosthesis:[1] variations on this metaphor show up throughout scholarship on the relationship between users and technology, from many different fields: history, philosophy, science and technology studies, media studies, education, and more. The metaphor perhaps began with Seymour Papert and Sylvia Weir's 1978 paper, "Information Prosthetics for the Handicapped," which suggested that "the computer can become an extension of the operator who can now do 'anything a computer can do' such as draw, compose music, gain access to information libraries, put text on permanent file and so on."[2] Notable figures in computer history have had the prosthesis metaphor applied to their understanding of computers and users. Lev Manovich describes J. C. R. Licklider's idea behind "Man-Computer Symbiosis" as: "an interactive digital computer can act as a kind of metaprosthesis that augments our memory, perception, decision making, and other cognitive operations."[3] Likewise, Thierry Bardini explains that Douglas Engelbart's computer interface with its mouse and chord keyset was "based on the premise that computers would be able to perform as powerful prostheses, coevolving with their users to enable new modes of creative thought, communication, and collaboration providing they could be made to manipulate the symbols that human beings manipulate."[4] With these and in other works, the metaphor usually goes unexplained, left to speak for itself in exactly what ways a computer can be a prosthesis for a human.[5]

What all these examples have in common is an attempt to describe the capability of the computer to augment human abilities. As Papert and Weir note—possibly referencing Marshall McLuhan—the computer can be an extension of a person, expanding their abilities and senses. The computer as extension explains why the prosthesis has been so widely latched onto as a metaphor, as it seems to provide a concrete, real-life example of what the computer is doing invisibly. We reach out via the computer, intellectually and with our senses, in a similar way as someone with a prosthetic arm reaches out to grasp an object. The prosthesis implies something like the opposite of an autonomous technology; it is integrated fully with the body, human and computer becoming one.[6] Going further with the possibilities implied by the metaphor, Lucy Suchman looks to near-future technologies to mesh computers with human bodies, with the work of Steve Mann and "the intersection of the wearable computer as environment and as prosthesis," where "the mirroring of environments and bodies in the projects of the disappearing and wearable computer suggests a desire always to be recognized, connected to familiar environments, while at the same time being fully autonomous and mobile."[7] Prosthetic technology provides a technological way of enacting human autonomy, extending the body and senses, while the user feels in control.

Flipping the metaphor, in 1990, John Perry Barlow wrote of cyberspace that "I don't know what to make of it, since, as things stand right now, nothing could be more disembodied or insensate than the experience of cyberspace. It's like having had your everything amputated."[8] The user is augmented by feeling like the body has been left behind entirely, leaving the mind floating untethered online, to do as it will. Employing these metaphors offers a way to get at what it feels like to use computers, to be able to do so many things our bodies, including our minds, could not without technology. Yet, what is missing from nearly all of these examples of the metaphor is disability and the reality of prosthetics. A prosthesis is assumed to be a perfect fit when the computer is talked about as one, a way for the user to reach beyond their body. The prosthesis here is a way of beating nature—technology conquering the incapabilities of the body.

With this fantastical image of the prosthesis, it is perhaps unsurprising that, when the metaphor is usually employed, it is not in consideration of actual computer users with disabilities: those who may use actual prostheses as they operate computers, along with those with other kinds of disabilities also having their abilities augmented by the computer. Or, as Katherine Ott puts it, "Cyborg theorists who use the term 'prosthesis' to describe cars and tennis rackets rarely consider the rehabilitative dimension of prosthetics, or the amputees who use them."[9] The full complexity of what a prosthesis means is absent from its part in the metaphor. Furthermore, to consider the subject literally, only a few recent works look at the relationship between computer technology and actual prosthetics, specifically attempts to impart a sense of touch to prosthetic devices using electronic technology.[10] Instead, the prosthesis—and, by extension, disability—often remain nothing more than a metaphor when technology is discussed. People with disabilities are rarely considered as computer users, and their place in computer history is not analyzed. The user is almost never one who wears a prosthesis in real life; they are instead able-bodied and their prosthesis only a play on words, not a technology replacing an actual missing limb. When a marginalized group is treated as merely a metaphor, they become further erased from the history they were a part of.

Disability studies scholars have published widely on the problems with using words and concepts related to disability as metaphors, particularly in literature and media. Carrie Sandahl argues, "Nondisabled artists in all media and genres have appropriated the disability experience to serve as a metaphor expressing their own outsider status, alienation, and alterity, not necessarily the social, economic, and political concerns of actual disabled people."[11] Disability metaphors also appear in politics, as Emily Russell has shown: "Despite representative democracy's consistent exclusion of disabled *individuals*, *figures* of anomalous bodies are often pressed into service as a metaphorical representation of the body politic."[12] Similar to the prosthesis metaphor, these other metaphors of disability rarely include actual people with disabilities but are instead appropriated by nondisabled people to mark some outsider status. The end result is, as Julie Avril Minich explains, that "pervasive disability representations like the overcoming narrative serve as metaphors for problems faced by able-bodied people or to reinforce the marginalization of disabled people."[13] These issues remain true for the prosthesis metaphor as well.

Vivian Sobchack suggests that an alternative approach to treating "technology as prosthesis" is to treat "prosthesis as technology."[14] This reversal opens the door to dig into the technologies that enable the computer to be a metaphorical prosthesis, those that allow access to it. All people require technologies of access to use the computer to its fullest: preferred input devices, ways of displaying information on the screen or through audio and other media, and various peripherals that allow us to enter something into the computer and receive something back. We all have different preferences and needs when it comes to the best ways to set up our computers for us to interact with them. This is all access—the technologies that connect us, body and mind, with computers. Thinking about human-computer interaction in this way leads to a shift in how we conceive of the interface, where the interface becomes the system of human and computer, along with all the various technologies the two need to communicate with each other. One way to understand these technologies is to center computer users with disabilities and the accessible technologies they use to operate the computer. This allows us to get at the diversity of bodies interacting with computers and what that might mean for the user-technology relationship. Frequently, when people with disabilities are mentioned as technology users, they are not talked about as normal users; instead they are a special case or a footnote to a standard history. Even scholarship focused on marginalized people and the relationship between different bodies and technology usually leaves out people with disabilities. Yet, there is a rich history of people with disabilities and their families tinkering with and adapting technology to fit their needs.[15] This is often done to make the built environment and consumer technology fit people who were not thought of as intended users. People with disabilities have always been technology users, and by understanding how technologies have been made to work for people with different bodies and needs we gain a more complete picture of the relationship between technology and users.

There is a well-known critique of the prosthesis metaphor from Sarah Jain, in which she argues that the metaphor itself falls apart as soon as you know anything about how prostheses work in reality.[16] She suggests some necessary questions to be answered that are left out of the metaphor: "Which bodies are enabled and which are disabled by specific technologies? How is the 'normative' configured? How does the use of the term prosthesis assume a disabled body in need of supplementation? How might the prosthesis produce the disability as a retroactive effect? Where and how is the disability located, and in whose interests are 'prostheses' adopted?"[17] Without such questions being addressed, the metaphor deflates, without any real substance. Jain also brings in an issue I will return to later, to not ignore the fact that technology—even metaphorical prostheses meant to augment human ability—also affect and change the body of the person using it: "Wearing glasses adjusts vision but also changes the comportment of the head and neck and over years changes the contour of the muscular-skeletal infrastructure, and the use of a thirty pound artificial leg strapped over the shoulder in the early century would have changed the weight distribution and physiology of the body."[18] This is as true for computers as for these literal prostheses, as Laine Nooney shows in this very edited volume, with all the forms of pain the computer has brought to the body.[19] Hunched shoulders, carpal tunnel and other repetitive stress injuries, and eye strain are all changes to our bodies that computer use has wrought in us.

I would like to take a different tack from Jain, however, by focusing on what we can learn about the relationship between people and computers when people with disabilities are foregrounded as technology users. Specifically, I argue that the prosthesis metaphor's focus on augmentation through embodied computer use can become a lens for critical analysis when we consider computer users with diverse bodies. By examining people with disabilities as normal computer users, we see not only the range of different bodies that must be made to fit with computer technology but also the creativity and frustrations behind trying to accomplish such. Once fit is achieved, then possibilities for augmentation open up, and yet, that in itself is called into question, in terms of what exactly about ourselves is being augmented by the computer. I find that we can keep something of the prosthesis metaphor in mind by considering questions of fit between the bodies of users and the technologies that allow them to access the computer. Explicit consideration of the role of the body in interaction with and part of the computer interface is still uncommon in the historiography of human-computer interaction, although more scholars have recently been centering the body in this fashion.[20] Doing so calls into question our understanding of exactly what the computer interface is and highlights the need to more fully understand the computer as an embodied technology.

I examine three case studies, of different computer technologies from the late 1970s to 2009 that could be understood as augmenting human abilities. This is a period of significant change in computer technology but also for the place of people with disabilities in society. This period begins at a low point for the disability rights movement, with a lack of progress in gaining further civil rights protections after earlier victories in the 1970s, but then surges forward with the passage of the Americans with Disabilities Act of 1990 and all the successes and challenges that have followed from it.[21] People with disabilities experienced far greater access to social participation over this timespan, which included new forms of participation through computer technology and the growing Internet. This increase in visibility and social activity also led to growing expectations among people with disabilities to no longer be just metaphorical outsiders.

Case 1: Unicorn Keyboard

The Unicorn Keyboard,[22] created in 1979 by Steve Gensler, was perhaps "the first widely used alternative keyboard."[23] Gensler invented the keyboard so that a friend of his with cerebral palsy could use a computer. The keyboard consisted of 128 programmable switches that could configure the keyboard however the user needed. This made the keyboard both simple and significant for people with disabilities. Because it was completely programmable, once the switches were covered with an overlay that was divided into keys, it could contain however many keys the user wanted, each doing whatever they needed. An overlay could be put on top replicating a typical computer keyboard and all of its keys, an overlay could just contain one key covering all of the switches that acted as a single-switch input, or the keyboard could be programmed to be anything in between. This total level of customizability allowed the keyboard to adapt to the users' abilities and needs.[24] The adaptability of the Unicorn Keyboard made it a technology of augmentation in a way that allowed it to fit the body of the user but also change with the user, making it particularly useful as an educational technology for children with multiple disabilities. A child could start with only one or two keys to learn cause and effect with how the computer responded to those key presses. From there, the overlays could be made more complex, to teach the user not only how to operate a computer but also help the user develop both cognitive and motor skills, making it an embodied technology in multiple ways.

Shoshana Brand was given one of the first Unicorn Keyboard prototypes when she was around five years old. Gensler met Shoshana's father at a computer class at which they were both trying to learn more about computer technology that might benefit people with disabilities in their lives.[25] Shoshana was born with cerebral palsy and had vision impairments; her parents, Jackie and Steve, hoped that the computer might help her learn to communicate. They got the Unicorn Keyboard working with their Apple II computer and started by having the keyboard contain only one key that had the computer play music whenever Shoshana pressed anywhere on the overlay.[26] This initial setup allowed her parents to determine Shoshana's abilities in terms of vision and motor control, while showing her that she could control basic cause and effect. She quickly advanced to pressing keys of different colors and animal pictures (the latter caused the computer to play the sound the animal made). As Jackie describes her daughter using the keyboard:

> Eventually the keys got smaller and smaller, there were more and more divisions on that board, until she had essentially a full keyboard to work with. Had we shown her that full keyboard right at the beginning, there was no way she could have done it. . . . It's like showing a very young child a standard keyboard and they go banging on it because they don't have the fine motor skills yet, and then they get bored and that's it. Instead, the computer became a real learning tool for her as it could develop and evolve on the keyboard as she developed and evolved both in a physical sense and gain the fine motor skills—and also in a cognitive sense as she went through the developmental stages.[27]

The Unicorn Keyboard was able to fit with Shoshana's body, to a striking degree, in both physical and cognitive ways. However, in spite of the promise of the keyboard, it still had to work alongside other technologies that may not fit as well; Steve Brand bemoaned the fact that so much software at the time was based on assumptions that the user could see the screen well, providing only visual output and not accommodating users with visual impairments.[28]

Another example of a Unicorn Keyboard user further illustrates how it could augment communication abilities. In 1992, a 15-year-old boy, Eric, with both hearing and vision impairments used the Unicorn Keyboard to learn Braille as his vision decreased, in order to complement his communication in sign language.[29] The keyboard was covered with an overlay of keys with raised dots on them, in order to get Eric used to feeling for the numbers of raised dots in Braille. He was then given tasks, such as to find and press a key with three dots, which would make the screen flash in response. Once he could correctly identify the numbers of dots on a key, an overlay with the partial Braille alphabet was introduced so that he could begin to learn the different letters in Braille. The keyboard could adapt to Eric's abilities and learning speed to effectively teach him a new form of communication that he would soon need to rely on.

While the Unicorn Keyboard held great potential to work with different people's bodies and abilities to allow them to access a computer,

it also presented certain technical obstacles that needed to be overcome. In addition to the problems with inaccessible software, the keyboard could not communicate directly with a computer until later in the 1990s, instead requiring an often expensive Adaptive Firmware Card (advertised for $520 in 1992)[30] that would translate between the keyboard and computer. While this workaround became easier to use over time, the Unicorn Keyboard also always required a significant level of expertise to set up and program the keys. As Jackie Brand described trying to make everything work together for her daughter: "We also realized that this was not easy stuff to do. It would have to be a lot easier to use before many people would benefit from it."[31] The keyboard may have fit the body well, but only after a significant amount of work was put in to make it do so.

Case 2: Macintosh GUI

This second case study[32] concerns a computer technology not intended specifically for disabled users but which significantly affected people with different kinds of disabilities: the graphical user interface (GUI). When the Apple Macintosh brought the GUI to a broad consumer audience in 1984, it carried with it new ways of interacting with personal computers: via a mouse and by clicking on icons, as opposed to entering text commands. This change, for the most part, fit users better. It was more user-friendly and easier to learn than text-based interfaces. However, it did not work with all bodies, as the GUI carried assumptions with it that users could see the screen in order to navigate with a mouse. The GUI demonstrates how a technology can be embodied in very different ways for different people, so that for some, there are new possibilities for augmentation and for others, a lack of access altogether.

An example of how the GUI was beneficial for people with certain kinds of disabilities can be seen with Mike Matvy, a psychologist with learning disabilities that affected his ability to read and write. He went to a disability and technology resource center after getting a job that required him to be able to use a personal computer to write reports and professional materials, and read patient records and office memos. In 1990, he detailed his experiences finding a computer that worked for him, after learning to use both an IBM PC and an Apple Macintosh:

> I could see why blind peaple would find IBM best for them. An IBM with voice out put does not require visusl skills. A person would need spelling skills, good memory for details, and ability to move through a system without visuat refrences. I could also see why I was able to move through the MAC system with such speed and eaze. It is built on a visual system, but it requires no spelling and verry little reading to oparate it. The fue writen words in the pull down minues and the dialog boxes are repeated identicly in all aplications. They are also kept with in a pictoral context which helps me know what the words are.[33]

A text-based operating system, like the IBM had with MS-DOS, could accommodate the needs of blind computer users through specialized screen reader software. There were not extensive graphics available on such computers, and a keyboard was used as input. Whereas the Macintosh GUI could accommodate the abilities of someone like Matvy much better, with its limited use of text in menus, consistency across software, and graphical representations in the form of icons. Matvy went so far as to say, "From what I have learned about IBM and MAC, it seams to me that, it is as if MAC were designed spicificly with my needs in mind."[34]

As more and more personal computers switched to GUIs in the 1990s, people like Matvy found an embodied relationship with computers that fit them well. However, blind computer users were increasingly denied access to new computers, as screen readers could not translate information on the GUI interface. There would eventually be a technological solution to this problem, but it would take until the late 1990s for screen readers to be able to work reliably with different GUI operating systems and commonly used software running on them. The GUI represents the way one technology can have very different kinds of embodied relationships with users. For many people, the GUI fit

them, accommodating people's needs and generally being more user-friendly. But for others, there was a complete lack of fit, such that they were denied access to personal computers with GUIs altogether for a number of years. Who has access to a technology at all is based on assumptions of how people's bodies work in terms of how they control input and process output. When differences in bodies are not considered, some people are left out of a relationship with the technology and its potential to augment abilities.

Case 3: DiamondTouch

The final case study deals with the DiamondTouch tabletop device and children with autism as computer users. Researchers at the Mitsubishi Electric Research Laboratories developed the DiamondTouch in the early 2000s for collaborative work,[35] and it quickly attracted attention from autism researchers and therapists. It was a touch-sensitive surface that acted as a computer input device with information displayed on it via a projector from above. Unusual for an input device, it allowed multiple users to interact with it at the same time and could even distinguish between touches of different individuals. This allowed, for example, for interactions that would require more than one person to act in concert to accomplish some task, while also making it so that one user could not jump in and do a task that someone else was assigned to perform. This technology created a unique environment for embodied use, bringing multiple people into human-computer interaction at the same time.

In 2009, a group of researchers created software for the DiamondTouch to help children with autism practice socialization skills. Their software, StoryTable, used the tabletop as an interface for collaborative narrative construction in which two children took turns adding visual pieces to a larger story (e.g., background images, characters, or objects). The researchers found that this program encouraged children to initiate social interactions with their peers and even showed some generalization of improved socialization beyond these controlled activities. The researchers also noticed another effect of the technology: a reduction in what they refer to as "autistic behaviors" (such as repetitive movements or stimming). From the researchers' perspective: "Stereotyped movements have been suggested to serve as a coping response; the extent to which they are performed is influenced, in fact, by how much an individual is affected by sub-optimal stimuli in the environment, i.e., by an environmental setting that is perceived as either under-stimulating or over-stimulating."[36] StoryTable apparently struck the right balance in terms of stimulation for its users. There is an assumption here that such behaviors are inherently negative, a symptom of imbalance that the computer helps correct. As Meryl Alper has argued, stimming is not necessarily a negative thing for autistic people: "Many autistic people report that the repetition of physical movements or movement of objects helps them maintain emotional balance, regulates their senses, and provides pleasure."[37] Computer technology, then, is capable of disciplining or regulating the body, and perhaps, to read this critically, even helping to make more acceptable bodies out of users. This could be a form of positive augmentation in achieving greater balance or possibly as a more detrimental form of control, depending on what is actually best for the children to be doing with their own bodies.

The DiamondTouch can be seen as a technology of augmentation, in the way that it was a tool through which cooperative socialization could be experienced. The children, as technology users, could interact with each other through and with the tabletop, controlling its virtual objects and text by touch. The tabletop was not only a communication system between the children, enabling the children to learn new skills as they operated it, but also helped them develop ones that they could take with them when not using it. It fit them and their abilities by being a computer technology they wanted to interact with that had an intuitive interface. But its embodied relationship extended further than just augmentation, also affecting bodily activity seemingly external to its operation.

Conclusion

These three case studies of computer users with disabilities operating different kinds of computer technologies demonstrate a way to get at issues of embodiment and augmentation by centering people with diverse bodies and abilities as users. Embodiment takes place through hands, eyes, ears, and brains, enabling relationships between humans and computers where cognitive, sensory, and perhaps even social abilities can be augmented. To return to the beginning then, can a computer ultimately be thought of as something like a prosthesis? Does this metaphor offer anything in attempting to understand the relationship between humans and computers, and the possibilities for augmentation of human abilities? Don Idhe has criticized the prosthesis metaphor for missing out on the lived reality of prosthesis use: "But actual users of prosthetic devices know better—prostheses are better than going without (the tooth, the limb, the hand), but none have the degree of transparent, total 'withdrawal' of a tool totally embodied. All remain simply more permanently attached ready-to-hand tools. Yet when one's body fails or is irreparably injured, or parts of it are removed, the prosthesis becomes a viable and helpful compromise."[38]

A prosthesis replaces a missing or damaged body part, to get as close as possible to the original or the idea of normal. To say that something is missing or damaged about the computer users in the examples I have given implies a wrongness in disabled bodies that needs to be corrected and would imply the same for nondisabled users as well. The question is if this is the connotation we want to embrace to understand computer technology and human bodies.

Yet an alternative way to use the metaphor may be possible if the body itself is explicitly centered in the analysis. The computer, then, is not about perfectly transcending an inherently flawed body. Augmentation is possible, but it is never a straightforward relationship between such technologies and the bodies that use them. The case studies I have offered here exhibit the complexity of different bodies and the ways they are augmented or not by computer technologies. Vivian Sobchack, herself a prosthesis user, describes her own feelings toward her technological leg and other technologies that augment abilities: "I have not forgotten the limitations and finitude and naked capacities of my flesh—nor, more importantly, do I desire to escape them. They are, after all, what ground the concrete gravity and value of my life, and the very possibility of my partial transcendence of them through various perceptual technologies—be they my bifocals, my leg or my computer."[39] Bringing the body into focus offers a reminder of both its power and its flaws. Technologies of augmentation are not about trying to escape the body but to go beyond what it can do on its own in certain small, but significant, ways.

A way forward with the metaphor is suggested by Robert Rawdon Wilson, in remembering the messiness of the body and what an amputation and prosthesis actually mean for people, where "any consideration of prostheses has to take into account their potential failure and, even, the conditions under which they might go wrong or turn against their users."[40] No prosthesis is a perfect fit, as is no metaphorical prosthesis. Tobin Siebers reminds us that "when prostheses fit well, they still fit badly. They require the surface of the body to adjust—that is rarely easy—and impart their own special wounds."[41] A prosthesis is not about making its user superhuman; it grants abilities but also rubs up against the body in harmful ways. To push the body-technology relationship with the metaphor, Wilson argues that "an appended body part not only recalls the previous, now missing, organic part, but actively calls into question the body's integrity."[42] This forces us to broaden the human-computer relationship to consider what we are without computers in our lives, with that augmentation missing. Further, if the computer can be a prosthesis, its negative effects on the body must also be understood, alongside its possibilities for augmentation. There is no single, normal body for the computer user. For the diversity of bodies out there, computers are always an imperfect fit. As previously mentioned, they cause carpal tunnel, bad posture, headaches, and other problems in their users, as shown by Nooney, along with Jennifer Kaufmann-Buhler.[43] But they also allow us to do things our bodies are incapable of, just like all technologies do. They augment us and allow us to go beyond what our bodies can do on their own—without ever leaving such behind.

Notes

1. With thanks to Cathy Gere, John Alaniz, and my colleagues at Rice University, especially Lan Li, Rodrigo Ferreira, and Elizabeth Brake. This work was supported in part by the US National Science Foundation under grant 1928627.
2. Seymour A. Papert and Sylvia Weir, "Information Prosthetics for the Handicapped," September 1, 1978, 2, https://dspace.mit.edu/handle/1721.1/6308.
3. Lev Manovich, "Visual Technologies as Cognitive Prostheses: A Short History of the Externalization of the Mind," in Marquard Smith and Joanne Morra, eds., *The Prosthetic Impulse: From a Posthuman Present to a Biocultural Future* (Cambridge, MA: MIT Press, 2006), 206.
4. Thierry Bardini, *Bootstrapping: Douglas Engelbart, Coevolution, and the Origins of Personal Computing* (Stanford, CA: Stanford University Press, 2000), 143.
5. Other examples can be found in Elizabeth Grosz, "Bodies-Cities," in Heidi Nast and Steve Pile, eds., *Places Through the Body* (New York: Routledge, 1998), 42–51; Michael Hardt and Antonio Negri, *Empire* (Cambridge, MA: Harvard University Press, 2000); Lisa Nakamura, *Cybertypes: Race, Ethnicity, and Identity on the Internet* (New York: Routledge, 2002); Mark B. N. Hansen, *Bodies in Code: Interfaces with Digital Media* (New York: Routledge, 2006).
6. Joseph Weizenbaum contrasts prosthetic machines with autonomous machines—the former act as extensions of human bodies, while the latter run on their own based on some model of the external world. He considers the computer to be an autonomous machine, and humans make decisions using constrained computer output. However, as David Mindell has shown, technologies that are described as autonomous are replete with many kinds of human actions and decision-making. See Weizenbaum, *Computer Power and Human Reason: From Judgment to Calculation* (San Francisco, CA: W. H. Freeman, 1976), 20–24, 38, and Mindell, *Our Robots, Ourselves: Robotics and the Myths of Autonomy* (New York: Viking, 2015).
7. Lucy A. Suchman, *Human-Machine Reconfigurations: Plans and Situated Actions*, 2nd ed. (New York: Cambridge University Press, 2007), 223–24.
8. John Perry Barlow, "Being in Nothingness: Virtual Reality and the Pioneers of Cyberspace," *Mondo 2000* 2 (1990): 42.
9. Katherine Ott, "The Sum of Its Parts: An Introduction to Modern Histories of Prosthetics," in Katherine Ott, David Serlin, and Stephen Mihm, eds., *Artificial Parts, Practical Lives: Modern Histories of Prosthetics* (New York: New York University Press, 2002): 1–42.
10. Lynette Jones, *Haptics* (Cambridge, MA: MIT Press, 2018); David Parisi, *Archaeologies of Touch: Interfacing with Haptics from Electricity to Computing* (Minneapolis: University of Minnesota Press, 2018). For a history of prosthetics prior to the use of computer technology, see Ott, Serlin, and Mihm, eds., *Artificial Parts, Practical*

Lives. Yulia Frumer has explored the history of robotics and prosthetics, notably recontextualizing Mori Masahiro's concept of the "uncanny valley." Frumer, "Cognition and Emotions in Japanese Humanoid Robotics," *History and Technology* 34, no. 2 (April 3, 2018): 157–83.
11. Carrie Sandahl, "Black Man, Blind Man: Disability Identity Politics and Performance," *Theatre Journal* 56, no. 4 (2004): 583.
12. Emily Russell, *Reading Embodied Citizenship: Disability, Narrative, and the Body Politic* (New Brunswick, NJ: Rutgers University Press, 2011), 5–6.
13. Julie Avril Minich, *Accessible Citizenships: Disability, Nation, and the Cultural Politics of Greater Mexico* (Philadelphia, PA: Temple University Press, 2013), 156.
14. Vivian Sobchack, *Carnal Thoughts: Embodiment and Moving Image Culture* (Berkeley: University of California Press, 2004), 216.
15. Beth A. Robertson, "'Rehabilitation Aids for the Blind': Disability and Technological Knowledge in Canada, 1947–1985," *History and Technology*, May 20, 2020, 1–24. Bess Williamson, "Electric Moms and Quad Drivers: People with Disabilities Buying, Making, and Using Technology in Postwar America," *American Studies* 52, no. 1 (October 22, 2012): 5–29. Jaroslav Švelch explores a related kind of tinkering in "Power to the Clones: Hardware and Software Bricolage on the Periphery" in this volume: he applies the concept of bricolage to the creation of hardware and software clones in Soviet bloc countries. The bricolage of Soviet computer developers, another group of what Švelch calls "marginal and marginalized historical actors," was similar, in many ways, to the work of people who make computer technology fit diverse bodies.
16. Sarah S. Jain, "The Prosthetic Imagination: Enabling and Disabling the Prosthesis Trope," *Science, Technology, & Human Values* 24, no. 1 (Winter 1999): 47.
17. Jain, "The Prosthetic Imagination," 33.
18. Jain, 41.
19. Laine Nooney, "'Have Any Remedies for Tired Eyes?': Computer Pain as Computer History," in this volume.
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