Media Theory
Vol. 6 | No. 2 | 77-110

http://mediatheoryjournal.org/

The Data Pharmacy: Wearables from Sensing to Stimulation

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Abstract

Taking up the therapeutic discourse of contemporary neuro wearables, this essay explores how models of the quantified self are increasingly supplemented by pharmacological mediations. We argue that contemporary neuro wearables are more than instruments for self-tracking; they are increasingly devices of therapeutic transmission. Pharmacological media rely on digital wellness ideologies and offer datafied solutions to the toxicity of both big tech and big pharma. Beyond questions of efficacy—that is, the question of whether neuro devices do what they say—this essay focuses on matters of cultural framing and aspiration that underpin the wellness industry. Our interest is to supplement current understandings of bio-technical management by tracing the emergence of what we term the *data pharmacy*—where data and pharma industries and cultural imaginaries are increasingly fused within an emergent paradigm of computational wellness. This pivot in big tech's wellness portfolio translates existing biodata and health analytics into pharmacological techniques that aim to automate ways of thinking, feeling, and being.

Keywords

data, drugs, neuro wearables, self-tracking, computational wellness

Contemporary neuro wearables are more than instruments for self-tracking. They are increasingly devices of therapeutic transmission. Apollo Neuro, for example, is a haptic device worn on the wrist or ankle that sends low-frequency sound waves to modulate heart rate variability (HRV) for desired states such as productivity, focus, and sleep.

Named after the Greek god of healing, inspiration, and music, Apollo is promoted as part of a "third generation of wellness wearables" that do not simply promise self-knowledge but aim to automate states of mind (Apollo Neuroscience, 2020). Alternatively, consider BrainTap, a wearable headset that directs binaural beats and imperceptible pulses of light through the retina and ear meridians to entrain brainwaves for relaxation and stress relief. This new generation of wearables is often discussed in the wellness marketplace using pharmacological references. For example, BrainTap markets its audiovisual entrainment programs as "Sleep Rx," suggesting the potency of medical treatment without the need for a prescription. According to the company, these programs retrain your brain to sleep on cue, more deeply, and awaken recharged by "boosting melatonin in a healthy, natural way," without negative effects like headaches, dizziness, nausea, and drowsiness (BrainTap Technologies, 2021c). Reviewing the latest neuro wearables, YouTuber Cody Rall MD with Techforpsych (2020) discusses how "the holy grail for these types of neuro-stimulation devices is to have a positive impact on the brain without side effects that you would get from medications."

Such comparisons of media to drugs are manifold and can be traced to numerous debates in recent decades, including concerns about television's somatization of public life (Postman, 1985) or longstanding anxieties about the power of new technologies to transform mental and attentional capacities (Simmel, 1950; Carr, 2010). More recently, popular discourses about social media addiction compare big tech companies to the tobacco industry and drug barons (Lundahl, 2020). Citing medical professionals and tech insiders, journalists report that social media is "not a drug, but it might as well be" (Anderson, 2018: para. 3) because it affects the same neurological pathways that drugs use (Lewis, 2017). Indeed, this focus on how social media, among other practices, increases neurotransmitters like dopamine, the brain's naturally occurring feel good chemical, makes this connection explicit. Technical devices and platforms are at once understood to control the release of chemicals into the body and framed as the very cures for the addiction or dopamine deficit that they create. This is both a clear example of the pharmakon's capacity to act as a poison and remedy at the same time and draws our attention to an important aspect of current *media pharmacologies*: networked devices like neuro wearables are understood not simply by analogy to drugs but as medicines themselves (Zhang, 2015; Spiegel, 2020). Wearable media's

imperceptible transmissions address the body's electrochemical systems, circumventing both user decision making and the traditional absorption and potential negative effects of medicine—as with ingesting a pill into the bloodstream or injecting a vaccine into the muscle. As one of the most conspicuous proposals to use datafied currents and stimuli to outsmart the toxic effects of the pharmakon, neuro wearables provide an aperture into the burgeoning ways media are transmitted to the body like a drug.

Taking up the therapeutic discourse of contemporary neuro wearables, this essay explores how models of the quantified self are increasingly supplemented by pharmacological mediations. Pharmacological media rely on digital wellness ideologies and offer datafied solutions to the toxicity of both big tech and big pharma. For example, the marketing of contemporary neurotech devices mirrors that of herbal drugs and other health supplements. Herbal drugs are understood to be safe and effective because they are seen as *natural* elements already "constituent of the body" (Kuhn et al., 1998: 220). Such framings are adapted by neuro wearables and work to connect new devices to alternative medicine and homeopathic practices. They also foster and are fostered by a growing distrust of pharmaceutical industries and state policies—as global anti-vaccine campaigns have demonstrated. Indeed, the herbal drugs industry was valued at more than $200 billion in 2021 and is expected to double by 2028 (Fortune Business Insights, 2022). These supplements are one slice of a global wellness market that is valued by McKinsey & Company at over $1.5 trillion and projected to grow 5 to 10 percent annually (Callaghan et al., 2021). Wellness products remain largely unregulated as they are sold as nutritional supplements, including so-called nutraceuticals, animating a wide range of communities of use outside of medical expertise and public welfare institutions. The proliferation of neuro wearables addresses this group of users and aims to grab a piece of a growing market. Building on this parallel, our interest here is how media devices and data industries claim to channel the potencies but not the perniciousness of traditional pharmacologies, including prescription drugs. These digital imaginaries of therapeutic transmission are reshaping understandings of the body and/as media (Thacker, 2004). Simply put, big data and big pharma now converge in new and mundane ways, signaling modes of economic, political, and cultural control that exceed familiar insights about surveillance capitalism and the platform economy (Neves et al., 2022).

What distinguishes third generation wearables from other popular devices, including the portable electroencephalographic (EEG) technologies analyzed by Melissa M. Littlefield (2018), is that they promise to do more than track, report, and visualize bodily states. Going beyond the datafied nudge or what James N. Gilmore (2016) calls the haptic instant, they operate as technologies of *wearable stimulation*, sending light, sound, vibration, electricity, and magnetism directly into the body. As BrainTap's promotional materials put it, the device "delivers gentle light pulses that travel through the retina and ear meridians, sending direct signals to the brain and guiding you into unparalleled brain states" (BrainTap Technologies, 2021d). These products aim to stimulate or condition mental and affective dispositions for specific tasks by feeding prescriptive biodata back into the body like a drug. Here we build on Littlefield's (2018: 9) conceptualization of *instrumental intimacy*—that is, "a means by which we learn about, access, and manipulate ourselves (in this case our brains) by interfacing with machines"—but also suggest a material and conceptual shift from the instrumental to the pharmacological. Departing from the emphasis on *pulling* biodata from the body, we suggest that third generation wellness wearables act instead as transmission or *push* technologies.[1] These developments are edging us out of the loop we typically understand as biofeedback. Data is quite literally becoming a drug. New neuro wearables, among similar techniques, claim to operate pharmacologically by coordinating our autonomic nervous system for us and stimulating capacities for concentration, productivity, and resilience not through habit but electrochemistry. This is to say that they remediate the body and self differently than models of self-tracking, which emphasizes human agency and the ways "people record, analyze, and reflect on data about themselves" (Neff and Nafus, 2016: 1-2).

At issue here are not primarily questions of efficacy—that is, the question of whether neuro devices do what they say—but rather matters of cultural framing and aspiration that underpin the wellness industry. Our interest is to supplement current understandings of bio-technical management by tracing the emergence of what we term the *data pharmacy*—where data and pharma industries and cultural imaginaries are increasingly fused within an emergent paradigm of computational wellness. By computational wellness we refer to a growing intersection within the global wellness industry that offers hardware remedies for homeopathic concerns. Distinguishing its techniques and practices from more "woo-woo" or new age segments of this market

(Aupers and Houtman, 2010), computational wellness brands itself as being scientifically backed, with many products spearheaded by medical teams and websites boasting of clinical trials or parallel academic studies. At the same time, since self-optimization is pursued through non-medical devices, computational wellness can be data-driven without being evidence-based. Neuro wearables thus capture something of the new age faith in health foods and herbal remedies, now extended to data pharmacologies.

Specifically, we trace a material and metaphoric shift from models of the quantified self, with its focus on "self knowledge through numbers" (Quantified Self, 2022), to media pharmacological modulations of mood, vitality, and cognition. Contextualizing promotional materials by Apollo Neuro, NeoRhythm, and BrainTap, we theorize a shift from sensing to stimulation industries and imaginaries. This pivot in big tech's wellness portfolio translates existing biodata and health analytics into pharmacological techniques that aim to automate ways of thinking, feeling, and being. Lost in translation is the fundamental notion of communication as cognizance that underpins humanist models of subjectivity and political ideals such as democracy. Our interest goes beyond explicating the erosion of human(ist) personhood (Chia and Ruffino, 2022) by neurocentrist or physicalist worldviews (Farah, 2012). At stake in this shift is a reconceptualization of the human body not only as anatomy or algorithmic organisms (Harari, 2016) but also as a node in networked systems more alive and intelligent than we ever need to be. Contributing to post-perceptual theories of media (Farocki, 2004; Hansen, 2015) and logistical theories of networked life (Rossiter, 2016; Hockenberry et al., 2021), we examine wearable stimulation as a pharmacological technique critical to data capitalism's electrochemical adaptations of wellness, productivity, and enhancement.

Wearable Stimulation

Third generation wellness wearables are not sensing, but *stimulation* devices. They stimulate or arouse activity in the body using light, sound, vibration, electricity, and magnetism, working almost imperceptibly to bring about optimal mental states. Apollo, NeoRhythm, and BrainTap are consumer wearables that do more than track, analyze, and even nudge us towards health, fitness, and productivity goals. Using haptic

vibrations, electromagnetic pulses, and binaural sound, these wearable stimulators go beyond their self-tracking predecessors by automating states of mind and body associated with emergent wellness categories. Notably, these are not medical devices but consumer wellness wearables that remain largely unregulated so long as they do not make medical claims or pose more than minimal risk to users (U.S. Food & Drug Administration, 2019).[2] Apollo uses sound touch therapy in the form of low-frequency sound waves to rebalance the autonomic nervous system. Apollo's "vibrations speak to your nervous system" to improve HRV, a biomarker for resilience to stress (Apollo Neuroscience, 2022a). Depending on the programmed frequency—for relaxation or liveliness—Apollo's vibrations modulate energy levels, heart rate, and blood flow by increasing or decreasing parasympathetic and sympathetic nervous system activity[3] in ways that are known in the scientific literature to correspond with a spectrum of seven desired states[4] (Apollo Neuroscience, 2021a). At first glance, Apollo looks curiously like a watch with no face. After all, the device is not meant to be *used* in a conventional sense. Instead, it is *worn* to act on wearers throughout the day, based on programs preselected on a smartphone app.

Shaped like a horseshoe and activated not by touchscreen but tap controls, NeoRhythm is also programmed in advance using a smartphone app. Worn on the head or neck, or placed under a pillow during sleep, the device uses Pulsed Electromagnetic Field Therapy (PEMF) to calibrate brainwaves for frequencies associated with sleep, relaxation, or focus, allowing users to "choose your mood" (OmniPEMF, 2021b). [5] NeoRhythm uses electromagnetic pulses at different frequencies and magnetic flux densities to stimulate our cells to mimic the brainwave patterns associated with mental states as specific as "Lucid Dreaming" and "Open Heart Meditation" (OmniPEMF, 2021a). These devices use different techniques for what is known in the wellness industry as brainwave *entrainment*: the synchronization of brainwaves to the rhythm of external stimuli such as Apollo's low-frequency sound waves, NeoRhythm's PEMF, or BrainTap's combination of binaural sound and pulsing light. Worn with the eyes closed, BrainTap is a bluetooth headset with a visor that combines binaural beats, 10-cycle holographic music, isochronic tones with pulsing light targeted at the retina and ear meridians. BrainTap's extensive catalogue of programs are available via subscription and designed using a "proprietary neuro-algorithm" (BrainTap Technologies, 2021d) to entrain brainwaves to alpha, beta,

gamma, delta, and theta frequencies, which are associated with varied states of calm and productivity. The wellness industry may promote brainwave entrainment as a kind of on-demand mood modulation. However, scientists cannot fully explain (Rose and Abi-Rached, 2013) and engineers cannot fully control the connection between brain states and mental states. Far from determining states of mind, brainwave frequencies are "the (electrical) *potential* of our brains to produce measurable states of mind and be open to intervention" (Littlefield, 2018: 4, original emphasis). Brainwave frequencies, HRV, and other biomarkers emerge from statistical practices that never verify or refute truths, "but rather are always involved in anticipating and mapping possible futures" (Blackman, 2019: 127). In this sense, biometrical states such as brainwave frequencies mediate sensor and stimulation technologies such as wearables.

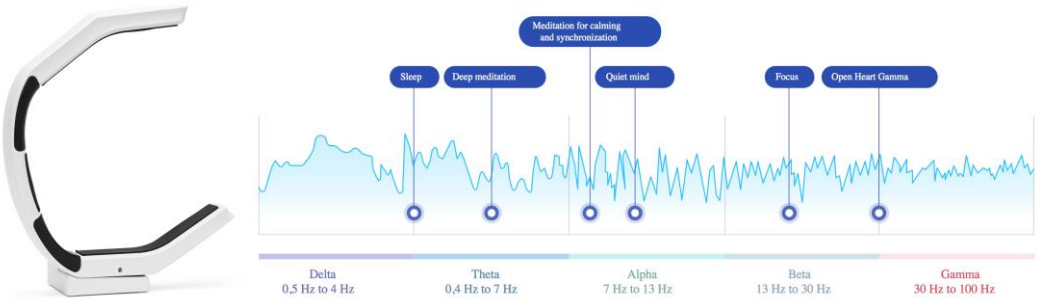

Figure 1: NeoRhythm operates by stimulating our cells to mimic the brainwave patterns associated with sleep, meditation, calm, focus, and pain relief (OmniPEMF, 2021a; 2021b).

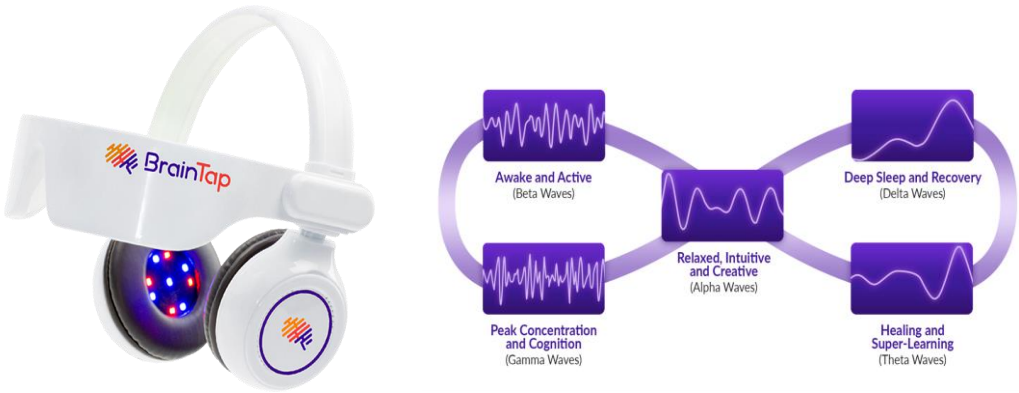

Figure 2: BrainTap Bluetooth Headset combines binaural beats, 10-cycle holographic music, isochronic tones, and pulsing light through the retina and ear meridians to entrain brainwaves to desired states (BrainTap Technologies, 2021a; 2021b).

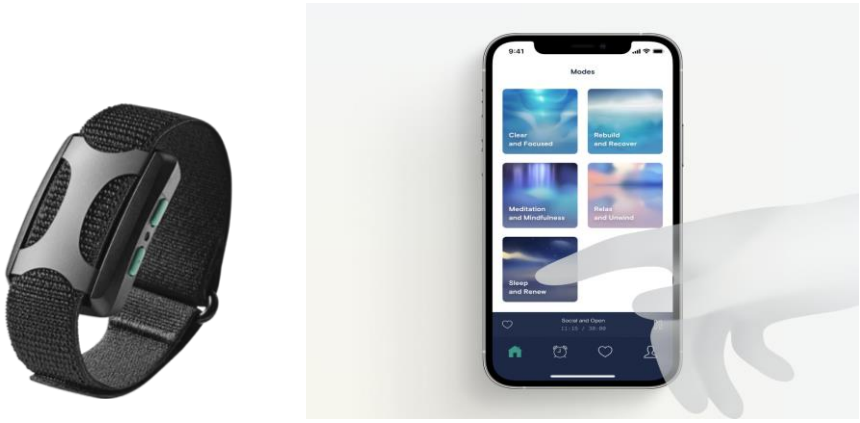

Figure 3: Apollo uses low-frequency sound waves, targeting touch receptors in the skin to send a signal of safety to sensory and emotional cortices in the brain, which rebalances the nervous system according to one's chosen mode (Apollo Neuroscience, 2021c; 2022a; 2022b).

Apollo devices do not monitor HRV, which must instead be tracked using supplemental wearables like the Oura ring. Worn on the finger, Oura monitors heart rate using photoplethysmography (PPG) by shining light into the skin and measuring the amount of light that is scattered by blood flow. Similarly, NeoRhythm and BrainTap are not designed to detect brainwaves, which requires EEG sensors like those found on the Muse headband, a second-generation wearable that senses brain waves during meditation and visualizes them for users on a smartphone app. Brain-sensing techniques such as EEG and brain stimulation techniques such as PEMF are not new—the innovation of Apollo, NeoRhythm, and BrainTap is their routine wearability and consumer use. This third generation of wellness wearables emerge from a longer history of electrical stimulation, including the current fascination with transcranial direct current stimulation (tDCS), among others.[6] Historically, such practices run the gamut "from electrical fishes to microcontrollers," as the title of a piece in *Psychological Medicine* summarizes (Sarmiento et al., 2016). "The first evidence of transcranial stimulation in history comes in Roman Empire times, when Scribonius Largus (the physician of the Roman Emperor Tiberius Claudius Nero Caesar) described how placing a live torpedo fish over the scalp could relieve headache in a patient" (2016: 3259). Indeed, for a millennium, fish electricity seems to have provided a variety of electrical stimulation treatments for pain, epilepsy, and the casting out of spirits. Machinic examples of therapeutic electrification emerged in the 18th century (McWhirter et al., 2015) and were taken up intermittently in subsequent years before

crystallizing in present day stimulation devices and do-it-yourself practices (Wexler, 2015).[7]

The putrid squelching of an electric ray pressed to a patient's scalp may seem far removed from the silent signals emitted by NeoRhythm's PEMF. Yet, both are transmitted to the nervous system instead of absorbed through the bloodstream to ameliorate bodily conditions and capacities. Like medical uses of stimulation techniques such as tDCS for treatment of clinical depression, piscine and wellness-based electric stimulation are forms of therapeutic transmission. Unlike its ancient precedents, the prescription of such bio-transmissions in medical settings involves sensing the body through EEG and other techniques in order to calibrate how to stimulate the brain. Sensing is also fundamental to second generation wearables such as Muse 2, a popular neuro wearable that uses EEG sensors to transform "brain signals into real-time feedback"—like the sound of stormy or calm weather—to help users steer their meditation session on course (Muse, 2019). Third generation wearables break this biofeedback loop: instead of prompting us to calibrate our wellness solutions according to data collected about our bodies, wearable stimulators use the wealth of preexisting wellness data analytics to systematize a catalogue of moods and modes. These devices no longer primarily address us with reports and suggestions for new habituations. Put differently: self-knowledge is no longer a condition of self-improvement. This marks a new paradigm of wellness in the mainstreaming of self-optimization practices, whereby datafied assets are transformed into regimes of stimulation without sensing.

This new regime of "senseless" stimulation shifts the computational pursuit of wellness from gathering personal biodata through self-tracking to deploying biopolitical data through therapeutic transmissions. What seems like an incremental step in the means of self-optimization is a shift of paradigm—and power—in the shaping of subjectivity through data. Data industries now have pharmacological and pharmaceutical ambitions. Self-tracking wearables such as Oura and Muse address their users as *knowing* subjects empowered to act on information collated about their bodies. These wearable sensors provide mediated access to data about ourselves that we otherwise could not know about, access, manipulate, or act on. For example, devices like Fitbit and Xiaomi smart band empower their users by collecting more and

better data about bodily actions. They aim to reveal hidden patterns and to trigger programmed nudges that users can interpret and incorporate into everyday life. Building on Brenton Malin and Otniel Dror, Littlefield describes this as a shift in the mediation of self, where self-knowledge is no longer primarily related to embodied experience but rather gained through technologies such as EEG wearables and algorithms that diagnose brainwave patterns. The implications of this machinic intermediation are a "paradigm shift in expectations about scientists'—and eventually our own lay—capacity to feel" (2018: 11). By mediating access to the body and the potential to manipulate it, sensor technologies and their algorithmic techniques reframe our understanding of our bodies and minds as unruly and in need of regulation through permanent tracking and micro-adjustments. This instrumental intimacy (Littlefield, 2018) relates to what Natasha Dow Schüll (2016: 325) calls "an informatic mode of perception" in which personal sensor technology provides "informational bits whose cumulative diagnostic value could never be detected by the eyes of a doctor in real-time." The human in this assemblage remains very much in the loop, even if its hyper-individualism is seen to "sidestep a more communal and socially determined understanding of health" (Dolezal and Oikkonen, 2021: 4). As a Fitbit promotional video encourages: "Small daily decisions = BIG results" (Cited in Schüll, 2016).

Apollo, NeoRhythm, and BrainTap, among many other such devices, bypass this informatic mode of perception where self-knowledge is mediated by instruments, analytics and constituted as a database (Schüll, 2016; Lupton, 2015). Third generation wellness wearables put the quantified self's "new kind of truth" to work in a new way (Hong, 2016; Gehard and Hepp, 2018). Here a database view of the self is not only revealed through the contextualization of individual biodata within statistical comparisons and correlations (Crawford, Lingel, and Karppi, 2015) but used to stimulate and harmonize the body to achieve desired states of calm, focus, and recovery.[8] Instead of mediated self-knowledge, these neuro wearables promise self-regulation unmediated by the knowledge, action, or even consciousness of the wearer. For example, BrainTap's licensed algorithms are described by its creator as having "nothing to do with your conscious mind, nothing to do with your willpower. It's basically the way our brain responds" to external stimuli (Dr. Jay Davidson, 2017). Decision making comes only in choosing a wellness device and adopting its prescriptive protocols. Wearable stimulation's catalogue of brain entrainment

programs is far removed from self-tracking's "small daily decisions" and the ideological justifications of the Quantified Self (QS) movement. In the late 2000s, QS principles and practices emerged from a dissatisfaction with and desire to wrest control from medical professionals by using personal sensor technologies to understand, manage and augment our own health and bodily capacities (Ajana, 2018). In this context, sensing devices were seen to record and suggest, rather than to organize or stimulate preconscious states.

The user of self-tracking wearables is expected to act upon the informatic insights gained through continuous sensing—to sit straighter, walk further, breathe slower. This expectation to act extends to wearables that nudge users towards their desired behavior using "haptic instants" to "orient, signal, and direct the flow of one's actions throughout any given day" (Gilmore, 2016: 3). Whether with haptic instants or other forms of audiovisual feedback, the database self is nudged, steered, and prompted to consciously *do* something (Schüll, 2016). Here, data is adopted incrementally to bring about new habits of living. Even when the nudge is unbidden or operates at a subconscious level, it still targets behavior: this extends to persuasive technologies such as choice architecture (Thaler and Sunstein, 2009), gamification (Fuchs, Fizek, Ruffino, and Schrape, 2014), or dark patterns in user experience design (Zagal, Björk, and Lewis, 2013) that use techniques from behavioral science to non-coercively shape users' actions to predetermined goals (Beattie, 2022). Unlike nudges, bio-transmissions do not modify behavior per se; they condition moods. For example, Apollo, addresses its wearers as not needing to do much at all:

> Apollo was based on the neuroscience of touch and music in that sound and music and if we listen to it and we are surrounded by it, it affects our body almost instantaneously without us having to really *consciously* do anything (Apollo Neuroscience, 2020; original emphasis).

Framed through such promotional claims, the third-generation wellness wearer does not need to mediate the knowledge or interventions of the quantified self. Instead, devices like Apollo, NeoRhythm, and BrainTap are presented as communicating *directly* to the wearer's body. For example, NeoRhythm describes its use of PEMF to calibrate specific kinds of brainwave frequencies as "emit[ing] frequencies that our brain *comprehends*" (OmniPEMF, 2021c, emphasis added). Similarly, Apollo's main function

is not to convey information for users to analyze according to their wellness goals, but to "send a signal to your body" (Apollo Neuroscience, 2020). Vibration, light, sound, electricity, and magnetism are framed not as information communicated to users, but as signals transmitted to wearers' bodies and brains. These signals harmonize the nervous system to to match entrainment frequencies that target brainwaves and heart rate. Indeed, many wearers can't quite articulate the effect these devices have on them: a review of Apollo reveals that "I have good feelings about this product, but can't be much more specific" (Apollo Neuroscience, 2021b). Within this imaginary, wearable stimulation harmonizes the body's electrochemistry in a manner akin to caffeine, nicotine or alcohol, among other herbal and pharmaceutical drugs. In contrast to self-tracking's biofeedback and haptic instants, wearable stimulation addresses users not primarily as thinking and acting subjects but as bodies or organisms. For example, in a discussion about how NeoRhythm can promote deep sleep, OmniPEMF's CEO explains:

> Your body will send signals, craving for more Delta time… *Your organism* will entice you to take a nap, during which your brain will try to get as much deep sleep as possible (OmniPEMF, 2021c; emphasis added).

By addressing users through their organs and as organisms, wearable stimulation imagines human subjectivity as incidental to the modulation of mood and mentality. The target of wearable stimulation is not an inquiring or even a cognizant subject, but their autonomic nervous system. Alongside political economic analyses of data extraction, critical research on self-tracking has focused on the self and subjectivity. However, the wellness wearables industry is moving beyond optimization as a project or narrative of self, towards optimization as a binary state change selected from a menu of codified moods and vitalities. This pivot in the computational wellness industry designates a mode of subjectivity defined not by self-possession through data but by self-automation through pharmacological media. As Mark Andrejevic (2020) puts it in his analysis of automated media and subjectivity: when automation operates through the transmission of signals, the self thus configured does not interpret—it executes. Embodied computing now takes on therapeutic roles where optimization is not habituated intentionally or assimilated subliminally, but enacted pharmacologically through electrochemistry, as a kind of prescription, not unlike taking a pill. Although

not prescribed by medical professionals, wearable stimulation is nonetheless prescriptive, programming our frames of mind using wellness industry data analytics and aspirations.

Data Pharmacy

The term *wearables* describes mobile technologies that can be easily worn or carried on the body. At once intimate and remote, these smart devices are positioned close to the skin's surface and are part of the Internet of Things (IoT). Much of the existing research about wearables emphasizes their surveillant capacities, focusing on fitness trackers, health and mood monitors, body cameras, intelligent fashion, and other skin electronics, whose overarching purpose is to capture, analyze, and report data collected from the body and its immediate surroundings, often in real time (see Andrejevic and Burdon, 2014; Neff and Nafus, 2016; Sharon and Zandbergen, 2017; Ruffino, 2018; Dolezal and Oikkonen, 2021). But this vision of the wearable technology industry overlooks other changes in the relationship between data and consumer wearables in recent years. As suggested above, the current stage of computational wellness focuses not only on capturing biodata but also in sending prescriptive frequencies—such as brain potentials, heart rate variability, and mood conditioning stimuli—into the body. In this way, wearable stimulation combines techniques of media transmission and pharmaceutical ingestion, expressing a particular iteration of *media pharmacology* that we term the data pharmacy. Here media technologies are understood to operationalize data as a pharmaceutical substance or signal designed to intervene in algorithmic organisms. Beyond biofeedback, the feed-forward of multi-scalar computational networks and intelligent sensors now extends from predictive (Hansen, 2015) to prescriptive capacities that are behavioral *and* electrochemical.

Reframing the human body, among other biological systems, as an algorithmic organism is key to neuro wearables' claim to immediately and noninvasively impact subjective states and capacities to perform. Such ideas about algorithmic bodies also challenge traditional models of liberal subjectivity and free will. While clearly controversial, the claim that "organisms are algorithms," which is perhaps most widely associated with the guru historian Yuval Noah Harari, who's *Homo Deus* has sold more than 10 million copies, has seeped into popular understandings of the self and society.

Harari sums up the shift from liberal individualism to algorithmic assemblages as follows:

> 1. Organisms are algorithms, and humans are not individuals – they are 'dividuals', i.e. humans are an assemblage of many different algorithms lacking a single inner voice or a single self.
>
> 2. The algorithms constituting a human are not free. They are shaped by genes and environmental pressures, and take decisions either deterministically or randomly – but not freely.
>
> 3. It follows that an external algorithm could theoretically know me much better than I can ever know myself. An algorithm that monitors each of the systems that comprise my body and my brain could know exactly who I am, how I feel and what I want. Once developed, such an algorithm could replace the voter, the customer and the beholder. Then the algorithm will know best, the algorithm will always be right, and beauty will be in the calculations of the algorithm (2015: 668-669).

This scientifically controversial[9] yet popularly endorsed conflation of humans and computers literalizes wearable stimulation's address of users as computational organisms. First, it imagines that the wellness industry has the necessary data to understand and reproduce desirable states of mentation and mood; and, second, it expects that these data constructs can be employed pharmacologically to sync bodily states within a networked system. In this context, the human body is both another *thing* within a network of things and constitutes a kind of nervous system for ubiquitous computing. This has precedence in the engineering blueprint of an Internet of People (IoP) or human intranet where wearable and implantable sensors and computation interface seamlessly and "in symbiosis with the functions provided by the body itself" (Moin et al., 2017: 18). Isabel Pedersen (2020: 24) cautions that such embodied computing instrumentalizes humans through bodily functions by tasking the body with "the labor of sensing, computing, energizing, storing (data), transmitting, and hosting a network." Wearable stimulation is a step towards an IoP where the body syncs to the vitalities of the computer and smartness imperatives, not vice versa. By operationalizing bodily processes and brain states into "the ordering and arrangement

of people and objects through feedback, remote control, and technological grids," neuro wearables can be understood as what Judd Case (2013: 392) calls logistical media. Situating bio-transmissions within IoT extends the logistical frame beyond its traditional focus on spatial or martial organization (Cowen, 2014; Rossiter, 2016; Harney and Moten, 2013) through "roads, railways, shipping ports, intermodal terminals, airports, and communication facilities and technologies" (Rossiter, 2016: xv). Notably, the networked algorithmic organism entails more than the internalization of logistics onto a technique of the self, where people compartmentalize their lives and selves as components in supply chains to be coordinated and rationalized (Dickinson, 2021), using, for example, productivity software, apps, and devices to pursue regimes of "personal logistics" (Gregg, 2018: 94). Algorithmic organisms instead suggest a new IoT subject engendered through big tech's datalogical pivot to wellness, exceeding frameworks of surveillance capitalism, among similar critiques.

Beyond commercial surveillance, including "Google's unique prowess in hunting, capturing, and transforming surplus into predictions for accurate targeting" (Zuboff, 2019: 80), the shift from sensing to stimulation theorized in this essay suggests a distinct set of concerns. This includes building on Shoshanna Zuboff's (2019: 94) insight that we should not understand users merely as products but instead as "the objects from which raw materials are extracted and expropriated for [big tech's] prediction factories." Here, mined data is not only sold in behavioral futures markets but becomes a raw material for proliferating computational wellness products and practices. Put differently, this model of extraction, value creation, and social control, takes on yet another vector: corporations like Amazon and Alphabet have launched or purchased their own pharmaceutical companies, including Amazon Pharmacy in the case of the former, and Calico and Verily in the latter, suggesting complex intersections that we are yet to appreciate. Stephen Gillet, president of Verily, describes the company's data driven mission: "Precision health leverages data from a wide variety of clinical and non-clinical sources to arrive at the best intervention for a person or community" (Verily, 2020). While many such projects are in development or prototyping, as suggested by the third-generation wearables addressed here, their merging of big data and big pharma paradigms signals both new opportunities for self-making projects and pleasures but also new fears about the mainlining of prescriptive health metrics that are derived from surveillance capitalism. No longer content to

merely synthesize behavioral and health analytics, and sell the results to the highest bidder, new neuro technologies act chemically on the body, promising to enhance our control over mental and affective performance. This pharmacological framing changes the terms of humanities criticisms of media effects (see Acland, 2012; Kowert and Quandt, 2015). Instead of engaging users perceptually, behaviorally, and/or culturally to purportedly addict them (according to media panics about video games or mobile media), wearable stimulation is framed as operating beneath the sensory threshold of mediation and its so-called effects.

In calling attention to this shift, we look beyond sensing devices and towards pharmacological stimulation techniques, arguing that new neuro wearables, among other emergent technologies (from smart drugs to Neuralink [10]), constitute a burgeoning data pharmacy. Here it is worth distinguishing pharmacology (the science of how drugs and other compounds interact with biological systems) and pharmacy (the application of pharmacological knowledge in the preparation and use of medicine) from the philosophical treatment of *pharmakon* and *pharmacology* in critical theories. The latter entered critical discourse through the work of Jacques Derrida (1981), especially his engagement with Plato's *Phaedrus*, not to mention later theorists like Isabelle Stengers (2010) and Bernard Stiegler (2013), among others. The Greek term for drug, poison, and remedy, the pharmakon is taken up by Plato to probe distinctions between written texts and orality, including the former's ability to disrupt the presence of speech and thus act as a peculiar technology or philter. "Operating through seduction, the *pharmakon* makes one stray from one's general, natural, habitual paths and laws" (Derrida, 1981: 70). Building on Derridean conceptions of the pharmakon as simultaneously toxic and curative, Susanna Paasonen (2022: 2) offers that describing something as a drug works rhetorically to position that thing "in opposition to both the natural world (as artificial) and social institutions (as a destabilizing, harmful force)." What matters here is that the pharmakon's fundamental ambiguity as both therapy and hazard is smoothed over by the popular rhetoric of neuro wearables that claim to animate the body's electrochemistry and thereby circumvent and remake subjectivity.

The shift from sensing the body to stimulating the mind is a critical aspect of wearable media's pharmacological ambition: chemicals and computation now mix to form a new

class of synthetic drugs/media. In this context, neuro wearables' claim of more direct communication with the body's autonomic systems is contrasted with the familiar balance of harm and healing associated materially and morally with medical and pharmaceutical industries. Prescription drugs like Adderall or Ritalin, which are widely used both on and off-label to modulate mood and attention, pose chronic risks: weight loss, abdominal pain, vomiting, dizziness, rapid mood swings, nervousness, impotence, and insomnia, among others. Even over-the-counter medications have lists of potential secondary effects. Bypassing such side-effects, wearable media, like other homeopathic remedies, are framed as less invasive and harmful, even peculiarly natural, because they purportedly mimic and reproduce bodily frequencies. For example, NeoRhythm communicates using frequencies the body "emits on its own throughout the day" (OmniPEMF, 2021c). Such stimulation is effective, BrainTap's creator explains, because "the brain doesn't know the difference between real or imagined" stimuli. A natural environment such as the ocean—which has a positive effect on wellbeing—resonates at a frequency that can be simulated by the device in a way that "changes your brainwaves" (Davidson, 2017). Within this imaginary of computational wellness, wearable stimulation operates beneath mediation's threshold of perception and beyond medication's margin of toxicity. Not really media, yet not quite a drug, neuro wearables' galvanization of data to outsmart the pharmakon exemplifies computational wellness.

While we remain interested in Plato's pharmacy, and related philosophical debates, we also want to emphasize how existing pharmaceutical practices inform models of computational wellness—and respond to current problems in media theory. Engaging with this neural imaginary casts the pharmakon as more than a metaphor or an analogy that connects longstanding notions of harm/cure to the materiality of media. Instead, new technologies are literally entangled with pharmaceutical techniques, practices, and economies (Neves et al., 2022). Pharmacological media, we suggest, draw our attention to an increasingly mainstream tendency in the career of so-called Big Data (see Schäfer and Van Es, 2017), where sensing and tracking data is operationalized as a drug to excite or soothe bodies for work, rest, exercise, creativity, sex, and other activities. While sensing and stimulation are basically entangled, emphasizing the latter helps us to identify the recent proliferation of consumer pharmacological technologies built on real and imagined pools of user data. Now that we have all of this information about

users' habits, health, and physiological states, start-ups like Apollo and BrainTap seem to suggest, shouldn't we *use* it to improve ourselves and modulate mental and affective performance. This embodied data relies on the widespread familiarity with high-tech medical devices, including ultrasounds and magnetic resonance imagining (MRI), as well as the idea that such practices are critical to the maintenance of health and wellbeing.

The operationalization of data in everyday and scientific practices of health may also be blurring its distinctions with optimization. Cognitive neuroscience, for example, renders biological processes computationally through stimulation models that deviate from traditional brain science. Johannes Bruder (2019: 110) observes that at "the heart of this reformulation sits a turn toward calculative and managerial techniques, such as simulation and prediction, that emphasize the generative dimensions of data analysis." This datalogical orientation towards prediction increasingly clouds the boundary between brain enhancement and treatment, especially "as corporate profit motive plays a role in the expanding use of psychopharmacology by the relatively healthy" (Farah, 2012: 597). Against this backdrop, the prescriptive bio-transmissions of third generation wearables add a new dimension to Michel Foucault's (1990: 140) conceptualization of biopolitics as "the calculated management of life" where the "objects of biopolitics are not singular human beings but their biological features measured and aggregated on the level of populations" (Lemke, 2011: 5). But, as Byung-Chul Han suggests in his reframing of Foucault's biopolitics as *psychopolitics*, "statistics and Big Data lie worlds apart" (2017: 21). Han adds that Foucault's emphasis on the "biopolitics of the population" (Foucault, 1990: 139) "proves altogether unsuited to the neoliberal regime, which exploits the psyche above all" (2017: 21). The data pharmacy has the potential to transform each of these insights. Where biopolitics governs individual freedom without touching the subject (Brown, 2015), and dataveillance diagrams the collective psyche without communing with the mind, the data pharmacy additionally automates individual dispositions without—literally or rhetorically—touching the body. Third generation wearables and other techniques of data pharmacy stand to automate biopolitics by syncing the friction of governance to networks of remote sensing and stimulation where the management of the self, the household, and the soul can be choreographed prescriptively and seamlessly.

Crucial to these shifts is the ongoing transformation of health and wellness by pharmaceutical companies. What Joseph Dumit calls *Drugs for Life*, for example, describes how the rise of clinical trials drives new understandings of chronic health, where people are understood to be "inherently ill," thus requiring lifelong interventions. According to Dumit, "the practical result for pharmaceutical companies is an unlimited imperative. They want to maximize prescriptions by expanding the market of those at risk, defining clinical trials as broadly as possible, and persuading us that all risks are, in fact, conditions that must be treated now with drugs" (2012: 16-17). This unlimited imperative offers an attractive market for the tech industry, including growing opportunities to capitalize on proprietary data and analytics, thereby carving out new revenue streams at a moment when smartphones and other hardware sales have plateaued. But in addition to reframing health care as risk management, the present is also marked by a growing emphasis on speculative or "surplus health" (2012: 17), including desires to be "better than well" (Kramer, 1993). The latter claim, popularized by psychiatrist Peter Kramer's 1993 study of the antidepressant Prozac, is increasingly associated with a shift from healing to enhancement. This includes growing concerns over "cosmetic pharmacology" (Kramer, 1993) and "cosmetic neurology," where health outcomes are tied to the ongoing optimization of "movement, mentation, and mood," including fears that these interventions act to increase existing inequalities and ableist structures (Chatterjee, 2004: 973). In the context of computational wellness, data's imperative for simulation, prediction, and optimization manifests in hybrid and changing wellness categories and compulsively updateable subjects.

One area of particular significance in regard to current media pharmacologies is the rise of the so-called attention economy: where tech platforms, content creators, and advertisers treat user attention as a finite commodity to compete for (Crogan and Kinsley, 2012). As Yves Citton suggests in *The Ecology of Attention*, the classical political economy "based on the scarcity of factors of *production*" has merged into an attention economy "based on the scarcity of the capacity for the *reception* of cultural good" (2017: 2). Citton critiques this corporate framework of attention as a fungible resource extracted from individuals, and instead reframes attention in relational terms, as constituted through collective socio-technical conditions. This shift and revaluation of attention is critical to a wide range of new drugs and devices, including the desire to

manage, sharpen, and prolong attentional capacities. Tiziana Terranova, for example, describes how the digital economy exacerbates longstanding themes regarding crises of attention (Crary, 1999), "this time elaborated in terms of the impact of Internet usage on the cognitive architecture of a neuroplastic and mimetic social brain" (2012: 1). For Terranova, this scarcity of attention gives it a new economic power "while also producing an *impoverished subject*" (2012: 7, original emphasis). This is because the cognitive labor that powers the information economy also leads to a depletion of these same resources on an individual and social scale. Neuro wearables, among related techniques, offer one response to the crisis at the center of contemporary value creation and exhaustion. This is also to suggest the importance of modulating attention within our current productivity culture as well as the diverse ways that data and pharma products respond to, and indeed generate, this crisis.

Neuro wearables are thus part of a growing pharmacological tool kit that operates as a form of mood control or *mood conditioning* (Neves, 2022). Like an air conditioning thermostat, the devices imagine human energy and states as programmable throughout the course of a day, week or year. Now work. Now play. Now sleep. Such claims are resonant with recent studies of music streaming apps, like Spotify and Pandora, whose playlists promise to help us chill, party, focus, exercise, rest, etc. (Anderson, 2015; Pelly, 2019). What we want to emphasize here is how new neuro wearables participate in a larger business of mood and affect management that is a mainstay of computational wellness's neoliberal stopgap (see Ahmed, 2020) for structural failures. "To be in a mood," Paul Allen Anderson notes, "is to think and feel at length through that mood about *everything*" (2015: 817, original emphasis). Algorithmic playlists and wearable constructs thus share an emphasis in stimulating distinct dispositions in order to curate durational capacities to act, while requiring little conscious engagement. In this sense, wearables, like sonic user interfaces, "are tools for building permeable microclimates or microspheres of mood within which individual users attempt to manage their diverse portfolios of resilience, hope, optimism, and self-efficacy" (2015: 814). From Spotify to Apollo to Neuralink, mood conditioning uses behavioral and health analytics to optimize attentional capacities and maximize outcomes. No mood or energy should go to waste. Beyond the sonic "microspheres" associated with algorithmic sounds, neuro wearables also signal an intensification of media's pharmacological address: data is now prescribed by wellness startups and taken daily

like a cholesterol medication or vitamin supplement that automates the endurance of everyday living and working as a chronic condition.

This is to say that wearables, like many smart substances, are *stimulants*. They aim to excite, arouse or quicken states like focus, creativity and calm. They do so by rerouting the predictive capacities of data back into the nervous system. In particular, neuro wearables use preexisting and proprietary data sets—including brainwave constructs, stress models, concentration indicators, and other metrics of health and wellness—to manage mood and amplify performance. Rather than addressing users as individual subjects whose unique data can be revealed to guide self-making projects, biodata is here employed as a technology of social calibration that frames human analysis—and even conscious awareness—as an obstacle. Instead, the body is imagined as an algorithmic system that can be programmed or automated for optimal effects by a wide range of pharmacological media, including neuro devices. Contextualized through discourses of physiological automaticity, these devices claim to go straight from stimulus to response, thereby reducing physiological, social, and cultural factors to neurological effects (Lamarre, 2020). While neuro-stimulators like BrainTap, NeoRhythm, and Apollo may strike the reader as fringe, gimmicky, or unproven, what matters here is that they exemplify a wider shift toward stimulants and stimulation within the computational wellness industry, including the galvanization of data into the body at the convergences between big tech and big pharma.

This includes high-profile and immensely well-funded projects like Neuralink, a brain computer interface (BCI) company planning human trials to implant chips in the brain to foster remote capacities and wellness. Neuralink's desired outcomes include allowing "a person with paralysis [to] control a computer mouse or keyboard" or inscribing information "back into the brain, for example to restore the sense of touch" (Neuralink, 2022). The startup is just one of many conspicuous examples in a growing data pharmacy, where stimulation technologies reimagine selfhood beyond phenomenological notions of subjectivity, and wellbeing beyond Foucauldian couplings of power-knowledge, now redistributed across a smart network. Indeed, Neuralink's promotional materials provide a crisp explanation of what we have examined as wearable stimulation, including the proliferation of techniques for

transmitting or ingesting (or implanting) data into the brain. The company describes the process of neural stimulation as follows:

> The knowledge that electric currents activate muscles and nerves is almost as old as knowledge of electricity itself. When small currents are delivered through an electrode, the changing electric field drives nearby neurons to fire one or more action potentials. By stimulating in the right temporal sequences across many electrodes, it is possible to create patterns of activity that elicit a desired sensation, for example the feel of an object in the hand or a visual image (Neuralink, 2022).

As with Apollo, BrainTap, and NeoRhythm, Neuralink's claims to pharmacologically mediate the body underscore important shifts in the tech industry's deployment of data, not to mention its claims on individual and social health. This includes current desires to capture and control brain states, heart rate, and mood, among other biomarkers, using media devices as drugs or philters within a computational wellness regimen. As we prepare for a future of human remote control through wearable stimulation, mood conditioning, and BCI, our concern lies less with the figure of the liberal humanist subject and more with the schematic of media theory and its critical flexibility to adapt to objects of inquiry that are redistributing and reconstituting, seemingly beyond recognition.

Coda: Stimulating Data

This analysis of third generation wellness wearables and the shift from sensing to stimulation has broader implications for apprehending contemporary media theories and pharmacologies. Most basically, our approach in this essay has been to put critical theories' investment in the pharmakon into dialogue with existing pharmacological devices and imaginaries. This includes the significance of pharmaceutical industries and rituals to understandings and applications of media for wellness, productivity, and self-improvement. Crucial to these fabulations are the ways that digital technologies and pharmacologies interact. Here traditional understandings of pharmacology as the science and effects of drugs on living systems are intensified and given new vitalities by the networked dynamics of data capitalism, just as computational media are remade

by pharma imperatives. Put simply, pharmacology is no longer mere analogy. This is because pharmacological media are not simply *like* drugs, as with current anxieties about social media or porn addiction, but are instead operationalized as wearable stimulators and therapeutic transmissions designed to automate states of mind. These supplements act not only by organizing or controlling the subject cybernetically, but also by intervening in the body's electrochemistry—addressing its cells, tissues, and organs.

Such interventions rely on the peculiar figure of the algorithmic organism, including the idea that human physiology and psychology are reducible to and explainable by algorithms. Antonio Damasio's rejection of the algorithmic organism thesis, which has "inebriated" biologists, neuroscientists, biohackers, and machine learning advocates, among others, thus offers a useful critical pause regarding pharmacological data. Indeed, Damasio reminds us that this resurgent idea is also an old one. He observes that:

> The idea that living organisms are algorithms helps perpetuate the false notion that the substrates of organism construction are not relevant. This is because embedded within the label "algorithm" is a notion of context and substrate-independence. Applying the same algorithm to new contexts, using different substrates, is presumed to achieve similar results. But this is simply not so. Substrates count (2016: para. 6).

Among others, this critique echoes N. Katherine Hayles' horror at the popular idea that consciousness can be captured and downloaded onto a computer unchanged (Hayles, 1999). Only here the substrate is not silicon but the human body and consciousness is not relocated into a timeless machinic future but recalibrated by data made flesh. In other words, what we call the data pharmacy asks us to reconsider how familiar problems in media theory may yield new insights when viewed through the lens of pharmacological and pharmaceutical industries and practices, not to mention important research from science and technology studies scholars that has yet to be heeded by media theorists.[11] What do we learn, for instance, by taking seriously the shift from sensing to stimulation, among other familiar and fantastic claims about technologized bodies and the potential to be better than well? And how are established understandings of smartness, platforms, and surveillance economies recast by

understanding media *pharmacologically*? We have only begun to address such issues here, but offer this essay, alongside other recent works, as a call for new research and debate at the intersection of data and pharma economies, practices, and theories.

One modest response offered in this essay is the claim that in addition to sensing, *data stimulates*. Here we move beyond discussions of capture, tracking, storage, filtering, prediction, and the like, and consider how data is literally imagined and put to use as a medicine or electrochemical therapy that acts to reshape human capacities. Stimulating data is part of a wider shift in self and social optimization protocols and underscores a new chapter in big tech's investment in datafied health and performance enhancement. From Spotify and Neuralink to Verily and BrainTap, data now reaches well beyond track and trace dynamics or what Philip Agre terms "grammars of action" to describe the ways that computational systems habituate us for capture (Agre, 2003: 746). Instead, data aggregates are manufactured into therapeutic stimuli that targets brainwaves, heart rate, mood, among other corporeal rhythms. In doing so, pharmacological data aims both to circumvent self-tracking's deliberative subject and to outflank the pharmakon's toxicity. Its promise is to use information gathered about users' habits and physiological states to build homeopathic hardware and software capable of "naturally" and immediately harmonizing bodies to changing wellness norms and performance demands.

Finally, these increasingly plastic norms and demands signal both a continuity and break in the biopolitical project to regulate the social body, as theorized by Foucault. This includes Byung-Chul Han's data-oriented extension of biopolitics as psychopolitics, where traditional *subjects* give way to *projects* that are "always refashioning and reinventing" themselves (2017: 1). Han's provocative rethinking suggests that while Foucault was correct in recognizing that disciplinary society was out of sync with the neoliberal forms of governance ascendent in the 1970s and after, his very categories (e.g., population, biopolitics) remained wedded to discipline and thus failed to describe the neoliberal regime. For Han, this is because neoliberalism, "a mutated form" of capitalism, is less interested in biological and somatic forms of management than the "psyche as a productive force" (2017: 25). Han's psychopolitics refers to this neoliberal regime, where big data's capture and surveillance has displaced prior statistical understandings of populations and power.

In a word, subjectivation has changed. Our analysis suggests a shift from Foucault's biopolitics and even Han's psychopolitics: wearable stimulation goes beyond surveillance capitalism's use of behavioral analytics to predict in order to change or augment behavior. The paradigm of stimulating data translates the "psyche as a productive force"—with its desires, narratives, and psychographic segmentations—to bodily capacities, moods, and brain states. Acting on the nervous system, such data is now consumed like a drug. Where big data's predictions sought to institute new habits and responsibilities, the target of data stimulation's electrochemical prescriptions are framed as more fundamental than actions, discourse, or even rational choice. This is also to say that the faith in data has a long history in animating social control: statistics enabled biopolitical governance of populations; behavioral analytics facilitated psychopolitical anticipation of consumer identities. Such data has always been mediated in the form of demographics, projection models, engagement metrics, and user telemetry. Its present mediations provide points of contact for friction, resistance, and transformation, which are necessary but not sufficient for democratic engagement. This move from wearable sensing to prescriptive stimulation changes the forms and the terms of datalogical mediation, with far-reaching implications for subjectivity, governance, and democracy.

Acknowledgements

The authors acknowledge having written this paper on an "equal contribution" basis. Aleena Chia would like to thank Feng Zhu for a discussion about Foucauldian theories of subjectivity. Joshua Neves would like to thank Marc Steinberg for suggestions included in the essay. Chia and Neves would like to thank the anonymous reviewers and issue editors for their valuable feedback.

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Notes

[1] Here we build on a range of debates about push and pull technologies in media theory, including McLuhan (1964) and more recent work on social media and streaming (Gilbert, 2019). In addition to a spectrum of passivity and activity set up in many such analyses, our interest is to distinguish between processes of capturing and transmitting user data.

[2] The cost of such devices is both relatively steep–Apollo: $349; NeoRhythm: $249; BrainTap: $647—and a mere pittance when compared to professionally administered electrostimulation or IV infusions, not to mention widely used forms of medical imaging, including magnetic resonance imaging (MRI), ultrasound, positron emission tomography (PET) and even X-ray.

[3] The parasympathetic and sympathetic activity are branches of the autonomic nervous system that are known to correspond with states of rest and recovery or fight-or-flight (Apollo Neuroscience, 2021a).

[4] Apollo's website links scientific studies of low frequency vibration's impact on HRV and the autonomic nervous system as the bases for the following modes or programs: Energy and Wake up, Social and Open, Clear and Focused, Rebuild and Recover, Meditation and Mindfulness, Relax and Unwind, Sleep and Renew (Apollo Neuroscience, 2021a).

[5] NeoRhythm also has a "pain control" setting that uses a dominant frequency of 303 Hz and magnetic flux density or 2.0 mT to decrease sensitivity to pain and pain perception when placed on affected parts of the body.

[6] See, for instance, reddit groups devoted to DIY tDCS: https://www.reddit.com/r/tDCS/.

[7] A detailed history of electrical stimulation is beyond the scope of this essay, but we both want to signal this history and call attention to its recent domestication in the form of consumer wellness products.

[8] Kate Crawford, Jessa Lingel, and Tero Karppi (2015) point out that only a fraction of this biodata is returned to users as most of it is retained and analyzed by "the parent company, third parties and possibly insurers and employers."

[9] For example, prominent neuroscientist Antonio Damasio (2016) has publicly critiqued Harari's thesis for its lack of evidence and scientific reductionism.

[10] For more about Neuralink, see the project's website: https://neuralink.com/science/.

[11] In addition to works cited above, this includes many crucial studies that have yet to be taken up by media theorists. See, for example: Dumit, 2004; Landecker, 2007; Preciado, 2013; Rajan, 2017; Vora, 2015; among others.

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