AFTERWORD

Critical Philosophy of Technological Convergence

Education and the Nano-Bio-Info-Cogno Paradigm

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The fateful question for the human species seems to me to be whether and to what extent their cultural development will succeed in mastering the disturbance of their communal life by the human instinct of aggression and self-destruction.

Sigmund Freud, *Civilization and its discontents*, trans. James Strachey[1]

… the relationships between the biological body and information technology is such that the body may be approached through the lens of information … is therefore subject to the same set of technical actions and regulations as is all information. In short, when the body is considered as essentially information, this opens onto the possibility that the body may also be programmed and reprogrammed.

Eugene Thacker[2]

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Fifth-Generation Mobile Cellular Technology and Techno-Nationalism

In *Civilization and its discontents* (1930), Freud explores the fundamental tension between the individual's instinct for freedom and civilization's demand for conformity. Matteo Stocchetti, the editor, draws a parallel between *The digital age and its discontents* and Freud's work, as 'an inquiry into the downsides of digitalization and the re-organization of the social world'. The ethos of the book differs in that contributors 'seek to conceive and construct alternative possibilities' based on the role of education. Stocchetti embraces critical social science as the means to mount a critical appraisal of societal digitalization and 'the ideological appropriation of technological development' by capitalism and its effects on the formation of education in the digital age. This is a massive question, but one that is urgent as the West and China fight over 5G as the next-generation standard for cellular wireless communications that promise a huge increase in data and its transmission with greater device connectivity. This fight is a symptom of the larger picture concerning 'the path to digital modernity' and whether and to what extent it will be neoliberal capitalism or 'socialism with Chinese characteristics'. These are both forms of enveloping global digital communication systems and both capitalist. It is not clear at this point whether the global systems will diverge or converge, but the effects of the bifurcation of the world system will be felt for the next decade and between them they will help to determine the next generation of applications not only in industry, but also in the social portfolios of health, education, welfare and based on greater connectivity and the harnessing of big data.

Digital cellular networks of 5G (10 Gbit/s) are 100 times faster than previous networks, with much faster response times and the capacity to transmit multiple bits of information simultaneously. The 5G technology will open up new applications of virtual reality and augmented reality, with the advantage of fast machine-to-machine continuous communication in the Internet of Things. The technology is well advanced and Korea has already demonstrated 5G, with other countries in the process of testing and adopting it. The discourse of tech talk suggests 5G will usher in 'the next wave of technology'. Worldwide, it will be dominated by a small group of companies, including Huawei, Intel and Qualcomm, as well as Cisco, Ericsson, Nokia, Samsung and ZTE for provision of infrastructure. The technology is expected to be rolled out in 2020 and take a decade to install, involving trillions of dollars. The stakes are high, as Paul Triolo and Kevin Allison of Eurasia Group's white paper, *The geopolitics of 5G*, indicate:

> [The report] explains how political forces, including the ongoing technology and trade confrontation between the US and China, will shape the development of next-generation mobile standards, spectrum allocation, and deployment in key markets and regions. It likewise addresses how 5G's development will shape economic, technological, and

> geopolitical competition between the world's leading technology superpowers. (Eurasia 2018: 3)

The key findings of the report focus on China's 'first-mover advantage' in 5G and the US efforts to exclude Chinese networking equipment suppliers from Western networks, with the prospect of 'a bifurcated 5G ecosystem' with 'politically divided and potentially non-interoperable technology spheres of influence'. 5G is seen as a *foundational* transformational technology because it enables many other applications of the 'next wave'. It will build the technology ecosystem within which other technologies can converge and set up new syntheses. It seems that already at this stage the 5G networks will enable new digital applications that require 'ultra-fast, low latency, high-throughput communications, including driverless cars, advanced factory automation, and smart cities' (Eurasia 2018: 5). As the report makes clear: 'These applications will be the biggest source of long-term economic and political advantage from 5G, and they will be the subject of intense competition between leading US and Chinese companies' (ibid.). At the same time, China's 'Belt and Road Initiative' also promises a related geopolitical advantage in Africa, Latin America and the Middle East, although it is also clear with the example of Italy that European countries will be involved in making risky trade-off political decisions for Europe and for European relations with the United States.

5G will be largely 'cloud native'—industry jargon for relying on AI software that are said to pose unique security concerns. In particular:

> The huge growth in the number of connected devices and large bandwidths means that the potential for unsecure or compromised devices to be used for malicious activity such as botnet-driven denial of service attacks goes way up, as does their size and severity. (Eurasia 2018: 8)

This risk is heightened by the fact that '[a]s the number of connected devices and the amount of data explode, a greater share of total global economic output will come to rely on global data networks' (ibid.).

Why should I dwell on this contemporary example in a book that addresses the discontents of the digital era and the role of education? Partly because, as Stocchetti informs us, 'the main task is to examine the role of technological innovation in relation to the nature and direction of social change associated with different interpretations of this role, and with the role of formal education' (Chapter 1 in this volume). In my view, critical social science needs to be sufficiently well informed about current developments or tied to what is happening now. How often have we heard the notion of the next 'technological wave': but in terms of Kandratiev waves it is useful to entertain the concepts of *foundational*, *transformational*, *emergent* and *convergent* (local and general) technologies. These concepts help us to distinguish the building of the technological ecosystem from its internal operations. I think it is useful also to work from

a bottom-up view to analyse 'discontents'. There are a number of implications I wish to draw from the 5G example and the methodological or philosophical aspects is but one of them. So, first, the interrogation of the role of technological innovation, especially in relation to the role of public education, demands an understanding of the successive waves of new platform technologies, emergent technologies and convergent technology.Second, a strange paradox perhaps, while education is a fundamental institution, it is a 'key arena or place of struggle between competing visions of the future of society' only after installation—at least in relation to 5G networks, not in a primary sense as a global institution that will affect outcomes, but, perhaps, only in a secondary sense concerning use, after the technology has been rolled out. Undoubtedly, education will be affected by 5G: it will be reshaped, certain incipient developments already on the way will receive increased use, speed and application—personalization, Internet research, academic publishing, increased speed of communication, virtual reality education, augmented intelligence and so on. The struggle will not be over whether or not 5G will be introduced, but, if anything, it will be over its uses and whether these support existing neoliberal policies of privatization or, by contrast, the symbolic production of global public goods and public good science in open platforms.

Third, the discourse of 'modernity' and 'Enlightenment' is not far away from the technical discussions of specs and uses. Indeed, it is to the forefront of both an emerging bifurcation of techno-world systems—Chinese or American. The Nineteenth Congress of the Communist Party of China (CPC) makes it crystal clear that China and the CPC now enter world history as a global power that advocates a path of modernity that is based on 'socialism with Chinese characteristics', where the White House and US trade representatives, realizing that in certain critical areas of technology, China has stolen a march on them that threatens the neoliberal world ascendancy of Silicon Valley, are kicking up at trade talks so as to slow China's advantage. Trump is even talking of great US state control and direction to match China's state capitalism and to provide greater steering capacity.

China has made incredible progress from the old days of copy strategies to support and develop a world-class indigenous technology sector that will propel China into the leading world position in high-tech industries in a few years, threatening the US Silicon Valley leading position in new digital technologies, and competing successfully in world biotech, nano-tech, new materials and energy technology markets. As Lorand Laskai (2018) comments: 'In the saga of the U.S.-China economic rivalry, *Made in China 2025* is shaping up to be the central villain, the real existential threat to U.S. technological leadership.' He notes also that Chinese planners have studied and learned from Germany's 'Industry 4.0'[3] based on adoption of intelligent systems and full automation in manufacturing that is commonly seen as the basis for the Fourth Industrial Revolution clustered around converging technologies[4] encouraging 'the global artificial intelligence race'.[5] The report does not mention deep machine and

quantum computing, in which China has made large investments earlier than the United States and other countries.[6]

The tables have turned in the era of monopoly digital capitalism when the field is dominated by (soon-to-be) trillion-dollar multinationals that seemingly can do what they like outside national tax laws. The big five—Amazon, Apple, Facebook, Microsoft, Google—defining a new historical stage of capitalism, are matched by the growth of Chinese Internet companies, Alibaba, Baidu, Tencent, JD.com and NetEase. There are already fears that the US 'big five' could destroy the 'Tech Ecosystem'. They will not only dominate the foreseeable future, but will also operate more like governments. There is also the new concept of 'techno-nationalism', which is now used with increasing frequency to describe the threat of China. Thus, Amol Rajan (2018) writes:

> One of the most important stories in the world right now is the battle to own the future by investing in technology, in which non-democratic states are becoming more assertive, strategically effective and—unencumbered by voters' preferences—able to think in epochal rather than electoral cycles … Techno-nationalism marries two trends that are central to our current historical moment. First, the remarkable acquisition of power through data and 'network effects' of just a few companies based mainly near San Francisco, and the escalating battle between these companies and Chinese rivals. And second, the decline of the post-1945 Western-led world order.

These fears of the emergence of the Chinese techno-state now worry Washington, which is abuzz with Chinese 'techno-nationalism' and the prospect of when China rules the web as the techno-service state. In another example, Adam Segal (2018) writes:

> In Xi's words, cyber-sovereignty represents 'the right of individual countries to independently choose their own path of cyber development, model of cyber regulation and Internet public policies, and participate in international cyberspace governance on an equal footing.' Three technologies will matter most for China's ability to shape the future of cyberspace: semiconductors, quantum computing, and artificial intelligence.

One significant theoretical question is which economic system will be more successful? Neoliberal America or Socialist China? Free capitalist America or State Socialist (capitalist) China? Are these even real alternatives? The global techno-ecosystem may be constrained by techno-nationalism, but it may also be enhanced through global market penetration. This is partly a question of international law in telecommunications and architecture of the Internet that is yet to be written. One thing for sure is that the trade wars initiated by Trump are in large measure spooked by fears of China's coming dominance in

the technological era of the future development. This fear and the eclipse of American technological dominance is one of the real sources of Trump's trade war with China.

5G is *only* fifth generation, yet we already experience the birth of digital convergence where the same multimedia content is ubiquitous and available to view on different types of devices where information is intermingled, sent, published and stored with the same efficiency without being downgraded. This digital convergence is one of the factors making technological convergence possible.[7]

'Convergent Technologies' and the 'Nano-Bio-Info-Cogno' Paradigm

The notion of so-called 'convergent technologies' and the 'nano-bio-info-cogno' (NBIC) paradigm has dominated the US National Science Foundation (NSF) for over a decade. The vision is still current. These technologies are not restricted to new digital technologies, but embrace a set of converging technologies, including the following:

- *Nano*: the branch of technology that deals with dimensions and tolerances of less than 100 nanometers, especially the manipulation of individual atoms and molecules.
- *Bio*: the exploitation of biological processes for industrial and other purposes, especially the genetic manipulation of micro-organisms for the production of antibiotics, hormones, etc.
- *Info*: information technologies based on the paradigm of quantum computing.
- *Cogno*: convergence of nano, bio and IT for remote brain sensing and mind control.

These are 'convergent technologies' purported to drive the next stage of the knowledge society as a 'paradigm for the future' which has clear implications for education in the intermediate term, with some disturbing convergences that harness info, bio and nano-technologies in relation to cognitive science.

The National Science Foundation (NSF) has published reports exploring the convergence of the 'NBIC technologies', including the chief application areas: expanding human cognition and communication; improving human health and physical capabilities; enhancing group and societal outcomes; strengthening national security; and unifying science and education. The claim advanced by NSF is that there is a new scientific 'unity at the nanoscale' (Bainbridge & Roco 2006). There were three important sources that guided subsequent discourse: first, the foundational report sponsored by the NSF and the Department of Commerce (DOC), entitled *Converging technologies for improving human performance* (2002); second, the 2004 report of the Science and Technology Foresight Unit of the European Union, entitled *Converging*

technologies—shaping the future of European societies (Nordmann 2004); third, a report entitled *The big down: from genomes to atoms* (ETC Group 2003). The notion of 'convergent technologies'—the *great convergence*—has guided NFS for over a decade and seems to have been recognized and adopted by European Science, and to be attracting much commentary from scholars around the world.

Nanotechnology, biotechnology, information technology (IT) and new technologies based in cognitive science signify an emerging harmony among the sciences. NBIC unification means NBIC fields are progressively merging, step by step, at an accelerating rate: '[The global convergence] will constitute a major phase change in the nature of science and technology, with the greatest possible implications for the economy, society, education and culture' (Roco & Bainbridge 2002: 1). A brief look at nanoscience and nanotechnology reveals: 'Recent advances in nanoscience and nanotechnology enable a rapid convergence of other sciences and technologies for the first time in human history' (Bainbridge and Roco 2005: 2–3) Biotechnology and biomedicine are taking place at the nanoscale—for example, genetic engineering (with DNA molecules), imaging (with quantum dots of a few nanometres), targeted drugs (with nanoparticles as carriers) and biocompatible prosthesis (with molecules 'by design').

Modern IT is based on microelectronics, which is rapidly evolving into nanoelectronics. Of the four NBIC fields, 'cognitive science is the least mature, but for this very reason, it holds very great promise. multidisciplinary convergence of cognitive, psychology, linguistics, cultural anthropology, neuroscience, and artificial intelligence with aspects of computer science' (Roco & Bainbridge 2002: 1). This is a significant staging point of convergence: nano-bio-info technologies have made huge progress, beyond expectations, and the next stage is the application, integration and convergence with cognitive science. Here's the expected pay-off for education. We are waiting for the next round of convergence and the breakthroughs for a cognitive science model of education.

Roco and Bainbridge (2002: 1) comment on an early statement of the 'converging technologies' theme:

> We stand at the threshold of a new renaissance in science and technology, based on a comprehensive understanding of the structure and behavior of matter from the nanoscale up to the most complex system yet discovered, the human brain. Unification of science based on unity in nature and its holistic investigation will lead to technological convergence and a more efficient societal structure for reaching human goals. In the early decades of the twenty-first century, concentrated effort can bring together nanotechnology, biotechnology, information technology, and new technologies based in cognitive science.

The document also addressed the prospect of unifying science from the nanoscale and integrative principles; cognitive, civic and ethical changes in a

networked society; breadth, depth, 'trading zones' and reshaping education at all levels; and changing the human culture.

Five years later, Bainbridge and Roco talk of 'Progressive Convergence':

> Technological convergence is progressive in two important senses of the term. First, the NBIC fields are in fact progressively merging, step by step, and apparently at an accelerating rate. Second, the unification of the great realms of technology will promote human progress, if they are applied creatively to problems of great human need. (2006: 2)

As Roco and Bainbridge (2013) indicate, convergence of knowledge and technology for the benefit of society (CKTS) is the core opportunity for progress in the 21st century, based on five principles:

> (1) the interdependence of all components of nature and society; (2) decision analysis for research and development based on system-logic deduction; (2) enhancement of creativity and innovation through evolutionary processes of convergence that combine existing principles, and divergence that generates new ones; (4) the utility of higher-level cross-domain languages to generate new solutions and support transfer of new knowledge; and (5) vision-inspired basic research embodied in grand challenges (Roco and Bainbridge 2013: 1).

Gro*w*ing convergence research at the NSF was identified in 2016 as one of 10 'big ideas' for future NSF investments:

> Convergence research is a means of solving vexing research problems, in particular, complex problems focusing on societal needs. It entails integrating knowledge, methods, and expertise from different disciplines and forming novel frameworks to catalyze scientific discovery and innovation. Convergence research is related to other forms of research that span disciplines—*transdisciplinarity, interdisciplinarity, and multidisciplinarity*. It is the closest to transdisciplinary research which was historically viewed as the pinnacle of evolutionary integration across disciplines. (NSF, Emphasis in the original)[8]

On 23 March 2018, the NFS issued another letter (DCL) on the *Growing convergence research at the National Science Foundation (NSF)*, based on research driven by a specific and compelling problem and deep integration across the disciplines:

> Proposals must reflect the characteristics of convergence outlined (and abridged) as:

> 1. A convergence project should make a compelling argument for why it is essential to bring together substantially different science and engineering disciplines to address a specific scientific challenge or social problem. The extent of disciplinary diversity may be assessed by the history of intellectual traditions; the development of different tools, techniques, and approaches; and the various venues for publication.
>
> 2. In order to make significant progress, the research team would need to provide evidence of readiness to engage in the proposed convergence research while simultaneously also representing different disciplines.
>
> 3. A convergence project should make a compelling case for the depth of integration of knowledge bases in the contributing disciplines; it should demonstrate strong coupling, high leveraging, and/or co-development of integrated and/or beneficially complementary tools and techniques from the contributing disciplines; and it should demonstrate novelty of the integrated research approach resulting from combinations of modes of thinking that are characteristic to the contributing disciplines.
>
> 4. Convergence projects are encouraged to provide new learning and experiences to undergraduate students, graduate students, and/or postdocs that would help prepare them to become the next generation of convergence researchers What roles will they play in learning to use new tools, instruments, and techniques that are central to convergence research? What concepts will they need to learn outside of their own disciplinary specialties, and how? Will the project provide new model learning environments that can be adapted in other convergence research projects?[9]

We are reminded that the 'great convergence' driving the NSF research programme should 'not be mistaken for the mundane growth of interdisciplinary or multidisciplinary fields' (Bainbridge & Roco 2005: 2).

We are told that NBIC convergence requires, and is made possible by, the radically new capabilities to understand and manipulate matter that are associated with nanoscience and nanotechnology. Not only do many of the key structures of the human nervous system exist at nanoscale, but that nanotechnology is enabling a convergence of other sciences and technologies for the first time in human history, including in the field of cognitive science, with an emphasis on education and the learning sciences combining advances in neuroscience and artificial intelligence, and connecting education and learning to biology (brain science) and information science.

This ethos and emphasis is prioritized at the national level through the NSF establishment of National Learning Centers (NLC). The 'cogno' convergence

with other elements of the paradigm is the least developed and the 'miracle-to-come' that promises the completion of the network platform that manages the nano-bio-info flows and self-circuitry. It is the focus that heralds a new *cognitive efficiency*, in part captured by 'intelligent technologies' of the Internet, Facebook, Google and the new wearables. The question is: Are there downsides? What are the discontents? The Institute of Medicine and National Research Council in 'Advances in technologies with relevance to biology: the future landscape", chapter 3 of *Globalization, biosecurity, and the future of the life sciences* (National Academies, 2006), begin a conclusion with the following quote from Matthew Meselson that bears some resemblance to Freud's quote with which I open this chapter:

> During the century just begun, as our ability to modify fundamental life processes continues its rapid advance, we will be able not only to devise additional ways to destroy life but will also be able to manipulate it—including the processes of cognition, development, reproduction, and inheritance (National Academies 2006:197)

The review that covers, among other topics, Computational Biology and Bioinformatics, Systems Biology, Genomic Medicine and Nanotechnology, remarks:

> An intriguing feature of the nanoscale is that it is the scale on which biological *systems build their structural components, l*ike microtubules, microfilaments, and chromatin. In other words, biochemistry is a nanoscale phenomenon. Even more intriguingly, a key property of these biological structural components—including, of course, the DNA double helix—is self-assembly. (National Academies 2006: 185–186).

We might say the nano-self has arrived and employ a Foucauldian riff on 'bio-politics' to argue that research biological knowledge and information science now treats the population as a living mass to be made cognitively efficient in the chain of the NBIC paradigm, disrupting our bodily identities and diminishing our control over our subjectivities in the name of optimizing national cognitive advantage. We now live in a global economy where nanotechnology, biotechnology, IT and cognitive sciences are converging into new capitalistic strategies or 'advanced capitalism', which aims to accumulate profits by investing in the 'commodification of all that lives' (Braidotti 2013: 59). By contrast, I call this 'bio-informational capitalism' (Peters 2012) to highlight the twin forces that between them shape humanity's destiny and also talk of 'algorithmic capitalism in the age of digital reason' (Peters 2017) as a means of mapping a resurgent fifth-generation cybernetic capitalism that led and profited from financialization and high frequency trading[10] (Peters et al. 2015).

National Learning Centers established by the NSF[11]

CELEST—The Center of Excellence for Learning in Education, Science, and Technology

https://www.brains-minds-media.org/archive/153/index_html/?searchterm=CELEST

CELEST began on October 1, 2004. Funded by a five-year $20,000,000 grant by the National Science Foundation of the USA, this new Center brings together leading scientists, educators, and technologists from Boston University, Brandeis University, Massachusetts Institute of Technology, and the University of Pennsylvania to study autonomous real-time learning systems by integrating experimental and computational brain science, biologically inspired technology, and classroom innovation.

LIFE—The LIFE Center

http://life-slc.org/about/about.html

The LIFE Center represents a collaboration between the University of Washington in Seattle, Stanford University, and SRI International, Inc., both in the San Francisco area. The LIFE Center is a multi-institution Science of Learning Center funded by the National Science Foundation. The University of Washington is the lead institution. Other institutions across the country also participate. LIFE Center researchers represent a broad range of fields, including neurobiology, psychology, education, speech and hearing sciences, anthropology, and sociology, and many of the issues LIFE investigates arise from their interactions. The … purpose is to develop and test principles regarding the social foundations of learning … investigators focus on complex human learning over the lifespan with the goal of understanding how and why human social processes affect learning. LIFE Center findings will inform learning theories, influence educational practices, and affect technologies designed to enhance learning.

PSLC—Pittsburgh Science of Learning Center

Learning Sciences and Technologies https://hcii.cmu.edu/research/pittsburgh-science-learning-center

https://learnlab.org/

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The Pittsburgh Science of Learning Center is leveraging computational theory and cognitive modeling to identify the instructional conditions that cause robust student learning. PSLC has created the Learnlab facility designed to dramatically increase the ease and speed with which learning researchers can create the rigorous, course-based experiments that pave the way to an understanding of robust learning. The Center is cross-organized by four research thrusts (Cognitive Factors, Metacognition and Motivation, Social Communicative Factors, Computational Modeling and Data Mining) and six LearnLab courses (Algebra, Geometry, Chemistry, Physics, Chinese, and English as a Second Language).

SILC—Spatial Intelligence and Learning Center

https://www.silc.northwestern.edu/

The Spatial Intelligence and Learning Center (SILC) brings together scientists and educators from many different institutions to pursue the overarching goals of understanding spatial learning and using this knowledge to develop programs and technologies that will transform educational practice, helping learners to develop the skills required to compete in a global economy. SILC participants include researchers from cognitive science, psychology, computer science, education, and neuroscience, as well as practicing geoscientists and engineers who are particularly interested in spatial thinking in their fields, and teachers in the CPS.

TDLC—Temporal Dynamics of Learning Center

https://tdlc.ucsd.edu/tdlc2/index.php

The Temporal Dynamics of Learning Center or 'TDLC' is a National Science Foundation-funded Science of Learning Center that has enjoyed over a decade of success. TDLC aims to achieve an integrated understanding of the role of time and timing in learning, across multiple scales, brain systems, and social systems. The scientific goal of the center has been to understand how the element of time and timing is critical for learning, and to apply this understanding to improve educational practice.

Visual Language and Visual Learning

Washington DC, United States – https://www.gallaudet.edu/news/vl2-nsf-meeting

Visual Language and Visual Learning (VL2) is a Science of Learning Center (SLC) on Visual Language and Visual Learning, one of six SLCs funded by the National Science Foundation. The purpose of VL2 is

to gain a greater understanding of the biological, cognitive, linguistic, sociocultural, and pedagogical conditions that influence the acquisition of language and knowledge through the visual modality.

'Now Is the Winter of Our Discontent'

In *Re-becoming human*, Heidi J. Boisvert asks: 'How did we get to a point where we so easily render our biological control and knowledge to technical affordances? Which mechanisms have been conducive to "self-amputation"?' (2015: 3, emphasis in the original). 'Self-amputation' is the term McLuhan uses for the media numbing of the biological self. Boisvert claims, 'the post-biological technocracy to which we are unconsciously ceding control of our cognitive and affective faculties … also explores how embodied, bio-adaptive game-based networked performance practices can serve as an antidote, restoring critical feeling' (ibid.: xi). She wonders: 'Can taking up the same intelligent technology in the service of aesthetics resist amputation, maintain autonomy and restore critical feeling to create more balance between the biological and technological self?' (ibid.: 3).

Her argument is that 'intelligent technology is a slow form of violence re-scripting the nervous system, which in turn affects physical well-being, interpersonal relationships, and by extension, the fabric of society' (ibid.: 6). I will not comment on her 'aesthetics of critical feeling', although it certainly seems to offer one 'post-industrial therapy'. In making this claim, she reviews the work of Hayles, Turkle and Damasio and clinical evidence to investigate how the dependence upon intelligent technology (IT) is changing the brain-wiring diagram and re-scripting nervous systems and the ways in which intelligent technology is numbing the biological self. In this project, it is not her intention to condemn intelligent technology, but 'to problematize it as an ambivalent artifact situated within an ecology of effects—social, cultural, neurological and biological' (ibid.: 10). Boisvert wants to offer a more balanced alternative to the emphasis on the new fifth-generation cybernetics that rules Google, Amazon and Facebook through what she calls 'ludic performance'. What concerns me here is her analysis that is well expressed rather than the alternative she proposes:

> Our dependence upon the Internet and mobile devices, and our increasing fascination with wearables and immersive displays, the latest self-extensions, appear to further amputate rather than augment the cognitive and affective faculties, such as reason, perception, memory and emotion. Current intelligent technologies, such as those listed above, are not only dissolving our knowledge schemas and rendering us emotionally void but also re-wiring our neurons to prefer technology to actual human engagement. (ibid.: 20)

The terms of her nalysis are set out in the section entitled 'Perennial conflict between autonomous technology & human agency' and she investigates 'Epistemic shifts & the six waves of technological innovation' in the subsequent section, following Schumpeter and Smilhula's (2010) 'Waves of technological innovation and the end of the information revolution', focusing on the hypothetical wave of the post-informational technological revolution. She explores the legacy of cybernetics in terms of 'the erasure of the body', 'the regulation of emotions' and the 'canalization of the senses', finally to examine the 'socio-cultural and neurobiological impacts of intelligent technology'. Against the utopian technical immortalists—Ray Kurzweil, Martine Rosenblatt, Aubrey De Grey, Kevin Kelly, Sergei Brin and Jason Silva—she claims we are being robbed of our autonomy; that we are becoming less human as we are integrated into the circuitry of fifth-generation resurgent capitalist cybernetic systems. The argument has a narrative complexity that propels itself harnessing the theories and studies in critical social science and demands attention, if even only as a programme of Popperian falsification in the NSF community.

The development of the adolescent's brain in a technological world constitutes a societal anxiety that ought to take priority in a research culture that focuses on cognitive efficiency.[12] Mary Helen Immordino-Yang suggests that the constant use of technology is hijacking one's ability to form high-level meaning within one's environment, putting the emphasis on the way in which we use technology to set expectations and receive validation as where issues can arise. Are we to believe, with Nicolas Carr (2010), that the Internet is rerouting the neurological pathways of our brains? To what extent is this a research question of the NFS learning centers? Is there room to entertain the counter-factual, the counter-hypothesis, the counter-theory, or are we condemned to accept the 'truths' generated by the consensus of an enthusiastic pro-tech community? To what extent are these alleged neurological effects impacts of a broader long-term tendency of a resurgent cybernetic capitalism now dominated by the soon-to-be trillion-dollar information service of US multinationals who ideologically embrace a higher moral purpose?

The clinical studies are in their early stages. While computers clearly help with the development of some cognitive skills, they also demonstrate negative impacts on verbal and social skills and curtailment of 'deep thinking', sometimes promoting anti-social behaviour and forms of technological addiction. The studies have mixed results. The effects of digital screen media are better known than interactive media (Anderson & Subrahmanyam 2017). These are complex questions that contain many variables and are not easily resolvable into grand conclusions and are unable to be effectively reviewed here.[13] Pamela Hurst-Della Pietra (2017) mentions 'Internet gaming disorder' which, as she reports, was defined in the DSM IV by the American Psychiatric Association (2013) as 'persistent and recurring use of the Internet to engage in games, often with other players, leading to clinically significant impairment or distress'.

The larger question of political economy aims to investigate the 'post-information' or 'post-digital' wave divides the community of scholars into those who

talk of its inevitability in visionary and moral terms and those in the critical tradition of social science who, by contrast, emphasize digital discontents. The bifurcation of Chinese and American techno-systems is at an early stage and it is difficult to predict divergence or convergence. Given that we are *only* in the fifth generation, edging into the sixth wave (if you accept this depiction), it is crucial that we set up research programmes which, against the tide of expectations, can raise questions of negative and detrimental impacts and 'discontents', and engineer larger questions—social, political and ethical—about emergent system effects in their entirety.

Notes

[1] Available at https://www.stephenhicks.org/wp-content/uploads/2015/10/FreudS-CIVILIZATION-AND-ITS-DISCONTENTS-text-final.pdf
[2] E. Thacker, Data made flesh: biotechnology and the discourse of the posthuman. (2003) *Cultural Critique, 53*(winter), Special issue: Posthumanism, 86.
[3] See https://www.plattform-i40.de/I40/Navigation/DE/Home/home.html
[4] See https://www.mckinsey.com/featured-insights/china/a-digital-upgrade-for-chinese-manufacturing
[5] See https://www.cfr.org/event/global-artificial-intelligence-race
[6] See http://www.chinadaily.com.cn/business/2017top10/2017-05/16/content_29359368.htm
[7] See the Technology Convergence Conference (http://teladatatcc.com/) and the International Conference for Convergence in Technology (https://www.ieee.org/content/ieee-org/en/error/404.html/).
[8] See https://www.nsf.gov/pubs/2018/nsf18058/nsf18058.jsp?WT.mc_id=USNSF_25&WT.mc_ev=click
[9] See https://www.nsf.gov/news/special_reports/big_ideas/convergent.jsp
[10] See http://www.uta.edu/huma/agger/fastcapitalism/14_1/Peters-Algorithmic-Capitalism-Epoch.htm
[11] All information is taken from the NLCs' websites.
[12] See https://www.youtube.com/watch?v=rq8P-25ybcc
[13] See Pamela Hurst-Della Pietra's 'Introduction' to an issue of *Pediatrics (2017) that includes articles, for example, by James et al. (2017) on* 'Digital life and youth well-being, social connectedness, empathy, and narcissism,' *Hoge et al. (2017) on* 'Digital media, anxiety, and depression in children' and Gentile et al. (2017) on 'Internet gaming disorder in children and adolescents', with other researchers investigating social effects of media and media content.

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