Hyperconnected Civilizations: Some Historic Perspectives

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ABSTRACT

It is natural to focus on the impact of modern information systems on our civilization as a recent phenomenon resulting from the unprecedented growth in the capabilities of information technology over the past seventy years. It is also natural for those developing the technology to focus on its intended benefits rather than potential adverse side effects. However, the impact of information technology on our everyday lives, societies and civilizations reflects basic human needs and motivations that have changed little throughout recorded history, and have both positive and negative aspects. This chapter provides a historic perspective on the development of hyperconnectivity in terms of the human needs that it addresses and the growth of the infrastructure of information technology. The overall objective is to provide greater understanding of its engagement with all aspects of society, and to provide conceptual frameworks for projecting its future development and social impact.

INTRODUCTION

We live in a world where computer and communication technology provides us with omnipresent capabilities to access human knowledge, communicate with one another, and perceive and interact with the world in new ways. The underlying technologies and their applications are rapidly developing and changing, yet some are assimilated so readily that we quickly take them for granted and find it difficult to understand how we lived without them (Ling, 2012).

Those applications that are widely adopted satisfy significant human needs and offer commercial opportunities to those that use new technologies to satisfy them. The innovators focus on the intended benefits of their products that will drive widespread adoption, but there are usually also opportunities for those who are parasitic on society to exploit them for anti-social purposes such as *spam* (Brunton, 2013), *malware* (Erbschloe, 2005) and *cybercrime* (McQuade, 2008). Unintended adverse side effects may significantly undermine the benefits of innovation.

These phenomena raise issues for individuals, social groups, organizations, cultures, national governments and international agencies. What are the personal benefits and dangers of adopting a new technology; how might it improve the processes of an organization and what risks are involved; how might it support or undermine cultural norms; can the interpretation of existing legislation be extended to cover the new technology; are there global impacts that go beyond national borders; are new laws required?

To even begin to understand such issues let alone answer such questions, we need some basis for understanding the new technologies in terms of their impact on individuals and society[1]. The rapidity of change in the technology and the difficulty of predicting in what ways it will develop and be used suggest the need to base any analysis on fundamental traits of individuals and society rather than short-term models of the impact of technology, taking into account that individuals and institutions are dynamic and some aspects of their natures will evolve with changes in their environment (Shotter, 2013; Tapscott, 2009).

This article provides a range of perspectives on the dynamics of civilization and the role of technology, none of which alone can provide definitive answers, but which together provide a framework for understanding much of what is happening as we move towards a hyperconnected civilization. There may appear to be a bias towards negative aspects of the use of the technology that undermine civilization. If there is, it is to counterbalance the natural optimism with which we develop technologies to improve the human situation and, in our focus on the benefits to individuals and society, can forget that the same technologies may also be repurposed in a way that we would regard as anti-social. One major lesson of history is the need to be *defensive* about possible adverse side effects and prepared to react quickly to the unexpected.

A HYPERCONNECTIVITY REVOLUTION, A HYPERCONNECTIVITY AGE?

It would be reasonable to apply the term *hyperconnectivity revolution* to the world wide transition to a socio-technical milieu in which a very high proportion of the population uses communication and computer technology to provide continuous access to other people, media and a wealth of computer services. However, the term 'revolution' itself indicates only that we are construing some phenomenon as triggering a major social change, and has probably become so over-used as to convey little meaning.

A search of my personal library catalogue shows over 200 books with the term 'revolution' in their title, American, English, French, Russian, writing, printing, scientific, chemical, industrial, financial, telephone, electrical, quantum, microelectronic, computer, genetic, and so on. The common feature in the diverse literatures is the recognition of a significant socio-intellectual change, an analysis of the underlying rationale and a study of the consequences, some of which are consistent with that rationale but others of which go beyond it in unintended and unexpected ways.

Much the same comments apply to the use of the notion that after significant change we live in a distinctive 'age,' a *modern* age, an *enlightened* age, a *post-industrial* age, a *computer* age, an *information* age, a *hyperconnected* age. The term focuses attention on the historic situation of the socio-cultural phenomena we wish to highlight, but has no deep meaning. It also tends to obscure the ongoing dynamics of any era of significant social change, the critical phenomena that cause us to recognize in retrospect a different age and then extend its chronology back to its presumed origins.

The phenomena of hyperconnectivity may be seen as a significant stage in the evolution of what have been termed the *information age* and the *computer age*, and it is useful to analyze these in more detail to provide a context for the hyperconnectivity revolution/age.

The Information Age

The term 'information age' has been widely used in the literature on information technologies and their social impact (Dizard, 1985; Hammer, 1976; Slack & Fejes, 1987). However, there is little consensus on what constitutes the information age and when it commenced. Alberts and Papp (1997) in the introduction their wide ranging *Anthology of the Information Age* note that the term is commonly used for "concluding years of the twentieth century and the beginning of the twenty first," but themselves raise issues about the meaning and chronology of the 'age.'

Castells (1996) in his monumental studies of the economic, social and cultural aspects of the information age dates it to the rise of a *network society* based on computer technologies. Some writers date it later to the invention of the transistor (Riordan & Hoddeson, 1997), whilst others date it earlier to 1800 and the spread of industrialization (Beniger, 1986), to 1700 and the dissemination and organization of the knowledge arising from of the scientific revolution (Headrick, 2000), or trace it through two and half millennia from the shift from oral to written communication through the development of printing to the growth of computer networks (Hobart & Schiffman, 1998).

The chronology of such early dating is largely an artifact of the availability of archeological data because our records of ancient civilizations are based on the remnants that happen to survive the destructive influences of their local environment. The highly active biological processes of Africa destroy evidence of human civilization very rapidly. The dry desert climate of the Middle East has preserved sufficient cuneiform inscribed clay tablets from Mesopotamia (Neugebauer, Sachs, & Götze, 1945; Nissen, Damerow, & Englund, 1993; Robson, 2008; Swerdlow, 1999) for us to recognize a numerate and literate intellectual culture predating that of the Greek enlightenment by more than a millennium (Bottéro, Herrenschmidt, & Vernant, 2000). Such tablets record astronomical and financial records, forecasts of harvests, mathematical and geometrical constructions, military engineering and strategy, and a range of other information processes paralleling those for which we use computers today.

Prior to Mesopotamian civilisations there are tantalizing glimpses of the information processes of previous ancient civilizations through artifacts such as bone carvings (d'Errico et al., 2003) and cave paintings (Lewis-Williams, 2002) that are relics of cultures many millennia ago that found it useful to record information for purposes that we do not yet understand and may never know. What we do know is that for most of our history, our evolution paralleled that of other animal species, but at some time in the past 100,000 years humans evolved to capture and communicate information symbolically to an extent that gradually came to differentiate us from other species.

These analyses suggest that we should view the acquisition, recording and communication of information as fundamental to, and characteristic of human civilization, and focus on the ways in which different advances in technology have supported these processes in different eras. In particular, there may be scope for modeling and understanding the social impact of new technology in terms of that of previous technologies, including experience from ancient civilizations that may appear very remote from our own.

Our technologies have co-evolved with our species (Basalla, 1988) but at a far more rapid rate. In contrast, the human condition and human interests have changed very little over the millennia and it can be argued that their analysis provides a better foundation for technological forecasting than does the dynamics of the rapid evolution of the technologies themselves (Gaines, 2013; Gilfillan, 1937).

The Computer Age

The terms 'computer age' and 'digital age' are often used almost interchangeably with 'information age,' but reference specific technologies subject to more precise analysis and dating. If we deconstruct the notion of *computer age*, while we can recognize a continuous evolution of computational technology through the ages (Williams, 1985), the *electronic stored-program digital computer* of today was an innovation of the intensive computer development to support military needs in the 1940-45 war (Goldstine, 1972). It was assimilated post-war to the product ranges of companies that were already major suppliers of electro-mechanical computing equipment (Cortada, 1993), but this was the natural evolution of 'business as usual' rather than significant social change. Similarly, the advent of interactive access through time-sharing in the 1960s changed the way in which computers were used and led to discussion of the *computer augmentation of human reasoning* (Sass & Wilkinson, 1965), but affected only a few scientific research communities.

The development of the silicon planar process in 1959 and ensuing development of integrated circuits including, in 1971, a complete central processor on a chip, increased the reliability and decreased the cost of computers to the extent that in the mid-1970s *personal computers* became affordable to hobbyists (Kidwell & Ceruzzi, 1994). The 1978 development of the interactive spreadsheet *Visicalc* (Grad, 2007; VisiCalc, 1984) on the Apple II made personal computers significant tools for business also, and computer technology began to diffuse into everyday life. The parallel development of *digital networking* through modems and phone lines supported communication between distant computers and their users, and the increasing use of chat, email, access to remote information sources, and, in the 1990s, the growth of the World Wide Web.

By the beginning of the millennium most of the infrastructure of the digital world as we know it today was in place, and use of, and dependence upon, networked personal computers had diffused into all areas of life. *E-banking* was common and companies such as *Amazon* and *Ebay* were already heavily engaged in *e-commerce*. *Google* was still in start-up phase, beginning to address issues of navigating the rapidly increasing volume of information available through the web but had not yet implemented its revenue generation through targeted advertising. Social networking through blogging (Stone, 2004) was in its early stages but *Facebook* and *Twitter* were still some years away.

So when did the 'computer age' commence: in the late 1940s with the advent of the first stored-program electronic digital computers; in the mid 1970s with the advent of the early personal computers; in the mid 1990s when ARPA commercialized the Internet and web traffic from many sectors of society began to dominate; in this millennium when smartphones and social media became ubiquitous? Or do we trace it back much earlier to Babylonian aids to accounting, Euclid's mechanical solutions to geometrical problems, the development of mechanical devices computing Ptolemy's model of the solar systems, Napier's development of his computational 'bones,' and so on?

What we see in practice is an evolutionary process of continual change in computing techniques with most innovations when tested in the market place failing to achieve widespread use, but a history that is biased to record the few successes that led to the widely used technologies today and gives a false impression of inexorable progress from milestone to milestone over the millennia.

The Convergent Evolution of Computer, Communication and Media Technologies

Hyperconnectivity is situated in the recent evolution of the information and computer ages, and reflects a new phase of *convergence* (Gaines, 1998; Yoffie, 1997) between computer, communication and media technologies. Advances in semiconductor technology did not only facilitate the development of computers, but also promoted other uses of electronics technology to support social processes such as telecommunications and mass media.

The telephone pre-dates the digital computer by some seventy years and had significant social impact (de Sola Pool, 1977), but not, for example, as much as the railways; no-one coined the term 'a telephone age' (Perry, 1977)[2]. However, in the 1990s microelectronics made possible the development of cellular phone services where small personal telephones that could be carried at all times were used to offer any place, any time access to the world-wide telecommunications network (Singleton, 1989, p.208). Electronic digital technology also supported improved access to, and quality of, mass media, and led to the convergence of processing, storage and presentation technologies for computer and media systems.

We are now in an era where computer, communication and media technologies have converged to the extent that distinctions between computers, telephones and televisions are ones of function rather than form. Multi-functional devices differing primarily in physical size are now used to support the wide range of different activities that previously required particular specialized technologies.

Hyperconnectivity is a significant by-product of this convergence, but we cannot understand it solely in technological terms. It is the functionality that is important, the affordances it offers for a wide variety of human psychological and social processes, the way in which it restructures the processes of the lifeworld but, to a large extent, leaves its underlying dynamics intact. It is only when we factor out the processes that have been fundamental to the human condition for all recorded time that we can perceive how they have been affected by their assimilation of new technology.

Martin's (1978) *Wired Society* in 1978 comes closest to predicting many aspects and impacts of our hyperconnected world: "the technology of communications is changing in ways which will have impact on the entire fabric of society in both developed and developing nations." Van Dijk's (2012) *Network Society* provides a comprehensive account of the socio-economic impact, and Castell's (1996) *Rise of the Network Society* and associated volumes situates the origins historically.

Winston (1986) has questioned any revolutionary impact of new media and characterized the 'information revolution' as hyperbole, noting that, "what is hyperbolised as a revolutionary train of events can be seen as a far more evolutionary and less transforming process" (Winston & Winston, 1998, p.1). In his analysis of the social impact of media evolution he proposes a "law of the suppression of radical potential… wherein general social constraints coalesce to limit the potential of the device radically to disrupt pre-existing social formations" (p.11), and provides detailed evidence of the phenomenon.

Piaget's (1975) notion of 'assimilation' in human learning nicely models the phenomena that Winston describes, the incorporation of some new technologies into the processes of the life-world that may radically change the way in which those processes are supported without necessarily significantly modifying the underlying human conditions that motivate those processes.

As information technologies have evolved, many have speculated on how they change our existing practices and industries. Some 40 years ago musing over the impact of early time-sharing systems (accessed through 10 cps, upper-case only ASR33 teleprinters!) I noted that:

> If fifty percent of the world's population are connected through terminals to one network, then the questions from one location may be answered not by access to an internal data-base but by routing them to users elsewhere—who better to answer a question on abstruse Chinese history than an abstruse Chinese historian. (Gaines, 1970)

Some 30 years ago in a review of the impact of the 'revolutionary' new Videotex (Sigel, 1980) and Viewdata (Fedida & Malik, 1979) systems on the printing industry I noted that:

> At one extreme we can see current videotex electronic publishing systems as poor simulations of books with limited characters per page, poor typography, restricted graphics, and high costs. At the other extreme we can see a future where computer and communication technology is advancing at such a rate that not just the printing and publishing industries but the very structure of society itself changes. (Gaines, 1982)

Some 20 years ago in an extensive review of multimedia technologies just prior to the commercialization of the web, I suggested:

> It is not unreasonable to compare what we see occurring on the net with the flowering of Greek culture in the Enlightenment and with that of European culture in the Renaissance. There is a new culture on the Internet which is no longer primarily technological but instead reflects a deep and unfolding relationship between human discourse and action, and its technological support. Widespread access to the Internet means also that the culture is not geographically located, and the nature of the human-computer interface also transcends many traditional divisions based on individual characteristics. It is by no means Utopian—the net reflects humanity and is being used in a wide variety of ways that reflect both the best and the worst of human traits. (Gaines, 1994b)

The technologies described in these articles from a few decades ago appear extremely primitive and antiquated relative to those of today, but their continuing development has led to the social impact that was projected. We do now have worldwide access to the social support and expertise of others, to the accumulated record of human knowledge, and to instrumentation that provides remote access to events locally and worldwide.

The transition to such hyperconnectivity is momentous and the resulting web of interconnected people and technologies may reasonably be classified with previous major advances in the connectivity of what the McNeill's (2003) characterize historically as the evolving *human web* of the flow of goods, people and information. However, the technologies of the human web have always been neutral to the good or evil of what they carry, and the massive rise in cybercrime shows that our new technologies also support "the worst of human traits." Our optimistic views of the benefits of information technology, which are echoed in some current articles on hyperconnectivity (Fredette, Marom, Steinert, & Witters, 2012), may have led us to be inadequately defensive about its potential for abuse.

The following sections provide some fundamental perspectives on the human condition and the dynamics of the lifeworld to provide a framework for understanding the way in which new technologies evolve and are assimilated into society.

PERSPECTIVES ON TECHNOLOGY AND THE HUMAN CONDITION

The human species has in common with other species its biological origins as living creatures with a limited life span whose survival requires an environment providing food, air, warmth and shelter. Obtaining resources for survival is the primary driver of human activity as it is for other animal species. Many species have developed collaborative social structures that are more efficient at jointly addressing basic needs than is possible for an individual or family group (Hoffecker, 2013; Lewisa, Wartzoka, & Heithaus, 2013). The human species has taken this strategy much further than any other species through the development of symbolic communication and elaborate social structures (Searle, 1998). Hyperconnectivity may be seen as technological support for these human strategies but it important to recognize the basic needs and processes that led to, and are supported by, language and sociality.

Evolutionary biology has made major advances in recent years, many of which have been critically dependent on parallel advances in information technology that have provided powerful new tools for all the sciences. The following sections provide biological, psychological, cultural and social perspectives on the human condition that are relevant to understand the role and impact of hyperconnectivity.

Systemic Perspectives on Evolution

Ayres (1994), a well-respected technological forecaster, wrote a remarkable book, *Information, Entropy and Progress: A New Evolutionary Paradigm*, that provides a coherent systemic model of physical, geological, biological, social, cultural, psychological and economic evolution, and, for example, models automobile manufacturing as an information process that creates a vehicle by imposing information on matter. He traces the growth of the human lifeworld back to the big bang and presents it as part of a continuous evolutionary process of structure formation in the physical universe.

Cybernetic/systemic models of such broad scope are fascinating and inspiring but perhaps too remote to have a direct impact on any of the diverse disciplines they encompass. However, in the past twenty years advances in molecular biology have made DNA sequencing technologies available to archeologists and anthropologists, and enabled information-flow models to be used to expose not just the systemic commonalities but also the mutual constraints coupling genetic, cultural and behavioral processes in living systems.

Oyama's (1985) *Ontogeny of Information* was the first such analysis to become widely influential through the *developmental systems theory* community. Jablonka and Lamb's (2005) *Evolution in Four Dimensions* provides a unified model of the transmission of variation between living systems encompassing genetic, epigenetic and behavioral sub-systems and their interactions.

The *extended synthesis* (Pigliucci & Müller, 2010) provided by these unified models provides a detailed account of how:

- *genomes* adapt to the environment through random mutation, encoding and propagating information that may enhance the fitness of future generations (Altenberg, 1995);
- *epigenetic processes* manage the expression of particular capabilities encoded in the genome 'library' to more rapidly propagate adaptations to major environmental change (Harper, 2005);
- *behavioral adaptations* are propagated through reinforcement and mimicry, both intrinsically and through pedagogy (Thornton & Raihani, 2010);
- *symbolic representations* of the information involved in all these processes may be used to facilitate them, amplify their effect, and enable them to be widely diffused through both space and time (Noble & Davidson, 1996).

The study of epigenetic processes is relatively recent and represents the recognition of biochemical mechanisms underlying Lamarckian transmission of adaptations effected during a parenting organism's lifetime (Gissis & Jablonka, 2011).

The communication of information between all levels and partitions of living systems provides a common framework for biological symbiosis, psychological foundations of socio-cultural systems and, through the symbolic signaling system of *money* (Ganβmann, 1988; Singh, 2001), for economic models of those systems. Hyperconnectivity is the current state of the art of technological support for the diverse communication processes involved.

Evolution of the Human Species

Our species, *homo sapiens sapiens*, diverged from *homo erectus* some 500,000 years ago, from *homo sapiens neanderthalis* some 300,000 years ago, developed some form of language some 50,000 years ago, was reduced by environmental catastrophe to a population of some 3,000 in Africa some 50,000 years ago, expanded worldwide through migration commencing in the Levant, and developed agriculture and social infrastructures some 10,000 years ago, commencing the Neolithic era of modern humanity. The details are contested in a massive research literature, but the overall framework is widely accepted (Endicott, Ho, & Stringer, 2010; Liu, Prugnolle, Manica, & Balloux, 2006; McBrearty & Brooks, 2000; Stringer, 2002).

For most of our history, genetic, epigenetic and behavioral processes dominated our evolution as they do in other animal species, but at some time in the past 100,000 years information came to be communicated and captured symbolically to an extent that gradually came to differentiate us from other species. The capability to capture and transmit the knowledge created by individuals and communities is generally taken in the archeological and anthropological literatures to be the major factor in the explosion of the human population—"humans became behaviourally modern when they could reliably transmit accumulated informational capital to the next generation, and transmit it with sufficient precision for innovations to be preserved and accumulated" (Sterelny, 2011, p.809).

The modern civilizations of our Neolithic era have been constituted through the co-evolution of social infrastructures, symbolic communication capabilities and knowledge recording technologies (Hatfield & Pittman, 2013). One long-standing puzzle about the evolution of social structures is that they generally involve *altruistic* behaviour in which an individual acts in a way beneficial to the survival of a community but adverse to its own survival. There are now a number of theories within an evolutionary framework that model the evolution of cooperation and altruism (Sterelny, Joyce, Calcott, & Fraser, 2013; Wilson, 2012) including the development of the associated emotions of shame and guilt, social mechanisms to penalize free-loaders, and explicit moral and ethical rationales for these phenomena (Bowles & Gintis, 2011; Boyd & Richerson, 2009).

The significance of this research for studies of hyperconnectivity is that they provide detailed models of how the norms of self-serving behaviour predicted by a simple evolutionary model become modified to those of socially acceptable behaviours. Those steeped in the associated cultures generally take this modification for granted and develop systems based on this assumption which may be inadequately defensive to those, even within their society, who do not.

Hyperconnectivity can exacerbate this problem by providing ready access to a society from those of other cultures where social norms may be very different. The literature on the evolution of social norms provides a wide ranging and balanced account of the variety of phenomena that may be expected, and a foundation for developing systems that are both socially acceptable and also robust against a wide range of contingencies.

Technology, Knowledge, Communications and Population Growth

Human population growth does not show a smooth progression over recorded history. There have been major die-offs due to climatic factors such as the ice ages, and diseases such as the Black Death (W. H. McNeill, 1989), but the overall trend has been hyper-exponential. Whereas the rate of unconstrained population growth in other species is proportional to the population size, and hence exponential, for the human species it is proportional to the square of the population, and hence hyper-exponential—until the 1960s when the population growth rate dramatically declined (Korotayev, 2005).

The additional multiplier is attributed to the generation and communication of technology/knowledge being proportional to the size of the population (Korotayev, 2005). In the Neolithic era there have been trends encouraging the generation and diffusion of technology/knowledge, such as the development of communities around population centres, which also increase the risk to life[3], for example, by facilitating the development and spread of disease (Cantor, 2001; W. H. McNeill, 1989) requiring the further development of technology/knowledge[4]. Thus, there are several interacting positive feedback loops involved in any model of the co-evolution of civilization, technology and population.

The communication of knowledge occurs through a heterogeneous and chaotic range of processes, including its appropriation through warfare. Gunpowder and firearms technology from China was disseminated to other countries through the Mongol conquests of the thirteenth century (Wikipedia, 2013), and the consequent studies of chemistry and metallurgy played a significant role in the industrial revolution (Kelly, 2004). The Arab conquest of Egypt and Syria in the seventh century provided access to Greek literature, and later Arab leaders collected Greek and Indian works systematically. The Arab conquest of Spain in the eighth century gave that country access to this literature and it became a centre for its translation into Latin and dissemination throughout Europe. The crusades accelerated this process by bringing the Arab conquests under European rule and treating the material in Arab libraries as spoils of war that provided the intellectual foundations for the Renaissance and the formation of the first universities.

Throughout recorded history there have been attempts to encourage and manage the communication of knowledge more peaceably, for example, through the recruitment of knowledgeable personnel from other civilizations, scholars visiting other communities, the exchange of copies of book between monastic and other libraries, the development of personal and national libraries, the development of centres of learning and teaching, and so on.

The earliest records of social systems being set up to manage the communication of knowledge are those of Mesopotamia some 5,000 years ago where postal systems were established to facilitate communications between the centre and outposts of the various empires (Casson, 1994, ch.13). Subsequent civilizations have each found the need for similar systems, and the resultant *correspondence networks* have played a major role in the management of commerce (Jardine, 1996, p.111) and the dissemination of knowledge (Gingras, 2010; Hatch, 1998). One significant extension was the development of scholarly journals as a means of open correspondence that traded the recognition of authorship of valuable knowledge for its dissemination to the world at large (Meadows, 1974; Vickery, 2000).

Technology began to play a significant role in the communication of knowledge with the invention of the printing press and moveable type that enabled large numbers of copies of printed material to be produced at a relatively low cost (Eisenstein, 1979). Technological support for real-time communication commenced with the development of electrical equipment in the eighteenth century and the telegraph system in the nineteenth century (Fahie, 1884). The telegraph system has been termed the *Victorian Internet* (Standage, 1998) and the history of some aspects of its usage is illuminating in terms of similar aspects of hyperconnectivity. For example when we read of marriages contracted by remote parties through Skype we might note that they were also conducted more than a century ago through the telegraph system, and that the prevention of fraud through telegraphy was a major issue, as was the use of encryption to ensure secrecy; people have long-standing motivations and repurpose new technologies to address them.

The breakdown in the long-standing relation between population and knowledge growth some fifty years ago raises interesting issues. Some technologies have led to significant social change by substantially increasing the productivity of human labour, for example the mechanization of agriculture greatly reduced the proportion of the population required to sustain food production, and the robotization of manufacturing industry is having a similar effect on the proportion required to manufacture products. It seems likely that hyperconnectivity may be playing this role in increasing the productivity of the service industries, including those whose focus is knowledge production (Kurzweil, 2005; Martin, 2000).

Quan-Haase and Wellman's (2006) study of the use of hyperconnectivity to improve internal coordination in a software engineering company provides an example of improving productivity in an industry notorious for projects being over-time and over-budget. It would be interesting to have similar studies of the communities responsible for major scientific projects such as the human and Neanderthal genome sequencing or the Higgs boson search to determine the role of hyperconnectivity in those activities.

FRAMEWORKS FOR MODELING HYPERCONNECTIVITY

The preceding sections have situated hyperconnectivity in the broad sweep of human and information technology evolution and their interplay. This section focuses on some specific frameworks within that broader context that are useful to modeling different aspects of hyperconnectivity and its social impact.

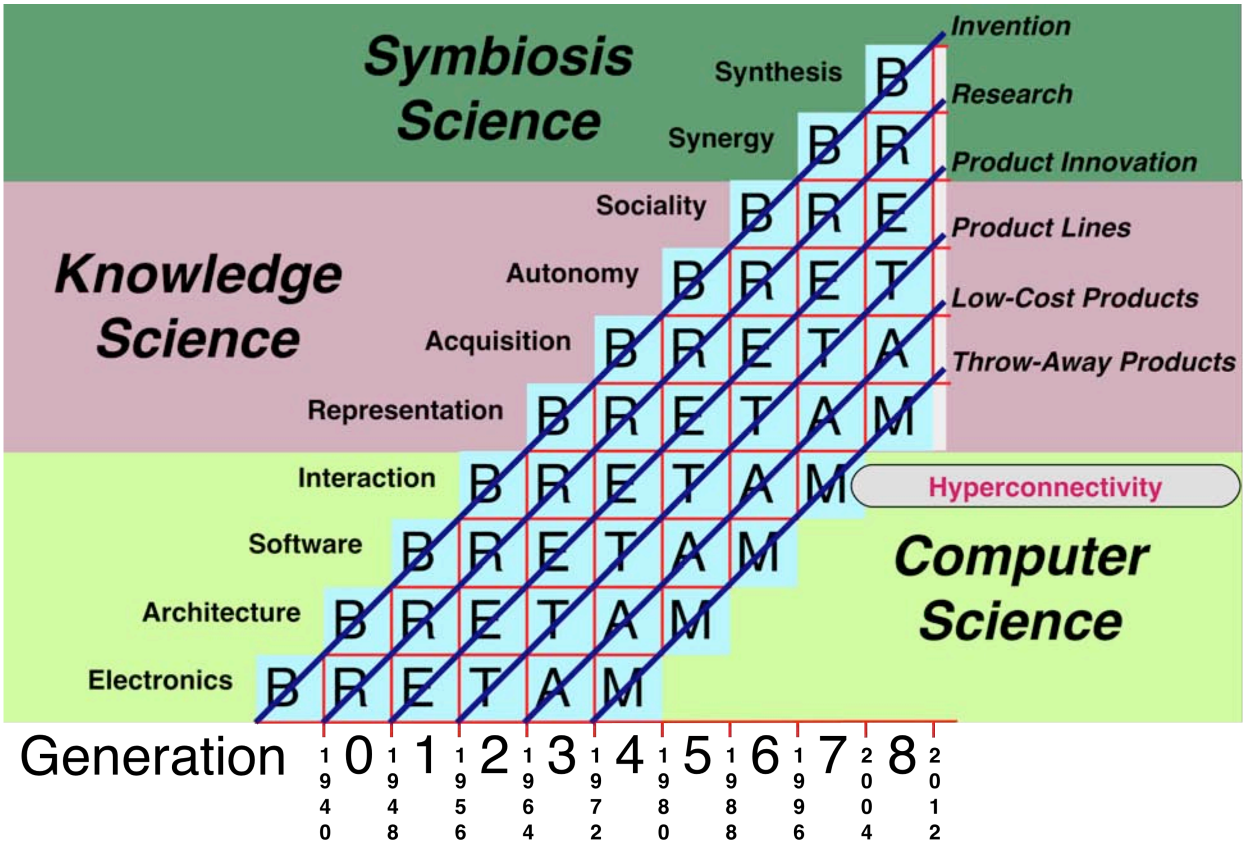
The Evolution of Information Technology

As already noted, new technologies evolve as part of the cultural evolution of the human species, and hyperconnectivity is an outcome of the convergence of three major innovations in technology: the development of digital computers in the 1940s; integrated circuits in the 1960s enabling computers to become low-cost, ubiquitous and of increasing capability; and digital cellular phone services in the 1990s enabling universal access to communication and computer services.

The sustained exponential growth of the number of devices on an integrated circuit chip (Mollick, 2006; Rupp & Selberherr, 2011) may be seen as the primary technological driver of convergence to low-cost, high-performance hyperconnectivity (Gaines, 1998). Exponential growth is common in many technologies, but never before by more than two orders of magnitude and then over timescales of the order of one hundred years rather than ten. Chip technology exhibits a doubling of capacity and a more than doubling of performance every two years, sustained over some fifty years, leading to the more than 10^9 devices on a chip today. This rapid sustained quantitative growth over five decades has triggered qualitative structural changes in the nature of the information sciences and their applications.

There is a simple phenomenological model of the evolution of technology as a logistic *learning curve* of knowledge acquisition (Marchetti, 1980). The logistic curve has been found to characterize the introduction of new knowledge, technology or product in which growth takes off slowly, begins to climb rapidly and then slows down as the innovation becomes assimilated. Such curves arise in many different disciplines such as education, ecology, economics, marketing and technological forecasting (Dujin, 1983; Stoneman, 1983).

It has also been noted in many disciplines that the qualitative phenomena during the growth of the logistic curve vary from stage to stage (Crane, 1972; De Mey, 1982; Gaines & Shaw, 1986). Figure 1 shows the latest version of a model of the tiered learning curves of information technologies originally developed in the early years of computers (Gaines, 1984; Gaines & Shaw, 1986) and extended through the years to model and project the evolving infrastructure of information technology (Gaines, 1991, 1998, 2013).



- Breakthrough: creative advance made
- Replication period: experience gained by mimicing breakthrough
- Empirical period: design rules formulated from experience
- Theoretical period: underlying theories formulated and tested
- Automation period: theories predict experience & generate rules
- Maturity: theories become assimilated and used routinely

Figure 1 Infrastructure of information technology

The underlying learning curve for each tier may be characterized by six phases:

1 The era before the learning curve takes off, when too little is known for planned progress, is that of the inventor having very little chance of success but continuing a search based on intuition and faith.

2 Sooner or later some inventor makes a breakthrough and very rapidly his or her work is replicated at research institutions worldwide.

3 The experience gained in this way leads to empirical design rules with very little foundation except previous successes and failures.

4 As enough empirical experience is gained it becomes possible to inductively model the basis of success and failure and develop theories. This transition from empiricism to theory corresponds to the maximum slope of the underlying logistic learning curve.

5 The theoretical models make it possible to automate the scientific data gathering and analysis and associated manufacturing processes.

6 Once automation has been put in place effort can focus on cost reduction and quality improvements in what has become a mature technology.

The tiers above the lowest level of electronics device technology have developed because the ultra-rapid growth in performance of the underlying technology facilitates applications that are so different in nature as to require new intellectual disciplines, each having its own learning curve. Ten tiers have been identified to date:

- the underlying digital electronics;
- its application in computer architectures;
- the programming of general-purpose computers through software;
- the development of computer-people and computer-computer interactivity;
- the representation of human knowledge;
- the acquisition of knowledge from interaction with the world, people and stored knowledge;
- the development of goal-directed autonomous knowledge creating processes;
- the increasing coupling of knowledge processing entities in social networks;
- the development of techniques to facilitate the synergy between human and computer processes;
- the synthesis of both into unified systems.

One may characterize the lowest four tiers as constituting *computer science*; of the next four as *knowledge science* (Gaines, 1986, 2000); and project those above to constitute a currently developing *symbiosis science* (Bradshaw, 2013; Gaines, 2013).

There is strong positive feedback between the levels. Advances in the tiers below support increased performance in the tiers above, and innovations in the tiers above support improved processes in the tiers below—computers are used in computer-aided design of electronic devices, networked communities collaborate in the design of software and the sharing of knowledge, and so on.

Empirically, from an analysis of the history of the computing and the information sciences, one may identify the time-scale of each phase, each *computer generation*, as 8 years. After the initial phase of invention, *research* is associated with the replication phase, *product innovation* with the empirical phase, *product lines* with the theory phase, *low-cost products* with the automation phase, and *ultra-low cost, throw-away products* with the maturity phase. This generates the diagonal trajectories shown where each tier of the hierarchy has its own research, development and product cycle.

The throw-away product trajectory is particularly interesting because it corresponds to technologies becoming so low in cost that they are essentially free, either literally so, or consumables purchased routinely with little budget impact. Web browsers have long been freeware as has access to much information through the Internet. Even major hardware items with significant manufacturing costs can follow this trajectory, for example, computers, displays, printers and cell phones[5].

From a technological perspective hyperconnectivity is the extension of the maturity phase of the interaction tier where the ultra low costs of connectivity between people, between computers, and between people and computers, has made such connectivity ubiquitous and universally available. From a technological forecasting perspective, what we may expect is increasing effectiveness in such connectivity where interfaces that we currently take for granted are either optimized or discarded in favour of much more effective ones.

In order to attempt to plan or forecast future developments one needs to go back to basics and examine what is being communicated and what is the most natural and effective way of doing so. For example, at the lower levels of the technology supporting hyperconnectivity, keyboards are a relic of bygone mechanical typewriting technologies that have become an impediment to the communication of ideas. Speech provides a faster, more natural mode of input but requires improved transcription to text for storage, indexing and retrieval. In the long-term brain instrumentation may provide direct access to the ideas that generated the speech (Cochrane, 2012)[6], but there will probably be a tortuous path of innovations *en route*. Similarly, displays are a form of electronic paper on which computers provide a visual image that would be more portably accessed through spectacles but will eventually be replaced by direct input to the optic nerve or brain (Ghezzi et al., 2011). The driving force for such technological change will be the human desire to remain connected to all relevant people, media and systems at all times in all situations, that is, to be fully and effectively hyperconnected.

Continuing innovation at the levels above interaction is essential to the further development of hyperconnectivity. For example, speech and handwriting recognition are critically dependent on advances in the knowledge level technologies. Hyperconnectivity is itself a critical technology to the emergent *brain-computer symbiosis* technologies (Schalk, 2008) where new organizational structures are emerging based on the close integration of human and computer capabilities to an extent that may herald a singularity in the evolution of human civilizations (Kurzweil, 2005).

Technology and the Human Condition

As already noted, the technology to support human needs has evolved very rapidly, particularly since the scientific revolution and in the information age, but the fundamental needs themselves have changed little over the millennia. One can better understand the social impact of new technology by focusing on the needs that the technology might address, and forecast the likely future development of the technology by considering how it might better satisfy those needs.

A useful perspective from which to analyze the impact of technology on the human condition is that of Maslow's (1971) *hierarchy of human need*s which provides a pragmatic, systemic classification of the dynamics of human motivations and priorities. The logic of his hierarchy is that upper level needs are of low priority until lower level ones are satisfied. We need to satisfy *basic biological needs* for sustenance, warmth and shelter before we are concerned with safety needs for protection from environmental hazards, and predators, and only when we are safe are we concerned with social needs such as belonging, esteem and realization of our own potentials. Too rigid an interpretation of the hierarchical relations is subject to debate (Lederer, 1980) but Maslow’s taxonomy provides a useful classification of our basic needs and the social, and technological, infrastructures that support them.

Figure 2 is the most recent variation of a model developed to analyze issues of trust in technology in the early years of computing (Gaines, 1987). The first two columns show Maslow's hierarchy of needs together with those social systems that have evolved to support the satisfaction of those needs. The next two columns show the beneficial and adverse impacts of technology on these processes, and the final column shows some of the impacts of information technology.

Hyperconnectivity is a significant component of information technology at all levels of the final column, providing the same technical functionality but having qualitatively varying social impacts as it addresses different forms of need.

For example, the two lowest levels involve primarily connection to the *Internet of Things* (Floerkemeier, Langheinrich, Fleisch, Mattern, & Sarma, 2008; Uckelmann, Harrison, & Michahelles, 2011). Hyperconnectivity supports engagement with, and management of, the physical world, such as domestic appliances (Brown et al., 2013), remote access to security cameras, empowering the disabled (Domingo, 2012), healthcare (Turcu & Turcu, 2013), safety monitoring in mines (Niu, Zhu, Du, Yang, & Xu, 2012), cyber warfare (Carr, 2012), and so on.

The middle two levels involve primarily the needs to belong to social groups and to build social capital. Hyperconnectivity supports these through a range of social media involving self-disclosure (Chen, 2012), grooming and gossip (Tufekci, 2008), scholarly discussion (Veletsianos, 2012), customer support (Gallaugher, 2010), marketing (Orsburn, 2012), and so on.

The top two levels involve the needs to realize one’s full individual potential and to go beyond that to comprehend, and transcend the bounds of the cultures that have both supported and constrained one’s lifeworld. Hyperconnectivity supports these by providing access to other cultures including mediated experience of their functioning, access to tools that support participation in creative communities world wide, and so on.

Needs hierarchy	Socio-economic infrastructure supporting needs	Beneficial impact of technology	Adverse impact of technology	Impact of Information technology
Transcendence	Moving beyond and subsuming mental, cultural, social and physical "realities"	Increased access to a variety of cultures & experience	Destruction of non-technological cultures	Extension of imagination, intuition, creativity
Self-actualization	Realizing personal potential; facing life as it is; aesthetics; peak experiences	Increasing availability of time for personal development	Alienation from a de-humanized society	Tools in the hands of individuals to give new perspectives
Esteem	Role in family, work and community; other recognized achievements	Extension of individual capabilities	Deskilling of respected job roles & achievements	Tools in the hands of individuals to perform role better
Belonging	Family, work, religion, politics, entertainment	Tele- & physical communications, mass media	Undermining of logic underlying family structure, job displacement	Communication, community, distraction, overload
Safety	Social norms; police, military, medical, insurance	Tele- & physical communications, arms control, robots in risk jobs	High risks & impact of technological disaster, pollution, biotech accidents	Command & control, crisis management, cybercrime
Biological needs	Agriculture, energy, housing, ecology, finance, physical communications	Automation, higher productivity, clean processes & energy production	Over-population, pollution, environmental destruction	Monitoring, planning, control, management

Figure 2 Role of technology in the hierarchy of human needs

Technology and the Worlds of Human Experience

Maslow's hierarchy focuses on the basic needs that motivate human action rather than the means by which they are addressed[7]. A more general framework for analyzing the roles of technological, social and knowledge resources as systems that have evolved to satisfy human needs is provided by Popper's (1974) ontology of conceptual *worlds*:-

- *World 1:* the physical universe;
- *World 2:* the cognitive and communication processes of individual and organizational agents;
- *World 3:* the knowledge created as a by-product of World 2 processes and captured symbolically to exist independently of its originators.

Maslow's hierarchy may be viewed as an ontology of needs within Popper's ontology of worlds.

In the early years of computers, Popper's notion of World 3 was used to model our expectations of the digitization of human knowledge to make it more actively available, of what became the current World Wide Web of documents, journals, books, audio and video recordings, datasets, and so on (Gaines, 1978). The ontology has also proved valuable in modeling person-computer interaction (Gaines, 1988) and organizational knowledge processes (Gaines, 2003). Nowadays hyperconnectivity technologies are also supporting the human communication processes of World 2, and mediated interaction with World 1.

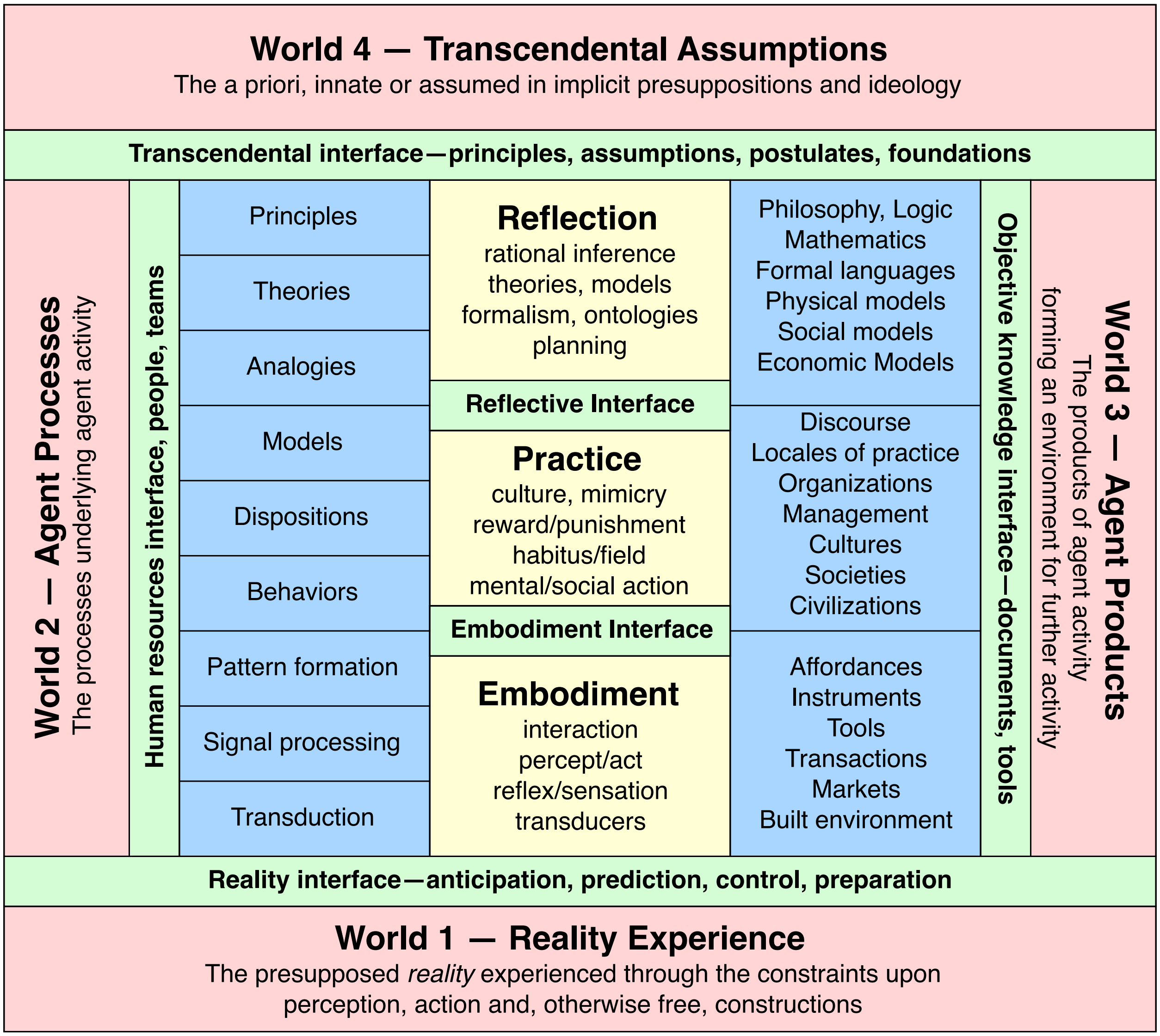


Figure 3 Ontological structure of the worlds of human experience

Figure 3 shows an extension of Popper's three worlds model to model the ontological structure of human experience which was originally developed to explain aspects of organizational knowledge processes (Gaines, 2003). It illustrates how human activities are unified across conceptual worlds, and adds an explicit *World 4* to capture the tacit assumptions presupposed in our models of each of the other worlds. Recognition of the existence of such presuppositions is important, that our world models are intrinsically biased and incomplete, and that any conclusions we draw from them involve assumptions of which we may be unaware.

The central region presents a three-layer model of human agents and their supporting infrastructures, whether roles, people, groups, organizations or societies. At the bottom are the subconscious processes of interaction with the environment, of percepts, acts, reflexes, sensation, transducers, and so on. At the top are the symbolic processes of reason, of rationality, reflection, planning and so on. In the middle are the tacit processes of practice (Wenger, 1998), of culture (Hall, 1959), habitus (Bourdieu, 1990) and field (Searle, 1998) characterizing mental and social, action, mimicry, reward and punishment.

The recognition that human agents, whether individual, organizational or societal, may, in many respects, by modeled in the same way suggests that we:

> adopt a collective stance to humanity and see it as a single organism, a neural network that is distributed in time and space by recursive partitioning into parts similar to the whole. The parts into which the human organism is recursively partitioned include societies, organizations, groups, individuals, roles, and neurological functions. Many concepts that apply to individuals may be applied to social systems without recourse to metaphor or analogy for systemically they are the same. (Gaines, 1994a, p.45)

This approach to modeling collectivities is now well developed in a variety of literatures and disciplines, such as the evolution of cooperation towards a *global brain* (Bloom, 2000), a *superorganism* (Kesebir, 2012), a *collective intelligence* (Lévy, 1997), and so on. In the economic literature, *transaction cost economics* (Pitelis, 1993) provides a rationale for the formation organizations in that the cost of a transaction within a collectivity having common goals and mutual trust is lower than that between unrelated entities; it has been applied to modeling the development of social capital on social network sites (Richter, Riemer, & Brocke, 2010). The collective intelligence model has also been applied in the management literature to the improvement of team performance (Fisher & Fisher, 1998), and the Quan-Haase and Wellman (2006) study provides empirical data on the role of hyperconnectivity in supporting collective intelligence.

There is not only a convergence of technologies leading to hyperconnectivity but also a convergence of the domains to which we are hyperconnected. This is important because needs at one level may be supported activities at another, for example the satisfaction of basic biological needs may be substantially enhanced by innovation in theories, and the development of those theories may be substantially enhanced through the development of new transducers providing better quality data.

We can factor hyperconnectivity as supporting:-

intra-world communication in World 1, for example, the integrated robotic production line of closely coupled machines, city-wide integrated traffic control systems;

intra-world communication in World 2, for example, the networked organization, whether it be commercial, governmental, military, terrorist, political or hobbyist;

intra-world communication in World 3, for example, the Google search engine (Langville & Meyer, 2006), the IBM Watson question answerer (Ferrucci et al., 2010); grid computing for bioinformatics (Talbi & Zomaya, 2008) and the SETI network (Shuch, 2011);

inter-world communication, for example, between World 3 and World 1 such as automated data collection and event detection in the Hubble telescope and Higgs Boson projects, or between World 2 and World 1 when one checks an array of traffic webcams to see if there are problems along routes one might take, or between World 2 and World 3 when one initiates a bot search of digital libraries for a particular configuration of ideas;

unified-world communication, where in future one will distinguish between the worlds less and less as one becomes more and more a part of hyperconnected networks of things, people and knowledge, playing a variety of roles in different cultures and projects.

By their very nature the tacit presuppositions of World 4 present obvious problems of analysis and support. However, crowdsourcing (Howe, 2008) multiple forms of material reflecting different cultures provides resources for tracing conflicts in assertions to possible differences in underlying assumptions that are not explicit and of which the originators may be unaware. As Derrida (1988) has emphasized, one can never break out of the box of all presuppositions but hyperconnectivity to many sources and cultures may make it easier to move from one box to another and develop new perspectives that make apparent innovative solutions to significant problems.

Thus hyperconnectivity extends beyond the support of collective intelligence through the improvement of interpersonal communications. It binds Popper's diverse conceptual worlds together in a way that has never previously been possible or imagined. It facilitates the emergence of a unified world of the virtual and the real, of agents and artifacts, where many of the distinctions we have made in the past are no longer appropriate and new ones need to be made.

FUTURE RESEARCH DIRECTIONS

One may distinguish two broadly defined directions for future research on hyperconnectivity, one concerned with the technology and the other with the social impact.

The technology is primarily that of the *interaction level* of Figure 1 that encompasses human-human, human-computer, computer-computer, and computer-world interfaces. There are strong pressures to improve the brain-computer interface and remove mechanical devices that impede high-bandwidth communication.

As the brain-computer interface develops the psychological problems of information overload, managing the focus of attention, keeping track of multiple tasks, backtracking to previous states, and so on will require continuing research on the nature of these psycho-neural processes and their effective support. The *ambient commons* (McCullough, 2013) will evolve from the physical to include the virtual with decreasing distinction between them, the demands on human attention will increase, and the support for the meta-cognitive management of the interface will become critical.

Fortunately, while the evolution of information technology is rapid, it is intrinsically limited by the rate at which it can be assimilated by people and economically controlled by its utility to society. The *net generation* (Tapscott, 2009) has already made major adaptations in many aspects of their lives and modes of functioning to accommodate advances in information technology.

There is well-justified concern that that these adaptations encourage browsing with shorter attention spans rather than in-depth reflection (Schuurman, 2012). However, these are trends that have long been part of the human response to information overload (Blair, 2010), and may be seen as necessary to take advantage of a hyperconnected world. Information overload, its consequences, its management and technological support for that management, will continue to be a central topic for hyperconnectivity research (Eppler & Mengis, 2004).

Dependent upon purpose, background knowledge and personal inclinations, what is information overload for one person may well be a highly desired rich environment for another. Development of an extensive and exemplified taxonomy of hyperconnectivity applications is one important research task, as are empirical studies of those applications.

Characterizing those who will function well in various forms of hyperconnected world is another significant area of research. The major differences in human personality that reflect individual reactions to stimulation, such as introversion-extraversion, have been well-studied (Cain, 2012; Kagan, 2010), and have *prima facie* relevance to reactions to different forms of hyperconnectivity.

Personality variables have been related to the use, and non-use, of social media (Baker & White, 2011; Yanru, Dion Hoe-Lian, Ilangovan, Shengnan, & Xiaotian, 2012), as have rationales for usage (Bertolotti, 2011; Tufekci, 2008; Yanru, et al., 2012). There are also other typologies that may have relevance to the usage of hyperconnectivity, such as Holland's (1996) for vocational guidance, and it would be interesting to have research studies involving these also.

The negative aspects of hyperconnectivity, and the means to defend against them will continue to be a major and growing area of research. Cybercrime is the latest manifestation of a long-term side effect of the evolution of human culture. A review of culture and the evolution of human cooperation notes:

> Honest, low-cost communication provides many benefits—coordination is greatly facilitated, resources can be used more efficiently, hazards avoided; the list is long. However, once individuals come to rely on the signals of others, the door is open for liars, flim-flam artists and all the rest. (Boyd & Richerson, 2009, p. 3283)

Dishonest communication may be the result of ineptitude or laziness rather than deliberate misrepresentation, for example, citations that are erroneous in scholarly documents may be plagiarized by other scholars without checking, propagate widely and be such that checking multiple, apparently independent, sources does not make the error apparent (Simkin & Roychowdhury, 2012). Published materials may be made available to others in good faith but may be erroneous or otherwise of low quality (Porcello & Hsi, 2013). However, whether deliberate or accidental, the propagation of false information undermines the integrity of a hyperconnected world and the research on improving the management of access to dubious quality material will require continuing effort and innovation.

A starting point for any analysis of cybercrime should be that crime/warfare, the acquisition of resources by stealing them or taking them by force, is a normal, rational and expected mode of human behaviour in evolutionary biology (Boyd & Richerson, 2009) and socio-economic modeling (Snooks, 1996). A major research issue in those disciplines is to explain the evolution of human cooperation, of honest, trustworthy, supportive interaction.

The explanation is generally in terms of the evolution of social norms relating to the 'three Rs': reputation, reciprocation and retribution:

> If cheaters are despised by others in their group, and, as a consequence, suffer social costs—lose status, mating opportunities, the benefits of mutual aid when ill or injured—then they may be motivated to cooperate, even though prosocial motivations are entirely absent from their psychology. (Boyd & Richerson, 2009, p.3283)

Support of these norms in hyperconnected worlds will be a continuing research topic (Ahonen & Wright, 2008; Clark, Paige, Polack, & Brooke, 2006), both for those who wish to sustain the norms and those who wish to violate them. For example, reputation, or social capital, is established through a track-record of valuable, trustworthy service to others, but its value depends on correct identification of the reputable agent (Al-Karkhi, Al-Yasiri, & Linge, 2012; Seigneur & Jensen, 2005). Hence, technology needs to provide reliable means to enable agents to establish the identities of other agents.

The 'three Rs' of reputation, reciprocation and retribution do not in themselves necessarily result in useful behaviour but can stabilize *any* pattern of behaviour within a group. institution or society (Boyd & Richerson, 2009). This can lead to some very unusual cultures (Henrich, Heine, & Norenzayan, 2010)[8].

Defensive provision of connectivity within a culture needs to take account of the norms of that culture, and support of that between cultures needs to be very much more defensive. Continuing cross-disciplinary research is on hyperconnectivity that is both effective and safe needs to take into account parallel research on the evolutionary dynamics of cultures.

CONCLUSIONS

As a technology, hyperconnectivity is the outcome of the last decade of convergence of communication, media and computer technologies in the mature phase of their development where their extremely low cost makes them universally available.

As a social phenomenon, hyperconnectivity is the latest stage in the evolution of human connectivity that has been a core necessity of the development of human civilizations for at least five thousand years.

The technologies of hyperconnectivity are evolving rapidly in a way that is difficult to forecast although one may expect impediments to effective communication to be increasingly bypassed with an eventual target of direct brain-to-brain and brain-to-computer interaction.

The human needs motivating human strategies requiring connectivity have changed little over recorded history, and the social impact and issues of hyperconnectivity can be best understood in terms of those needs and strategies.

The human species is unique in having evolved systems for symbolic communication and storage that have enabled much larger social units than the family group to develop and function in a stable fashion that gives advantage to the individuals forming the group and sustains the group itself beyond the lifetimes of particular individuals.

The natural basis of social behaviour in all animal species is a competitive and adversarial, although some degree of cooperative behaviour has evolved between those in family groups in some species.

Honest, trustworthy, supportive interaction within a group is enforced and reinforced through the social norms of the group, notably reputation, reciprocation and retribution.

Groups are generally part of a hierarchy of larger groupings which themselves have social norms intended to result in honest, trustworthy, and supportive interaction, but these norms generally become weaker as one moves up the hierarchy.

The central role of hyperconnectivity in human communication with others, computers, stored knowledge, and the mediated physical world, implies that these social issues will play a major part in the assimilation of the technology in society.

Hyperconnectivity is playing a major role in increasing the productivity of increasingly knowledge-based societies, but it also introduces equally major risks of abuse that can undermine the functioning of those societies.

Defense against those risks is already a major consideration in the development and application of the technology, and this concern will become pivotal in the evolution of the technology and its applications.

NOTES

1. McLuhan’s (McLuhan & Powers, 1989) *tetrad model* of the impact of new media provides a generic framework for the analysis of all major socio-technical change, that something is *gained*, something *lost*, something that had been lost is *regained*, and the outcomes may *reverse* into something unexpected and possibly negative in terms of the original motivation for the innovation. These notions may be used to analyze the social impact to any significant technical or organizational change, and the value of doing so is generally in the process of trying to think in these terms rather than the product of having done so.

2. In this age of ready access to the digital archives that resemble Borges’ (1944) *Biblioteca de Babel* where every combination of words occurs, it is dangerous to state that a term has never been coined—the trade journal *Telegraph Age* founded in 1883 was renamed *Telegraph and Telephone Age* in 1909. It is also noteworthy that, while the term ‘railway age’ is still in common usage (Hylton, 2007) the term ‘road age’ is uncommon even though the development of roads had as much, or greater, social impact than that of railways (Hindley, 1972). There seems to be no consistent basis for the choice to mark a particular era with the term ‘age’ or ‘revolution.’

3. In our era the environmental side effects of excessive population growth and world wide industrialization pose the greatest risks to the survival of the human species (Ehrlich & Ehrlich, 2013).

4. Wojciechowski (2001) models the growth of knowledge as process whereby more knowledge must be continuously created to combat the adverse side-effects of the application of prior knowledge. He develops twenty-five laws of knowledge, for example:

- Law 1: The number and variety of causes of stress are proportional to the amount of knowledge.
- Law 2: The perception of the complexity of the consequences of knowledge is proportional to the development of knowledge.
- Law 6: Humans’ ability to determine the development of humanity is proportional to their knowledge.
- Law 10: The need for communication is proportional to the size of a society, the number of groups within the society, and the amount of knowledge available.

Law 19: The development of a society is proportional to its storage and use of information.

Law 25: The capacity to do good or evil is proportional to knowledge.

Such considerations suggest that the evolution of human capabilities leading to the growth of knowledge is not intrinsically a 'survival trait.' Bickerton (1990) notes that one possible outcome of the power of intelligence is species destruction.

5. For example when I needed a new toner and toner drum for my high-speed, high-resolution, duplex laser printer I found that the cost of these was $280 but the cost of a new printer that included them was $150. The printer itself had become a throw-away item whose cost had essentially become negative.

6. Neurological interfaces have become a major focus of research (Ghezzi, et al., 2011; Kotov et al., 2009) and the primitive *chip in the head* is already with us (Schalk, 2008) and becoming a valuable aid to the severely disabled (Ohl & Scheich, 2007).

7. A socio-economic perspective on the general strategies adopted to satisfy these needs is provided in Snooks' (1996, 1998) monumental series of books on the *laws of history*. He identifies the major strategies through which societies acquire resources as *family multiplication*, *conquest*, *commerce* and *technology*. He models of the cycles of strategies adopted in ancient and modern civilizations and enables one to trace through the ages the social, communication and knowledge processes involved that support medicine, warfare, commerce and science/technology.

8 Hofstede's (1983) extensive studies of the differences between national cultures, and studies deriving from them (Kirkman, Lowe, & Gibson, 2006), also provide useful insights into cultural similarities and differences but are primarily targeted on organizational management issues.

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ADDITIONAL READING SECTION

This chapter has been very wide ranging, and suggestions for reading obviously depend on what aspects of presentation are interesting to a reader and relevant to her or his area of research. Note that the term ‘hyperconnectivity’ rarely appears in book or journal titles as yet. Related literature may be found under terms such as ‘ubiquitous computing,’ ‘ubicomp,’ ‘pervasive computing,’ ‘ambient computing’ and similar terms. The journal *Cyberpsychology, Behavior, and Social Networking* is an excellent entry point for research on the psychology and sociology of hyperconnectivity.

One major argument of this chapter may be summarized by the statement from Ecclesiastes that there is nothing new under the sun. In particular, that human nature has changed little over the millennia of recorded history, that any new technology will be purposed, or repurposed, to address long-standing human needs, and that much of the trajectory of technological evolution can be best forecast on that basis. Reading about *Daily Life in Ancient Mesopotamia* (Nemet-Nejat, 1998), its literature, sciences, recreations, music, plays, religion, postal services, and so on, can be very persuasive that humanity 5,000 years ago was very similar to humanity today.

Another aspect of that argument is that technological forecasting is possible based on projecting expected technological advances against continuing human needs, noting, as Wojciechowski (2001) emphasizes, that an evolving aspect of those needs is to address adverse side effects of past technological advances. Martin’s (1978) *Wired Society* is a surprisingly accurate account of the impact of hyperconnectivity from 35 years ago, and also makes it very worthwhile to read his more recent work, *Alien Intelligence* (Martin, 2000), that projects the role of artificial intelligence as one of complementing human intelligence rather than emulating or replacing it. Kurzweil’s (2005) *The Singularity is Near*, may then be seen as projecting a significant change in the way that humanity functions that is consistent with Martin’s projections.

The fundamental problem with technological forecasting, that one may project based on human needs and available or expected technologies but one is rarely correct in guessing what technology will satisfy a major need, is best seen from the science fiction literature. Asimov has Multivac having superhuman intelligence but communicating its conclusions through punched cards. Doc Smith has space technology evolving rapidly beyond any current bounds but knowledge bases stored on magnetic tape. Of current writers, Asaro comes closest to projecting a plausible technological future with direct neural connectivity and faster-than-light communication, and Gibson most convincingly portrays the organizational hegemonies and criminal infrastructures of future (current?) cyberspace.

The McNeill's (2003) study of the evolution of the *Human Web* throughout recorded history provides a long-term background for the significance of connectivity and its evolution to hyperconnectivity as detailed in Van Dijk's (2012) *Network Society*.

Books that examine the social impact of the early technologies that are foundational to hyperconnectivity, such as electricity (Marvin, 1988) and its application to telegraphy (Standage, 1998) can provide very helpful perspectives on analogous social phenomena today.

The more specialist topics covered in this chapter, such as cybercrime, trust, authentication, and the relevance of cultural evolution studies, each have their own citations intended to be entry points to the relevant literature.

The cited publications by the chapter author are available at http://cpsc.ucalgary.ca/~gaines/reports.