Treading Data

Staying Afloat in a Sea of Information

Richard Yonck

Information. Our world is swimming in it. With each passing day, our lives become more dependent on it. Yet, the very magnitude of this torrent of data directly impacts how beneficial it is to us.

Newspapers. Magazines. Telephones. Radio. Television. The Internet. E-mail. Virtual Communities. Search engines. Smartphones. Blogs. Facebook. Twitter. The amount of data our world generates is expanding rapidly, and the rate of growth is rising. What's more, there's no sign it's going to let up anytime soon.

When it comes to information, many of us think we can't get enough of it. Unfortunately, given the tools we have now, we're going to find it increasingly difficult to use information well. The distracting, the erroneous, the inconsequential—all of it is encroaching on our lives to an ever greater degree. The signal is being incrementally drowned out by the noise.

Of course, with information as with so many things in life, more may not necessarily be better. Can we make do with less of it? Is it possible to come up with better ways to reduce the flow, or perhaps even turn it off? Is it in our interest to do so? How we address the issues surrounding the information explosion and the overload that accompanies it will directly impact how we develop

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our society and technologies in the future.

Mind and Body

The desire for information is rooted deep within us, evolved into our genes. Essentially an outgrowth of food foraging behavior, information foraging provides similar neurological payoffs. In a now famous 2009 study on monkeys, Ethan Bromberg-Martin and Okihide Hikosaka demonstrated that dopamine neurons treat information as a reward. In other words, looking for and finding information makes us feel good.

Unfortunately, this also means the act of seeking and collecting information can lead to compulsive behavior. If you doubt this, consider how often you or someone you know habitually checks e-mail or a Facebook account or turns to a search engine for the merest scrap of information. The behavior reinforces itself and makes us want to do it again.

At the same time, the sheer volume of information available to us makes us inclined to seek breadth of knowledge rather than depth. We delve into a task or subject just a bit before we're drawn away to something else. Our attention is continually being pulled toward a different target than the one we're currently semi-focused on. In the end, it's a little like being at a smorgasbord buffet: There are so many dishes, we can't properly savor any single one of them.

It's a conundrum. Faced with so many stimuli vying for our time and attention, we attempt to always be on, always part to the dataflow, as if by some sort of magic, this will make us more efficient, more connected. Technology theorist Linda Stone has coined a phrase for this: *continuous partial attention.* According to Stone, "With continuous partial attention, you're motivated by a desire to be a live node on the network. You want to be connected, busy, in demand. That's what makes us feel alive in this day and age. We want to scan for opportunities, to be in touch with the best opportunity, the best activity or the best people at any given time and at the heart of it is, we don't want to miss anything."

As a result, we're more inclined to merely skim the surface, forgoing the wealth of knowledge and insight that could come if we'd only allow ourselves to go deeper. But in truth, knowledge isn't just about taking information in. It's about savoring it, digesting it, letting it roll around inside of us, allowing it to bring forth new work and new ideas. By adopting this less-focused behavior, we're forgoing the rumination, the follow-through that gives all this information its full meaning and value.

All this information and the technologies that accompany it have led to an ongoing dialogue about the pros and cons of our advances. Nicholas Carr, for instance, has written at length about the impact the Internet is having on our thinking. In his most recent book, *The Shallows,* Carr argues that information technology is changing our brains, making us less focused, less capable of deep thought. Others, such as technology writer Clay Shirky, futurist Jamais Cascio, and cognitive scientist Steven Pinker, have acknowledged that, while we are changing in response to all of our progress, these are patterns that have occurred throughout human history. Time and again, we've adjusted our ways of thinking in response to our technological advances. As man the toolmaker, we've used our devices to change the world, and in turn they've changed us.

There's no denying that the relentless inundation of information that encroaches on our consciousness severely hampers our ability to concentrate. Interruptions and distractions abound, invading our mind, making focused thought far more difficult. A study by Microsoft Research found that, following even a minor interruption, it typically takes us 15 minutes to fully refocus on the subject at hand. The study's authors reported that they were "surprised by how easily people were distracted and how long it took them to get back to the task."

Already, video, music, e-mail, and the rest of the Internet are regularly vying for our attention, instantly delivered courtesy of our computers and smartphones. These data tethers have the potential to keep us up to date with more information than we can possibly digest, much less make full use of. Soon, these will be enhanced with augmented reality—data overlays updating us with even more information about our immediate environment. Not too many years beyond that, we can expect to have these overlays directly superimposed onto our vision, possibly through the use of virtual retinal displays or active contact lenses. Beyond that, brain–computer interfaces (BCIs) will eventually provide even more direct access to information. The potential for data overload is quite literally mind numbing.

The Coming Deluge

Data grows exponentially. According to market research and analysis firm IDC, the world's digital output is doubling every one and a half years. In 2010, they expect the world to create and replicate a record 1.2 *zettabytes* of data. That's over a trillion billion bytes, or a stack of DVDs reaching to the Moon and back. By 2020, IDC expects this number to grow to 35 zettabytes, or enough DVDs to reach halfway to Mars. But there are reasons to believe this estimate may fall woefully short.

Right now, data only *seems* to be everywhere, but in the near future it really will be. High-speed wireless technologies such as 4G, LTE, and beyond will soon enable us to access information from almost any location at speeds approaching those of wired networks. At the same time, devices that generate that data will increasingly be distributed throughout our environment. Embedded networked processors and *smart dust*—sensor networks made up of billions, even trillions, of nodes—will be everywhere, providing real-time data streams about everything, all the time.

One example of this is HP's Central Nervous System for the Earth (CeNSE). Still in early development, CeNSE would distribute as many as a trillion inexpensive networked sensors throughout the environment. These minute devices would continuously gather and relay information about everything from the structural integrity of bridges to the flow rates of waterways to the presence of pathogens in the air. The amount of information such a network could produce would be vast indeed.

Lifelogging is another development that could exacerbate our data problem. As cameras, recording devices, and storage media continue to shrink, the ability to record every instant of our lives becomes not only feasible, but possibly even appealing. Used in conjunction with intelligent search methods, lifelogging could provide us with the equivalent of near total recall. Where was I on the night of the thirteenth? What was the name of that associate I met for a few seconds five years ago? And perhaps most importantly, where did I leave those darn keys? These kinds of questions could become trivial using such a system, but the storage and data processing involved would not.

Gordon Bell, formerly of DEC, now works for Microsoft Research, where he is the subject of the MyLifeBits lifelogging project. In his recent book, *Total Recall,* he writes, "E-memory will become vital to our episodic memory. As you live your life, your personal devices will capture whatever you decide to record. Bio-memories fade, vanish, merge, and mutate with time, but your digital memories are unchanging." Such technology will bring with it many benefits as well as many unintended consequences, not the least of which will be an explosion of additional digital information.

New fields such as biotechnology will also contribute to the problem. The Human Genome Project generated many terabytes of data. This was a lot of expensive storage at the time. But this quantity pales compared with what will be produced by the biotech studies of proteomics, metabalomics, and bioinformatics. The data that this research will create will likely need new strategies for dealing with extremely large datasets.

Then there's the sheer volume of *metadata* that will be created by computers. The examination of primary data—whether it's Web links or cell-phone habits or demographic voting habits—yields a tremendous amount of secondary or derivative information. Analysis of smartphone records can generate information about traffic flow and population movement. Tweets and search-engine queries can contribute data for analysis in epidemiological studies of infectious diseases. As each set of data is recombined and reanalyzed, it generates still more data.

This brings us to the Semantic Web. Conceived by Tim Berners-Lee, the father of the World Wide Web, the Semantic Web aims to take information that is currently only machine readable and make it machine *understandable.*

"The Semantic Web is not a separate Web but an extension of the current one, in which information is given well-defined meaning, better enabling computers and people to work in cooperation," Berners-Lee and co-authors wrote in a 2001 *Scientific American* article. "In the near future, these developments will usher in significant new functionality as machines become much better able to process and 'understand' the data that they merely display at present."

If this vision is fully realized, it will greatly boost the intelligence that computers can bring to data manipulation. This would likely have the effect of generating tremendous amounts of new data, as existing information is analyzed and recombined in ways we've never even thought of—all at the speed of our fastest computers.

Body area networks (BANs) will also be a source of new information. A set of wearable or implanted sensors that monitor body functions, these BANs would keep us and our health-care providers apprised of our well-being with continuous data streams. As sensor costs plummet, such monitoring holds the potential to drastically reduce health costs by alerting us at the earliest stages of an illness. But while such devices may have considerable benefit, they also threaten to add greatly to the world's data load.

Under this onslaught of information, how will we function, much less use these resources effectively? A number of developing technologies may hold the key to managing our data-rich future.

Filtering

There will be an ever-growing number of ways for us to channel information to ourselves, whether it's about the world around us, our personal lives, or the workings of our own bodies. At the same time, businesses, marketers, pollsters, prospective employees and employers, and many others will all be vying for our attention. So it will be necessary for us to develop new ways of filtering and blocking unwanted information, allowing through only those data streams we consider important or of interest. A current-day counterpart would be the "ad-zapper" used in digital video recorders. This feature allows users to circumvent the commercials that checkerboard the television schedule. Similarly, ads, banners, and other commercial efforts might be filtered out by software that's able to distinguish it from relevant content.

Of course, such devices run counter to the intentions of the marketers and sponsors. So corporations will be spending millions of dollars to develop ways to disable, handicap, or circumvent such features. Still other companies will see this as an opportunity to gather more information about our habits. In some ways, knowing what you don't want to see is almost as valuable as what you will allow through. Such data can provide demographic insight that allows advertisers to modify their approaches for specific target audiences.

So, in many ways, the battle for our attention will be a technological escalation between media and viewer. Just as viruses lead to better virus filters, which then drive the development of still craftier viruses, this will create its own sort of arms race. Over time, the methods used by both sides will become increasingly intelligent and capable of self-adaptation. This sort of evolution would probably lead to some very strange and unexpected approaches to gaining our attention. Regulation will only be able to go so far in quelling this and will no doubt be opposed by many sectors and factions.

How We'll Cope

All this brave new data will result in many changes. We'll adjust our behavior and habits just as we always have when confronted with technological paradigm shifts. We'll also create new technologies to deal with various issues and concerns.

Adaptive Approaches

Changing our own behaviors in how we handle information is at once the easiest and most difficult of the options. On the one hand, we can decide for ourselves how and when we want to do certain activities, whether it's checking e-mail or surfing the Web or watching TV. We can even choose to opt out entirely, cutting off all but the most basic forms of communication. On the other hand, such habits are often very difficult to break for the same reasons they can lead to compulsive behavior. And while there may be certain benefits to going completely "cold turkey," such a decision could find the user increasingly cut off and at a disadvantage in society.

Despite the possible difficulties involved, setting aside regular time each day to shut down the information flow can definitely yield benefits. Such a hiatus creates time to absorb, digest, and reflect on what's been learned. Taken even further, incorporating regular meditation into one's schedule can help to diminish the negative physiological and psychological effects of information overload. It can also contribute to further insight, as can REM sleep. But such methods can only take us so far, especially when the volume of data in our world continues to escalate.

Existing Technologies

A number of possible strategies for dealing with information overload can be found within existing technologies. As these technologies mature and are imbued with more intelligence, they'll go a long way toward helping us manage all the information we'll be dealing with in our daily lives.

For instance, various software can already be used to direct, consolidate, and filter information, channeling only what is useful and relevant to our attention. Writer and educator Howard Rheingold has coined the term *infotention* to describe the "tools we all need to find our way online today, a mind–machine combination of brain-powered attention skills with computer-powered information filters." Starting with "dashboards" that aggregate information streams such as RSS feeds, he applies "radars and filters" to update, sort, and further tune the data. Such strategies offer a logical starting point for better managing our information diet.

Another approach involves repackaging information, condensing and distilling it into its salient points. Converting raw data into charts and graphs is probably the most common example of this. When we look at a stock chart, we see daily open, high, low and close prices presented in a form that is considerably easier to absorb than if we were just looking at a spreadsheet of numbers.

Some of the best examples of distilling complex information into graphics have been explored by statistician and professor emeritus Edward Tufte, author of a number of books on data visualization. Tufte encourages the use of data-rich illustrations in which every data point has value while conveying trends and patterns when viewed as a whole. Tufte writes, "Of all the methods for analyzing and communicating statistical information, well-designed data graphics are usually the simplest and at the same time the most powerful." While in many ways as much an art form as a technical discipline, the development of automated data visualization techniques could go a long way to helping us readily absorb large, rich data sets.

Other developing visualization trends include the animation of data elements. These progressions can readily convey changes through time. Treemaps are another recent development, which maximize the amount of information that can be presented on the screen. This technique arranges hierarchical information into a set of nested rectangles and is well suited for displaying information about large data sets. Though they don't allow for precise comparisons of values, they're well suited for identifying predominant trends. Node-link visualizations are another method that is useful for consolidating information about our increasingly interconnected world. Such visualizations can be an excellent means of displaying complex relationships of linked entities, such as in social networks.

Fields like visual analytics seek to advance analytical reasoning by using computers to amplify human cognitive capabilities. These use visual interactive interfaces that allow for the close coupling of human and machine analysis. Visual analytics tools can be used to help make sense of very complex data. For instance, the U.S. National Visualization and Analytics Center develops tools and technology for the purpose of identifying and assessing terrorist threats from wide-ranging and disparate sets of information.

Natural language processing of unstructured data has long been an objective in the field of information retrieval. A good example of this is IBM's DeepQA Project, better known as Watson, which captured the public imagination earlier this year on the popular quiz show, *Jeopardy.* According to IBM, "Watson is an application of advanced Natural Language Processing, Information Retrieval, Knowledge Representation and Reasoning, and Machine Learning technologies to the field of open-domain question answering." As this already impressive technology matures, it will find applications in many fields, including health care, business analytics, and as personal assistants.

A very different approach to processing and improving the way we access information can be found in the knowledge engine Wolfram|Alpha. The brainchild of Stephen Wolfram, the eponymously named program computes answers to queries based on structured data. Rather than returning lists of documents as does Google, Wolfram|Alpha consolidates the information into relevant answers and visualizations. According to the project's mission statement, "Wolfram|Alpha's long-term goal is to make all systematic knowledge immediately computable and accessible to everyone." While this may strike some as an extremely lofty objective, no one can accuse the creator of Mathematica and author of *A New Kind of Science* of ever thinking small, his work in particle physics notwithstanding. Wolfram has stated that Wolfram|Alpha's processing of structured data is very different from the way DeepQA works with unstructured data. He's also suggested that if there is ever a Watson 2.0, it could benefit from integrating the Wolfram|Alpha API.

Developing Technologies

The data overload we're experiencing is the direct product of the information technologies of the twentieth and twenty-first centuries. As media, communications, and computing have developed and matured, they've increased our daily data diet manifold. But just as our technologies have created the problem, they're likely to be our best hope for developing ways to deal with it. Though such assistance will no doubt take many forms, one thing most of them will have in common is improved intelligence, which will make them increasingly transparent and intuitive to use.

As mentioned earlier, the Semantic Web has considerable potential to aid us in managing our information, even as it promotes the generation of still more data. Using well-defined standards and tools, the Semantic Web alters the relationship between data and machine. It gives data *meaning*. Currently, computers treat most information on the Web merely as strings of letters and numbers, so that "The quick brown fox" has about as much meaning as "Sgd pthbj aqnvm enw," at least at the machine level. But with the Semantic Web, "quick," "brown," and "fox" are all formally represented concepts with defined relationships to other concepts. The ontologies that define these concepts establish meaning that can be understood by our computers. With these improvements, our computers will be able to readily compile information from a range of sources without human oversight and consolidate it into a format that best suits our needs. As information comes to be better structured and defined, all sorts of new ways of working with it will become possible.

Once the Semantic Web is widespread, one category of software that should develop rapidly are intelligent agents. These machine assistants are programs that will be able to perform routine tasks for us, whether it's making appointments, locating supplies, handling inquiries, or planning a vacation. Over time, these agents will become increasingly intelligent, capable of learning our individual preferences. Eventually, they'll become so good that they'll almost be able to mirror our own thought processes. At some point, these "virtual selves" might even be able to go into the world (or at least virtual worlds) as autonomous avatars, our representatives in the world-at-large. As technology advances further, it may become possible to reintegrate these virtual selves, acquiring their experiences with such fidelity that it would seem like we'd been there ourselves. Such tools could go a long way toward helping us deal with a world swimming in information.

New Interfaces

The development of new interfaces will change not only how we think about and visualize information, but also how we work with it. New large-scale multitouch screens and gesture interfaces already allow us to work with virtual 3-D models in ways that are far more like manipulating objects in the real world and therefore much more intuitive. As these develop further, *Minority Report*–like interfaces will give us the means to work with large amounts of complex information quickly and with ease.

Three-dimensional displays are another tool that will allow us to pull much more information from visual displays. Currently, these use special glasses, but high-quality 3-D displays that don't require glasses will be available later this decade. This will allow for the use of complex spatial relationships in visualizing information.

Augmented Reality

Augmented reality applications are already available for our smartphones and are developing rapidly. Nevertheless, they are still very much in their infancy. Augmented reality superimposes digital information and artifacts over maps and real-life images to convey additional information to the user. The combination of features available in today's smartphones—mobility, camera, display, GPS, compass, accelerometer—make them the medium of choice for these applications. Already, augmented reality apps can direct you to a nearby bus stop or tube station, recommend a local restaurant, or act as a travel guide. In coming years, more-sophisticated applications will provide virtual devices and dashboards in mid-air, personalized, contextual datafeeds, and advertising customized to our individual preferences. While this technology will be responsible for still more information finding its way to us, it will also play a major role in compressing and consolidating information that will be almost instantly available for our needs.

Human Augmentation

Transforming our tools will only go so far in helping us keep our heads above the rising sea of data. In order to stay afloat, we may eventually find it necessary to transform ourselves. Such augmentation, generally called *cognitive enhancement,* will probably follow a number of parallel paths.

- **Pharmacological.** Caffeine and other stimulants have long been used to help us focus on tasks. More recently, pharmaceuticals have been used for similar purposes. Adderall, Modafinil, and Ritalin are used frequently as productivity enhancers, particularly by college students. But there's a lot of anecdotal evidence indicating that, while some abilities such as focus are improved, other functions related to creativity can suffer. Additionally, these drugs can be addictive and increase the potential for psychosis over time. Since this usage is off-label—meaning it isn't what they were actually developed or prescribed for—it seems likely that improved versions may be possible, hopefully with fewer side effects. Other categories, such as vasodilators—e.g., gingko biloba—claim to improve brain function by delivering more blood and oxygen to the brain. Here again are potential avenues for improving brain function.

True smart drugs, or *nootropics*, hold significant potential to improve learning and retention. Current research aimed at helping Alzheimer's and dementia patients may eventually lead to drugs that have other uses, such as learning augmentation. *Ampakines*, for instance, are a new class of compounds that improve attention span and alertness as well as facilitating learning and memory. Ampakines have been studied by the Defense Advanced Research Projects Agency (DARPA) for use by the military.

- **Genetic/Biotechnology.** Many genetic studies are being done to identify therapeutic strategies that promote neuroplasticity—the formation of new neural structures in the brain—and improve learning ability. A study at the European Neuroscience Institute published in 2010 found that memory and learning ability of elderly mice was restored to youthful levels when a cluster of genes was activated through the introduction of a single enzyme.

A number of stem-cell research studies offer hope not only for degenerative mental pathologies but also for restoring our ability to learn rapidly. In a 2009 study, older mice predisposed to develop the plaques associated with Alzheimer's were treated with neural stem cells. These cells stimulated an enhancement of hippocampal synaptic density, which resulted in better performance on memory tests a month after receiving the cells. (The hippocampus is a region of the brain that plays important roles in long-term memory and spatial navigation. It is one of the first regions to suffer damage from Alzheimer's.)

Another recent study of mice exposed to the natural soil bacterium *Mycobacterium vaccae* found their learning rate and retention greatly improved. It's been speculated that this was due to their brains' immune response to the bacterium. As we learn more about the chemical and genetic processes our brains use in acquiring knowledge, it should eventually become possible to enhance them in very targeted ways.

- **Brain–Computer Interfaces.** The possibility and potential for brain–computer interfaces (BCIs) cannot be overlooked. While still some way off, the continuing and accelerating progression of technology may one day allow us to offload a small or large portion of our memory and processing to machines. To some, this may seem far-fetched, but there is already considerable research taking place in this and related fields. Today, there are already interfaces that give quadriplegics and people with locked-in syndrome the ability to control computers and operate wheelchairs. There are even headsets available that allow users to operate computer games, all through the power of thought. Though one day we will no doubt look back on these as primitive devices, they do offer a glimpse of what may become commonplace.

The information-management potential of an advanced BCI would be significant. We might have the ability to generate separate threads that take care of several tasks at once, transforming us into true multitaskers. We could gather information on a subject from a broad range of sources and have it condensed into just the format we needed. We could draw on immense external computer resources to rapidly resolve a problem that might take months for a team of present-day experts. We could learn at the speed of thought, only the speed of thought would be many orders of magnitude faster than it is today.

There are people, such as futurist Jamais Cascio, who believe we will forgo BCI in favor of one of the other forms of cognitive enhancement, and he may be correct. The problem of being lumbered with last year's BCI model as these technologies continue to develop could well dissuade many potential augmenters. But this presumes that the BCIs of tomorrow will be as permanently fixed as the computer hardware of yesteryear. Due to just this sort of concern, the neural equivalent of a firmware upgrade may be devised. Or nanotechnology may offer a means for "rewiring" the interface in a straightforward manner as new advances are made. It's far too early to say for sure, but the possibilities should and will continue to be explored.

Intelligence Escalation

Rapidly increasing amounts of data, improvements in technology, and augmentation of our own mental processes, combined with competitive pressures, are already creating a positive feedback loop. This is producing additional incentives for generating more information, leading to more and better technology to work with it, giving us further motivation to make ourselves even more capable of accessing and utilizing it. The result of such a cycle will be an escalation of intelligence, both in our technology and ourselves. Like so many technological trends, this one could potentially accelerate and continue up to the point when limiting factors bring it to a halt. But because improved intelligence would give us better tools for discovering and creating new ways to manipulate the primary physical laws of the universe, this threshold may be a very distant one.

Some theorists have speculated that our computers will continue to shrink and improve until every particle of matter in a block of material could be utilized for computation. Quantum theorist Seth Lloyd has referred to this as the "ultimate laptop," and its upper bounds are defined by a pair of theorems. (The Margolus–Levitin theorem sets the fundamental limit on quantum computation, and the Bekenstein bound states the maximum information that can be stored in a finite region of space.) Such a device would be so calculation-intensive that a kilogram of it could perform 10^{51} calculations per second and store 10^{31} bits of data. This would be 10^{33} times faster than today's fastest supercomputer. (That's a billion trillion trillion times faster.) Moore's law asserts that computer performance doubles every one and a half to two years. If this trend were maintained—and that's a *big* if—then this upper limit could be reached sometime in a little over two centuries.

Conclusion

What would we do with so much computer processing power, so much data, and presumably so much intelligence? Would we spend our days pondering the remaining mysteries of the universe? Or would we become a world of navel-gazers, tweeting and friending at the speed of thought (or whatever it is we'll be doing with Web 327.0)? In all likelihood, it will be something in between, something that will seem utterly fantastic to the us of today and quite mundane to the us of tomorrow. We may even still be arguing about how some new technology is going to render us less focused, less capable, or less human than our forebears—just as we always have when confronted with new information technologies.

In the face of all this, only one thing seems certain: Whether we're swimming in the shallows or diving to the deepest depths, in the future we'll be working hard trying to stay afloat in a sea of information.

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