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Accessibility to digital technology: Virtual barriers, real opportunities

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ABSTRACT

The potential of digital technology to assist persons with disabilities has always been known. The capabilities of digital devices have been improving so impressively for so long, that the assumption that in parallel the same is happening with accessibility is common. Unfortunately, accessibility for persons with disabilities is neither certain nor constant, and in fact, a conscious and systemic effort is required to ensure that the potential of digital technologies for inclusion is realized.

Digital accessibility is best understood as a chain of dependencies where training, hardware, software, content, and standards must work together harmoniously, and each of these elements must be understood as a dynamic process. For example, smartphones can be incompatible with hearing aids required by the deaf, touch screens too sensitive for those with motor impairments, and web pages often lack the text labels needed by screen reading software used by the blind. Even if each of these examples is fixed, the accessibility may be short lived if the production process behind that hardware or software was not corrected, as the digital world is constantly being updated. Training, hardware design, software development, content production, and standards definition processes, must be pursued taking accessibility and affordability into account.

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Introduction

Accessibility to digital technology is often seen as a technical challenge. This of course, is not an unreasonable perspective, but it is hopelessly simplistic for stakeholders interested in meaningful improvements to the existing situation. Even calling the current state of digital accessibility a "situation" is inadequate, as evidence demonstrates accessibility to be intricately tied to technological cycles. Accessibility is therefore better thought of as an on-going and dynamic process rather than a state.

Looking at technology as a process, we will describe what digital, physical, legal, economic, and social structures make-up the environment where we need accessible design. The digital equivalent of architectural standards for ramps, walls, and steps, are technical standards, involving both software and hardware choices. Finally, a process being shaped by physical and virtual structures involves trade-offs, with inevitable social, economic, and technical consequences. These trade-offs are codified into patents, copyright, and consumer protection laws, and these in turn are shaped by the values of our societies.

Our attention to the processes, structures, and values, that most closely affect accessibility, stems from an understanding that the effectiveness and longevity of any initiative to improve this human right, will naturally greatly depend on our skill at taking these factors into account.

Cycles – constantly changing, intermittently accessible

The potential of electronic technologies to offer new opportunities for persons with disabilities has been recognized since the early days of digital computers.(HLisaStevens, 2008) In addition to the capabilities of this technology, its extremely rapid development in the last few decades has motivated much excitement in the general public. Yet, this accelerated rate of change is not inherently positive for those with disabilities.

For example, among persons who are blind, access to computer interfaces was not possible for many years when mainframes and minicomputers were dominant. In fact, access to these machines became possible just as microcomputers, or personal computers (PCs), started taking the technological and market lead (Cooke, 2004). Personal computers, in turn, remained partially accessible for many years, just as their importance and widespread use was growing exponentially (Goodrich, 1984) Yet again, as blind-access to PCs was at last becoming routine, the emergence of graphical user interfaces (GUIs), on those same devices rendered the latest software unusable in the early 1990s (Times, 1991).

History continues to rhyme in the twenty-first century as graphical interfaces have become much more blind-friendly over time and the accessibility challenge has moved from the local computer desktop to the web (Isaak, 2000). As the web evolved from static to interactive pages, and now, fully web-based applications, digital barriers are once again being built and are belatedly and inconsistently been torn down (Gould et al., 2014, 2015).

Of course, platforms can be hardware or software-based and so can the barriers that emerge with each new technological generation. Although the web remains a key digital environment for persons with disabilities, opportunities and barriers are no longer restricted to computer operating systems, applications, and web pages. The early years of the twenty

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first century brought with it personal digital assistants (PDAs), smartphones, and tablets, with their own operating systems, applications, and virtual environments, as well as devices such as smartwatches and virtual reality headsets, with their own novel interfaces (G3ICT., 2015). In addition to links, buttons, forms, and images with inadequate labeling, there are now touch screens and other physical controls which can be unusable for older persons or for someone with a motor impairment (Rahman & Sprigle, 1997); video streams without captioning for the deaf; three-dimensional simulations with insufficient auditory information for those who are blind (White et al., 2008); and interfaces which are usually too complex or inflexible for persons with intellectual disabilities (Borg et al., 2014; Sevilla et al., 2007).

For these and many other reasons, although the rate and quality of technological change has become a tired cliche in international conference presentations, these factors remain central to the challenge of achieving and sustaining digital accessibility for persons with disabilities. Instead of considering closely the specific characteristics of existing and emerging digital barriers in any given platform, such as smartphones or online services, the optimal approach might be to analyze the major elements or factors which are present in all of them. In fact, it is perhaps best to understand digital accessibility not as a state, but as a constantly changing interactive process, similar, in spirit, to the concept of disability being the result of the interaction between individuals and their physical and cultural environment, different mainly in the speed and frequency of change in the various environmental factors (Layton, 2012).

Different scale, same pattern

While the history of digital technology provides us with periodic cycles with gain and loss of accessibility, the pattern can also be observed at the much smaller level of specific projects and services.

There are many examples of operating systems, software applications, and web sites, which have had their inaccessible problems fixed, only to then become inaccessible again once a new version or online campaign is launched or another update takes place (Sánchez-Gordón & Moreno, 2014). Although "regressions," i.e. the accidental reintroduction of software problems, is a common enough challenge in the software industry, this is not the phenomenon being described. The more common pattern when it comes to accessibility, is that corrections are made, but the production process itself is not improved. As a consequence, as soon as external accessibility consultants or an especially knowledgeable developer leave and an update is required, old and new accessibility problems are recreated (Cooper et al., 2012).

In other words, fixing the result is a largely wasted effort, if the software production process itself, is not improved to include accessibility in the same way that it includes usability, security, and other key criteria. In fact, to the extent that accessibility is used to rethink qualitatively every aspect of the design and production process, it can improve the overall user experience for everyone (Microsoft, 2010).

Structures – practical software and hardware requirements

Just like a wheelchair user depends on his or her skill, physical strength, wheelchair characteristics, sidewalk and public transportation conditions, and the behavior of others, to experience a more or less accessible commute to work; a computer user who is blind or deaf will also depend of factors such as: attitude and skill at using the operating system (Scherer et al., 2005), screen reader, and application; the quality of each of these technologies; the file format or communication protocol in use by the application; and certain characteristics of the content being accessed. As with the wheelchair example, variations with any link in this virtual chain of dependencies can render the overall experience anywhere from disabling to wonderfully empowering.

Too often, even in circumstances where this chain of dependencies is mostly working as it should, persons with disabilities still encounter many obstacles. For example, a person who is blind might hear most of the text and links of a web page, but then encounter buttons and images without labels. In such situations the screen reading software on the computer, tablet, or smartphone, will say generic words such as "image," "link," or "button," which is almost entirely useless. Other obstacles can be more subtle, including pages with hundreds of links or dozens of paragraphs, but without properly defined titles and subtitles, forcing the user to read it from beginning to end, instead of quickly focusing on the most relevant sections, as a sighted person would (Fukuda et al., 2005).

In turn, even when there are no operating system or application problems, a person who is deaf might be excluded from online presentations if no captioning or sign language interpretation is provided. Content which is prerecorded can also be inaccessible if no transcript is available, and at times, even computer or smartphone notifications, such as error messages or updates, can be inaccessible if there is too much reliance on purely auditory indicators and no visual or physical indicators (Pascual et al., 2015). Then again, these factors might be properly designed and implemented and the experience can still be inaccessible, depending on entirely physical elements.

For persons who are deaf or hard of hearing and who require interoperability between hearing aid and telephones, there have been both digital and physical standards which had to work together to ensure accessibility (FDA, 2020). Earlier this century, the functionality of near-field magnetic induction (NFMI) (Galster, 2010), used for coupling via hearing aid telecoils, was very helpful in improving audio quality for users of hearing aids, but the hardware requirements were not consistently implemented by telephone manufacturers. Fortunately, the Bluetooth wireless standard is replacing this arrangement with a more consistent and reliable digital bridge between phones and hearing aids (Yanz, 2005). However, while this replacement of telecoils with Bluetooth capabilities has been beneficial for those who are deaf, this improvement cannot be seen as inevitable. In the absence of a conscious adoption of accessibility as a requirement,

market forces and technical change may or may not enable equal access for those with disabilities.[1]

The chain of dependencies described earlier, where an accessible experience depends on every link in that chain (from user training to application design and content formatting), can be divided much more finely in its technical links. The importance of some of these links is well understood by technical experts, and since there is a clear technical hierarchy, where general-purpose technologies are the foundation for progressively more specialized higher-level software, it makes sense to think of these as visually analogus to layers; and so our analogy moves from links to layers (Lessig, 2009).

Layered by design

Conceptually, the analogy of layers in the way information is transmitted on the Internet can also be applied to the written word. Letters, numbers, and symbols can be thought of as the lowest, i.e. most fundamental layers, while words, sentences, or books can be thought of as higher level protocols or standards. On the Internet this concept has equivalency in how fundamental low-level protocols like TCP/IP, are the building blocks for SMTP, better known as electronic mail, or HTTP, also known as the web.

Communication protocols are not the only type of standard which is relevant for accessibility, but it is perhaps the easiest to understand. As the word "protocol" is used with regard to telecommunications and related technologies, is not significantly different in meaning to its use in international affairs. A protocol defines what is acceptable and even expected in human behavior in the context of diplomacy, and it does the same when it defines (in software and/or hardware terms) (Whitt, 2012), how digital devices can exchange information (Doctorow, 2020).

Two essential characteristics of the layered design of Internet and other digital technologies is that higher level protocols need access to at least one lower level protocol in order to work. In other words, one would not be able to use the protocol "postcard" or "book" to communicate, if the protocol "sentences" was not available. This is directly relevant to accessibility since some Internet protocols are closed, i.e. undocumented, encrypted, and/or patented (Sawetrattanasatian et al., 2019), restricting its use. Proprietary protocols or file formats, leave persons with disabilities entirely dependent on the willingness of the entity controlling the protocol in question, to make its interfaces accessible. This has not helped the cause of accessibility even in societies with good accessibility legislation (Blanck & Sandler, 2000).

Under the same general social and legal conditions, an open protocol such as that which is used for electronic mail, allows persons with disabilities the choice of switching to more accessible applications, as any individual or organization is free to develop software for open protocols and networks. Yet, while there is ample consensus on the importance of keeping the lower level protocols open, no such agreement prevails with regard to higher level ones, such as those for instant messaging. On a sidenote, a similar dynamic affects governments and their problems with information silos, but we will keep our focus on the private citizen (UNDP, 2007).

In the absence of accessible interfaces or open protocols, interoperability with other messaging applications or networks could still be achieved through what are usually called "gateways" or through "application programming interfaces" (APIs). These are alternative means for interacting with otherwise closed networks, but in the absence of clear legal requirements, these channels are not always available nor consistently maintained. Ultimately, the true obstacle is not a technical one, but the precision with which society translates its values into laws and the care with which it enforces them.

Values – balancing private and public interests

For years the adoption of digital features were optional in originally analog devices ranging from voice recorders to motorized wheelchairs. The advances integrated circuits and software brought were attractive, but rarely an actual requirement. However, the digitization of the world no longer means just feature-rich devices for use in our otherwise physical environments, but an increasingly digitalized world containing virtual spaces which seek to complement or entirely replace places such as the offices, libraries, or classrooms of the physical world.

The growing importance of digital or virtual spaces has been evident for many years now, but the 2020 Covid-19 pandemic has accelerated the adoption of these tools (Rosenblum, 2020). While matters related to Internet connectivity and the availability and level of adoption of computers and smartphones varies greatly across the world, the overall movement toward the digital realm has suddenly made web and other forms of digital accessibility absolutely crucial for the continued participation of persons with disabilities in a growing number of activities. Fortunately, these new challenges are not as novel as they seem, and plenty of legislation already takes into account information and communication technologies.

For example, Article 9 of the CRPD, specifically mentions the requirement of equal access to "information and communications technologies and systems" (UN, 2006). The right to accessibility is also stated in a variety of national laws and technical standards, of which the best known are the "Accessibility requirements suitable for public procurement of ICT products and services in Europe" (EN 301 549 (EU)) (Accessibility requirements suitable for public procurement of ict products and services in europe, n.d.), the ISO/IEC 40500:2012 [Web Content Accessibility Guidelines (WCAG) 2.0 (ISO, 2019), and Section 508 of the U.S. Rehabilitation Act (Section 508 of the rehabilitation act, n.d.). Yet, adoption of accessibility standards by law go far beyond the better known European and United States standards, including countries as varied as Australia, Canada, China, India, Israel, Japan, New Zealand, and the Republic of Korea (W3C., n.d.).

[1]Even though Facebook was launched in 2004 (Phillips, 2007), it only created an accessibility team in 2011 (Metz, 2015), after it had already become the Internet's most popular destination.

The challenge is of course that even though some accessibility legislation has been enacted more than two decades ago (Mueller, 2008), the evidence so far is that it has not been sufficiently effective. As was the case in previous technological cycles, each new technological platform starts becoming widely accessible only years after mainstream adoption, and even then, accessibility is suboptimal. Perhaps the time has come to consider more broadly, how each structure shaping the digital environments of persons with disabilities can be part of the solution. In fact, as a growing number of societies understand more clearly the importance and influence of Internet technologies in both public and private activities, it is natural to reassess and redesign the relevant structures so they are supportive of public policies.

Just as curb cuts make sidewalks significantly more accessible to persons with disabilities, and simultaneously friendlier to those without disabilities, modifications to accessibility, patent, and copyright law could also benefit everyone. Since the recognition of the importance of Internet technologies for information sharing, education, employment, and numerous other activities, is now gaining momentum; this time is propitious as a potentially new regulatory regime could also include accessibility as a core consideration.

Legal tools such as patent or copyright law are a widely accepted attempt at balancing private interests and public good by allowing a legal monopoly on the commercial exploitation of a product or technology, so as to reward the individual or entity which developed it. However, these legal monopolies take many forms and key sectors, like the pharmaceutical industry, operate under restrictions such as a time limit on their patents, to ensure that the public good is also well served. In this context, a different time period might be appropriate for the fast-moving information technology industry (Breyer, 1970).

Regardless of the specific changes adopted, the focus must remain on digital accessibility. An open standard is not helpful if interoperability with more accessible software applications is prevented through other means. Ultimately the fact that privately owned and controlled virtual spaces have now become essential infrastructure (Srinivasan, 2019), for communication, education, social interactions, work, and much more, must be acknowledged and managed. In fact, since property ownership rights are not absolute and these online services have become so important for societies, adjustments similar to those observed in the physical world, as it relates to essential infrastructure, are possible and desirable.

For example, a requirement such as interoperability (Riley, 2020), between messaging networks or social media platforms, can stimulate competition and potentially bring enormous benefits to both persons who have a disability and the general public. While those who have a disability gain the right to replace the default interface with whatever service or software client is most accessible, the general public also gains the opportunity to choose interfaces based on any number of factors, from pricing, privacy, or convenience, to usability, hardware compatibility, or efficiency. Beyond the more immediate benefits to end-users, the economic and societal benefits are potentially enormous, as even the largest platforms lose a great deal of their monopoly power and are forced to compete on whatever criteria users find important, stimulating innovation and discouraging rent-seeking behaviors.

Barriers to digital accessibility

Having described digital accessibility, or the lack thereof, as resulting from the interaction between factors such as end-user training, operating system, applications, assistive technology, file formats and communication protocols, as well as hardware standards, we must categorize these in a proper list of barriers. These classifications can of course be organized differently, but the essential conclusion is not the crucial role that any single factor plays, but that we cannot overlook any one of these major elements, without causing damage to the process of inclusion of persons with disabilities.

Awareness

While there is evidence of progress in a few wealthy societies, (Level Access, G3ict & IAAP, 2020) there is still limitted awareness of all the assistive technologies available, including those which are free. This is especially the case among populations for whom Internet access is limited or non-existant, or when they are inexperienced with online research. Moreover, technical literacy is often insufficient in general and not just with regard to assistive technology, which restricts effective self-guided learning.

Training

Too often persons with disabilities do not have access to guidance and assistive technology training (Newman et al., 2017), and occasionally, have access to training or information which is out of date or incomplete. Sometimes new technologies are launched with seemingly arbitrary changes in product or service design, increasing cost or requiring additional guidance and causing unnecessary confusion among persons with disabilities (Mason & Netz, 2002).

More broadly speaking, there is still great scarcity of trained personnel for purposes of assistive technology referral, assessment, and selection, as well as fitting, training, maintenance, and repairs. For example, in LMICs it is still too common for a child with a visual or hearing impairment to be mistakenly treated as someone with a mental disability; which in turn is too often assumed to be entirely untreatable.

Language

Persons who communicate through sign language or speak other minority languages might have difficulty accessing information, particularly technical information. There are also languages which are spoken by tens of millions of persons, i.e. large percentages of the populations of some countries, which are underrepresented as far as the availability of digital content

and tools. These tend to be languages which were judged to not be profitable enough for investment by the private sector.

Underrepresented languages also place persons who are blind at a disadvantage, as speakers of these languages do not usually have access to compatible optical character recognition (OCR), and speech synthesis technologies. These are significant barries to accessing digital information in general and to efficiently digitizing books and other texts for use in smartphones, tablets, and computers.

Finally, even for speakers of languages which are more widely supported, it is common to find web form elements, such as captchas, which even when available in audio form, are spoken in foreign languages. This happens even when the actual text on the page is already properly translated to the local language and handled well by screen reading software.

Physical interfaces

Buttons and touch screens are sometimes inadequate for older persons or individuals with motor or visual impairments. For example, buttons or batteries in some hearing aids can be too small for older persons, and touch screens might be inadequate for persons with reduced dexterity due to motor disabilities.

Operating system, application, or web interface

Design and implementation problems persist in applications and online environments such as web sites and online marketplaces. These obstacles are most damaging for persons with disabilities as they are still prevalent in web sites and smartphone Apps related to government services, educational institutions, online stores, and even freelance marketplaces. Beyond day-to-day needs, these barriers can also be observed in interfaces related to crucial services and benefits such as emergency notifications, unemployment insurance forms, and other types of support for citizens.

Communication protocol, file format, and other standards

Most messaging networks are designed in a way that prevents or makes interoperability with other networks difficult; and this restricts persons with disabilities to the messaging application of a single provider, where inconsistent accessibility is the norm. At the same time, in the vast majority of online services, there is no easy way to either ask for help with or complain of an accessibility problem. Finally, the use of proprietary, i.e. closed protocols and file formats, prevents most persons with disabilities from utilizing alternative applications with more accessible interfaces.

Availability of assistive technology

Most digital devices are manufactured in a relatively small number of countries, and importing these devices is often complex and expensive. In addition, regardless of whether the assistive technology is produced locally or imported, high cost and numerous other market failures work to restrict access to these technologies for the vast majority of persons with disabilities.

Purchase and maintenance cost

Too often digital devices are not designed in a way that allows for easy replacement of parts, and in some cases, connections and technical specifications are engineered so as to limit consumer choice, forcing the end-user to depend on a single and more costly manufacturer (Newman, 2011). In addition, planned obsolescence, i.e. the purposeful design of incompatibilities in hardware or software so as to force hardware replacement before its natural end-of-life, unnecessarily increases costs for all markets, with an especially harsh impact among persons with disabilities living in LMICs (Marcus, 2020).

These factors contribute to an unnecessarily high "total cost of ownership" (TCO). Since persons with disabilities depend on digital technologies not merely for convenience, but as an enabler of essential life functions, what is for the average consumer unfair, for those with disabilities is unjust and a substantial barrier to the natural continuity of daily life.

A way forward

Given the rate of technological change that humanity has experienced since digital computers were first developed, it is most fruitful to think of and manage technology as a process, rather than a state. Consequently, accessibility must be understood as a process as well. In other words, no technology automatically remains accessible after adequate accessibility adjustments are made, if accessibility is not one of the criteria in the production cycle itself (Cooper et al., 2012).

This applies to all relevant processes, including expert and end-user training, hardware design, software development, content production, and standards definition. The ultimate objective must be for all products, services, and content to be "born" accessible (DAISY, 2020). In other words, accessibility considerations should be part of the research and development (R&D) process of all entities developing new digital tools and environments. The closer accessibility is integrated into R&D, the cheaper and better will be the typical experience for persons with disabilities, and arguably, for all users.

In addition to a conscious understanding of the fact that constant change and renewal is a day-to-day reality in the information industry, societies must take into account all layers of technology, without arbitrary differentiation. For example, today there is ample agreement on the need to keep the most fundamental communication protocols freely usable by all, i.e. as open standards. However, any technological layer, from communications protocols to file formats and web page interfaces, must be subject to legal requirements sufficient to enable freely available interoperability and accessibility, whenever such technologies or services become de facto essential infrastructure. This is not yet the case, as today the largest online services have absolute power with regard to interface design, interoperability arrangements, and support for open standards, despite the fact that they have become essential infrastructure for society.

Ultimately the objective is for persons with disabilities to enjoy access equivalent to that which is afforded all other citizens, without being forced to wait for years. More

importantly for society as a whole, reforms that improve overall accessibility also boost marketplace competition, as all private firms are forced to compete on the basis of utility rather than by establishing artificial barriers for competitors and other rent-seeking behaviors (Moore, 2018).

Specific areas of interest

While the objective must be to reduce the barriers described earlier, the methods to do so must be accommodating of the incredible dynamism of the world of digital accessibility and respectful of how much of future technologies is unknown. In practice the strategy should include elements of education, regulation, and delegation among all stakeholders, the objective being an effective, dynamic, and sustainable digital accessibility regime.

Education

There is ample opportunity to increase the quality of digital accessibility by making sure that curricula in technical courses in higher education include the latest techniques and concepts relating to universal design and accessibility. In fact, universal design principles must not only be taught, they must be applied in the design and provision of technical and all other courses (Whitney et al., 2011). When universal design is a core criterium, all students benefit, not just those with disabilities (Izzo & Bauer, 2015). In education, as in all other sectors, the objective is to offer opportunity for personal development and employment for persons with disabilities, while simultaneously incentivizing an ecosystem of accessibility services and expertise.

Outside the technical courses, students of public policy must also gain an understanding, not just of the importance of open standards on ensuring competitive markets (West, 2004), but the effect of those standards on digital accessibility.

In addition to technical and public policy experts, there must be better training of instructors of persons with disabilities, so that they are aware of the latest products as well as of advanced features of their own technologies, and yet are not limited to specific vendors. Educational institutions cannot be seen as a technical support arm of large corporations, but as a source of generally applicable principles and practices.

Beyond the educating of experts and persons with disabilities, societies must better inform their political and administrative leaders which have long been out of formal schooling. The concept of accessibility cannot be the exclusive concern of experts, persons with disabilities, and their families. At a basic level, everyone should understand digital accessibility as well as they understand a physical ramp.

Finally, retraining and updating cannot be an exceptional activity, taken after the educational, economic, or rehabilitation system becomes irrelevant due to obsolescence. Updating and retraining must be integrated as naturally as physical maintenance into budgets in all public and private institutions. Of course, when appropriate the training must focus on all the structures which shape the digital world. Too often training includes only programming languages, without any coverage of the strategic implications of the legal and technological structures mentioned earlier and the implications that technological choices have for society.

Regulation

The rapid growth in the economic and social importance of information technology companies, has only recently stimulated a more careful consideration of what might constitute an adequate regulatory regime for the industry. Even though these considerations affect much more than the right to products and services which are compatible with assistive technologies, accessibility cannot be required in isolation from other criteria to be considered in the institutions and practices that define this industry. Quite the contrary, an effective and sustainable digital accessibility strategy must be fully integrated into the same processes used to research, develop, and deploy the technologies and products which shape digital environments for all persons.

As demonstrated earlier, in the absence of perfectly implemented digital accessibility regulations and enforcement, the use of open standards enable widespread interoperability and provide choice of interfaces for the end user, allowing the use of alternative applications with accessible interfaces. While the argument could be made that all that is needed is strict interface design requirements defined by law,we have not seen any evidence of legislation that is strict and specific enough to be effective in the short term, while remaining relevant as technology evolves. It seems wiser to provide market incentives where a company can keep proprietary standards only while ensuring a high level of accessibility. Finally, no standard should be allowed to remain proprietary beyond a specific maximum number of years, so that accessibility, and other public goods such as competitive markets, are encouraged through more than one approach.

Just as importantly, all technical standards and industry practices which have an impact on accessibility, be these formulated by public or private companies or standards associations, must take into account accessibility. Governments in turn must not limit their work to considering digital accessibility merely in the context of whatever regulations it implements to align the behaviors of information technology corporations with desirable social and economic principles. It must also consider other policy levers, such as consumer right-to-repair legislation (Svensson et al., 2018), the requirement of open standards in both software and hardware, and public procurement, where accessibility requirements are bound to have a powerful cascading effect bringing accessibility to many sectors of society (Astbrink & Tibben, 2013).

This systemic approach is not just important from the point of view of maximizing the effectiveness of government initiatives, but it also makes sense in industry itself. Accessibility must not be seen as an optional or premium feature, but as a core requirement. It can also no longer be only targeted to the "retail" market. In other words, content producers, not just content consumers, need accessible interfaces and tools for their work. Entrepreneurs and experts need accessibility, not just consumers, otherwise high unemployment among persons with disabilities will persist (Jaeger, 2006).

Finally, society now understands that in the digital economy, market power is achieved with strategies which are significantly different from those which tempt large companies with physical products, but in both cases the size of the enterprise is a key factor (Haucap & Heimeshoff, 2014). Taking this into account is not just

helpful, it is actually essential. Market dominance brings with it disproportionately large power in the digital realm (Bamberger & Lobel, 2017), and if such market power is allowed to persist (McKenzie & Lee, 2008), it must then also result in more strict accessibility requirements. For example, where a startup might potentially have the choice between accessible interfaces or open standards, a market dominant company should have both requirements.

Delegation

While the use and need for digital assistive technologies predates the Internet, the manner in which this network of networks emerged, developed, and spread is instructive as we design the best path forward to improve accessibility. The adoption of a decentralized and layered design, as well as the use of freely available open standards, were fundamental factors in the explosive growth of the Internet. At the core of this design is a minimalist approach where the lowest layers of the technology only have the most basic functionality for moving bits of information without a central hub directing the process. Higher layers implement additional functionality, which allows maximum flexibility and innovation. This approach is not merely wise, future-proofing infrastructure, it is also democratic for not requiring centralized control (Russell, 2014).

In practice, the decentralized approach adopted by the original Internet designers, has enabled a cooperative process for making technical decisions, adopting new open standards, and managing the incredibly fast growth of the largest network ever created on earth. This strongly suggests that as various private and public entities consider the best ways to modify the structures that rule the digital world, to promote greater accessibility and numerous other objectives, their work should take a similar approach, i.e. jointly and openly develop through cooperation between public, private, and civil society organizations (Werbach, 2005); of course, adjusted to ensure the participation of persons with disabilities through their own representative organizations. This balance of interest is absent today. Government participation went from absolute, as the technology was developed, to almost nonexistent relative to most other sectors of society.

Conclusion

Given how central digital technologies have become to social, educational, and work activities, the potential benefits, for persons with disabilities, of improved compatibility of digital devices and services with assistive technology are revolutionary. Just as the current benefits and obstacles have resulted from a constantly changing interaction between public policies, technical advances, and market forces, any accessibility improvements will have to be derived from changes in these structures and processes. Making the right choices then will be as complex as it sounds, and for this reason, we must have the wisdom of firm principles and legal guidelines, combined with a high level of delegation, where public, private, and nonprofit sectors play to their strengths.

Ultimately, given all the benefits to society as a whole, it is only reasonable to assume that a better balancing of public good and private interests will yield a more systematic inclusion of persons with disabilities. Assistive technology will then no longer be a lesser technology, but one more essential layer on the infrastructure of modern society.

References

Accessibility requirements suitable for public procurement of ict products and services in europe. (n.d.).

Astbrink, G., & Tibben, W. (2013). The role of public procurement in improving accessibility to ict. *Telecommunications Journal of Australia*, *63*(2). https://researchbank.swinburne.edu.au/items/5cc03e36-fe35-42b2-ad85-d572f611f6cb/1/https://researchbank.swinburne.edu.au/file/5cc03e36-fe35-42b2-ad85-d572f611f6cb/1/tja_2013_vol63_no2_21-astbrink_tibben.pdf

Bamberger, K. A., & Lobel, O. (2017). Platform market power. *Berkeley Technology Law Journal*, *32*, 1051. https://doi.org/10.15779/Z38N00ZT38

Blanck, P. D., & Sandler, L. A. (2000). ADA title iii and the internet: Technology and civil rights. *Mental and Physical Disability Law Reporter*, *24*(5), 855–859. https://www.jstor.org/stable/20785496

Borg, J., Lantz, A., & Gulliksen, J. (2014). *Accessibility to electronic communication for people with cognitive disabilities: A systematic search and review of empirical evidence*. Univ Access Inf Soc 14, 547–562 (2015). Springer. Retrieved May 8, 2021 from https://link.springer.com/content/pdf/10.1007/s10209-014-0351-6.pdf .

Breyer, S. (1970). The uneasy case for copyright: A study of copyright in books, photocopies, and computer programs. *Harvard Law Review*, *84* (2), 281–351. https://doi.org/10.2307/1339714

Cooke, A. (2004). *A history of accessibility at ibm*. In *AccessWorld*. American Foundation for the Blind. Retrieved October 12, 2020 from https://www.afb.org/aw/5/2/14760.

Cooper, M., Sloan, D., Kelly, B., & Lewthwaite, S. (2012). A challenge to web accessibility metrics and guidelines: Putting people and processes first. In *W4A 2012: 9th InternationalCross-Disciplinary Conference on Web Accessibility, 2012-04-16- 2012-04-18*, Lyon, France. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.368.4163&rep=rep1&type=pdf

DAISY. (2020). *It's time to use the modern digital publishing format for your organization's documents*. Retrieved October 1, 2020, from https://daisy.org/info-help/time-to-use-the-modern-digital-publishing-format/ .

Doctorow, C. (2020). *IP*. Locus Online. Locus Publications. Retrieved September 20, 2020 from https://locusmag.com/2020/09/cory-doctorow-ip/.

FDA. (2020). *Hearing aids and cell phones*. U.S. Food and Drug Administration. Retrieved September 28, 2020 from https://www.fda.gov/radiation-emitting-products/cell-phones/hearing-aids-and-cell-phones.

Fukuda, K., Saito, S., Takagi, H., & Asakawa, C. (2005). Proposing new metrics to evaluate webusability for the blind. In *Extended abstracts of proceedings of the SIGCHI conference on humanfactors in computing systems, CHI'05* (pp. 1387–1390). ACM Press.

G3ICT. (2015). *PhoneGap/cordova: A key to apps portability for all users*. Retrieved September 23, 2020 from https://g3ict.org/publication .

Galster, J. A. (2010). A new method for wireless connectivity in hearing aids. *The Hearing Journal*, *63*(10), 36–38. https://doi.org/10.1097/01.HJ.0000389925.64797.e5

Goodrich, G. L. (1984). Applications of microcomputers by visually impaired persons. *Journal of Visual Impairment & Blindness*, *78*(9), 408–414. https://doi.org/10.1177/0145482X8407800904

Gould, M., Leblois, A., Bianchi, F. C., & Montenegro, V. (2014). Convention on the rights of persons with disabilities 2012 ict accessibility progress report. *Survey Conducted in Collaboration with DPI—Disabled Peoples' International*. G3ict.

Gould, M., Leblois, A., Cesa Bianchi, F., & Montenegro, V. (2015). Convention on the rights of persons with disabilities, assistive technology and information and communication technology requirements: Where do we stand on implementation? *Disability and Rehabilitation. Assistive Technology*, *10*(4), 295–300. https://www.tandfonline.com/doi/abs/10.3109/17483107.2014.979332

Haucap, J., & Heimeshoff, U. (2014). Google, facebook, amazon, eBay: Is the internet driving competition or market monopolization?

International Economics and Economic Policy, *11*(1–2), 49–61. https://doi.org/10.1007/s10368-013-0247-6

HLisaStevens. (2008). *History of assistive technology*. Timetoast. Retrieved November 1, 2020 from https://www.timetoast.com/timelines/history-of-assistive-technology/ .

Isaak, J. (2000). Toward equal web access for all. *IT Professional*, *2*(6), 49–51. https://ieeexplore.ieee.org/iel5/6294/19198/x0341588.pdf

ISO. (2019). *ISO/iec 40500:2012 [web content accessibility guidelines (wcag) 2.0*. International Organization for Standardization. Retrieved on October 15, 2020 from https://www.iso.org/standard/58625.html .

Izzo, M. V., & Bauer, W. M. (2015). Universal design for learning: Enhancing achievement and employment of stem students with disabilities. *Universal Access in the Information Society*, *14*(1), 17–27. https://doi.org/10.1007/s10209-013-0332-1

Jaeger, P. T. (2006). Telecommunications policy and individuals with disabilities: Issues of accessibility and social inclusion in the policy and research agenda. *Telecommunications Policy*, *30*(2), 112–124. https://doi.org/10.1016/j.telpol.2005.10.001

Layton, N. (2012). Barriers and facilitators to community mobility for assistive technology users. *Rehabilitation Research and Practice*, *2012*, 1–9. Article ID 454195. https://doi.org/10.1155/2012/454195

Lessig, L. (2009). *Code: And other laws of cyberspace*. ReadHowYouWant.com.

Level Access, G3ict, & IAAP. (2020). *The state of digital accessibility report*. Level Access, G3ict; IAAP. Retrieved October 1, 2020, from https://g3ict.org/publication .

Marcus, J. S. (2020). *Promoting product longevity. How can the eu product safety and compliance framework help promote product durability and tackle planned obsolescence, foster the production of more sustainable products, and achieve more transparent supply chains for consumers?* European Parliament. https://www.europarl.europa.eu/RegData/etudes/STUD/2020/648767/IPOL_STU(2020)648767_EN.pdf

Mason, J. K. M., & Netz, J. S. (2002). *Manipulating interface standards as an anti-competitive strategy*. Ann Arbor, MI: University of Michigan. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.7.4063&rep=rep1&type=pdf

McKenzie, R. B., & Lee, D. R. (2008). *In defense of monopoly: How market power fosters creative production*. University of Michigan Press.

Metz, C. (2015). *Meet the team that makes it possible for the blind to use facebook*. Condé Nast. Retrieved October 2, 2020 from https://www.wired.com/2015/02/meet-team-makes-possible-blind-use-facebook/ .

Microsoft. (2010) . *Engineering software for accessibility*.

Moore, D. (2018). You gotta fight for your right to repair: The digital millennium copyright act's effect on right-to-repair legislation. *Texas A&M Law Review*, *6*(2), 509. https://doi.org/10.37419/LR.V6.I2.6

Mueller, J. (2008). *Accessibility for everybody: Understanding the section 508 accessibility requirements*. Apress.

Newman, J. M. (2011). Anticompetitive product design in the new economy. *Florida State University Law Review*, *39*(39), 681. https://heinonline.org/HOL/LandingPage?handle=hein.journals/flsulr39&div=30&id=&page=

Newman, L., Browne-Yung, K., Raghavendra, P., Wood, D., & Grace, E. (2017). Applying a critical approach to investigate barriers to digital inclusion and online social networking among young people with disabilities. *Information Systems Journal*, *27*(5), 559–588. https://doi.org/10.1111/isj.12106

Pascual, A., Ribera, M., & Granollers, T. (2015). Impact of web accessibility barriers on users with a hearing impairment. *Dyna*, *82*(193), 233–240. https://doi.org/10.15446/dyna.v82n193.53499

Phillips, S. (2007). *A brief history of facebook*. The Guardian. Retrieved October 2, 2020 from https://www.theguardian.com/technology/2007/jul/25/media.newmedia .

Rahman, M. M., & Sprigle, S. (1997). Physical accessibility guidelines of consumer product controls. *Assistive Technology*, *9*(1), 3–14. https://doi.org/10.1080/10400435.1997.10132291

Riley,C. A . (2020). Unpacking interoperability in competition. *Journal of Cyber Policy*,*5*(1), 94–106. Retrieved May 8, 2021 fromhttps://doi.org/10.1080/23738871.2020.1740754

Rosenblum, C.-M. (2020). *Flatten inaccessibility: Impact of covid-19 on adults who are blind or have low vision in the united states*. American Foundation for the Blind. Retrieved September 30, 2020 from https://www.afb.org/press-room/press-release-archive/announces-flatten-inaccessibility-report.

Russell, A. L. (2014). *Open standards and the digital age*. Cambridge University Press.

Sánchez-Gordón, M.-L., & Moreno, L. (2014). Toward an integration of web accessibility into testing processes. *Procedia Computer Science*, *27* (27), 281–291. https://doi.org/10.1016/j.procs.2014.02.031

Sawetrattanasatian, O., others. (2019). *Access to information of disabled people on the web: A dispute between accessibility and digital rights management*. Global Academy of Training; Research (GATR) Enterprise.

Scherer, M. J., Sax, C., Vanbiervliet, A., Cushman, L. A., & Scherer, J. V. (2005). Predictors of assistive technology use: The importance of personal and psychosocial factors. *Disability and Rehabilitation*, *27*(21), 1321–1331. https://doi.org/10.1080/09638280500164800

Section 508 of the rehabilitation act. (n.d.). United States Congress. Retrieved September 28, 2020 from https://www.fcc.gov/general/section-508-rehabilitation-act.

Sevilla, J., Herrera, G., Martinez, B., & Alcantud, F. (2007). Web accessibility for individuals with cognitive deficits: A comparative study between an existing commercial web and its cognitively accessible equivalent. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *14*(3), 12–es. https://doi.org/10.1145/1279700.1279702

Srinivasan, D. (2019). The antitrust case against facebook: A monopolist's journey towards pervasive surveillance in spite of consumers' preference for privacy. *Berkeley Business Law Journal*, *16*(39), 39. https://heinonline.org/HOL/LandingPage?handle=hein.journals/berkbusj16&div=5&id=&page=

Svensson, S., Richter, J. L., Maitre-Ekern, E., Pihlajarinne, T., Maigret, A., & Dalhammar, C. (2018). The emerging 'right to repair'legislation in the eu and the us. *Proceedings from Going Green–Care Innovation*, Vienna, Austria.

Times, N. Y. (1991). *Bridging a gap for blind pc users* (pp. Section 1, Page33, Nationaledition). New York Times. Retrieved October 3, 2020 from https://www.nytimes.com/1991/02/16/business/bridging-a-gap-for-blind-pc-users.html .

UN. (2006). *Convention on the rights of persons with disabilities*. General Assembly of the United Nations. Retrieved October 12, 2020 from https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities.html#Fulltext .

UNDP. (2007). *E-government interoperability: Guide*. United Nations Development Programme. Retrieved October 2, 2020 from http://www.unapcict.org/sites/default/files/2019-01/e-GovernmentInteroperability-Guide.pdf .

W3C. (n.d.). *Web accessibility laws & policies*. Retrieved October 15, 2020 from https://www.w3.org/WAI/policies/ .

Werbach, K. (2005). Breaking the ice: Rethinking telecommunications law for the digital age. *Journal on Telecommunications and High Technology Law*, *4*(2005–2006), 59. https://heinonline.org/HOL/LandingPage?handle=hein.journals/jtelhtel4&div=10&id=&page=

West, J. (2004). What are open standards? Implications for adoption, competition and policy. *Standards and Public Policy Conference; Federal Reserve Bank of Chicago*. Chicago, Illinois. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.98.786&rep=rep1&type=pdf

White, G. R., Fitzpatrick, G., & McAllister, G. (2008). Toward accessible 3D virtual environments for the blind and visually impaired. *Proceedings of the 3rd International Conference on Digital Interactive Media in Entertainment and Arts*, 134–141. ACM Digital Library, Association for Computing Machinery.

Whitney, G., Keith, S., Bühler, C., Hewer, S., Lhotska, L., Miesenberger, K., Sandnes, F. E., Stephanidis, C., & Velasco, C. A. (2011). Twenty five years of training and education in ict design for all and assistive technology. *Technology and Disability*, *23*(3), 163–170. https://doi.org/10.3233/TAD-2011-0324

Whitt, R. S. (2012). A deference to protocol: Fashioning a three-dimensional public policy framework for the internet age. *Cardozo Arts and Entertainment Law Journal*, *31*(2012–2013), 689. https://heinonline.org/HOL/LandingPage?handle=hein.journals/caelj31&div=33&id=&page=

Yanz, J. L. (2005). Phones and hearing aids: Issues, resolutions, and a new approach. *The Hearing Journal*, *58*(10), 41–42. https://doi.org/10.1097/01.HJ.0000285784.75866.1a