

The technology in your cell phone wasn't invented for you

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Abstract

This paper presents an abridged history of technologies used in cellular phones with respect to disability, and outlines the history of the concept of universal design. The fact that so many of the technologies in modern cell phones have their roots in solving disability access problems is then discussed in light of the fact that mainstream cell phones remain predominately inaccessible to people with sensory, physical and cognitive disabilities. Associated laws and guidelines in the US and Australia are considered briefly, with the argument that contemporary policies are having little effect on businesses who make information and communications technologies. The results of recent research into business and design practices relating to universal design is described. A discussion of the need for research beyond the design department, to encompass wider business aspects is also briefly presented. The central argument is that what we can learn from distant and recent history is that new policies are needed, and such policy needs to be informed by new directions in research in the universal design and business fields. Research recently started at RMIT University on the implementation of universal design practice in ICT businesses is introduced.

Introduction: credit where it's due?

This paper briefly presents the history of technologies used in cellular phones with respect to disability, and briefly outlines the history of the concept of universal/inclusive design. Incorporating features into standard cell phones to enable them to be usable without vision, usable without hearing, and usable with limited physical capabilities could broaden the market for cell phones, home phones, desk phones, and other types of information and communication technology (ICT). This type of design approach is commonly called "universal design" (UD) or "inclusive design". When I say in the title that *The technology in your cell phone wasn't invented for you* I am referring to the fact that the *invention* of many technology components of the phone came about through solving a problem of disability access to technology. The *you* part of the title refers to people who do not have what we traditionally think of as "disabilities". *Innovation* of inventions for people with disabilities (PWDs) has led to products for everyday use that are largely inaccessible. The history section of this paper presents this argument.

The mainstream world of cell phone design remains mostly inaccessible to people with sensory, physical and cognitive impairments. For over a decade there has been guidance from the academic community on how to achieve UD, and there have been laws in the US from the late 1990's that *required* manufacturers to make cell phones accessible (Architectural and Transportation Barriers Compliance Board, 1998). Studies are necessary to understand how UD guidance and laws can best be packaged in order to effectively support people at all stages of product development in achieving UD goals. To achieve that, research on business practices is needed. A research project along these lines will be described at the end of the paper.

It has been easy for some historians to overlook the disability-based contributions of inventors and innovators. For example, in his 1997 biography of Alexander Graham Bell, James Mackay writes "I must confess that although I was familiar with Bell's role in pioneering the telephone, I was quite unaware of his work in phonetics, acoustics and the education of the deaf." (Mackay, 1997, p11). To lay the groundwork for the later arguments in this paper, it will be useful to look back at the lessons of the past. I would first like to give credit where it is due by examining the history behind the technological inventions behind a lot of progress in ICT. The inventions behind the cell phone are used as an example.

An abridged history of disability and cell phones

Telephony. The integrated circuit. SMS. Vibrating alerts. Digital Camera CCD chips. Polyphonic ring tones. Speech Recognition. Speech Output. This technology in the cell phone in your pocket owes its existence to inventions intended to meet the needs of people with disabilities.

The necessary components of telephony were discovered before Bell was even born: electromagnetism (1820), induction (1831), the telegraph (1837) (Mackay, 1997) but Alexander Graham Bell was the first to put them together and first to the patent office. At the age of seventy, Bell wrote: "recognition of my work for and interest in the education of the deaf has always been more pleasing to me than even recognition of my work with the telephone" (Bruce, 1973, p379). Bell's wife Mabel, and mother Eliza, were deaf. In his early years in Scotland he worked on and helped with his father's invention of "Visible Speech," showing the articulation of sounds as a means to teach deaf people to speak. (Grosvenor & Wesson, 1997). In 1874 he saw a device

called a Phonoautograph, invented by Frenchman Leon Scott. As one spoke into the device, a wavy line was drawn (via a stick, a membrane and a bristle) on a piece of smoked glass. The wavy line varied according to the type of sound (what we might call a waveform). "If we can find a definite shape to each sound, what an assistance in teaching the deaf and dumb", Bell reportedly exclaimed (Burke, 1978). What Bell was trying to do, in June of 1885, was to break down speech sounds into visualizations for the deaf, which would be recognizable if the speech were split into different frequency bands. To do this he needed multiple phonoautographs. In hooking up the experiment he accidentally crossed a wire, and amazingly, when he spoke into the microphone of one phonoautograph, another one spoke too. Thus was the telephone discovered/invented (Kurzweil, 1997).

Essential components of cell phones, transistors and integrated circuits had similar inspirations from deafness. The transistor, invented in 1947, was not developed in order to make smaller hearing aids, but it eventually did, and this indirectly led the invention of the integrated circuit.

Miniaturization of hearing aids had been a goal for a long time, as early models encompassed huge batteries that only lasted for a few hours. At the time of the first commercially available transistors, the use of miniature vacuum tubes was the latest thing for hearing aids (Braun & Macdonald, 1982, p49). John Bardeen, Walter Brattain and William Shockley had been working at Bell Labs on the transistor idea, primarily driven by the need to find a replacement for the power-hungry vacuum tube (Riordan & Hoddeson, 1997). The first major commercial success of the transistor was the portable radio, Sony's first hit-product (Simcoe, 2004) but the first commercial use was in hearing aids. The first licenses for transistors in hearing aids were given royalty-free by Bell Labs in honor of their founder's work and interest in the field (Riordan & Hoddeson, 1997).

A number of companies were producing lower-cost hearing aids as a result of the transistor. Centralab, based in Milwaukee, had been using silk-screen techniques to print electronic circuits on ceramic wafers to make rugged miniature circuits. A man called Jack Kilby's had his first job at Centralab, and after hearing a talk by Bardeen at local Marquette University, he headed a group making new hearing aids that coupled the silk-screen techniques as well as the transistor. According to Riordan and Hoddeson's detailed account of the history of the birth of the information age, it was Kilby's goal to bring about the concept of the "monolithic integrated circuit" (a circuit in a solid block with no connecting wires) first proposed by Geoffrey Dummer in 1952. Jack Kilby's idea, 10 years after the transistor's invention, was to use a single slice of silicon as the basis for the integrated circuit. He knew that the small Centralab company would not have the capacity, so he looked for a new employer. In his first couple of weeks at Texas Instruments, he worked through his ideas for presentation to his new bosses (Riordan & Hoddeson, 1997). Early in 1959 a patent was filed by Kilby. The first commercial application of the integrated circuit was for hearing aids, in 1963 (Braun & Macdonald, 1982).

Also from deafness we have SMS (short messaging service) and vibrating alerts. The first alphanumeric pagers were developed for use by people who are deaf (McGraw, 1977) and these then proved useful and proliferated for asynchronous mobile communication for non-deaf persons too. Alphanumeric pagers were the ancestors of SMS, so common today. The first vibrating alert devices were developed for deaf persons to know when something important was happening, such as a doorbell ringing (Fossard & Joly, 1974). Vibrating alerts are now used by vast numbers of cell phone

users for instances when they cannot use a ringer, in a meeting, for example, or when the environment is too noisy, such as a concert or at a building site.

Blindness led to a number of inventions and innovations too. Optical Character Recognition (OCR) is the basis of scanning printed text into electronic formats. OCR already existed in 1974 but was limited to one or two fonts. Ray Kurzweil founded a company to develop a program that could, by the end of that year, use OCR with any type of print. In Ray's own words: "What was it good for? Like a lot of clever computer software, it was a solution in search of a problem." (Kurzweil, 1999, p174). Two key encounters he had with blind persons had a great deal of impact on a number of technologies. The first was when he sat next to a man who was blind during a flight. The man complained that access to printed material was a major barrier for him. Subsequently, in 1975, Ray's company developed two more inventions: flat-bed scanners that used CCDs (Charged Coupled Devices) and text-to-speech synthesis. Combined with Omnifont OCR, these technologies comprised the "Kurzweil Reading Machine" (KRM). Stevie Wonder heard about the reading machine that had been demonstrated on TV, and this led to the second key encounter, a personal meeting in which Ray demonstrated the device, after which Stevie Wonder took the first KRM home with him. Ray Kurzweil and Stevie Wonder became friends, and with Stevie as adviser, they developed the music sampler a decade later in 1985. The K250 was "considered to be the first electronic musical instrument to successfully emulate the complex sound response of the grand piano and virtually all other musical instruments" (Kurzweil, 1999, p176). The camera in your cell phone uses CCDs, first used in the KRM, and the polyphonic ring tone's existence can be traced in part back to the first music sampler.

Computer speech recognition and generation also have their roots in disability access. We are all familiar with IVR (Interactive Voice Response) systems that use a combination of speech recognition and speech output when we use the telephone to get bank balances and to book airline tickets, for example. The production of speech by artificial means has an extremely long history, with the earliest known example was basic trickery, where "the ancients attempted to show that their idols could speak, usually by hiding a person behind the figure or channeling voices through air tubes" (Olive, 1996, p146). There were many such mechanical examples, but the speech output of the KRM was the first text-to-speech generation by a computer. The quality of text-to-speech from the KRM days was quite poor and robotic sounding, but subsequent development and refinement of text-to-speech applications used by blind persons for access to computers at work has contributed greatly over the years to highly intelligible text-to-speech. For the other part of IVR, speech recognition, Ray Kurzweil also developed the first voice-activated word processor, by developing automatic speech recognition (ASR) (Kurzweil, 1997), as a means of enabling computer access for people who could not use their hands. In addition to facilitating IVR when using the phone, speech recognition technology is in many cell phones, used for dialing by speaking a name.

So, a lot of the essential components of cell phones came about because of disability access. Ironically, for a great deal of time after its invention, the telephone was not usable by people who were deaf. And, SMS on cell phones is not usable without vision, because cell phones do not speak their interface elements. People who are deaf could initially use analog cell phones by plugging portable text telephone devices into them. When digital cellular technology was introduced, the analog signals used by the text telephones were compressed out of the signal because the designers of the

compression software had no idea of the issue or existence of text telephones for the deaf. This meant that people who were deaf had an unwanted hiatus, until a solution was developed years later.

Furthermore, most of the functions of your cell phone today rely on the screen display. You know that you could casually hand your cell phone to a friend or colleague who needs to borrow it, and they could make a call without your assistance (unless the design and operation are non-standard and confusing). But you could not simply hand it over if your friend or colleague who is blind.

A standard cell phone that everyone can buy and usable by all, without having to buy add-ons for people who are blind, is a concept and not a real product. However, the technology to make standard cell phones accessible has existed since the mid 1990s (Vanderheiden & Law, 2000). Not only that, a law in the US has mandated since 1996 that manufactures should build telephony products to be usable without vision (and without hearing, with physical manipulation difficulties, etc.). Section 255 of The Telecommunications Act of 1996 led to the creation of the Telecommunications Act Accessibility Guidelines (Architectural and Transportation Barriers Compliance Board, 1998).

Some companies have developed low volume, high production cost, no screen "cell phones for the blind" but these are not universal because you would probably have a hard time using the audio-only interface of their phone if a blind friend or colleague handed it to you. There is also expensive third-party add-on software available to work with standard phones, but again this is not universal design.

As we can see, the UD-type legislation of Section 255 has not resulted in accessible cell phones in the high street electronics stores, almost a decade since its inception. In Australia, where the Disability Discrimination Act has been in place since 1992, similar guidelines as in the US are still seemingly a distant vision. The Human Rights and Equal Opportunity Commission stated: "To date, little real progress appears to have been made in [the mobile telephony] area, and people who are blind remain largely excluded from all but the most basic features of mobile telephony" (Australian Human Rights & Equal Opportunity Commission, 2005). The same is true in other developed countries, and even where guidelines are in place, UD is rarely seen.

New knowledge needed for new policies

We can see from distant and recent history that current policies and practices around the world are not having a universal design affect on the design of current cellular phones. While there are a number of specialist products designed for and marketed towards PWDs that provide access for certain types of disability (e.g., "for the blind"), it is not possible for someone who is blind to go to the local electronics store and buy a phone "for everyone" that happens to be usable without vision. There are a handful (relative to the total number) of websites that follow established accessibility guidelines, and some ATMs (Automated Teller Machines) and similar equipment that are accessible to some people who can read Braille (which is only a small percentage of people who are "blind").

Much prior research on *how* and *why* to do UD has been done (and there are plenty of resources explaining the concepts, e.g., (Preiser & Ostroff, 2001; Vanderheiden & Henry, 2001). Since there is still prevalent inaction on the part of ICT businesses, it stands to reason that the most significant barriers to adoption are not centered on technical problems. They are more likely to be business problems. The actions of people in business environments, and the processes and procedures associated with

product development should be investigated. A few prior studies have been conducted, and they have provided initial insights:

- As part of the European Union's cross-national program of research, "Telematics Application Programme Disabled and Elderly Sector", an interview study was conducted on 68 managers in ICT domains in 11 European countries. The resulting report (Van Dusseldorp, Paul, & Ballon, 1998) provides a broad (but not deep) sweep of the sorts of issues involved in the potential implementation of UD. The researchers concluded that the concepts of UD and accessibility are not well known among mainstream ICT product managers, but that they might be interested in the potential for the approach to expand their markets to include older people and PWDs. In addition, where the researchers found existing processes that did include considerations of the needs of PWDs and people who are aging (although not necessarily pure 'UD'), they relayed descriptions of the practices within these organizations.
- In 1998, a short conference paper was published on surveys of people in industry and their motivations and barriers for UD practice (Tobias, Vanderheiden, & Vanderheiden, 1998). The UD Research Project (UDRP) survey, headed up by researchers at the Trace Center, targeted people in industry known to the researchers, including former students of design for accessibility courses at the University of Wisconsin-Madison. The conference publication included a short description of the methods used, but did not convey numerical results. A generalized bulleted list of facilitators and barriers was presented from this project. Government regulation (or threat thereof) and issues of the negative perceptions of profitability in this area were considered primary facilitators and barriers (respectively) to UD adoption.
- In 2004 the US National Council on Disability published a report (NCD, 2004) of a study which included the investigation of UD practices in six companies. The NCD had a broad study to look at UD activities across six "product lines": ATMs, cell phones, distance learning software, PDAs, TVs, and voice recognition software. One company from each product line was included in the company studies. For groundwork, they used a list that was similar to, but much more extensive than, the UDRP's. This list was used to generate a list of topics to be covered as the researchers interviewed people in the companies to find facilitators and barriers to UD. The researchers found among other things (p202) that [applicable legislation] was either not being adhered to or is being adhered to inconsistently; there was a lack of realistic standards, guidelines, and principles for accessible design; often there was a lack of communication across departments in companies regarding accessibility requirements; and middle management often perceived accessible design to be in direct conflict with schedule and budget requirements.

The issue of the "lack of realistic standards, guidelines, and principles for accessible design" had also been a concern for the author and colleagues. In study on "Universal Design in Practice" based at the Georgia Institute of Technology, UD resources that were produced by government and academic groups, in terms of websites, guidelines and standards were investigated for how well they meet the needs of designers in industry (Choi, Yi, Law, & Jacko, accepted; Law, Jacko, Yi, & Choi, 2006). Numerous problems were found with the majority of resources. Whilst some of the suggestions in the design resources were reasonable, as a whole they were found to

place unreasonable demands on designers and the manufacturers they worked for. For example, the text of the resources often failed to facilitate trade-off decision making in the design process. Long lists of design requirements were given with no comparative value or priority system attached (Law, Jacko, Yi, & Choi, 2006), but most product design features incremental product improvements rather than wholesale redesign (Lawson, 2006). How is the designer to choose which accessibility requirements are the most important when they do not have UD expertise?

We also found that the typical model for trying to integrate UD within business is by treating it as a *special* and therefore *separate* (not integrated). The NCD found this too. In their report on promoting inclusion in the ICT marketplace (NCD, 2004) it was explained that the common practice for large companies was, firstly, to use consultants for initial assistance with dealing with accessibility issues, and then if needed, secondly, they up their own in-house accessibility program office (APO). The NCD found that four of the six companies studied had used this model. In follow-up studies to our own research on design resources we also looked at the practical set-up in government groups and industry, and found APOs in four of four government groups, and two of three industry groups (with an internal consultant model used in the third group). So the set-up of the APO model is commonly seen (at least in the US). By creating a separate department there is an implied assumption that the needs of consumers with disabilities are inherently different to the needs of other users (i.e., *special*). Many academic advocates of UD argue that a product should be usable without vision regardless of the cause, whether it be from the *environment*, e.g., darkness; from the *situation*, e.g., eyes-busy elsewhere; or from having a *disability*, e.g., blindness (Preiser & Ostroff, 2001; Vanderheiden & Henry, 2001). However, by relegating UD concerns to a separate department, those departments naturally then focus on disability, and *special solutions targeted at PWDs*. And, since major manufacturers of mainstream ICT do not typically make such *special products*, the voice of the APO staff is often going to be ignored: "Unfortunately, the accessibility program office in the four companies that had program offices demonstrated very little control over design decisions that directly affected the accessibility of the final product" (NCD, 2004, p190).

The ideal situation would be one where designers are making ICT usable without vision, without hearing etc. as part of their normal design processes. But that ideal situation is hard to find being practiced in the ICT arena. UD *how-to* books provide valuable and well-thought through insights on achieving good design, e.g., (Keates & Clarkson, 2003), but most of the available guidance and texts on UD do not really address the APO model of operation. In the APO model, one can assume that the designer who actually controls the function, appearance, and behavior of the product's interface will not generally be reading such UD guidance books. Instead, a person who is hired into the APO, who may have extensive experience with existing *special* products has to interact with the designer(s) to the best of their ability, making convincing UD arguments along the way, and being able to advise on trade-offs, big-picture issues, and juggle all manner of concerns from other departments in the business. So, design texts are not targeted at the APO officer, even though they are the ones most commonly on the "front-lines" for accessibility issues with any given company.

Some academics and consultants have produced illuminating texts on how designers think (Lawson, 1994, 2004, 2006) and how programmers think and operate (Cooper, 1999). So far it has been difficult to find references on how such persons in industry

think and operate *with respect to disabilities*. Understanding what they think and how they react in these sort of cases would be helpful in determining what policy changes are needed in order to facilitate UD. We know many of them react by setting up APOs presumably as a way *not* to deal with disability access. The pathology of UD in business is still in its early days. The psychology and sociology of people in business, and an understanding of the larger context of the constraints and issues of business in practice may yield clues that explain the pathology.

A research project has begun at RMIT University in Melbourne, Australia, on implementation of UD in ICT businesses. As stated earlier, there have been only a few prior investigations of business practices with respect to design for disability or UD, and therefore there is a lot of existing practice-based knowledge that is yet to be extracted, understood, and distilled from people in industry. In areas of architecture and transportation there have been a number of great advancements in terms of UD over the past decades, and understanding the business successes in those fields might shed some illumination on what is (not generally) happening in the ICT field. A number of questions are planned to be addressed in the RMIT study, for example:

- From an examination of past and current practice in business, what can we learn about stakeholder behavior to explain why special solutions remain the prevalent solution to accessibility problems, even when UD solutions are available?
- Can a comprehensive understanding of the APO and external consultants be achieved through systematic study of past and current processes?
- What are the psychosocial reactions and behaviors of people in business to disability issues?
- What is the most effective way to disseminate UD knowledge so that it can be easily used/implemented in APOs?
- Has UD-type legislation been enforced only when requirements were objectively measurable (e.g., in architecture)?

Methods for this study were in the planning phase at the time of writing. Generally, the study is proposed to use (1) historical account case studies to reveal the decision processes that were employed in cases where UD was successful or where it failed (e.g., resulting in special products); (2) business process/practice case studies which will include field-study interviews; (3) development of theories of UD in business and (4) the development and testing of more appropriate interventions/resources for the ICT business community.

There is undoubtedly scope for much more research beyond the present RMIT study. Other research centers around the world are looking at this problem from different perspectives. But, given the scale of the problem, with the enormous numbers of people making ICT products and the relatively tiny number of people interested in inclusive or universal design, finding the appropriate leverage point to make UD widespread or pervasive may still take some years.

Concluding thoughts

We have all seen people making package deliveries from their vehicles to customer premises. In the "old days" most of this was by way of the back entrance and service elevators, or via the front entrance with rather clumsy stair-climbing carts. Nowadays the delivery person just wheels their cart using the front entrance of a public building's wheelchair ramp. If they have both hands full with a particularly weighty cart they

might also hit the automatic door opener (the button with the wheelchair symbol "for the disabled"). The number of people benefiting from such ramps on a daily basis may well outnumber the people who use wheelchairs. We can hypothesize that the same could be true of UD of ICT, that people who benefit from UD while performing a task where they are limited by their situation or environment may outnumber those who we traditionally label "disabled". This is not a new hypothesis. The author has both presented and heard this argument repeatedly at UD sessions at academic conferences over the past decade. What is needed now is a new understanding of how these arguments play out in the minds, actions, and balance sheets of people in the business of producing ICT. From there, perhaps new and more appropriate policies to facilitate UD adoption in practice will emerge.

Adam Greenfield, in his recent collection of theses around the coming age of ubiquitous computing, says that we (society) are at a juncture where decisions on standards that dictate how the world will look with "Everyware" (ubiquitous) computing can be made for the good of society. To sit around passively and let ubiquitous computing *happen* without proper regard for the needs of users is a recipe for repression, he argues (Greenfield, 2006, p6). Similar notions in the minds of people involved with disability led to new ICT standards, government laws, rules and policies around the world from the mid 1990's. Those laws, standards and guidelines didn't really work as expected, and PWDs remain repressed, or at the very least, marginalized. The typically-seen creation of the *special* APO as a response to *universal* design requirements may not in fact be malicious. It may well be a carry-over from philosophies of the past where PWDs are not equal members of society. It will be interesting to find out from the RMIT research, and from others' research elsewhere, what is really happening.

A final task for the reader...

Now, with your cell phone turned off and the interface out of your sight in your pocket, try to turn it on, look up a friend's phone number and call them.

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