SMART PHONES IN NEUROLOGIC PRACTICE

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INTRODUCTION

Case Study: Solving a spell on the scene. A young man feels funny and then loses consciousness. His friends record the event with the cameras on their cell phones, documenting left head and eye deviation with left arm posturing. A subsequent EEG demonstrates a temporal lobe seizure focus. [1]

The case study only hints at the potential for smartphones to revolutionize medical care. As Zeiler and Kaplan, the case authors, say, "One picture is worth a thousand guesses." Often patients cannot accurately describe their neurologic spells, and neither can witnesses. Mobile voice and data interchange in the medical information domains of patient data, clinical decision support and practice management bridges time and space, thus allowing near instantaneous diagnosis and treatment while at the same time redefining the meaning of "the point of care." [2-4]

This chapter addresses mobile healthcare via smartphones. One might expect that the biggest advances would come about in developed countries, but this is not the case. A United Nations report describes mobile phones as having the greatest impact in developing countries. [5] Although many developing countries do not have widespread or even dependable broadband Internet access, much of their population has access to cell phones. These devices make it convenient to schedule appointments, receive medical results, and ensure timely alerts and reminders regarding upcoming tests, procedures and medications. [6, 7]

A disclaimer is in order. Technology articles are out of date as soon as they are written. The emphasis in this chapter, therefore, will be on concepts and principles rather than specific hardware models and software versions.

THE BIG PICTURE – SETTING THE STAGE

Hardware/Network/Software Trends

Several interrelated developments will change how we access and provide healthcare. [8] Computing and communicating devices are not only getting smarter, smaller, faster, and cheaper, they are evolving from fixed to portable, non-networked to networked, wired to wireless, location- and orientation-agnostic to location- and orientation-aware. We are moving to a world of health information technology literally at our fingertips, available at the point of care in our practices.

Mobile Phones

Mobile phones are devices that not only transmit voice messages, but also transmit text and multimedia messages (messages composed of text, moving or still pictures, and sounds). Mobile phones can now acquire multimedia with built-in cameras and voice recorders. They are continually gaining computing power.

Computer User Interfaces

Virtually all recent models of desktop and laptop computers employ a graphical user interface controlled by a mouse and other pointing devices. In contrast, most of the successful smaller portable devices have adopted a touch-based interface in which the user taps and chooses icons, words, etc. with either a stylus or a finger. Recently introduced multi-touch (or gesture) interfaces allow users to manipulate the objects on screen by touching two or more places on the screen at once; for example, touching a picture with two fingers and spreading them apart will enlarge the picture. [9] This makes the interaction between the user and portable device much more intuitive than through the use of a tiny trackball, pointing stick, stylus, etc., to interact with its display.

Networks

Advances in networks, most notably the ongoing transformation from wired to wireless, have accelerated the mobile computing revolution. Wireless networks can be either narrower in range (a Bluetooth personal network, for example), or provide wider coverage (e.g., the Internet) than many traditional local wired networks. Many mobile devices will use several types and ranges of network interfaces including satellite channels, cellular networks, Wi-Fi and Bluetooth.

Cellular wireless networks depend on a series of "cells" -- towers loaded with transmitters -- which automatically transfer the user's signal as he/she moves from one tower's coverage area to another's. Each cell phone carrier uses proprietary network technology which, with few exceptions, is incompatible with those of other carriers. It has recently been proposed that all cellular carriers begin sharing the same core network technology in order to allow devices acquired from one cellular carrier to be used on another carrier's network.

Wi-Fi is a local type of cellular network with a range of about 300 feet. Wireless access points broadcast a signal that users' devices pick up. The handoffs are usually not automatic when leaving one Wi-Fi coverage area and entering another; nevertheless, Wi-Fi transmission speeds are faster than on existing cellular networks.

Bluetooth personal networks allow the creation of a short-range personal area network up to about 30 feet in range. For example, Bluetooth can connect a mobile phone to a wireless headset, a car's audio system, or a printer.

VOIP, Voice over Internet Protocol, may greatly increase access to long-distance telecommunications. Voice is translated into data that goes over the Internet rather than through a cell phone carrier's proprietary networks. Users whose devices are equipped with VOIP applications, such as Skype or Vonage, and who have broadband Internet connections can call similarly equipped devices anywhere in the world without paying cell phone charges.

Global Positioning System (GPS) and Accelerometers

The Global Positioning System (GPS) relies on location data computed from signals from satellites orbiting the Earth. GPS allows users of appropriately equipped mobile devices to detect their location (actually the location of their device), broadcast it to others, to find nearby attractions and resources (with reviews) and generate directions, either as a list or in real time, turn-by-turn. If the device is lost or stolen, GPS can help find it. GPS enhances social networking applications by pinpointing friends' locations. A built-in compass will add to the GPS functionality.

Accelerometers inform the device about its orientation in space. Appropriately equipped smartphones can automatically switch from portrait to landscape view when they are rotated. Accelerometers enhance user input options and can be used to control games or other devices. They can even act as an electronic carpenter's level.

Cloud Computing

"Cloud computing" is an evolution of client-server computing. The client (your computer) is networked (wired or wirelessly) to a larger computer somewhere else (the Cloud) in which a lot of data and computing power resides. [10] This greatly enhances the information technology capabilities of small, relatively underpowered, computing devices such as smartphones, since they are now able to offload large amounts of data storage and computations to more capacious and capable machines. The Cloud can also be used to back-up data on your mobile device. If you lose your device, you simply retrieve the backup from the Cloud onto your replacement device. Moreover, the Cloud allows synchronization of data among various devices. A user can ensure that desktop, laptop, and mobile devices contain the same contacts, calendar, web browser bookmarks, etc., by synchronizing them with the server located in the Cloud.

ABOUT SMARTPHONES

What are Smartphones?

Smartphones represent the convergence of mobile computers and cellular telephones. [11] We no longer need to carry around a communication device and a separate mobile computing device. Smartphones are the logical successors of traditional cell phones and personal digital assistants (PDAs), with more capabilities than both,

whether separate or in combination. Just as it became inconceivable to buy a computer without Internet networking capability, one would no longer think of buying a mobile computing device or a PDA without network potential. We have mobile access to computing power, multimedia communications, the Internet, and our physical location in the palms of our hands. Phone numbers are now user-specific, not location-specific.

The Smartphone Market

Cell phones are replacing landlines as the preferred method of telephone communication. [12] The percentage of cell phones that are smartphones is relatively low in the world today, but the numbers are rising. In 2008, of the 1.19 billion mobile phones sold worldwide, 155 million (13%) were smartphones. Experts predict that in 2013, 280 million (20%) of the 1.4 billion phones sold will be smartphones. [13]

Major Smartphone Platforms

Currently, the two major smartphone platforms in the United States [14] are the Apple iPhone (http://www.apple.com/iphone/) and various RIM (Research in Motion) Blackberry models (http://www.rim.com/). There are other smartphone platforms with lesser market shares. Palm makes smartphones based on its new operating system, Web OS (the Palm Pre and Pixi) (http://www.palm.com/). They have phased out their older platform, the Palm OS, a previous market leader. Google provides its Android smartphone operating system for free and various manufacturers are developing devices based on this platform (http://www.android.com/). The Windows mobile platform (http://www.microsoft.com/windowsmobile/) has been around for years but is losing market share to these newer rivals. Nokia (http://www.nokia.com/) is the world leader in smartphones with its Symbian platform (http://www.symbian.org/), but has only a small market share in the United States. There are smartphones based on Linux (http://www.access-company.com/) and other proprietary technologies, but these constitute only a tiny portion of the market.

The Smartphone Ecosystem

Each smartphone lies at the epicenter of its own ecosystem. The smartphone is connected via its cellular and/or Wi-Fi network to:

1. An application store that contains software which can be loaded on the smartphone
2. The Internet for e-mail and web access
3. The Cloud for synchronization, backup, and, in some cases, more intense data processing

Smartphones have spawned a robust accessory market. The most popular accessories include wired and wireless headsets and speakers, cases, and wall and car chargers.

Because the different smartphone hardware operating systems are mutually incompatible (except for all being able to access the web via browsers and e-mail), their ecosystems are all separate. The Apple iPhone ecosystem is the best developed (http://www.apple.com/iphone/apps-for-iphone/, http://www.apple.com/mobileme/), but others are currently playing catch-up with their own application and accessory stores and with cloud computing systems.

SMARTPHONE APPLICATIONS

Overview of Smartphone Functionality

Smartphones can think, sync, and link. They think by accessing references and databases that reside on the smartphone itself. They sync to other devices and to the Cloud. They link to the Internet. Smartphone applications include those that are generally available to the public and those that are specific to a specialty such as medicine.

There are three sources of applications – those built-in by the manufacturer, those downloaded from third parties then installed by the user, and those accessed via the mobile phone's web browser. [15] Different manufacturers provide varying numbers and types of built-in applications. Third-party applications can be downloaded for some devices directly from the developers, but in other smartphone ecosystems only via an intermediary. For example, iPhone applications can only be downloaded and installed (officially, at least) via the iTunes application store. Web-based applications are not installed on the device--they are accessed via an active Internet connection.

Built-In Smartphone Applications

Most smartphones come with many built-in applications. They cover the core functions of smartphones, both traditional, such as notes, and newer ones, such as GPS.

The primary function, of course, is the telephone. The software enables not only one-to-one voice communication, but allows one to easily set up conference calls and voicemail for messages. Some of the newer smartphones feature visual voicemail, which streamlines the process of retrieving messages via the generation of a detailed list on the smartphone itself, thereby obviating the need to call and listen to a cumbersome audio menu. Messaging is a basic function of smartphones. This includes not only text messages, but also multimedia messages, which incorporate still or moving pictures or sound.

In addition to information entered by the device owner, the contact management and calendar applications can include information provided the user's organization. Some corporate contact and calendar databases reside on the Cloud. For example, Microsoft Exchange uses ActiveSync to synchronize frequently updated data on a corporate server with the user's mobile device.

Web and E-mail access are now standard smartphone features. Mobile web browsers enable users to search, browse, and interact with content formerly available only on desktop and laptop computers. E-mail applications can access individual or private accounts and organizational and corporate ones. With some e-mail protocols, the messages reside on the user's device, but with others, such as Microsoft Exchange, the device only views the mailbox contents – their contents are stored on a server somewhere in the Cloud.

Notes and to-do lists are holdovers from original PDAs such as the PalmPilot. Notes are small snippets of text used for references and reminders. To-do lists are useful as reminders of tasks recently assigned and yet to be completed. The more feature-rich smartphones allow notes and to-do lists to be synchronized to the Cloud or to the user's desktop or laptop computer.

Multimedia capabilities are becoming incorporated into consumer and corporate smartphones. They allow users to access and acquire music and voice, photographs and video. With voice recognition the user can say the name of a person or organization or its phone number, and the device will process the request and dial the correct number.

Newer smartphones have system-wide indexing and search. A single screen provides a gateway to relevant information in contacts, e-mail, calendars, notes, etc.

Location- and orientation-based applications are enabled by GPS and accelerometer capabilities, respectively. Some are built-in, such as the map application and photo geo-tagging on the iPhone.

Add-On Applications for Smartphones

Some add-on applications are useful to a wide variety of users and reside on the device. They can extend built-in functionality – for example a barcode reader extends the functionality of the built-in camera - or they can add new functionality, such as an electronic wallet. Some applications act as a front-end to web-based services including search engines such as Google or Yahoo, social networking sites such as Facebook or Twitter, news sites and RSS readers, Wikipedia and other references, and blogs and wikis.

Any website can be considered an add-on application because it can contribute functionality that is not built in to the smartphone software. Some websites are friendly to the limited feature set of mobile web browsers, but some are not, so their utility varies by site and device.

Health Care Applications for Smartphones

There is a rapidly expanding universe of specialized healthcare applications for the stakeholders on all the major smartphone platforms. Applications for patients and providers are highlighted below.

Applications for Patients

"Lifestyle applications" can help manage weight loss, diet and cooking, exercise of brain and body. There are many applications for patient information and education, including general references such as Consumer Reports Health (http://www.consumerreports.org/health/) and the Mayo Clinic Health Letter (http://healthletter.mayoclinic.com/). Some are very specific, for example a list for hikers of "the most poisonous snakes." Applications may reside on the device or be accessed via the web. A good example of the latter is the NINDS disease database with direct links to patient support groups (http://www.ninds.nih.gov/disorders/disorder_index.htm).

Smartphones allow patients to communicate with their healthcare providers by voice, text and multimedia. In certain circumstances patients are able to show their healthcare providers what is going on from a distance as was demonstrated in the initial case study in this chapter, in which a video of abnormal movements was shown or sent to the patient's neurologist. Communication can also be facilitated through foreign language translators. Patients can access and share personal medical information on smartphones. These include medication, allergy, and problem lists, and can include comprehensive personal medical records. Medical social networks and communities such as the Brain Talk Communities (http://brain.hastypastry.net/forums/) can be developed or accessed via mobile phones. For those patients with substantial neurologic impairments such as limited mobility, access to virtual communities may greatly expand their horizons and sense of empowerment. [16]

Mobile phones have the potential to enhance the provision of healthcare around the world, wherever a cell phone infrastructure exists. Even in less developed areas, mobile phones can be used to send and receive test results, alerts and reminders and advice. For example, text messages can remind patients to take their anti-HIV drugs. Mobile phones can be used for disease management, for remote monitoring of symptoms and epidemics, [17] and for questionnaires. They can even be used as prosthetics for sensory or cognitive impairments. For example, a smartphone application called "Speak it!" can transform text into speech. [18] It can give a voice to those who have been rendered voiceless, and can assist those who are sight-impaired. Another smartphone application helps compensate for anterograde amnesia in memory-challenged patients. [19]

Applications for Health Care Providers

There is a rich array of applications for healthcare providers. Some of the most compelling uses rely on built-in core smartphone functions. Many other applications are easily installed. Even more functionality is available if additional infrastructure -- hardware or software on desktop or laptop computers-- is also installed and utilized.

Physicians and other providers can use smartphones to easily communicate with office, answering service, colleagues, and patients. Pagers can be replaced by the 2-way messaging capabilities.

Reference material and databases are plentiful. Some contain preclinical content such as anatomical and radiographic atlases, and there are even audio collections with heart sounds. Clinical references cover diagnosis, treatment, practice guidelines, and practice parameters. Mobile versions, reformatted to best fit the mobile device's small screen, exist for a number of relevant websites, including the mobile version of the American Academy of Neurology's website at http://m.aan.com

Users can search and retrieve full text of peer-reviewed medical literature either via specially designed applications such as *PubMed on Tap* for the iPhone, or via the smartphone's web browser. Reference management tools are available. *Papers* for the iPhone, for example, is a kind of iTunes for articles and abstracts saved in portable document form (PDF) format. There are instructions on how to perform medical procedures, incorporating sound and video. A series of instructional resources on how to perform EMG and nerve conduction studies by Dr. Joseph Jabre is particularly useful. Continuing Medical Education (CME) credits can be achieved over the web on a number of free services.

Drug databases contain names of drugs, their indications, dosages, pharmacology, interactions, contraindications, cost, pill identifiers, etc. Drug-drug interactions calculated at the point of care are critically important. There are also databases for diagnostic tests that list indications, normal/abnormal values, and how to interpret certain laboratory results.

There are many multifunction clinical calculators such as the free *MedCalc* [20], and more specific ones such as the *NIH Stroke Scale Calculator* for point of care stroke documentation and medical decision-making. Practice

management resources are also available for many smartphone platforms. These include reference material, searchable databases and calculators for proper ICD-9, evaluation management, and procedure CPT coding.

Applications can assist in diagnostic testing. *EyePhone*, an application for the iPhone, is a visual acuity test optimized for the iPhone screen. Basic telemedicine can be achieved with smartphones by taking pictures or videos and sending them as multimedia messages between patient and provider.

More advanced telemedicine capabilities are possible with appropriate infrastructure. [21, 22] A sophisticated camera and electronic medical record system at the point of care could transmit images and data to an offsite physician who is carrying only a smartphone. Access to imaging studies can be done via a smartphone if it is connected to the hospital or organization's digital radiology system. Mobile telephone microscopy is emerging in which the camera of the smartphone is connected to a microscope, and the images of the slides are sent for interpretation to offsite pathologist. Remote patient monitoring is available for smartphones if they are connected to the intensive care unit monitoring devices in the hospital.

Computer-assisted medical decision-making is best done when the smartphone is connected to other computers. Patient alerts and reminders, electronic medical records, rounding lists, charge capture, and electronic prescribing are available as standalone applications, but functionality is greatly enhanced if the mobile device acts as a client for the hospital or organization's main electronic medical record system.

The same is true for physician quality measure reporting. Under the current model of the physician quality reporting initiative (PQRI), providers submit numbers of patients with a particular diagnosis who received a certain type of treatment or advice. This works best if the patients' diagnoses and treatment have been stored in an electronic medical record. It would be very difficult to do this from a smartphone operating in isolation. The basis of continuous quality improvement is to model, measure, and manage (another way to say this is plan, study, act). By closing the feedback loop through the use of data collection at the point of care, smartphones will enable more valid continuous quality improvement projects in medicine.

Tying mobile phone data collection into a remote database permits epidemiologic studies to be carried out even in developing countries. Clinical trials are also greatly extended using smartphone based data collected by patients and providers. Location-specific capabilities enable patient tracking. [23]

Mobile phones are being used as remote controls for games and for other electronic devices. It is probably not far off that simple robotic surgery will be controlled by an offsite surgeon using his mobile phone!

Patients often use the same applications that their providers use. Many patients use Epocrates, the NINDS website, and PubMed. It is useful to access these resources from time to time and try to see them from your patients' point of view.

SMARTPHONES AND PDAS IN MEDICINE – THE LITERATURE

It has been shown that health information technology can improve health care. [24] Case studies [25, 26] and peer-reviewed medical literature [27] attest to the usefulness of smartphones and personal digital assistants in medicine. In community hospitals and ambulatory clinics without wireless networks, real-time access to current medical literature may be achieved through applications on smartphones. Immediate availability of reliable and updated information obtained from authoritative sources on the Web makes evidence-based practice in a community hospital a reality.

An up-to-date bibliography is always available via a PubMed MEDLINE search (http://www.pubmed.gov) using the following phrase: "Cellular Phone"[Mesh]. As of October 25, 2009, 1624 relevant articles were retrieved, 105 of them reviews. One recent study concluded that "enhancing standard care with reminders, disease monitoring and management, and education through cell phone voice and short message service can help improve health outcomes and care processes have implications for both patients and providers." [28]

CHALLENGES AND SHORTCOMINGS

Although smartphones are very promising devices and getting better almost every week, they have certain challenges and shortcomings. Interoperability is problematic for developers and end users. Platform-specific applications (those loaded directly on to the smartphone) are faster and may access more specific features of the

smartphone, but they require more resources and development time. [29] Small developers have to decide how many platforms they will support. The potential solution is to make well-designed, web-based applications that are platform-neutral. However, their functionality is more limited due to their inability to access some of the key built-in features of specific devices, which make the smartphone such a compelling platform. For example, network-based applications may be impeded by patchy, uncertain, or slow connectivity.

Data input is often clumsy and error-prone [30]. Some smartphones have physical keyboards that are small and cramped, and typing on them is error-prone. Some have virtual keyboards. Virtual keyboards can be reformatted for portrait and landscape modes, different keys can be available for different applications or different languages, but there is no tactile feedback. Typing is slower on the virtual keyboard than on a physical keyboard, although many users do not mind or adjust to it within a short time.

Battery life can be limiting. Many smartphones will get only a few hours of active battery life, barely enough to get through a full business day without recharging. Although battery life can be extended by turning off some of the features of the smartphone (GPS location, Wi-Fi, Bluetooth, etc.), that partially defeats the intended purpose of the smartphone.

Do smartphones actually access the real Web? The answer is sometimes yes and sometimes no. The small screen can be an impediment to users, because it is like looking at the Internet through a keyhole. Although almost all websites can be visited, in order to visualize many at a font size that is reasonable a fair amount of horizontal and vertical scrolling is required, which may become quite tedious. One particularly troublesome development is the increasing use of plug-ins such as Adobe Flash for websites. At the present time, Flash solutions are either absent or not completely satisfactory for smartphone platforms. Websites that do not have alternative non-Flash versions will not have full functionality on smartphones. The solution, of course, is visiting websites optimized for web browsers, but here the tradeoff is often a loss of functionality.

Privacy is concerning. Not only are there HIPAA concerns about patient information on mobile devices, but also users of the devices may object to certain smartphone features. Carriers could monitor how devices are used on their networks and potentially intercept e-mail and web transmissions, etc. Location-based services could monitor a user's location without their knowledge or approval.

Security remains a challenge with smartphones. What to do about loss or theft? Although Microsoft Exchange-based systems have Remote Wipe and Apple's MobileMe has introduced this functionality to their smartphones, there are ways to circumvent this safeguard.

Cloud computing has its downside. If all user data resides on remote servers and they fail without adequate back-ups, then important information can be irretrievably lost. [31]

What about viruses and worms ("malware") for smartphones? These will probably become an increasing threat as more hackers devote their attention to these platforms. This is one instance in which the multiplicity of operating systems is actually a good thing. Since no smartphone maker controls the vast majority of devices (unlike the Windows-dominated PC world), it would be difficult for malware to inflict as great a negative impact on smartphones as it can on PCs. Antivirus software makers are starting to explore products for smartphones due to the anticipated threat.

HEALTH PROBLEMS (POTENTIAL AND PROVEN) AND UNINTENDED CONSEQUENCES

All technological advances have negative aspects, and many cannot be predicted or anticipated. Edward Tenner terms this "the revenge of technology." [32] The potential adverse health consequences of cell phones are increasingly recognized. [33]

The biggest unsettled health-related question is whether cell phones cause cancer. [34-36] Although this has never been proven despite much investigation, absence of evidence is not evidence of absence. Some, but not all, authorities opine that further studies are needed.

Certainly, minor medical maladies have been associated with overuse of smartphones. There is the so-called "Blackberry thumb," from overuse of the thumb-based keyboard. [37] There are scalp and ear dysesthesias reported from holding a cell phone too close to one's ear during prolonged talking. [38]

More serious are the decreased attention and difficulties with multitasking inherent in having a conversation (either voice or data) on a cell phone while doing something else important. [39, 40] Talking or texting on cell phones while walking or driving leads to more accidents. [41] Hands-free conversations have been shown to be no less distracting than holding the device to one's ear. [42] State and Federal lawmakers are beginning to prohibit certain cell phone uses while driving. [43]

Cell phones may cause stress since the user is always available and on call. Users may become addicted to the Internet or to their devices (the so-called "Crackberry" phenomenon). [44] Cell phones can sometimes serve as vectors of infection, just as neckties are. [45] Prolonged cell phone conversations can potentially have adverse electromagnetic [46] and thermal effects on central and peripheral nervous tissue [47]. Loud sounds through the receiver can cause hearing loss. This is more likely to occur from listening to music than from conversations. [48] Finally, there are concerns about sterility caused by cell phones, which is currently under investigation. [49]

There are potential problems with the software as well as the hardware. The old adage "garbage in – garbage out" applies to medical software as well as any other software. Users entering the wrong data will lead to the wrong decisions. More perniciously, medical software deficiencies or bugs may give erroneous results. A reported software bug caused a patient to get the wrong dose during radiation therapy with fatal consequences. [50]

Cell phones can cause electrical interference with other medical devices. [51, 52] These can be in or on the patient (for example, a pacemaker or a ventriculoperitoneal shunt valve), or around or connected to the patient, such as a monitor, respirator, etc. The available literature demonstrates that different combinations of cell phones and devices have different degrees of electrical interference ranging from none to serious. Clearly, as cell phones become more ubiquitous, manufacturers of cell phones and medical equipment will need to electrically isolate these devices from one another. When in doubt, one should ask the information technology personnel at your hospital or organization test the devices to see if they are compatible before allowing them to be used together.

WHAT DEVICE AND APPLICATIONS SHOULD I GET?

The answer depends on what problems you want to solve. [53, 54] What do you want to sync and link to? What are your e-mail habits? What are your favorite applications? What carriers and networks work best in your area? What can you afford? What does your institution or organization mainly use? What does your institution and organization support? Are you willing to go it alone to use a device that will not supported by your IT staff?

Currently the iPhone and BlackBerry platforms are most popular among physicians. [55] The abundance of medical applications favors increasing popularity of the iPhone in the future. [56]

WHERE DO WE GO FROM HERE?

Extrapolating from current trends, smartphones potentially can lead to pervasive computing, with these devices serving as the "remote control for your life." [57, 58]

It is a safe bet that we will have smarter, smaller, faster, and cheaper devices and faster, more widespread networks that will allow seamless carrier conversions and/or carrier interoperability. As long as the applications are allowed, there may be liberation from the hegemony of the carriers by allowing users to avoid cellular networks with Voice over IP.

More convergence lies ahead. Smartphones are becoming sufficiently capable that they can replace desktops and/or laptops for many applications. In some small businesses, networks of smartphones may replace landline telephones and PBX systems. There will be phone number convergence. Google Voice and related services will intercept messages from multiple different phone numbers and assign them to a single new number. There should be better integration between the users' contacts and activities, especially by location-based services.

There should be better Internet-based applications, better ability to download, upload, and sync and backup to and from the Cloud. There should be better integration with social networking services, location-based services, other digital healthcare applications and platforms, and virtual communities. There should be smarter alerts and reminders via background patient monitoring applications.

We hope for better battery life and better displays - some may be projected, some may be flexible and able to be rolled up or folded out. There may be better input with improved voice recognition, and perhaps even projected keyboards onto larger spaces. There may be better accessibility for the visually and hearing impaired. There may be better security including biometric logons (for example, using fingerprints).

We cannot predict future disruptive technologies or economic circumstances. As the saying goes, “the only guaranteed part of life is change.” We should anticipate the unanticipated - that one or more unexpected devices or applications will have a major impact on the world of mobile devices in the not-so-distant future.

SUMMARY

Smartphones make mobile computing at the point of care practical. Smartphones can think, sync, and link. Built-in and user-installed applications facilitate communications between neurologists and their medical colleagues and patients and augment data acquisition and processing in the core medical information domains of patient data, clinical decision support and practice management. Mobile telemedicine is becoming practical in certain scenarios. Smartphones can improve neurologic diagnosis and treatment, teaching and research. Our patients can benefit from smartphone technology as well. In addition to enhanced communication, patient education and social networking, these devices can promote healthy lifestyles, preventive medicine, compliance, and can even serve as monitoring and prosthetic devices.

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