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The Clinical Relevance of Smartphone Applications in Medicine and Audiology

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Introduction

The invention of the smartphone has changed the way billions of people operate in day-to-day life as well as in the workplace. Smartphones, by definition, are the mobile phones that have similar capabilities as computers, such as Internet access (Medical Apps for Smartphones, 2010). By the standards of this definition, the first smartphone was the Simon that released by IBM in 1992 (Medical Apps for Smartphones, 2010). In the decades since the release of the Simon, other companies have also released their own versions of the smartphone, with the Apple iPhone becoming the most renowned. The Apple iPhone stood out compared to other smartphones of its time because it gave consumers the App Store, a place where iPhone users can download programs to use on their devices (Medical Apps for Smartphones, 2010). Today, the App Store offers millions of applications (otherwise known as apps) that consumers use in a variety of ways. Related to the medical field, smartphone apps are now beginning to be implemented in clinical practice. The exact number of medical based apps varies at any given time, however, a brief search in the App Store generates thousands of medical apps that may be relevant to the medical and healthcare professions.

Similar to any search on the Internet, in the App Store, apps may surface that may or may not be what the user intended to find. The term "medical" is very broad, leading to a large variety of apps that loosely relate to the medical field in some manner. Physicians have reported difficulty in finding relevant apps because of the quantity of apps that emerge during any given search. The importance of a useful app is crucial to its success. Physicians will not use an app that wastes time instead of saves it. Although

there are benefits for physicians who incorporate medical apps in practice, many

physicians do not use apps regularly because they struggle to find apps practical to use.

To this end, researchers have developed a framework (McCurdie et al., 2012) that

helps app developers create apps to benefit the user, including healthcare professionals.

According to the framework of the user-centered design process (UCD), the user needs to

be considered at every developmental process. This ensures that the over design will have

optimal benefits for the people it serves (Biediger-Friedman, Crixell, Silva, Markides,

and Smith, 2016). Every step of the process is directed toward the benefits of the user.

There are three steps involved in the creation of apps following this model. Each one

requires reflection and evaluation of the app to determine how well it will serve

consumers. Many apps using this model are available to physicians and patients in the

medical field in areas such as diabetes, asthma, and cardiovascular health. For example,

the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC)

developed an app using the UCD framework to promote healthy behaviors for mothers

postnatal. The app provided mothers with newborns information on child development

and nurse assistance when a question arose. The participants of the study were pleased

with the outcome of the app and found it very beneficial (Biediger-Friedman et al., 2016).

This model can be implemented across various areas in the medical field that makes it

appropriate for multiple audiences to use (McCurdie et al., 2012).

The usefulness of apps in the medical field is widespread with a variety of ways

to implement medical apps. Physicians can use mobile phone apps as a method of

teaching, for collecting data, for record keeping, and for assessing and treating patients.

There are also apps available that will allow patients to monitor health status. Smartphone

apps can be used as study tools for medical students, such as patient simulations or

flashcards for studying anatomy or physiology, providing invaluable learning

opportunities. Record keeping and data collection are especially important in the medical

field because it allows physicians to fully understand a patient's case history that could

ultimately determine a diagnosis. Apps that support this area of the medical field are

useful because they track patient data in an organized manor. A physician can also find

apps that aid in the assessment and treatment of patients. Physicians can use these apps if

another source needs to be consulted before a diagnosis can be reached. Certain apps also

provide diagnostic testing needed to form a diagnosis. The apps that aid in treatment are

also important for the physician and the patient. For example, apps allow patients to

monitor their symptoms, and physicians can use apps to prescribe medications

(Weichmann, Kwan, Bokarius, & Toohey, 2016, Vashit, Schneider, & Luong, 2014). The

innovations made with the use of apps have aided the medical field in multiple ways that

ultimately are more efficient if used correctly.

The difficulty that some physicians have, preventing them from using medical

apps, is finding the best app to use in practice. Approximately 82-85% of physicians and

medical professionals own a smartphone and, of that number, only 30-50% use apps

regularly in their clinical practice (Weichmann et al., 2015). Some of the apps being used

by these professionals are *Epocrates* (pharmaceutical), *VisualDx* (dermatology), *5min*

EM Consult (emergency medicine), and *NeuroToolKit* (calculator; Weichmann et al.,

2016). These apps aid physicians in a variety of fields such as dermatology, emergency

medicine, etc. In the medical field, there is debate over the approval of medical apps.

When apps are made following an effective framework they have been proven to be

useful. However, many physicians continue to struggle locating the best apps to use. Physicians often need to sift through the App Store to find the most effective apps. With more research available to identify the most effective app professionals could change their stance in favor of the medical apps.

The field of audiology has seen a surge of implementing apps in clinical practice. Traditionally, the role of the audiologist is to diagnose and treat impairments of the auditory and vestibular systems (Martin & Clark, 2015). In most clinical settings, an audiologist will refer to a series of tests that need to be conducted to diagnose and treat a patient. This can be referred to as an audiologist's "tool belt." When assessing a patient an audiologist needs to collect a case history, perform Otoscopy, and conduct a series of audiometric tests.

The first step is to collect the patient's case history. The audiologist collects this information to determine if there is an underlying cause for a hearing loss. After the case history is collected the audiologist will perform otoscopy to examine the structures of the outer and middle ear. This examination is important because it determines if there are any abnormalities in the ear that could potentially impact hearing test results.

Following the case history and otoscopy, the audiologist will conduct audiometric testing, or pure tone audiometry, to determine the severity and type of hearing loss. Audiometric testing involves finding the patient's hearing threshold to a tone at several frequencies to determine the extent of hearing impairment. Pure tone audiometry assesses hearing using air and bone conduction that is used to determine the type of hearing loss. When testing for air conduction headphones are used, and when testing for bone conduction, a clinical bone transducer will be placed on the mastoid

bone, located behind the ear. The types of hearing loss are classified as conductive, sensorineural, and mixed. A conductive loss means the patient exhibits a loss due to abnormalities in the structures of the middle and inner ear. A patient with a sensorineural hearing loss has damage to the structures of the inner ear. Finally, a patient with a mixed hearing loss has a sensorineural hearing loss as well as a conductive hearing loss. In order to determine the type of hearing loss, a patient has the audiologist has to run a series of audiometric testing. Finally, during a hearing evaluation, an audiologist will also test a patient's ability to understand speech by asking the patient to repeat a series of words. The patient will hear these words at varying levels of loudness. In order to conduct this hearing evaluation, an audiologist needs reliable and calibrated equipment such as an audiometer, sound booth, and headphones or earphones. This equipment is rather costly, and calibration to maintain the equipment is completed annually.

Intervention for hearing loss varies depending on the type of hearing loss. Patients with mild-severe hearing losses typically use hearing aids. If the patient has a severe-profound hearing loss, they may be a candidate for a cochlear implant. For specific listening situations, patients can use hearing assistive technology such as FM systems and amplified phones that help improve their understanding of speech in background noise or on the phone, respectively. Additionally, aural rehabilitation can provide adults and children with hearing loss an opportunity to improve their communication. AR can consist of sensory management; a form of intervention that improves audibility for individuals with hearing loss (Jessen, 2015). The purpose of this type of intervention is to improve the communication ability for individuals with hearing loss (Martin & Clark, 2015).

Related to assessment and treatment of hearing loss, there are a multitude of apps available for audiologists and hearing healthcare professionals. These apps are continually in development, however, there are many audiologists who embrace these advancements in technology. Paglialonga, Tognola, & Pinciroli. (2015) have categorized apps used in audiology based on their purpose for clinical use including a) screening and assessment, b) intervention and rehabilitation, c) education and information, and d) assistive tools. Each app that has been developed for an audiologist or an individual with a hearing loss has many benefits to its user. There are more apps available for the intervention and rehabilitation of hearing loss compared to the other categories, however, all apps offer services necessary for treatment and diagnosis (Paglialonga et al., 2015). However, with the rising awareness of the apps available in audiology, there is the potential for more to emerge in coming years.

The purpose of this essay is to investigate the usefulness and clinical relevance of smartphone apps in the medical and hearing fields. Specifically, we will a) evaluate the variety of apps available in the healthcare field, b) explore the apps that are available for the diagnosis and treatment of hearing loss and their overall effectiveness, and c) determine the limitation and risks associated with smartphone apps in the medical field.

Summary of Findings

The Clinical Relevance of Apps

The medical field has begun to adopt a variety of apps in clinical practice. Many apps are used in a variety of medical subfields and have proven to be very effective. There are key components of an app that make it useful for physicians to use in everyday practice. Patients can also use these apps to improve their quality of life. Clinically useful apps can aid medical professionals in important decision-making; they have the ability to influence a decision (i.e., diagnosis or treatment). Physicians are often drawn to apps because they have the ability to store high quantities of information and perform many actions through one interface (Franko & Tirrell, 2012).

Medical apps can also serve as important teaching tools. As previously stated, apps can provide patient simulations or serve as a reference library of anatomical terms. However, apps can also assist medical students with respect to clinical practice beyond patient care. Documentation is crucial for the medical field. It helps maintain records of patient information such as medical history and insurance plans. Medical students need to fully grasp the concept of documentation and need to be skilled in how to effectively write a medical report. If a physician makes a mistake when completing a report, the outcome could be catastrophic. Due to the stakes involved in documentation, it is important that students learn correct methods right away. A program started at the Saudi Neurosurgical Residency Program created an app to track the progress of their residents in all aspects of medicine from surgery to documentation. This website and app entitled *ROTCES* has five steps to ensure resident success: a) login (resident), b) case entry, c) login (attending physician), d) case approval and evaluation, and e) report (Sehli, Esene,

& Baeesa, 2016). Every step in this process allows a resident to submit a case, get

approval from an attending physician, and follow through with the case and get constant

feedback. This method highlights a resident's strengths and weaknesses, and provides

information to aid in intellectual growth. This method has shown residents'

improvements in areas such as knowledge, skills, and attitude toward the profession. All

of these aspects are important to the medical field and will make residents more

competent (Sehli et al., 2016).

     Apps are important to patients as well. There is a rise of apps available to aid in

symptom management. These apps can drastically improve a patient's quality of life.

Apps that serve this purpose help patients to keep track of their vitals (i.e., glucose levels

and blood pressure) as well as facilitate communication between doctors and their

patients (Vashit, Schneider, & Luong, 2014). These apps will allow patients to feel more

confident and achieve a greater level of independence because the patients themselves

can monitor their symptoms easily and can communicate any changes in their status

directly their physician in a timely manner.

     Categorization of apps is important to consider when medical professionals are

searching for apps to use in practice. Using categories to sort apps can determine what

apps can be used in specific scenarios. A framework for effective categorization comes

from Paglialonga et al. (2015). These researchers have created a framework to categorize

apps in the field of audiology. However, the framework they have created can easily be

adapted to the medical field as well. Apps found in the App Store that have clinical

relevance can be sorted into the following categories: a) screening & assessment, b)

education & information, c) assistive tools and, d) intervention & rehabilitation

(Paglialonga et al., 2015). Each of these categories serves an important role in classifying apps by clinical relevance.

The first category listed, screening & assessment, aids medical professionals in the diagnosis phase of patient care. Many of these apps provide reference tools to diagnose or aid physicians in administering tests. An example of an app that can be categorized in this section is *One Minute Ultrasound*. This app provides a quick and efficient tool for physicians to get an ultrasound for their patient. This app is clinically relevant because it provides an image for physicians to use in diagnosing certain conditions and disorders (Vashit et al., 2014). Another app that is important for screening and assessing a patient is *Diagnosaurus ddx*. This app is intended to aid physicians in diagnosing a patient in a timely manner. This is useful for physicians who may need assistance in assessing a patient in a timely matter (Medical Apps for Smartphones, 2010). Both of these apps are useful for physicians to use in practice because they provide tools that help form a diagnosis.

The education and information category is important to physicians and patients who need a reference tool to learn about specific medical conditions. Many of these apps are created for patients, and physicians can refer their patients to these tools as needed. One app that provides patients with necessary information is the prototype Texas WIC is currently developing. The prototype offers information about infant growth and development as well as information about exercise and healthy eating habits. The participants who utilize this app are satisfied with the results and the information is available to them (Biediger-Friedman et al., 2016). The Center for Disease Control and Prevention (CDC) also provides the general public with apps that have valuable

information when traveling abroad. For example, when visiting a foreign country, you

might be susceptible to different medical conditions. The CDC has developed many apps

to inform people of vaccinations needed to travel abroad as well as diseases that a

traveler has a higher risk for contracting. One app called *CDC Health Information for*

International Travel provides information about health recommendations to follow when

traveling abroad. This app is important for the prevention of diseases that can be brought

back into the United States while traveling (Seed, Khov, Binguad, Abraham, & Aungst,

2016).

Another important category to consider for medical apps is assistive tools that

assist physicians in meeting their patients' every day needs. One app that specifically

supports the physician is *Epocrates*. This app is one of the most widely used medical

apps. Franko and Tirrell (2012) reported that approximately 75% of physicians surveyed

in their study used *Epocrates*. This app helps physicians prescribe medications as well as

assign dosages (Vashist & Luong, 2014). *Epocrates* has been proven to be an accurate

app to use, explaining why so many physicians use it widely.

Andrus et al. (2015) reported that of over 1,000 medications prescribed using

Epocrates, 89.4% of the medications were accurately prescribed. Even though the app is

not completely successful in all cases due to miscalculations of dosages or changes in

prescriptions, the majority of medications were correctly prescribed. Over-the-counter

medications have led to differences in how medications are prescribed. For example,

insurance policies often dictate which medications are used for a patient based on

coverage policies, and this has changed the dosage that is prescribed by *Epocrates*

compared to what is in the patients' traditional electronic health records (EHR).

Moreover, *Epocrates* provides prescriptions with greater accuracy for patients with Blue

Cross Blue Shield. Oftentimes, the differences that occurred between *Epocrates* and EHR

were due to the medications that certain insurance companies covered (Andrus, Forrester,

Germain, & Eiland, 2015). However, physicians who prescribe medication without an

app can also make mistakes, such that the errors of *Epocrates* could equate to the errors

of physicians.

     MedCalc is another app that falls into the category of assistive tools that

specifically helps in patient care. Similarly to *Epocrates,* this app is a medical calculator

that provides calculations for prescriptions as well as completion of formulas, such as risk

score for stroke (ScyMed, 2016). Overall, these apps aimed at providing additional tools

to physicians make some basic tasks more efficient in the medical field.

     Apps that assist in intervention and rehabilitation are specifically helpful for

patients because they assist with management of symptoms. One app that is particularly

helpful for patients is *GluCoMo*. This app aids patients with diabetes track their glucose

levels, diet, and insulin intake. This app is important for rehabilitation because if glucose

levels drop to a certain level, the app with notify the patient. As a result, this app will

prevent complications of diabetes, making it a crucial app for symptom management

(Vashit et al., 2014). Another app that is important for symptom management is *ihealth

myvitals*. This app also maintains a record of the patient's blood pressure, body mass

index (BMI), and calorie intake. A patient utilizing this app wears a wristband that will

monitor blood pressure. This app is important for patients who consistently need to

monitor their vital signs. It allows them to feel comfortable going about their day because

the app notifies the patient immediately if there is a change in health status such as heart rate (Vashit et al., 2014).

The variety of medical apps categorized here is important for patients and physicians for many reasons. Even though there are plenty of apps currently available, many physicians need more information before they can commit to use of a particular app. There is a lack of scholarly research available to assess the effectiveness and usefulness of these apps. More research is necessary to determine which apps are clinically relevant and those that are not. Further categorization of apps is also important for a number of reasons. Categories help physicians determine the best app to use that will ultimately lead to optimal use. Apps have the potential to help physicians in all areas of the medical field once physicians understand their clinical relevance.

The Clinical Effectiveness of Apps in Audiology

Apps in the field of audiology have shown clinical relevance targeting multiple audiences, including audiologists, patients, and family members, and in a variety of ways. Audiologists can use smartphone apps to identify information for patients, communicate with patients, and diagnose and treat a hearing impairment. The use of an app compared to standard audiometric testing can be quite efficient, however, the question of how accurate these apps are is often put to question. Patients can also benefit from the use of apps that serve as resource tools, providing information about hearing loss or tools to enhance communication, as well as detecting a potential hearing loss prior to seeing an audiologist. Apps are also available in sound amplification that can be helpful when patients have difficulty conversing with others or hearing sounds in the environment.

These apps have the ability to drastically improve the quality of life for individuals with hearing loss as well as to assist audiologists in patient communication and diagnosis.

A study by Paglialonga et al. (2015) has provided a unique framework to categorize apps in audiology, as was summarized in the previous section on apps in the medical field. An app is assigned to a category based on its function as well as by the description that the App Store provides (Paglialonga et al., 2015). These categories of hearing apps are: a) screening & assessment, b) education & information, c) assistive tools, and d) intervention & rehabilitation.

At the time of their research, Paglialonga et al. (2015) found 203 apps that had relevance to audiology and 17% of those apps fell into the category of screening & assessment. A variety of tests can be conducted through apps such as pure-tone audiometry and otoscopy. One app that has been developed for screening & assessment is *AudCal. AudCal* helps to conduct audiometric testing and determine the level of handicap associated with hearing loss. To measure the validity of this app, Larossa et al. (2015) conducted a study to compare the use of their audiometric testing app to traditional clinical testing. For validity of the audiometric testing using *AudCal,* a nonrandomized test was conducted. In the study, 110 participants were tested with conventional pure tone audiometry in a sound treated booth with an audiometer using standard headphones, and with the *AudCal* using Apple earbuds. The hearing thresholds collected using each testing method were compared. The results found no significant difference in the thresholds obtained from the conventional methods of hearing testing and from *AudCal*. When testing the accuracy of the hearing handicap, researchers compared results of a web-based calculator used to determine the hearing handicap using the same audiograms

of participants. There was also no significant difference in results obtained with either

method of obtaining results related to hearing handicap. Therefore, *AudCal* can be

considered an effective app to use when conducting audiometric testing and measuring

hearing handicap (Larrosa et al., 2015).

Another app that can be used for audiometric testing is *EarTrumpet*. Similarly to

the study conducted by Larrosa et al. (2015), the results from *EarTrumpet* were compared

to standard pure-tone audiometry (Derin et al., 2016). Thirty-two participants were

recruited for hearing testing using both methods of conventional audiometry and testing

using *EarTrumpet*. The severity of the hearing loss was first collected using pure-tone

audiometry and then it was compared to results collected from *EarTrumpet,* both

methods were tested using over-the-ear headphones. Out of the 64 ears tested throughout

the study, 39 were diagnosed with the same severity of hearing loss using the two

methods. In cases where there was a significant difference in results obtained between the

two testing methods, *EarTrumpet* often overdiagnosed the degree of hearing loss. For

example, using conventional pure tone audiometry, 12 participants had normal hearing,

however, *EarTrumpet* diagnosed 9 of those participants with mild hearing loss (Derin et

al., 2016). In this case, patients with normal hearing who were diagnosed with a mild

hearing loss would need a complete hearing evaluation that leads to unnecessary testing

and more of a financial burden on patients. However, despite the differences in diagnosis

for some patients, overall, the results show that *EarTrumpet* is also an effective app that

can be used to diagnose a hearing loss (Derin et al., 2016).

Additionally, there are also apps available that assist in otoscopy, or conducting

an outer and middle ear examination for assessing anomalies and infections. *CellScope* is

an app that allows physicians to perform otoscopy using a smartphone. This app used the

camera that comes with the smartphone to examine a patient's ear. The app was

originally developed for use by the general public, however, physicians can also benefit

from this app. The intentions of this app were to diagnose ear infections early and

potentially prevent unnecessary appointments to one's physician. To perform otoscopy,

the user needs a specific case for the phone with a scope attachment. The app takes

pictures of the middle ear and those photos can be submitted to a website to compare it

with pictures of healthy ears. The app's capabilities provide convenience for physicians

and patients (Vashit et al., 2014).

Tinnitus matching is another aspect of screening and assessment that can be

accomplished using apps. Traditionally, tinnitus matching is performed in a sound treated

booth with standard audiometric procedures to find the pitch or loudness of the patient's

tinnitus or the minimal masking level. This procedure produces varying results from one

patient to the next, in much the same way that tinnitus varies in sound frequency and

level across patients. One study investigated pitch matching using smartphone apps and

traditional audiometry. In the study, 17 participants completed loudness matching using

conventional methods in a sound treated booth and using the smart phone app with an

iPod. They found differences in the pitch between the two methods. More specifically,

the smartphone app produced lower tinnitus pitch matches compared to conventional

testing, however, participants noted that it was easier to use the app (Wunderlich et al.,

2013). The results of this study show that tinnitus can be assessed with the use of a

smartphone app. Even though tinnitus pitch matches were different using each method,

participants noted it was easier to use the app. More research is needed to improve the

quality of the tinnitus measurements obtained with smartphone apps.

　　　　Apps are also available that serves as education and information tools for patients,

family members, patients, as well as hearing professionals. Apps in particular that assist

both audiologists and smartphone users are sound level meter apps. Similar to actual

sound level meters, these types of apps determine the loudness of the surrounding area.

To make it more user-friendly, many of these apps will report the overall sound level of

the environment, indicating if hearing protection is necessary. One study conducted by

Nast, Speer & Le Prell (2014) compared five sound level measurement apps to traditional

sound level meters. Both apps used A-weighted and C-weighted capabilities to test sound

levels. Statistical analysis of the apps showed that most apps reported higher decibels

(dBs), and only one app was within 5 dB of the measurement recorder from an actual

sound level meter (Nast, Speer & La Prell, 2014). If an error occurs using a sound level

meter, it is typically within 1-2 dB of the actual loudness of the environment, implying

that the apps are not as accurate as the actual device. Their study also found differences

within A-weighted and C-weighted levels. C-weighted levels typically yielded more

accurate loudness levels, researchers found this was due to the limited filtering of the C-

weighted sound levels. Overall, this study, it seems that use of a traditional sound level

meter is the best method for obtaining sound level measurements in the environment.

Smartphones may not have the capabilities and technology to accurately calculate sounds

with varying frequencies and decibels, therefore, more research and development is

needed to improve the reliability of smartphone measurements of output sound levels.

Apps are also available that assist in the intervention & rehabilitation of hearing impairments. Some of these apps include sound amplification and tinnitus management. At the time of the study, approximately 52% of apps related to audiology assisted in intervention and rehabilitation (Paglialonga et al., 2015). Tinnitus management is a specific hearing disorder that has been targeted using apps. Because tinnitus can vary from person to person and can change depending on environment, it is difficult to treat and difficult for patients to cope with associated symptoms (e.g., depression, anxiety). The *Phonak Tinnitus Balance App* is one of the many apps available to assist patients in masking their tinnitus. The app allows the user to select a pre-recorded sound, such as ocean or campsite, or music from the smartphone's music library (Phonak, 2016). Hearing aid users who also have tinnitus can benefit from this app, if an individual uses a Phonak hearing aid, the masking provided with this app can be delivered to the hearing aid via Bluetooth instead of traditional in-the-ear headphones (Phonak, 2016). This app is can discretely provide relief from tinnitus, making it very convenient for its users.

Another app that serves an important role for the intervention and rehabilitation of hearing impairments is *Ear Machine*. This app offers sound amplification for individuals with hearing loss. It uses earphones to transmit amplified sound into an individual's ear and volume gain can be controlled with a smartphones volume control. A study by Amlani, Taylor, Levy, & Robbins (2013) compared three different methods of sound amplification including *Ear Machine*, conventional hearing aids, and *PocketLab,* another sound amplification app, to determine which offered the best amplification. All 18 participants in the study were diagnosed with mild-to-moderately severe sensorineural hearing loss. Results of this study showed that apps like *Ear Machine* and *PocketLab* are

not as effective as hearing aids in providing participants with the greatest audibility. These apps are useful for short-term instances, however, sound amplification for permanent hearing loss should be provided using conventional hearing aids (Amlani, Taylor, Levy, & Robbins, 2013). Conventional hearing aids have the greatest success in achieving better speech understanding for individuals with hearing loss.

Assistive tools are also available to help individuals with hearing loss. Some of these apps include alerts or sign language reference tools. Overall, this category makes up about 7% of all hearing-related apps (Paglialonga et al., 2015). These apps can be beneficial for individuals with hearing loss as well as family members and friends of individuals with hearing loss. Alert apps can serve a variety of functions such as alarm clocks or alerts of fire or severe weather. These apps have vibrotactile or visual cues to alert an individual. Apps for sign language tools can help individuals communicate with others (Paglialonga et al., 2015). There are apps available that serve as resources to learn American Sign Language such as *ASL Coach* or *The ASL App* (Duchy Software, 2012; Ink & Salt LLC, 2016). Apps in the assistive tools category can drastically improve quality of life for individuals with hearing loss because they promote independence. While these apps can be useful for smartphone users, there is a lack of research on their effectiveness.

In sum, apps emerging in the field of audiology cover these areas of screening, intervention and rehabilitation, education, and assistive tools. However, it is difficult to determine whether there is clinical relevance to these apps because they are all relatively new. The paucity of research studies on hearing apps makes it difficult to determine the overall effectiveness of these apps. Hearing professionals may be skeptical to utilize

these apps because of their varying results and lack of research. The field of audiology

has, thus far, focused on apps that provide screening and assessment of hearing abilities.

There is ample research to support various apps for conducting audiometric testing,

however, the other categories, such as intervention and rehabilitation and assistive tools,

lack this same level of support. Therefore, more research and development is needed in

the areas of sound measurement and sound amplification if hearing apps are to be

embraced fully by hearing professionals and audiologists.

Limitations and Risks of Smartphone Apps

Throughout this essay, the types of apps and their role in the medical and

audiology fields have been discussed. Overall, we have found a variety of apps that assist

medical professionals in a multitude of ways, such as patient management and

audiometric testing. However, in this section, the limitations of these apps will be

discussed. There are many limitations of smartphone apps in the medical and hearing

health fields, such as security and safety concerns, that should be reviewed.

Despite many positive aspects of these apps, limitations remain that prevent them

from widespread use in the medical field. There is high variability in app users and what

medical fields utilize apps. Many younger physicians such as residents use apps in

practice, however, more experienced physicians use apps far less in practice. Franko &

Tirrell (2012) found that about 70% of residents who participated in their study used apps

while only 40% of attending physicians with over 15 years of experience used apps. The

gap in app use can be attributed to the age of each physician; older physicians do not find

it necessary in clinical practice because they did not have access to this kind of

technology while they were in school. This can be discouraging for many app developers

because, as Frank & Tirrell (2012) report, almost 90% of medical professionals use smart phones.

There are a multitude of reasons why physicians are skeptical in implementing apps in their clinical practice. When a smartphone user purchases an app from the App Store, they cannot return it. Many apps that could be suitable for use in practice have an added expense, and physicians do not want to purchase an app if it will not be beneficial. The only way to assess the reliability and usefulness of an app is to read app reviews and survey research for a given app. References tools on the app store also tend to cost more than a typical app. The price of these apps can equate to the price of a reference book that provides the same information. At this point, many physicians opt to purchase the book because they can examine it prior to purchase (Franko & Tirrell, 2012). The quantity of apps in the App Store continues to be a problem for medical professionals. When searching the App Store and typing in a key word such as "anatomy" or "surgical tools," irrelevant apps can be some of the first to appear. Miscellaneous apps, such as games, tend to appear in the results that will not provide assistance in practice. It is difficult to sift through apps when so many of the apps serve no professional purpose. Many medical professionals already know the types of materials they prefer to use and would be unwilling to change, especially if the process of locating apps can be inconclusive.

A main concern that exists with the use of smartphone apps in the medical field is safety and security. Huckvale, Prieto, Tilney, Benghozi, and Car (2015) reported that approximately half a billion smartphone users (including both physicians and patients) use a health or wellness app, a number that is expected to increase within the next three years. The growing market for smartphone apps in the medical field also leads to a

growing market to intercept private medical information of smartphone users. In general, the Health Insurance Portability and Accountability Act (HIPAA) and the Food and Drug Administration (FDA) regulate medical practices in terms of privacy and treatment to protect patients. Due to the newer technology made available, the FDA and HIPAA created their own set of regulations to monitor medical apps. However, there are gaps in the legislation that can disrupt the protection of health-related app users (Flaherty, 2015). The FDA can only regulate apps that "constitute medical devices and/or pose significant risks to patients" (Flaherty, 2015). It is difficult to determine which apps pose risks for app users, making it difficult for the FDA to regulate these apps. Apps that do not fall under FDA regulation are not considered medical devices, such that many apps fall outside of the jurisdiction of the FDA. However, apps that are considered medical devices and classified as "low risk" can escape FDA regulation (Flaherty, 2015). For example, apps that are considered "low risk" can still provide medical recommendations and send user information to outside parties and typically are exempt from FDA regulation (Flaherty, 2015).

Furthermore, smartphone apps are exempt from HIPAA compliance rules, unless the app distributes patient information to third party companies. Although this constitutes a small number of apps, some apps do send private information to third party companies. This results in a breach of security that many app users may not recognize. According to HIPAA, the only medical information that must be concealed are "covered entities" that include health plans, healthcare clearinghouses (used for billing), and healthcare providers who transmit health information in electronic form (Flaherty, 2015). As long as

these apps do not distribute any identifying information, the app developers do not need

to follow HIPAA.

The nature of these apps allows them to escape regulation of the FDA and

HIPAA, making them vulnerable for security breaches. Huckvale et al. (2015) reported

that many medical apps have limited security measures because "low risk" apps do not

need high security measures. A cross-sectional assessment of 79 apps labeled as safe, do

not have full safety measure in place that would prevent outsider users from intercepting

confidential patient information. Of the 79 apps that were assessed during the study, 89%

transmitted personal information online. There were no apps that store personal

information to a local server. Of the 35 apps that sent identifying information over the

Internet, 66% did not use encryption, which protects confidential information. According

to the study, 78% of the apps that acknowledge that they send information did not

disclose the nature of the information (Huckvale, Prieto, Benghozi, & Car, 2015). The

lack of security measures that app developers utilize makes apps very susceptible to

hacking. The type of information that can be intercepted from the apps is also unclear,

personal information can be viewed without the consent of the user. The results of this

study question the reliability of the accreditation system that determines whether or not

an app is safe and trustworthy (Huckvale et al., 2015). Modification of the regulations in

place for smartphones apps needs to be adapted to ensure full protection of app users.

Viruses and malware can also jeopardize the protection of information with

regard to medical apps. Choudri, Chatterjee, Javan Radvany, and Shih (2015) report that

many smartphones do not have built in virus protection software. This can make it easier

for third parties to take private information from app users. The lack of virus protection

software can be seen across the board in multiple smartphones such as Apple and

Android (Choudri, Chatterjee, Javan, Radvany, & Shih, 2015). However, some

companies do have limited protection against viruses. For example, iOS (for Apple

products) does not allow third-party software to access memory from the system,

protecting other apps. However, Android has not adopted a similar stance and has a larger

quantity of malware (malicious applications) compared to Apple (Choudhri et al., 2015).

The type of smartphone a medical app user has can affect the safety of personal

information.

   Theft or misplacement of a smartphone is another possible security concern for

medical app users. Due to the size of the smartphone, it is easier to steal or misplace. If

the phone is not password protected, there is the possibility that someone else can read

the information on the medical app. To prevent another person from viewing confidential

information, both iOS and and Android have adopted the remote wipe. This allows users

to clear all information from the smartphone from a remote location (Choudhri et al.,

2015). This feature can prevent the release of private medical information. Physicians can

also benefit from the remote wipe because they can conceal patient information that they

may keep on their devices.

   However, the security concerns smartphone apps have may not be the only factors

that inhibit widespread use of apps in medical practice. The lack of evidence to support

the accuracy of each app can determine patient safety. The lack of research can lead to

safety concerns for app users. With the limited safety standards in place, excluding

security measures, apps have the potential to cause serious medical errors (Buijink,

Visser, & Marshall, 2013). For example, apps like *Epocrates* that help assign dosage and

medication to patients have the ability to make errors. These errors can directly affect the lives of patients. The risks that these apps pose need to be fully assessed before they are used to prevent harm to a patient. Many apps are beginning to be peer-reviewed by physicians, however, there needs to be thorough research of these apps to fully determine their effectiveness and accuracy (Buijink et al., 2013). Extensive research is crucial because it can help determine which app developers create the best apps to use in practice. Pharmaceutical companies have begun creating apps to assist in the assignment of treatment options, however, the motives of these companies are to market their products even regardless the apps' effectiveness (Buijink et al., 2013). These companies have the potential to harm patients with their recommendations, and the validity of their outcomes needs to be examined.

In sum, medical apps have many limitations that restrict physicians and healthcare professionals from selecting these apps and integrating them in clinical practice. Overall, security concerns are a major factor for these apps, however, people need to consider that security breaches can occur without the presence of an app. Information can be intercepted from a patient's file just the same as it can be from an app. Physicians and healthcare professionals needs to determine if the risk of security breaches outweigh the convenience that apps provide. Apps have the potential to be successfully used in clinical practice when appropriate safety precautions are used. Finally, more research is needed on the effectiveness of medical and audiology apps, given the sparse number of studies in this area of development within the medical field.

Conclusion

Overall, the research to date shows a good amount of evidence on the effectiveness of smartphone apps in the medical field. There are a wide variety of apps that are currently used by medical professionals and patients; attempts have been made to evaluate these apps by their clinical usefulness.

In clinical practice, physicians prefer to use apps that are convenient and yield the most accurate results. Physicians do not as often use apps that are used for screening and assessment because studies show that traditional methods for diagnosing a condition are more accurate. However, apps that fall into the assistive tools category are more often used in the medical field because these apps help medical professionals execute routine tasks such as perform medical calculations and prescribe medication with greater ease. Apps that serve a role in intervention and rehabilitation tend to be more patient driven and are often more effective in assisting patients in a variety of ways, such as symptom management.

However, as discussed throughout this essay, the main concern that arises with app usage in the medical field is the lack of research available in specific categories of smartphones apps. Any smartphone user can venture to the App Store and find that there are thousands of apps in the "medical" category. However, because few studies have been performed to determine their overall effectiveness, this lack of evidence leads to safety concerns. In the medical field, apps providing assistive tools and intervention and rehabilitation have a greater quantity of evidence regarding their effectiveness, whereas in audiology apps used for screening and assessment and intervention and rehabilitation have been studied to a greater degree. Some of the apps previously discussed have the

potential to seriously harm a patient if they were proven to be ineffective, such as

Epocrates and *MedCalc*. Due to these limitations, currently, many medical professionals

are unwilling to use medical apps in clinical practice.

In audiology, the apps that have been developed to date are mostly used for

screening and assessment. Studies show that pure-tone audiometric testing apps such as

EarTrumpet and *AudCal* often diagnose patients with the same degree of hearing loss as

conventional testing methods used in the clinic, though differences in the severity of

hearing loss were found. Even though these apps are convenient and effective in

determining the degree of hearing impairment for a patient, it is unlikely that audiologists

will use them in clinical settings because professionals find traditional procedures more

effective. Because these apps are used to screen patients' hearing abilities, other

professionals such as teachers, speech-language pathologists, and nurses will likely find

them more useful. Based on the results of the screening with an app, it is likely that a

referral to an audiologist could be made for more thorough clinical testing. This method

may prove with time to be more cost effective and convenient for patients and health care

professionals, and save time for audiologists to engage in more extensive testing when

needed.

Finally, guidelines need to be established for the use of apps in health care to

ensure the safety these apps. Technological advances have the ability to expand the way

in which apps are used, and medical professionals should consider the usage of apps that

are deemed safe and effective.

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