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Current research and trends in the use of smartphone applications for mood disorders

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ABSTRACT

Background: Smartphone applications for mental illnesses offer great potential, although the actual research base is still limited. Major depressive disorder and bipolar disorder are both common psychiatric illness for which smartphone application research has greatly expanded in the last two years. We review the literature on smartphone applications for major depressive and bipolar disoders in order to better understand the evidence base for their use, current research opportunities, and future clinical trends.
Methods: We conducted an English language review of the literature, on November 1st 2014, for smartphone applications for major depressive and bipolar disorders. Inclusion criteria included studies featuring modern smartphones running native applications with outcome data related to major depressive or bipolar disorders. Studies were organized by use of active or passive data collection and focus on diagnostic or therapeutic interventions.
Results: Our search identified 1065 studies. Ten studies on major depressive disorder and 4 on bipolar disorder were included. Nine out of 10 studies on depression related smartphone applications featured active data collection and all 4 studies on bipolar disorder featured passive data collection. Depression studies included both diagnostic and therapeutic smartphone applications, while bipolar disorder studies featured only diagnostics. No studies addressed physiological data.
Conclusions: While the research base for smartphone applications is limited, it is still informative. Numerous opportunities for further research exist, especially in the use of passive data for, major depressive disorder, validating passive data to detect mania in bipolar disorder, and exploring the use of physiological data. As interest in smartphones for psychiatry and mental health continues to expand, it is important that the research base expands to fill these gaps and provide clinically useful results.

1. Introduction

Mood disorders remain a common but disabling condition, with a 9.5% 12-month prevalence among the U.S. adult population (Kessler et al., 2005). Two major mood disorders include major depressive disorder with a 6.9% prevalence (National Institute of Mental Health) and bipolar disorder with a 2.9% prevalence (National Institute of Mental Health). Despite the prevalence of mood disorders, only 51% of those suffering from major depressive disorder, and 49 % of those with bipolar disorder, are receiving any treatment, and of those, only 21% and 19% are receiving minimally adequate care respectively (National Institute of Mental Health; González et al., 2010). In light of both this high prevalence and unmet need, there has been recent interest in the utility of new tools, such as smartphone apps, for patients with mood disorders. A similar situation exists for nearly every psychiatric condition, with mobile mental health offered as a means to increase access to care, reduce stigma, improve diagnosis, and expand treatment modalities. Although much has been written about this potential, there is currently a sparse evidence base supporting mobile mental health's use (Powell et al., 2014). While the literature base on mobile mental health for mood disorders is small, there is value in understanding the current efforts and future trends. In this paper, we provide a review of smartphone-based app research applied towards major depressive and bipolar disorders, offer a framework for clinicians and researchers alike to classify and understand such research, and explore future trends.

While mobile mental health is a broad and evolving field, smartphones stand out as a novel tool. Integrating the abilities of a

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phone, computer, journal, Internet connection, survey platform, and a host of sophisticated sensors, smartphones have an array features that can be applied towards mental health (Glenn and Monteith, 2014). Patients within the mental health system increasingly own smartphones and are interested in using their smartphones to monitor their health (Torous et al., 2014a,b). In only a few years, thousands of commercially available health related applications have emerged (Powell et al., 2014) and many of these are targeted towards mental health (Chan et al., 2014). While several recent content analyses of commercially available mental health applications suggest that few have been formally evaluated (Savic et al., 2013), this has not deterred patients, and a recent study in a primary care population noted that 57.2% of patients have downloaded a health-related app to their smartphone (Carras et al., 2014). Thus, between its proposed potential and current commercial applications, the reality of mobile mental health cannot be ignored.

Given the evolving and dynamic nature of mobile mental health, it can often be difficult to draw firm boundaries and definitions of technologies such as apps. Responsive webpages can load on smartphones and mimic apps only when an Internet connection is available, some apps only work in the context of larger sensor network-based interventions (e.g. a fitness tracker sending activity level to a smartphone app), and many apps discussed in the research literature are not actually commercially available. Acknowledging the inherent complexity in reviewing the literature in this rapidly progressing field of mobile mental health, we define a smartphone app as a program downloadable and saved to a smartphone that runs with or without Internet availability and utilizes the graphic and computing capabilities of the smartphone.

Understanding the mobile mental health literature can appear daunting, given the complexity of mental illness, diverse applications of new smartphone technology, lack of standardized measurements and outcomes, and finally pilot nature of much of the work. However, through understanding some basic concepts about this research, a useful framework to contextualize mobile mental health emerges. These smartphone apps can be broadly broken down into those that are active and passive. Active apps require direct participation from the patient, such as completing mood logs or recording subjective experiences. Passive apps do not require active participation of the patient, and can autonomously gather data through a smartphone's GPS, accelerometer, or other sensors. In addition, mobile mental health apps can be separated into two further distinct categories, those that mainly serve a diagnostic role by monitoring or recording symptoms versus those offering interventions such as mobile therapy or health reminders. As is shown in Table 1, a two by two matrix with mobile mental health apps that are active versus passive and diagnostic versus interventional on each axis provides a useful framework to organize and understand the current research.

Using this framework, we review the published outcomes literature on app research for major depressive and bipolar disorders with the objective of providing insight into the current state and future directions of smartphone based research for mood disorders. We hypothesize that while much of the evidence will be preliminary in nature, utilizing this framework can help elucidate current research efforts and suggest emerging trends. Understanding the current research base can also help clinicians understand what is more evidence-based versus more speculative in the use of smartphone apps for mood disorders.

2. Methods

We conducted a literature search of PubMed and Medline for relevant articles published on or before November 1st, 2014. We aimed to identify studies utilizing native smartphone apps applied for screening or clinical care for either major depressive or bipolar disorders. Our search query was restricted to the English language and included a combination of the words “bipolar”, “depression”, “depressive” “mHealth”, “smartphone”, “mobile”, and “app” yielded 1025 results. Two studies were added by hand based on review of references. Both authors manually examined the abstracts, and if necessary the body, of each study in order to determine whether it should be included or excluded based on the below criteria. Disagreements were discussed until consensus was reached. Of these 1025 results, 430 were not directly related to mental health and were thus excluded. Of the remaining 595 studies, 509 were not directly related to directly to bipolar disorder or major depressive disorder, or discussed mental health in broad generalized terms, and so were also excluded. We sought to only target studies featuring smartphone apps and so excluded a further 55 studies that did not feature modern smartphones in that they did not have Internet capabilities, the ability to run apps, and feature either a touch screen or QWERTY keyboard. Of the remaining 31 studies, 17 did not provide quantitative results or were protocols for potential studies, and thus were excluded. Ultimately, only 14 of the initial 1025 studies were included in the review. Consensus was initially not reached for three studies regarding final eligibility, but all three were deemed not eligible after one round of discussion between the authors.

In order to contextualize the literature, we employed the matrix outlined in the introduction. Of note, we subdivided the diagnostic categories into diagnostics related to patient symptoms, patient behavior, and physiology domains based on the National Institute of Mental Health's Research Domain project's units of analysis (Insel et al., 2010). We also subdivided smartphone-based interventions into those related to psychoeducation, medication administration, and therapy.

3. Results

3.1. Major Depressive Disoder

We identified ten studies on the role of smartphone applications for major depressive disoder (Bush et al., 2013; Bindhim et al., 2015; Pelletier et al., 2013; Webb et al., 2013; Kauer et al., 2012; Hammonds et al., 2015; Schaffer et al., 2013; Ly et al., 2014; Watts et al., 2013; Burns et al., 2011).

3.1.1. Active data for diagnostics

Apps that collect data related to validated psychiatric instruments have been a focal area for research. Four studies examined the feasibility of actively surveying patients' symptoms of major depressive disorder on a smartphone for the purpose of delivering diagnostic information. One study showed high inter-reliability of PHQ-9 data collected on paper versus an iPhone app in a population of 45 soldiers (Bush et al., 2013). Many of the other studies have focused on demonstrating the feasibility and acceptability of data collection. Feasibility studies have examined collecting PHQ-9 scores using a publicly available app (8421

Table 1
Smartphone research studies categorized by the type of app studied.
(Major depressive disorder studies are bolded; bipolar disorder studies are in italics).

	Diagnostics			Interventions		
	Patient symptoms	Patient behavior	Physiology	Psycho-education	Medication related	Therapy
Active/reported	**13,14, 15, 16**			**17**	**18,19**	**20,21**
Passive	*25, 26*	**22**				
Active and passive	*23, 24*					

individuals in 66 countries) (Bindhim et al., 2015), conducting the 21 question Beck Depression Inventory via an app (40 individuals) (Pelletier et al., 2013), and administering the Quick Inventory of Depression scale on an app (478 individuals) (Webb et al., 2013). All these four studies all showed positive results for actively monitoring patient self-reported symptoms on a smartphone.

3.1.2. Active data for interventions

Several researchers have studied the impact of apps on treatment. One study collected active self-report data on symptoms of major depressive disorder but instead of using such to deliver and trend symptom information, offered subjects psychoeducation in the form of emotional self-awareness. This randomized study of 118 youth featured an app versus control group and demonstrated that self-monitoring symptoms of major depressive disoder with an app increases emotional self-awareness which itself may decrease depressive symptoms (Kauer et al., 2012). Two other studies involved the use of actively collected data to increase adherence of antidepressant treatment in college students (Hammonds et al., 2015) and predicted clinical response to antidepressant medications (Schaffer et al., 2013). Finally, two studies explored the potential of using smartphone apps to deliver therapy targeted towards major depressive disorder. One study compared a behavioral activation app versus a mindfulness app over an eight week period in a community sample of 81 individuals with major depressive disoder and demonstrated feasibility and a nearly equivalent improvement in depressive symptoms for both apps (Ly et al., 2014). The other study randomized patients with depression to use a cognitive behavioral therapy (CBT) app or computer based CBT program for six weeks and reported that both interventions led to similar reductions in depressive symptoms (Watts et al., 2013).

3.1.3. Passive data for diagnostics

There has been some interest the use of passive data for diagnostics, due to the greater potential level of adherence and ability to collect potentially more objective data. One study employed an app which collected passive data by recording objective information from a smartphone's ambient light sensor, GPS, accelerometer, and call logs, with the goal of automatically detecting patients' states and when they may need assistance (Burns et al., 2011). Eight patients with depression were able to use the app for eight weeks, and results showed the feasibility of such a system, although the app's predictive capabilities for mood were rated as poor. Of note, this study was conducted in 2011 and represents the first ecological momentary intervention for depression.

3.2. Bipolar DIsoder

While there has been less published research on the role of smartphone apps in bipolar disorder, as compared to major depressive disorder, there is an emerging evidence base. Although we identified four studies (Bardram et al., 2013; Faurholt-Jepsen et al., 2014; Grunerbl et al., 2015, 2014), two of the studies concerned the same app.

3.2.1. Active and passive data for diagnostics

Due to the variable nature and complex presentation of bipolar disorder, there has been an interest in researching mobile diagnostics. One study (Bardram et al., 2013) reported feasibility of data collection through both active and passive data streams in 12 bipolar disorder patients over a three month span. The passive data, assumed to be objective as it was recorded by the phone and not the patient, included speech duration (minutes of speech/24 h), social activity (numbers of outgoing and incoming calls and text messages/24 h), physical activity (measured by an accelerometer every 5 min), and cell tower ID (ID of the cell tower the smartphone was connected to, sampled every 5 min). The study demonstrated the feasibility of the app, although it did not offer any clinical correlations. An additional study (Faurholt-Jepsen et al., 2014) on this app studied 17 patients with bipolar disorder who used the app for three months, during which time they completed subjective mood scales on the app and had passive data recorded as described in the initial study. Interestingly, there was a significant correlation between the passive data measured by the phone, movement between cell tower ID, and manic symptoms, but after adjusting for age and sex, this correlation no longer remained significant. However, there was a significant correlation between Hamilton depression scores and the active data collected by the app. This study thus suggested that its passive monitoring results may not correlate as strongly with clinical observations compared with active monitoring. A third pilot study relied entirely on passive data, with the study app requiring no patient interaction. This 12 week study of 10 patients with bipolar disorder featured an app that collected passive data on phone calls, including the number of calls, length of calls, and number of unique calls, sound features of calls, GPS data, and accelerometer data. While the authors did not draw any clinical conclusions, they noted 76% agreement in patient state as determined by psychiatric scales and the passively collected data, as well as the ability to automatically detect changes in state (transitions between depression and mania) (Grunerbl et al., 2015). The same group also reported on the use of passive smartphone data to detect changes in state, as compared directly to patient self-reported data, in a study of 9 patients with bipolar disorder for a 12 week duration with results suggesting passive data results are closer to objective psychiatric diagnosis (Grunerbl et al., 2014).

4. Discussion

Our review identified fourteen studies, with ten examining the role of smartphones for major depressive disorder and four for bipolar disorder. While this is not a large literature base, it offers an interesting perspective on the current state and future efforts of mobile mental health for mood disorders. Interestingly, the depression literature featured mostly (9/10) studies involving active data collection, and only one with passive. This passive study (Burns, 2011) was published nearly four years ago, and given advances in smartphone technology and sensors, it is likely that even more passive data could be collected today. While the bipolar disorder literature focused on passive data collection, at this point, results do not support a strong correlation between passive data and clinical symptoms. Whether this is due to the limitations of the existing studies, noting one study (Faurholt-Jepsen et al., 2014) had almost significant results for mania and movement detected by the smartphone, or represents a limitation of mobile mental health remains an intriguing question that future research will illuminate.

The major depressive literature literature demonstrated the feasibility of active data collection, and the scalability of active data regarding self-reported symptoms. As all four studies showed positive results, including one (Bindhim et al., 2015) which collected 8421 PHQ-9 scores from 66 countries, it seems reasonable to suggest that there is now an evolving evidence base regarding active collection of self-reported symptoms of major depressive disorder. However, an important unanswered question remains regarding the correlation of these self-reported mood symptoms to more standard clinically-conducted assessments (Torous et al., 2015). Earlier research on real time self-reported mood symptoms versus more traditional measurement techniques suggest that this is a complex question (Ben-Zeev et al., 2009; Ben-zeev and Young, 2010) and that it actually may be more productive to view different data streams as complementary rather than competing. The utility of smartphones to provide interventions through delivering psychoeducation, medication management, or therapy appears promising from the published literature, although more studies are necessary before any conclusions can be drawn. The role of passive smartphone data in depression remains largely unexplored and will likely be an area of active research given the opportunities it offers. The actigraphy literature, featuring for example the use of sensors on

watches, is already exploring the correlations between passive data, such as movement data, and depression (Kim et al., 2014). As interest in smartphone passive data grows, the actigraphy literature may serve as a guide for its potential.

The bipolar disorder literature was smaller, with only four studies, and evidenced a different approach to data as compared to the major depressive disorder literature. Every bipolar disorder study featured an app with passive data, and the reasoning for such takes into consideration the definition of bipolar disorder. The unique, and often distinguishing factor, of bipolar disorder compared to major depressive disorder is a hypomanic or manic episode. At least in theory, the increased activity levels associated with such an episode may be captured by the passive data of the phone through GPS, accelerometers, or call logs. However, this theory has yet to be fully supported by the existing smartphone literature, and it is likely that future studies will aim to more firmly correlate passive data with mania. There also appears to be the opportunity for several technically simpler studies exploring the role of active data in bipolar disorder. The lack of literature on interventions suggests that more research on smartphone diagnostics in bipolar disorder may be an area of future studies. Again, the actigraphy literature may serve as a guide to illustrate the potential of smartphone passive data in bipolar disorder.

It is worth noting that although we have discussed the different nature of active and passive data streams, they differ greatly in regards to privacy. By its nature, passive data collection is less intrusive, although it captures a tremendous amount of personal data. Each time a subject provides active data in the form of a survey question, the subject makes a choice to complete that question. In contrast, passive data collection is often 'always on' unless deliberately disabled, and thus may require higher levels of subject understanding and consent. Obtaining this consent can make research efforts more difficult. It is also unclear at this time if patient recruitment for passive studies will prove more difficult. Regardless, understanding the privacy implications of passive data is an important point that patients, clinicians, and policy makers should consider when making decisions.

While the literature on apps for mood disorders is still nascent, it is growing rapidly. Of the fourteen studies we identified in this review, all but one was published within the last 18 months. Our review identified many gaps in evidence for the role of apps, including a lack of studies on the role of passive apps in major depressive disorder and apps to deliver interventions in bipolar disorder. None of the studies collected any data on physiology, despite such being increasingly possible especially in the form of heart rate or pulse monitoring through smartphones' sensors. Although this paper does not explore wearable sensors such as various fitness bands, collecting physiological data may potentially be of utility to mobile mental health research. Physiology is one of the eight Research Domain Criteria units of analysis specified by the National Institute of Mental Health, reflecting the importance of its further study (Insel et al., 2010). While the technology to collect high quality physiological data from a smartphone continues to evolve, it will likely offer a new direction for mobile mental health research to explore. Although we did not aim to assess the quality of the literature, it is worth noting that the majority of the 14 studies were pilot or feasibility studies.

None of the fourteen studies we identified reported on any negative outcome or adverse effects from smartphone app use. While there is still a paucity of data regarding negative outcomes with mobile mental health technologies (Rozental et al., 2014), it is important for clinicians and researchers to remember that every intervention carries some risk and that such will likely be an area of future studies for mobile mental health.

Finally, we acknowledge that mobile mental health, and especially smartphone research, is a dynamic and evolving field and that any efforts to review it are limited first by the need to create firm inclusion criteria that may not match the fluidity of technology and second by rapid progression of technology. Our focus in this paper has been smartphone apps, although tools involving sensors, actigraphy, and web applications are all complementary.

5. Conclusion

Mobile mental health is an evolving and dynamic area of research. Through understanding the basic principles of smartphone data collection and the diagnostic versus interventional aims of apps, it is possible to contextualize this research and discern trends. While apps for major depressive disoder have largely focused on active data collection, especially for self-reported symptoms, and bipolar disorder apps on passive data collection to detect behaviors, the existing evidence remains largely preliminary in nature. There are several large gaps in research, notably regarding physiological measurements. The potential of mobile mental health has been well explored, but realizing its clinical potential for major depressive and bipolar disorders remains a target for the field. The efforts of the research studies discussed in this paper represent those first steps towards that realization.

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