Apps and wearables in the monitoring of mental health disorders

ABSTRACT

Recent advances in smartphone technology have revealed new opportunities for the diagnosis, monitoring and provision of mental health care. Such digital approaches have the potential to enhance our understanding of the course of mental disorder, enable early diagnosis and generate new treatment targets. However, issues relating to mobile phone ownership, misuse of clinical data, commercial devices and the ethics of such approaches need to be overcome if smartphones are to be routinely used in mental health care. This article reviews the potential as well as the challenges posed by the use of such technologies in mental health settings.

Smartphone technology has the potential to revolutionize mental health care. Current mobile phones typically have internet access and an operating system capable of running downloaded applications (apps), enabling them to perform many of the functions of a traditional computer (Oxford University Press, 2018). Accordingly, these pocket-sized devices are becoming an ever more indispensable part of daily life and approximately two-thirds of adults in the UK now own one (with this proportion being even higher in younger adults) (Ofcom, 2015). The growing sophistication and abundancy of smartphones, in combination with the ubiquity of mobile networks, means that smartphones could also increase patient access to mental health information and services. This innovative approach would be in keeping with the objectives of the World Health Organization (2013) and the Department of Health (2011) of using electronic and mobile technologies to expand the delivery of mental health care. Moreover, smartphone apps may offer novel assessment and monitoring methods which could be used to improve the management of patients with mental disorders.

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Mental health apps may improve the quality of subjective clinical data

The cornerstone of psychiatric assessment is the patient's subjective account of his/her symptoms. These symptoms, along with the observations of the clinician, are then used to establish whether a patient meets the diagnostic criteria for a specific mental disorder (World Health Organization, 1992). The inevitable corollary of this is that psychiatric diagnosis is heavily dependent on anamnesis which is cross sectional in nature and vulnerable to recall biases (Harrison et al, 2018).

Smartphone technology may provide a solution to this issue as there are now apps available which allow the user to self-monitor his/her symptoms. Self-monitored data collected via smartphone apps has been shown to be comparable with data obtained through clinician-rated assessments for early psychosis (Niendam et al, 2018) and also correlates significantly with clinically rated depressive and manic symptoms in patients with bipolar affective disorder (Faurholt-Jepsen et al, 2015). It also facilitates accurate longitudinal representation of the illness course (McKnight et al, 2017) and ultimately offers a relatively unobtrusive and low-cost way of monitoring patients that could significantly improve their care (Prociow and Crowe, 2010). This approach is advantageous compared to paper-based mood self-monitoring tools because it prompts the user to record his/her mood, allows real-time assessment in a natural setting and gives verification of the timing and compliance of the data collection (Faurholt-Jepsen et al, 2016).

Mental health apps could provide new objective clinical data and treatments

At present, there is a shortage of reliable objective methods for monitoring illness activity in patients with mental health disorders (Faurholt-Jepsen et al, 2015). Smartphone apps could be used to provide objective data about the user's behaviour and activity (via sensors such as cameras, microphones, gyroscopes and accelerometers) which may correlate to changes in the user's mental state (Grnerbl et al, 2015; Hollis et al, 2015). Promisingly, smartphone apps which generate objective data on illness activity in patients with bipolar affective disorder (by monitoring the frequency and duration of incoming and outgoing calls and texts) have been shown to significantly correlate with clinically rated depressive and manic symptoms and could be used to distinguish between different affective states

(Faurholt-Jepsen et al, 2015). Other markers such as geolocation have also been demonstrated to correlate well with self-reported mood states (Palmius et al, 2017). The degree to which people leave their houses, visit different locations and travel changes when people are depressed. A combination of these geolocations metrics has been shown to accurately predict depressive symptoms (Palmius et al, 2017).

Data captured via smartphone apps could also be translated into objective disease markers, which may prove to be more reliable than the subjective data obtained during traditional psychiatric assessments (Valenza et al, 2014). Such data have challenged our current conceptions of mental illness and have contributed to the emergence of persistent mood instability as a possible new 'digital phenotype' of bipolar affective disorder. Rather excitingly, this has also inspired further research into the origins, mechanisms and therapeutic implications of different bipolar affective disorder phenotypes (Harrison et al, 2018).

There are also encouraging therapeutic advances for other psychiatric conditions. Smartphone apps can deliver a simplified and more accessible form of psychological treatment for depression which is as effective as traditional face-to-face treatments (Cuijpers et al, 2017), and apps promoting psychoeducation, relaxation and social engagement can reduce symptom severity in patients suffering from post-traumatic stress disorder (Roy et al, 2017).

Mental health apps combined with other wearable technologies

Smartphone apps can also be used in conjunction with other wearable technologies (wearables) to assist with differentiating between different mood states. Data from patients with bipolar affective disorder wearing T-shirts with sensors monitoring cardiovascular and respiratory dynamics (such as heart and respiratory rate variability) can be used to accurately distinguish euthymic affective states from pathological affective states such as depression, hypomania and mixed affective states (Valenza et al, 2013). These autonomic nervous system data can then be combined with behavioural data about activity levels (which can be detected by accelerometers on the monitoring T-shirt) to characterize transitions between mood states once the data, which is collected by an app on the patient's smartphone, have been sent to a centralised server for processing (Lanatà et al, 2015).

Actigraphy can also be used to analyse sleep and activity levels throughout the 24-hour sleep–wake cycle thereby permitting a greater understanding of activity patterns in patients with bipolar affective disorder within the context of circadian rhythms (Scott et al, 2017). Synthesis of app data and wearable data may also be relevant to improved phenotyping of patients with certain personality disorders as positive correlations between subjective mood variability (captured through apps), and objective physiological and behavioural signs such as heart rate, sleep pattern and activity level (captured through wearables) have been found in patients with borderline personality disorder (Carr et al, 2018).

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Despite the potential benefits of smartphone apps in mental health, the evidence base is still relatively limited and there are also important ethical, legal and practical considerations that must be taken into account before the widespread implementation of this technology can occur.

Tolerability

It is worth noting that a qualitative study exploring the experiences of bipolar affective disorder patients wearing mood and activity monitoring technologies demonstrated that there were some apprehensions about its tolerability and patients have emphasized the need for personalization and flexibility when deploying these monitoring techniques (Saunders et al, 2017).

Unconvincing clinical validation and market regulation

The majority of existing mental health apps are still yet to be fully clinically validated, with their safety and efficacy remaining largely unproven (Craven et al, 2013; Hollis et al, 2015). Much of the research into these apps to date has involved pilot studies, randomized trials have often been small and unreplicated, placebo-controlled trials suggest that some of the positive results may be caused by a digital placebo effect and many of these studies have been undertaken by the apps' developers rather than independent researchers (Anthes, 2016). Many commercially developed mental health apps are rapidly offered directly to the general public (Craven et al, 2013; Hollis et al, 2015) and therefore regulatory bodies have struggled to appraise mental health apps with the same rigour as new psychological or pharmacological treatments. The NHS has established a health apps library (with 23 mental health apps) (Hollis et al, 2015) but a number of these 'safe and trusted' apps have not provided conclusive evidence to support their claims (Anthes, 2016).

Furthermore, there is an increasing trend for the public to use health technology to make more decisions about their health on their own (Champagne et al, 2015) and this suggests that patients may independently review their mental health app data without the collaborative support of mental health professionals. Professional supervision is also not without its challenges as clinicians would need to be educated on how to use the apps in order

to ensure they are gathering, interpreting and acting on the data correctly, and some clinicians may be resistant to embracing this new technology in the first place.

Discrimination against technology non-users

There is currently a digital divide between those who do and do not have access to smartphone devices, with approximately one third of adults in the UK not having access to them (Ofcom, 2015). Part of this population is made up of people who cannot afford smartphones and distributing mental health apps to these potentially disadvantaged individuals therefore becomes a challenge (Anthes, 2016). Additionally, older adults report a reduced confidence and familiarity with the technology (Ennis et al, 2012), reflected by the fact that only 50% of 55–64-year-olds are smartphone users compared to 90% of 16–24-year-olds (Ofcom, 2015). These discrepancies would need to be addressed if mental health care is to be delivered by smartphone apps so as to prevent discrimination against patients who do not have access to smartphones and patients who are not acquainted with the technology.

Digital mental health data storage and misuse by private companies

Private smartphone companies now provide a platform for their users to record their health data and this puts them in the powerful position of having control of the personal health data of their customers, especially given the long agreements on data rights these companies often deploy (The Economist, 2017). This is clearly in conflict with the fundamental principle of informed consent that is central to medical practice, and fears that these companies may be too cavalier with personal health data were underlined in the USA where the US Supreme Court upheld the legal right of businesses to harvest and sell patient information without their permission (Thielman, 2017). There is reason to be more optimistic about the regulations surrounding the handling of such data in the UK, as demonstrated by the Information Commissioner's Office's ruling which found that London's Royal Free Hospital failed to comply with the Data Protection Act when it gave patient data to the Google subsidiary DeepMind (Hern, 2017). However, modern data scientists can circumvent such restrictions as they are able to compile individual patient dossiers by making accurate predictions from cross-referencing anonymised patient data with named customer profiles elsewhere, such as information from fitness devices and search engines, which are not regulated as strenuously as health data (Thielman, 2017).

There are also concerns that health insurance companies may use health data obtained from wearables to discriminate against certain patients. For example, the American health insurance company Aetna announced a partnership with Apple where they planned to provide the Apple watch to large employers. It is not inconceivable that insurance companies may obtain access to the health data recorded by such devices and use it to determine the insurance premiums for its customers (Purbasari, 2016).

Even a nationalised (rather than privatised) mental health database would likely face considerable difficulties with public acceptance, as highlighted by the initial delay in the implementation of Care.data (a central database to link primary and secondary care non-identifiable patient records) resulting from a crisis of public confidence about its privacy safeguards (Triggle, 2014). It is essential that the storage of any mental health data obtained from smartphones abides by strict security regulations in order to ensure that patient rights are maintained (Hollis et al, 2015).

Conclusions

The expanding capabilities and ubiquity of modern smartphones gives this technology the potential to transform mental health care and this article evaluates the benefits and limitations of smartphone apps in mental health. Early studies have encouragingly revealed that smartphone apps can provide more reliable subjective clinical as well as previously inaccessible objective clinical data about patients with mental disorders, both of which can then be used to improve the management of these patients.

Two particularly exciting areas within this are the combination of apps and other wearables to differentiate between mood states and the use of the technology to facilitate the identification of new phenotypic characteristics of mental disorders which have not previously been feasible to measure. This novel information could also be merged with other projects which are using big data in psychiatry (such as data mining and machine learning) to further our understanding of mental illnesses and offer patients more personalised care (Monteith et al, 2015).

However, there are still several important obstacles with the technology that need to be solved such as a shortage of clinical validation of the apps, insufficient regulation of commercial apps, discrimination against non-technology users and the misuse of digital mental health databases. Nonetheless, mental health apps are currently readily available and therefore it could be contended that the medical profession needs to embrace the technology as soon as possible so that it can support and protect the patients that are already using it. Research exploring this pioneering field of apps and wearables in mental health is ongoing and it is hoped that further progress can be achieved so that we can continue to improve the lives of the millions of people who suffer from mental disorders worldwide. BJHM

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KEY POINTS

- Advances in smartphone technology have the potential to revolutionize mental health care.
- Apps and wearables are already widely used by patients and are well tolerated.
- Significant academic, regulatory and ethical questions remain and need to be urgently addressed if patients are to benefit from these techonological advances.

Anthes E. 2016. Mental health: There's an app for that. (accessed 1 March 2018) https://www.nature.com/news/mental-health-there-s-an-app-for-that-1.19694

Carr O, Saunders KEA, Tsanas A et al. 2018. Variability in phase and amplitude of diurnal rhythms is related to variation of mood in bipolar and borderline personality disorder. Sci Rep. 8(1): 1649. https://doi.org/10.1038/s41598-018-19888-9

Champagne D, Hung A, Leclerc O. 2015. The road to digital success in pharma. (accessed 1 March 2018) https://www.mckinsey.com/industries/pharmaceuticals-and-medical-products/our-insights/the-road-to-digital-success-in-pharma

Craven M, Selvarajah K, Miles R et al. 2013. User requirements for the development of smartphone self-reporting applications in healthcare. In: Kurosu M ed. Human-Computer Interaction Applications and Services. Berlin: Springer 36–45

Cuijpers P, Kleiboer A, Karyotaki E, Riper H. 2017 Jul. Internet and mobile interventions for depression: opportunities and challenges. Depress Anxiety. 34(7): 596–602. https://doi.org/10.1002/da.22641

Department of Health. 2011. No health without mental health. London: HM Government

Ennis L, Rose D, Denis M, Pandit N, Wykes T. 2012. Can't surf, won't surf: the digital divide in mental health. J Ment Health. 21(4): 395–403. https://doi.org/10.3109/09638237.2012.689437

Faurholt-Jepsen M, Vinberg M, Frost M, Christensen EM, Bardram JE, Kessing LV. 2015 Nov. Smartphone data as an electronic biomarker of illness activity in bipolar disorder. Bipolar Disord. 17(7): 715–728. https://doi.org/10.1111/bdi.12332

Faurholt-Jepsen M, Munkholm K, Frost M, Bardram JE, Kessing LV. 2016 Dec. Electronic self-monitoring of mood using IT platforms in adult patients with bipolar disorder: A systematic review of the validity and evidence. BMC Psychiatry. 16(1): 7. https://doi.org/10.1186/s12888-016-0713-0

Grnerbl A, Muaremi A, Osmani V et al. 2015 Jan. Smartphone-based recognition of states and state changes in bipolar disorder patients. IEEE J Biomed Health Inform. 19(1): 140–148. https://doi.org/10.1109/JBHI.2014.2343154

Harrison PJ, Geddes JR, Tunbridge EM. 2018 Jan. The emerging neurobiology of bipolar disorder. Trends Neurosci. 41(1): 18–30. https://doi.org/10.1016/j.tins.2017.10.006

Hern A. 2017. Royal Free breached UK data law in 1.6m patient deal with Google's DeepMind. (accessed 1 March 2018) https://www.theguardian.com/technology/2017/jul/03/google-deepmind-16m-patient-royal-free-deal-data-protection-act

Hollis C, Morriss R, Martin J, Amani S, Cotton R, Denis M, Lewis S. 2015 Apr. Technological innovations in mental healthcare: harnessing the digital revolution. Br J Psychiatry. 206(4): 263–265. https://doi.org/10.1192/bjp.bp.113.142612

Lanatà A, Valenza G, Nardelli M, Gentili C, Scilingo EP. 2015 Jan. Complexity index from a personalized wearable monitoring system for assessing remission in mental health. IEEE J Biomed Health Inform. 19(1): 132–139. https://doi.org/10.1109/JBHI.2014.2360711

McKnight RF, Bilderbeck AC, Miklowitz DJ, Hinds C, Goodwin GM, Geddes JR. 2017 Dec. Longitudinal mood monitoring in bipolar disorder: course of illness as revealed through a short messaging service. J Affect Disord. 223: 139–145. https://doi.org/10.1016/j.jad.2017.07.029

Monteith S, Glenn T, Geddes J, Bauer M. 2015 Dec. Big data are coming to psychiatry: a general introduction. Int J Bipolar Disord. 3(1): 21. https://doi.org/10.1186/s40345-015-0038-9

Niendam TA, Tully LM, Iosif AM, Kumar D, Nye KE, Denton JC, Zakskorn LN, Fedechko TL, Pierce KM. 2018 Jan. Enhancing early psychosis treatment using smartphone technology: A longitudinal feasibility and validity study. J Psychiatr Res. 96: 239–246. https://doi.org/10.1016/j.jpsychires.2017.10.017

Ofcom. 2015. *The Communications Market Report: United Kingdom*. Ofcom

Oxford University Press. 2018. Definition of smartphone. (accessed 1 March 2018) https://en.oxforddictionaries.com/definition/smartphone

Palmius N, Tsanas A, Saunders KEA, Bilderbeck AC, Geddes JR, Goodwin GM, De Vos M. 2017 Aug. Detecting bipolar depression from geographic location data. IEEE Trans Biomed Eng. 64(8): 1761–1771. https://doi.org/10.1109/TBME.2016.2611862

Prociow PA, Crowe JA. 2010. Towards personalised ambient monitoring of mental health via mobile technologies. Technol Health Care. 18(4–5): 275–284. https://doi.org/10.3233/THC-2010-0590

Purbasari A. 2016. Health insurance giant Aetna will pay you to wear an Apple Watch. (accessed 1 March 2018) https://www.theverge.com/2016/9/28/13092880/aetna-apple-watch-wearable-wellness-program-deductions

Roy MJ, Costanzo ME, Highland KB, Olsen C, Clayborne D, Law W. 2017 Aug. An app a day keeps the doctor away: guided education and training via smartphones in subthreshold post traumatic stress disorder. Cyberpsychol Behav Soc Netw. 20(8): 470–478. https://doi.org/10.1089/cyber.2017.0221

Saunders KEA, Bilderbeck AC, Panchal P, Atkinson LZ, Geddes JR, Goodwin GM. 2017 Mar. Experiences of remote mood and activity monitoring in bipolar disorder: A qualitative study. Eur Psychiatry. 41: 115–121. https://doi.org/10.1016/j.eurpsy.2016.11.005

Scott J, Vaaler AE, Fasmer OB, Morken G, Krane-Gartiser K. 2017 Dec. A pilot study to determine whether combinations of objectively measured activity parameters can be used to differentiate between mixed states, mania, and bipolar depression. Int J Bipolar Disord. 5(1): 5. https://doi.org/10.1186/s40345-017-0076-6

The Economist. 2017. A digital revolution in health care is speeding up. (accessed 1 March 2018) https://www.economist.com/news/business/21717990-telemedicine-predictive-diagnostics-wearable-sensors-and-host-new-apps-will-transform-how

Thielman S. 2017. Your private medical data is for sale – and it's driving a business worth billions. (accessed 1 March 2018) https://www.theguardian.com/technology/2017/jan/10/medical-data-multibillion-dollar-business-report-warns

Triggle N. 2014. GPs voice fears over giant patient records database. (accessed 1 March 2018) http://www.bbc.co.uk/news/health-26151458

Valenza G, Gentili C, Lanatà A, Scilingo EP. 2013 Jan. Mood recognition in bipolar patients through the PSYCHE platform: preliminary evaluations and perspectives. Artif Intell Med. 57(1): 49–58. https://doi.org/10.1016/j.artmed.2012.12.001

Valenza G, Nardelli M, Lanatà A, Gentili C, Bertschy G, Paradiso R, Scilingo EP. 2014 Sep. Wearable monitoring for mood recognition in bipolar disorder based on history-dependent long-term heart rate variability analysis. IEEE J Biomed Health Inform. 18(5): 1625–1635. https://doi.org/10.1109/JBHI.2013.2290382

World Health Organization. 1992. The ICD-10 Classification of Mental and Behavioral Disorders. Geneva: World Health Organization

World Health Organization. 2013. Mental health action plan 2013–2020. Geneva: World Health Organization