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Tech world and medicine come together to harness digital medicine

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Chances are you own a smartphone. There is also a chance you use only a fraction of the functionality your smartphone offers. Most people use the core communication functionality their smartphone provides, without comprehending the power that resides in the palm of their hand. The technology is 120 million times more powerful than that of the 1971 Apollo spacecraft [1]. True, the ability to stay connected via speech or short text-based messages is a 21st century phenomenon that allows humans to engage and relay information like never before but more impressive and perhaps, more important options exist. Dig a little deeper and you find there is so much more to be utilised from those sleek, shiny contraptions that beep or vibrate when someone tags you in a picture or informs you of their next social activity.

Recent revenues generated from smartphone applications (apps) exceeded $76 billion, an amount that is set to grow as the number of smartphone users worldwide reaches almost 3 billion by 2020 [2]. Communication-based apps are the most commonly downloaded, with WhatsApp being one of the most popular. Yet, the app's use has extended beyond the norm to include use as a tool for mentoring provincial and district health teams during a bed nets universal coverage campaign in Mozambique [3] and preliminary interpretation of neonatal chest radiographs in clinical settings [4]. In these examples, the integration of an instant messaging voice over internet protocol with a smartphone became a tool to study and support health and well-being in diverse environments.

But why stop there? Smartphones are equipped with more than just a camera. Additional environmental and personal sensing capabilities can include barometers, accelerometers, gyroscopes, magnetometers, proximity sensors, touch screens, ambient light sensors, microphones [2] and biometric sensors. Coupled with significant on-board computing resources, the sensing capabilities become extraordinary. Take the recently unveiled Galaxy Note 9, which has an octa-core processor, 6 GB of RAM, 128 GB of storage (capacity for 2 TB via a microSD slot), category 18 LTE modem, a 1440p screen, and all-day battery life (depending on usage). No longer does one require a laptop and/or customized equipment to conduct field research. The ability to gather and process large and rich data sets now resides in the palm of your hand and fits neatly in your pocket. Even more computationally intense application components can be offloaded from smartphones to servers for remote execution [5].

Smartphones are just the beginning. They have become the mechanism to gather, compute, and communicate data from remote sensors such as wearable technology worn discretely on the person, or static technologies in the home such as a weighing scale. Thus, smartphones and remote sensor technologies can offer individualised approaches for modern medicine. Yet, their introduction to routine clinical practice is challenging due to education and cost [6]. They can also present usability issues relating to the devices being fit for purpose, and accuracy issues relating to the

activities performed and/or the environmental context [7]. Although these barriers may be reduced by the rise in consumer-grade technologies with smarter sensing algorithms, they subsequently introduce regulatory issues relating to safety, validation, and accuracy. Consumer-grade mobile technologies offer mesmerising visual displays, gamification of activities with competitions and challenges, publication of feedback on performance using social influence principles, or reinforcements by virtual rewards for achievements [8]. Consequently, commercial mobile technologies may provide erroneous data and unnecessary and/or unrealistic targets that may prove counterproductive to routine clinical care. In addition, lack of technical understanding of how mobile technologies quantify and analyse physiological data may misguide interpretation in clinical studies.

When used correctly and with transparency, mobile devices have the power to revolutionise health care. Use of mobile technologies has been of utmost interest in neurological research. A recent series explored advances in Parkinson disease [9]. Espay and colleagues [10] detailed efforts to improve academic and regulatory environments for technology developers by encouraging open standard platforms for technology-based measurements and treatments by the EMA and the FDA. Of interest was the latter's cofounding of the Clinical Trials Transformation Initiative (CTTI) to improve efficiency and quality in clinical trials [11]. In a little over ten years, CTTI has worked with over 400 organisations to create freely available recommendations and resources [12, 13]. Of note, CTTI's Mobile Clinical Trials program aims to reduce barriers to incorporation of mobile technology into clinical research and practice. The program and collaborators recently conducted a systematic review of feasibility studies promoting the effective use of mobile technologies in clinical research [14] and created an open, interactive database summarising, for example, sensors and algorithms in various therapeutic areas [15].

Growth in mobile technology innovation has seen the birth of novel terminologies and new non-profit organisations to support them. Two recent examples include the Digital Therapeutics Alliance (DTA) [16] and the Digital Medicine Society (DiMe) [17]. DTA was founded in 2017 by industry and stakeholders engaged in evidence-based advancement of "digital therapeutics," a "new treatment modality in which digital systems (e.g. smartphone apps) are used as regulatory body-approved, prescribed therapeutic interventions to treat medical conditions" [18]. DiMe takes a more holistic approach, describing "digital medicine" as a field concerned with the use of technologies as tools for measurement and intervention in the service of human health where its products are driven by high-quality hardware and software.

Unambiguous communication is essential for efficient translation of promising scientific discoveries into approved medical products [19]. This is even more true when multiple disciplines come together to develop technologies to improve human health. Specifically, DiMe aims to serve

patients and professionals at the intersection of the global health care and technology communities, supporting them in developing digital medicine by providing an active platform for interdisciplinary collaboration, research, teaching, and the promotion of best practices. There is increasing emphasis on health care professionals to engage with and use more objective measures, targeting improved individualised patient assessment [20]. Mobile technologies are one possible solution that facilitate diverse data capture with powerful analysis and onward integration to cloud infrastructures, which can provide accessible data output on an individual or population basis.

Although adoption and uses of digital medicine are increasing, barriers to pragmatic and evidence-based use exist. New and emerging societies like DiMe are critical to reducing burden while creating freely available evidence for the robust, evidence-based, and harmonised use of mobile technologies in medicine.

Contributions

All authors contributed equally to the editorial.

Conflict of interest

Alan Godfrey is a strategic advisory board member of the Digital Medicine Society but (DiMe) receives no financial support. Pamela Tenaerts is a member of the Scientific Leadership Board of DiMe but receives no financial support. Samuel Stuart declares no conflict of interest.

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