HEALTH CARE DELIVERY

Open mHealth Architecture: An Engine for Health Care Innovation

Standardized interfaces and shared components are critical for realizing the potential of mobile-device–enabled health care delivery and research.

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Chronic diseases like diabetes, asthma, and obesity account for 46% of global disease burden (*1*). The traditional model of episodic care in clinic and hospital-based settings is suboptimal for improving chronic disease outcomes (*2*). Mobile communication devices, in conjunction with Internet and social media, present opportunities to enhance disease prevention and management by extending health interventions beyond the reach of traditional care—an approach referred to as mHealth (*3*). However, mHealth is emerging as a patchwork of incompatible applications ("apps") serving narrow, albeit valuable, needs, and thus could benefit from more coordinated development (*4*). A public-private partnership to define and instantiate an "open" mHealth architecture (described below), in the context of economic incentives and enabling policies, could support medical discovery and evidence-based practice about managing and preventing chronic disease.

Why mHealth?

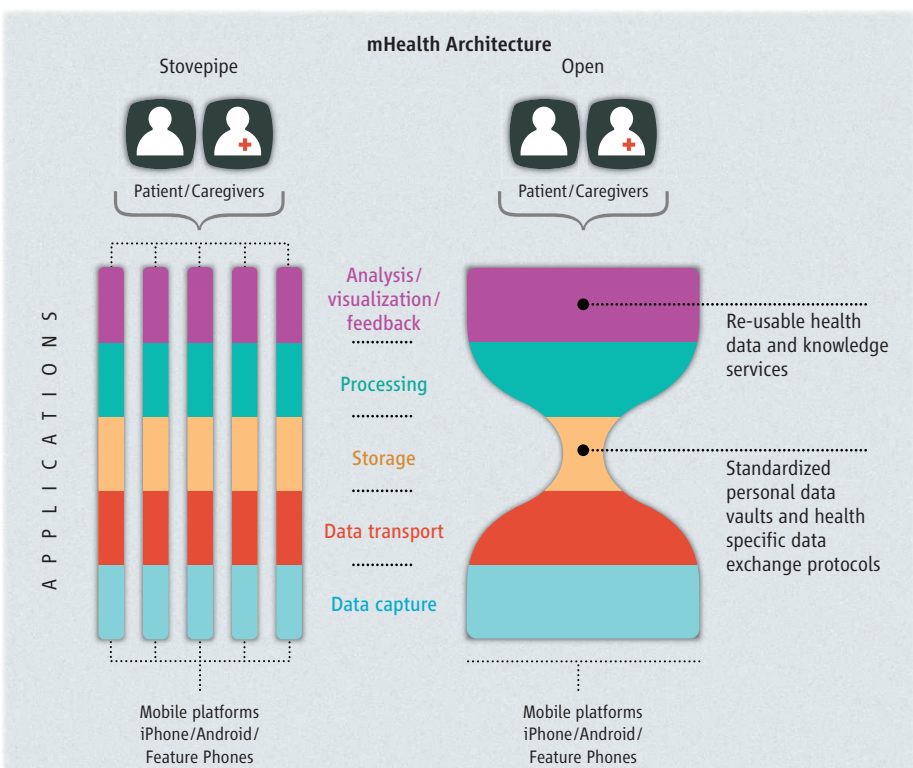
Development and treatment of chronic diseases take place in daily life outside of traditional clinical settings. To determine and adjust treatment for these diseases, clinicians depend heavily on patient reports of symptoms, side effects, and functional status. Typically, patients report at clinic visits that are months apart, and recall accuracy can be highly variable (*5*). mHealth makes it feasible for patients to collect and share relevant data at any time, not just when they happen to visit a clinic, allowing more rapid convergence to optimal treatment. For example, a patient with epilepsy can self-report on drugs and dosages taken and the number and severity of seizures and side effects. The app sends this data in real time to the clinician, who can look for patterns of response and guide the patient to titrate his medications over weeks instead of months.

mHealth apps can contribute to a rapid, learning health system, but this may be difficult if each app is built as a closed application with its own proprietary data format, management, and analysis. Such a "stovepipe" or "siloed" approach fundamentally limits the potential of mHealth by impeding data-sharing with other apps and with electronic and personal health records (EHRs and PHRs). Inefficiencies and lack of innovation plague health information technology (IT) systems that are closed and rigid (*6*). For example, a patient who is diabetic, hypertensive, and suffering from depression is unlikely to sustain use of multiple, siloed, noncommunicating, disease-specific apps that each monitor diet and medications. An open architecture built around shared data standards and the global communication network already in place to support interoperable voice and data transfer can promote the scaling, coherence, and power of mHealth. Such an architecture should complement broader ongoing developments for scalable and sustainable health information systems, including various national (*7*, *8*) and international (*9*, *10*) initiatives.

Open Architecture Benefits

In an open architecture, components have well-defined, published interfaces that allow interconnection and use in ways other than as originally implemented or intended (*11*). They allow interested parties to expand the functionality of the system without modifying existing components.

Open architectures act as innovation infrastructure much like transportation, telecommunications, and financial systems. Although not perfect (for example, because of weakness in built-in security), the Internet's open architecture sparked unprecedented cycles of innovation across all sectors of the economy.



mHealth architecture: Stovepipe versus Open. The narrow waist of the open hourglass will include at least health-specific syntactic and semantic data standards; patient identity standards; core data processing functions such as feature extraction and analytics; and data stores that allow for selective, patient-controlled sharing. Standards should be common with broader health IT standards whenever possible.

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The Internet's "hourglass" architecture, with its "narrow waist" a common Internet protocol for transferring data, and open interfaces on all sides (e.g., multiple transmission technologies and applications), was critical to its success (*12*). Just as this architecture allowed "killer" (i.e., transformative) apps such as the Web to emerge, a similar open, mHealth architecture (see the figure), with interoperability standards [e.g., (*10*)] enabling a narrow-waisted shape, may promote chronic disease prevention and management as a driving "killer app."

Clinical Care Research and Innovation

Open mHealth architecture may encourage innovation in health practices by easing application development. Shared standards and reusable components may enable rapid authoring, integration, and evaluation of personal data capture for clinical care and research. Hospitals, accountable care organizations, and public health practitioners could mix and match from a rich, flexible set of data acquisition and analysis components to configure custom apps [e.g., what symptoms to monitor, when, where, and how, or what data sources to incorporate (*8*)].

The experience base in mHealth is nascent, so research is needed to determine effective applications. Open architecture mHealth apps could be iteratively specialized to maximize usability across particular populations, diseases, and treatment protocols, and many underlying modules could be reused across applications. If architecture is coupled with a mechanism for updating shared components based on ongoing user evaluations, and appropriate incentives and policies exist, then best practices may be quickly propagated across apps to promote shared learning for mHealth usage across a broad range of health objectives.

By opening mHealth architecture, and thus lowering the barriers to entry, a broad community of patients, clinicians, family, and others could be involved in collaborative, participatory design of mHealth apps, providing new tools for extending care into the daily lives of families and communities. mHealth can amplify benefits of such real-world contexts in which "health happens," while exploring possibilities among youth and other early technology adopters (*13*). With the right architecture and shared building blocks, stakeholders could strive to create mHealth apps that protect patient privacy while using emerging data and identity standards to achieve semantically coherent interoperation with other systems.

Such accessibility to tools and populations with ubiquitous mobile devices could advance clinical care and research at a scale and resolution never before affordable. For example, despite the prevalence of depression, we lack good evidence on the long-term comparative effectiveness of antidepressants (*14*). In 2005, 27 million U.S. patients were prescribed antidepressants (*15*). Suppose every patient prescribed an antidepressant were invited by text message to participate in an antidepressant study. Patients would download an app that secures informed consent, prompts collection of standardized data (e.g., depressive symptoms, side effects, and daily activity levels), sends data to the EHR for clinician review to inform medication titration, retrieves predefined covariates from the patient's EHR (e.g., age and other medications), and anonymizes the data before sending it to the study coordinator. If only 1 out of 250 antidepressant patients in the U.S. consented to this study, the more than 100,000 enrolled patients would exceed the total number of patients enrolled in all antidepressants studies conducted worldwide as registered in ClinicalTrials.gov since 2005, when prospective trial registration first took hold (*16*).

Internationally, mHealth projects have focused on community health workers rather than on direct engagement of patients and have been limited by small scale and lack of technical and policy coordination (*5*, *17*). A patient-centric, global, open mHealth initiative could usher in transnational health promotion and research projects that are prohibitively costly today.

Why Now?

Siloed approaches have plagued development of health information systems, creating expensive barriers to entry and hampering health care innovation (*6*). Lacking an open architecture, new entrants to mHealth, including app developers, care providers, and patient communities, would proliferate solutions based on this dominant, siloed framework. But given the early stages of development, there are relatively few mHealth legacy systems and entrenched silos to overcome. Thus, this is an opportune time for a new approach, in which those same parties could leverage an open architecture to expand mHealth capacity. In the developing world, where there are few legacy health IT systems in general, the benefits of this approach may even extend beyond mHealth to the broader care system.

A modest, coordinated investment is needed to nucleate a reference implementation of this architecture informed by early pilots. A shared underlying architecture will enable much-needed scalable, affordable, and systematic research to determine which apps work best and for what populations and diseases. Defining the proper contents and interfaces to the narrow waist for mHealth is not trivial, but neither is it a complex, technical research challenge. To oversee the myriad technical, governance, and business issues, a public-private partnership is needed to balance public and commercial interests and combine the best of technology development and health care expertise. This could foster an economically and socially rewarding mHealth marketplace that uses the best health care evidence.

Approximately 25 years ago, government and industry invested in expanded access at a crucial time in the Internet's development (*12*). The resulting networks and ubiquity of access provided fertile ground for technologies, ideas, institutions, markets, and cultures to innovate. The payoff from this investment created a commercially viable and largely self-governing ecosystem for innovation. The same can be done for global health. Government, commercial, and nongovernmental entities involved in health IT and innovation should cooperate to define and instantiate architecture, governance, and business models and to steer initial mHealth investments into open architecture.

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