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Apps for immunization: Leveraging mobile devices to place the individual at the center of care

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Mobile technology and applications (apps) have disrupted several industries including healthcare. The advantage of apps, being personally focused and permitting bidirectional communication, make them well suited to address many immunization challenges. As of April 25, 2015 searching the Android app store with the words 'immunize app' and 'immunization app' in Canada yielded 225 apps. On the Apple App Store a similar search produced 98 results. These include apps that provide immunization related information, permit vaccine tracking both for individuals and for animals, assist with the creation of customized schedules and identification of vaccine clinics and serve as sources of education. The diverse functionality of mobile apps creates the potential for transformation of immunization practice both at a personal level and a system level. For individuals, mobile apps offer the opportunity for better record keeping, assistance with the logistics of vaccination, and novel ways of communicating with and receiving information from public health officials. For the system, mobile apps offer the potential to improve the quality of information residing in immunization information systems and program evaluation, facilitate harmonization of immunization information between individuals, health care providers and public health as well as reduce vaccine hesitancy. As mobile technology continues to rapidly evolve there will emerge new ways in which apps can enhance immunization practice.

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In January, 2007 Steve Jobs took to the stage at Macworld in San Francisco to announce the first iPhone, bearing the slogan "This is only the beginning".[1] It was the beginning of what would become a revolution in communications technology. Particularly transformative was the 2008 introduction of third party application (app) development, which allowed programmers to build software that could run on the device, now a key component of the functionality of all smartphones. Smartphones, which include the iPhone (running iOS) and other devices running operating systems such as Android, have experienced exponential growth since their introduction. Android surpassed a billion shipments of devices in 2014 and there have been over 700 million iPhones sold since 2007.[2-3] The increasingly ubiquitous use of these devices has disrupted numerous industries. Health is perhaps one of the most affected areas with mobile apps permitting individuals to be more engaged with their health than ever before. Apps can use the smartphones built in accelerometer to act as fitness trackers, the phone's camera to measure heart rate and use Bluetooth to link with external biometric sensors and systems to produce ECG readings and permit access to health records. The influence of mobile on healthcare and health research became impossible to ignore when Apple Inc. announced its app "Health" and accompanying Healthkit application program interfaces (APIs) for developers in 2014 and ResearchKit in 2015.[4-6]

Immunization is no stranger to mobile. Short Message Service (SMS) has been shown to increase immunization coverage in both children and adults as well as facilitate reporting of adverse events following immunization (AEFIs).[7-13] We believe

immunization practice stands to benefit from mobile apps by preserving the benefits of SMS while offering additional features native to smartphone devices. The advantage of apps, being personally focused and permitting bidirectional communication, make them well suited to address many immunization challenges such as fragmentation of delivery, surveillance and vaccine hesitancy.[14-17] We discuss how mobile applications can both empower users and usher in the next generation of immunization information systems.

Immunization Applications (APPS)

As of April 25, 2015 searching the Android store with the words 'immunize app' and 'immunization app' in Canada yielded 225 unique apps. On the Apple App Store a similar search produced 98 results (**Table 1**). These apps are diverse and provide a variety of functionality for their users. The majority of these apps are designed to provide immunization information to individuals or health care providers such as recommended vaccination schedules, relevant news, frequently asked questions, immunization statistics (e.g. coverage rates), safety and storage tips and relevant immunization events and conferences. Some examples of these apps include "Immunization Summary", "CDC" and "Vaccines on the Go". Other immunization apps offer functionality which help individuals track their own vaccinations and create personalized vaccination schedules (e.g., Canadian VacApp). iVaccinate is a tool developed specifically for health care providers, allowing them to create patient vaccination schedules, maintain vaccination records, send upcoming appointment reminders to their patients, and plan and place vaccine purchases. Some apps are designed with a patient portal and a physician portal allowing physicians to create specialized immunization schedules (e.g. Vaccination Reminder). There are even apps for tracking animal vaccinations for both pet owners and veterinarians (e.g, Pet Health Record). Some apps permit gaming and others are developed as education tools (e.g., Doctor Kids, Virtual Medical Center, Vaccine Epi-KAREN). In our search, 2 apps were identified that permit adverse event following immunization reporting (AEFI) and evaluation (e.g. Immunization Toolkit, iDsurv). Other app functions included tracking health information, locating health care services, accessing health records and accessing information about a specific clinic or hospital.

We developed ImmunizeCA which combines functionality with a Pan-Canadian app which combines information delivery with functionality for creating personalized vaccination schedules, permitting tracking of individual and family members immunization records as well as appointment reminders and alerts for vaccine preventable disease outbreaks in their area.[17] We have also tested the potential for AEFI reporting using mobile applications.[18]

Table 1. Immunization related apps

	Google Play		App Store	
General	n	%	N	%
Total	225		98	
Free	183	81	62	63
Paid	42	19	36	37
Users				
Parents	33	15	32	33
Public	33	15	15	15
Health Care Providers	27	12	17	17
Public & Health Care Providers	5	2	9	9
Pet Owners	9	4	0	0
Women	3	1	1	1
Veterinarians	2	1	0	0
Conference Attendees	2	1	3	3
Patients	23	10	1	1
Travelers	0	0	5	5
Other	4	2	5	5
Unspecified	85	38	10	10
Functions				
Information	69	31	60	61
Recommended Schedule	41	18	21	21
Personalized Schedule	20	9	18	18
Tracking	34	15	32	33
Reminders	26	12	18	18
Medical Record	37	16	12	12
Other				
Game	16	7	1	1
Animal/Pet Health	12	5	2	2
Education/Tool	20	9	7	7
Baby/Child Raising	32	14	11	11
Clinic Locator/Clinic Information	8	4	1	1
Travel	3	1	6	6
Miscellaneous	3	1	5	5

Benefits of Mobile APPS for Vaccination Tracking

While there is variety in the functionalities offered by immunization apps, perhaps the most valuable is the ability to serve as a mechanism for individuals to conveniently access and interact with their vaccination information (**Table 2**). This portability provides significant advantages over traditional paper records or patient portals only accessible through desktop computers by allowing individuals to check and change their health information data in real time, at the place of immunization. In many jurisdictions, 10–60% of paper records are missing important information or contain data errors.[19-20] Mobile apps can facilitate the recording of immunization information through manual entry, drop down menus or potentially mobile scanning of 2D vaccine barcodes. The latter can also permit the inclusion of the Global Trade Item Number (GTIN)

and lot number of the vaccine administered, substantially improving the value and quality of the information contained within the vaccination record.[19-21] Apps can also assist individuals with the logistics of vaccination including scheduling appointments in their calendar, reminding them of boosters and overdue vaccinations and helping them locate immunization clinics.[22]

By improving ease of reporting immunization status for individuals, apps can also improve the quality of information that resides in immunization information repositories. Fragmentation of vaccine provision has made it challenging for a single health care provider to have complete and accurate records for an individual. Thus increasingly the individuals' record serves as the single source of truth. Enabling mobile reporting of immunization status could facilitate the transmission of this information, potentially captured at multiple settings, directly to public health authorities. This can occur through a web service and API or as a direct upload into an immunization repository.

By allowing individuals to record and report immunization information on their mobile devices, apps can also facilitate and complement immunization surveillance activities. An example of this is the reporting of AEFIs. Apps and mobile devices could permit individuals to immediately report suspected AEFIs to their public health unit or healthcare provider. Removing barriers to the passive reporting of AEFIs may allow early signal generation of possible adverse events that can be later examined through active surveillance systems and epidemiological analyses.

Communicating with Individuals and Opportunities to Improve Vaccine Hesitancy

While mobile devices can allow individuals to send immunization information to public health officials they also open up new mechanisms for the converse; for public health to communicate directly with individuals. Apps can permit targeted messaging to geographic specific areas using devices global positioning systems (GPS) or the creation of region specific profiles.[14] Public health officials can, for example, notify individuals of vaccination clinics or outbreaks of vaccine preventable diseases within their region. Apps could also permit public health officials to send lot specific notifications to individuals in case of a lot failure or lot related adverse event.

Another potential benefit of apps is the opportunity they provide to improve vaccination confidence and rates. Three major reasons for not vaccinating include logistics, concerns about vaccine safety and concerns about whether vaccines are necessary [22] In the app we created, ImmunizeCA, we have included measures to address each of these[17] Logistical challenges are partially addressed through scheduling and automated reminder/recall features. Reminding individuals of the importance of vaccination is enabled through the inclusion of notifications of vaccine-preventable disease using an API provided by HealthMap.[23] The app also contains accurate information about vaccinations to counter misinformation that is prevalent on the Internet and social media. Mobile apps can also help public health officials address vaccine hesitancy through other mechanisms. For example, mobile apps can permit targeted messaging. Through digital detection, such as what is being accomplished in the "Vaccine Confidence Project," the possibility exists for public health officials to identify, in real time, regions where vaccine hesitancy conversations are occurring.[24] They can also identify the vaccine in question and topic of concern. A mobile app could then be used by officials to deliver tailored messages to individuals in a certain region to specifically address these concerns.[16]

Disadvantages of APPS

While apps offer potential to improve immunization practice they also have some limitations. Perhaps foremost are barriers to use. The use of smartphones is increasingly widespread, however, the willingness to use mobile applications for managing health information remains uncertain. While a younger generation of digital natives may be more willing to embrace mobile technology, older users may not be as comfortable using mobile applications to manage health information. Barriers include simple physical barriers, for example difficulties reading small screens and manually entering information. However, there are also barriers related to technology readiness reflecting a general discomfort with the use of new technology to accomplish goals in work or home life.[25-26] Our experience is that these barriers should not be underestimated. Developing the best technology is not of value if individuals are not prepared to download and use it. Strategies to

Table 2. Advantages and disadvantages of mobile apps for immunization

Advantages	Disadvantages
Record keeping based on core minimum data elements	Access to smartphones
Bar code scanning allows for data upload directly into the device	Requires maintenance and updates with advancing operating systems and hardware devices
Ability to set data standards and link to other systems	Adoption of technology and variation in population technology readiness
Automated Recall/Reminders	Privacy and security of information
Provision of information	Authenticity of information entered
Outbreak alerts	
Location of vaccine clinics	
Immunization fact sheets	
Vaccine status and AEFI reporting	Relies on individuals to enter and manage data
Targeted messaging by public health officials based on user location	

overcome "vaccine technology hesitancy" should focus on providing real value to the user, such as allowing reporting of immunization status directly to public health.

Data security is a concern related to both storage of information on a device and transmission of information. Current encryption technology offers a mechanism to provide necessary security. Password protection of both device and potentially app can provide 2 levels of security. Password protection of the device can be associated with encryption of the device itself such as is done by Apple iPhones. Mobile devices also permit remote wiping if the device should be lost removing any personal health information that may be stored. Utilizing these options would result in the security of the information on the digital record exceeding that of a paper record.

Data access could be viewed as the flipside of security. Changing devices, the need to share information with other family members and the ability to access data from several platforms may be important functionality that individuals expect. Cloud based storage could permit this allowing individuals to securely back up data, sync data with family members and access data across both mobile devices and desktop/laptop computers.

Concerns also could arise about the quality and veracity of the data on a mobile device. Manual entry and self-report may not be considered valid, particularly in jurisdictions who primarily rely on provider entered data. Mechanisms to overcome this include having a health care provider validate the information being entered by the individual on the app. This could be enabled through a signature function, allowing the vaccine provider to sign next to the entered data directly on the device with a stylus. If the data is entered using the phones camera to scan the barcode, it could also serve as a method of verifying that the immunization was received.

Manually entered data also raises the concern of standardization. If individuals are contributing data to a larger repository, it is important that data is standardized in a fashion that renders it useful for calculations of vaccine safety, coverage and effectiveness. If an immunization information system has multiple data sources, an app being one, it is crucial that all contributors are using the same standards. One such standard being used in Canada for immunization data is the systematized nomenclature of medicine clinical terms (SNOMED CT), a product of the international health terminology standards development organization.[27] These standards are traditionally used for electronic health records and should be an important consideration in the development of a mobile immunization app.

The Future

Mobile applications will almost certainly represent the future of immunization records and trigger the advent of the next generation of immunization information systems. Increasing fragmentation of immunization delivery will increasingly necessitate individuals to be empowered to track their own immunizations. Mobile applications will facilitate this and by permitting a mechanism for sharing of information between an individual, their healthcare provider and central immunization information repositories enable all 3 to have the same immunization data in real time. Quality and granularity of immunization data will improve with mobile applications, something that will be facilitated by barcode scanning. Mobile adverse event reporting and public health officials addressing vaccine hesitancy through geofenced targeted communication will be possible. Digital immunization passports that are recognized by country border officials as proof of immunization are likely to soon be developed and could address International Health Regulation requirements for proof of vaccination at borders, as is required for the yellow fever vaccine in some instances.

We envision a future where mobile applications will allow patients, providers and public health all to have access to real time information about an individual's immunization status. The individual is aware whether they are fully up to date, have upcoming vaccinations or are overdue and may be vulnerable to vaccine preventable diseases. Providers are also aware of this status and can provide recommendations and counsel their patients appropriately. Public health uses this information to calculate population vaccine coverage, safety and effectiveness. These calculations form policy, resource allocation decisions and ensure program success. As mobile technology continues to change and evolve the potential of mobile applications to continue to enhance immunization practice will only increase, benefitting individuals and the public.

Disclosure of Potential Conflicts of Interest

The authors were responsible for the development of ImmunizeCA, a pan-Canadian immunization app.

References

1. Apple reinvents the Phone with iPhone. January 9, 2007. Available at https://www.apple.com/pr/library/2007/01/09Apple-Reinvents-the-Phone-with-iPhone.html
2. Price R. Android just acheived something it will take Apple years to do. February 2, 2015. http://www.businessinsider.com/android-1-billion-shipments-2014-strategy-analytics-2015-2
3. Ingraham N. Apple has sold 700 million iPhones, 25 million Apple TVs http://www.theverge.com/2015/3/9/8164357/apple-watch-event-700-million-iphones-sold. The Verge: Vox Media 2015
4. https://www.apple.com/researchkit/
5. https://developer.apple.com/healthkit/
6. https://www.apple.com/ca/ios/whats-new/health/
7. Kharbanda EO, Stockwell MS, Fox HW, Andres R, Lara M, Rickert VI. Text message reminders to promote human papillomavirus vaccination. Vaccine 2011; 29(14):2537-41; PMID:21300094; http://dx.doi.org/10.1016/j.vaccine.2011.01.065
8. Stockwell MS, Kharbanda EO, Martinez RA, Vargas CY, Vawdrey DK, Camargo S. Effect of a text messaging intervention on influenza vaccination in an urban, low-income pediatric and adolescent population a randomized controlled trial. JAMA 2012; 307(16):1702-08; http://dx.doi.org/10.1001/jama.2012.502
9. Stockwell MS, Kharbanda EO, Martinez RA, Lara M, Vawdrey D, Natarajan K, Rickert VI. Text4Health: impact of text message reminder–recalls for pediatric and adolescent immunizations. Am J Public Health 2012; 102(2):e15-e21; PMID:22390457; http://dx.doi.org/10.2105/AJPH.2011.300331
10. Stockwell MS, Kharbanda EO, Martinez RA, Vargas CY, Vawdrey DK, Camargo S. Effect of a text messaging intervention on influenza vaccination in an urban, low-income pediatric and adolescent population: a randomized controlled trial. Jama 2012; 307(16):1702-8; PMID:22535855; http://dx.doi.org/10.1001/jama.2012.502
11. Stockwell MS, Fiks AG. Utilizing health information technology to improve vaccine communication and coverage. Hum Vaccines Immunother 2013; 9(8):1802-11; PMID:23807361; http://dx.doi.org/10.4161/hv.25031
12. Hofstetter AM, Vargas CY, Kennedy A, Kitayama K, Stockwell MS. Parental and provider preferences and concerns regarding text message reminder/recall for early childhood vaccinations. Prev Med 2013; 57(2):75-80; PMID:23624252; http://dx.doi.org/10.1016/j.ypmed.2013.04.007

13. Stockwell MS, Westhoff C, Kharbanda EO, Vargas CY, Camargo S, Vawdrey DK, Castaño, PM. Influenza vaccine text message reminders for urban, low-income pregnant women: a randomized controlled trial. Am J Public Health 2014(0):e1-e6
14. Wilson K, Atkinson K, Keelan J. 2014. Using Mobile Technology To Overcome Jurisdictional Challenges to A Coordinated Immunization Policy. Health Affairs Blog. Available http://healthaffairs.org/blog/2014/11/14/using-mobile-technology-to-overcome-jurisdictional-challenges-to-a-coordinated-immunization-policy/
15. Wilson K, Atkinson KM, Deeks SL, Crowcroft NS. Improving vaccine registries through mobile technologies. A vision for mobile enhanced immunization information systems. J Am Med Inform Assoc; In press
16. Wilson K, Atkinson K, Deeks S. Opportunities for utilizing new technologies to increase vaccine confidence. Expert Rev Vaccines 2014;12(8):1-9
17. Wilson K, Atkinson KM, Penney G. Development and release of a national immunization app for Canada (ImmunizeCA). Vaccine 2015; 33(14):1629-32; PMID:25704801; http://dx.doi.org/10.1016/j.vaccine.2015.02.022
18. Canadian National Vaccine Safety Network; iTunes; Accessed December 2014; URL:https://itunes.apple.com/ca/app/canadian-national-vaccine/id938262382?mt=8
19. Pereira JA, Quach S, Hamid JS, Quan SD, Diniz AJ, Van Exan R, Malawski J, Finkelstein M, Samanani S, Kwong J, et al. The integration of barcode scanning technology into Canadian public health immunization settings. Vaccine 2013; 32(23):2748-55; PMID:24252700
20. Public Health Agency of Canada (PHAC). Measuring up: Results from the national immunization coverage survey 2002. Canada Communicable Diseases Report (CCDR). 2004;30. Availiable from: http://www.phac-aspc.gc.ca/publicat/ccdr-rmtc/04vol30/dr3005a-eng.php
21. Pereira JA, Quach S, Hamid JS, Heidebrecht CL, Quan SD, Nassif J, Diniz AJ, Van Exan R, Malawski J, Gentry A, et al. Exploring the feasibility of integrating barcode scanning technology into vaccine inventory recording in seasonal influenza vaccination clinics. Vaccine 2012; 30(4):794-802; PMID:22119585; http://dx.doi.org/10.1016/j.vaccine.2011.11.043
22. Huston JE, Mekaru SR, Kluberg S, Brownstein JS. Searching the web for Influenza vaccines: HealthMap vaccine finder. American Jour of Pub Heal 2015; e1-e6.
23. Mills E, Jadad AR, Ross C, Wilson K. Systematic review of qualitative studies exploring parental beliefs and attitudes toward childhood vaccination identifies common barriers to vaccination. J Clin Epidemiol 2005; 58(11):1081-88; PMID:16223649; http://dx.doi.org/10.1016/j.jclinepi.2005.09.002
24. Health Map http://healthmap.org/en/ Accessed January 20, 2014
25. Larson HJ, Smith DM, Paterson P, Cumming M, Eckersberger E, Freifeld CC, Ghinai I, Jarrett C, Paushter L, Brownstein JS, et al. Measuring vaccine confidence: analysis of data obtained by a media surveillance system used to analyse public concerns about vaccines. Lancet Infect Dis 2013; 13(7):606-13; PMID:23676442; http://dx.doi.org/10.1016/S1473-3099(13)70108-7
26. Parasuraman A. Technology Readiness Index (TRI) a multiple-item scale to measure readiness to embrace new technologies. J Service Res 2000; 2(4):307-20; http://dx.doi.org/10.1177/109467050024001
27. Parasuraman A, Colby CL. An rpdated and streamlined technology readiness index TRI 2.0. J Service Res 2014:1094670514539730
28. International health terminology standards development organisation. SNOMED CT, The Global Language of Healthcare. http://www.ihtsdo.org/snomed-ct. Accesssed May 4 2015