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Wearable Technologies for Healthcare Innovation

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ABSTRACT

Healthcare is becoming more and more prone to technology. For this reason products are being developed geared toward implementing more sufficient ways of providing healthcare. Wearable technology has become one of the leading and considerably most valuable assets within the category. There are many types of wearable technology that do various tasks concerning health. Whether intended focus is on filling a void where human-error can be present or creation of a process where one was obsolete, wearable technology's presence is felt within healthcare today. This exploratory study reviews wearable technologies that exist, are being used, as well as those that are developing or in the ideation phase concerning healthcare. We present a summary of wearable technologies used in healthcare and sample categorization to serve as a working framework for understanding the future direction of the field. Exemplar cases are provided.

Keywords

Wearable technology, healthcare, health IT, innovation, wearables

INTRODUCTION

Technology has become ever more pervasive in healthcare ranging from individualized self-care and disease management to improvements in hospital efficiency. Traditionally, the healthcare industry has shown to be resistant to change (Romanow, Cho, & Straub, 2012), but the advent of wearable technology and its applicability to healthcare may prove otherwise. The purpose of this study is to provide an exploratory review of wearable technologies for health-related purposes that exist today and may possibly appear sometime in the near future. The aim is to provide a basis of knowledge for future research with a working framework for categorizing this emerging technology.

TECHNOLOGY IN HEALTHCARE

Chronic illnesses and disease have been discussed as requiring frequent patient contact for assessment of changes in clinical status (Adler-Milstein, J., & Linden, A., 2011). The ability for patients to physically be in a doctor's office or hospital for assessments or routine check-ups can pose problems for some individuals. The dilemma creates an opportunity for information technology (IT) to fill the void and enable a chronic disease management (DM) program through use of IT. Remote tele-monitoring (RMT) is a technology described as being able to support the intervention and monitoring components of DM programs which enable data collection from patient to clinical staff between visits (Adler-Milstein, J. & Linden, A., 2011). Remote tele-monitoring and similar technologies allow for use and integration of wearable technology into the healthcare field, as the need for such technology is demanded when home and mobile diagnostics are enabled.

Examining the end-user of a technology is the ultimate answer to whether the technology will be useful or usable in the way intended. For example, previous studies show regarding integration of electronic health records (EHR) into Danish hospitals that user dissatisfaction was associated with usability issues. Reports continued to inform how significant positive statements, concerning the prototype, were made when faced with straight-forward and uncomplicated cases yet, how more negative feedback arose when situations or cases were complicated (Nøhr, C., & Boye, N., 2011). There could be valuable insight to gain and apply from these studies when implementing wearable technology into healthcare for healthcare professionals and for users of the technologies; this insight can lead the field towards easier interaction of clinical activity supported by computers, information, and wearable technology.

WEARABLE TECHNOLOGY

Wearable technology can be defined as those products worn on the body of the user for extended periods of time with experience of significant enhancement as a result of the product being worn. The definition is subjected to two-tests. Test 1 assesses whether the product is wearable, questioning the length of time being worn and significant user experience enhancement. Test 2 for wearable technology assesses whether the product is smart, questioning advanced circuitry, wireless connectivity and independent processing capability (Walker, S., 2013). This definition and tests were taken into account when investigating wearable technologies in healthcare.

REVIEW OF WEARABLE TECHNOLOGIES IN HEALTHCARE

An exploratory review was conducted to determine wearable technologies that exist, are being used, as well as those that are developing or in the ideation phase concerning healthcare. The wearable technologies were selected by conducting searches using popular web-based search engines with Google.com being dominant. Searches were further refined through referrals by health information technology experts of wearable technologies that then returned the most in search engine results. For purposes of this review, those technologies that may be deemed more of a fitness tracker were included within the report as a wearable technology in healthcare if they monitor health-related functions such as heart rate, sleep, and muscle fatigue.

Table 1 presents a summary of the 43 wearable technologies used in healthcare between 2010 and 2014 that were discovered. Particular related websites and periodicals are listed in the References. The table consists of four categories which include product, company, description, and status. The *product* category refers to the actual wearable technology while the *company* category represents the organization or people that supply, invented, or inform of the wearable technology. The *description* category is a brief explanation of the product and its purpose while the *status* category informs of the product's availability, current stage, or process in which it is at the time of the reporting source's publication. The technology was categorized according to if it was: in-the-market, developing, or an idea at the time of the reporting source's publication. Exemplar cases of each category follow.

Product	Company	Description	Status
Adidas miCoach	Adidas	Fitness tracker - three part system that includes an accelerometer-based sensor, a heart rate monitor, and receiver.	In-the-market
Apple Various TBD	Apple	Reports of Features under consideration: Sensors for monitoring health-related data such as heart rates. Apple has filed at least 79 patent applications that include the word "wrist," including one for a device with a flexible screen powered by kinetic energy.	Developing
B1	Basis	Heart rate monitor, activity metrics, sleep metrics, perspiration monitor, skin temp, and pattern detection all automatically classified into a personal data feed that communicates externally via Bluetooth.	In-the-market
Bilirubin Blanket	Philips	Soft baby-blanket that provides treatment to baby for neonatal jaundice.	Developing
BioMan	AIQ Smart Clothing	Wearable electrodes combined with modern information technology that provides vital sign monitoring.	In-the-market
Blood Pressure Monitor	Withings	Instant visibility of your systolic, diastolic blood pressure and heart rate through iOS device.	In-the-market
BodyGuardian Remote Monitoring System	Preventice	Remote monitoring system for individuals with non-lethal cardiac arrhythmias, monitors key biometrics.	In-the-market
BodyTel Products	BodyTel	Home diagnostics, includes blood glucose meter, a blood pressure meter, and scales.	In-the-market
EEG Headset	Imec	Monitors brain and heart activity.	Developing
Electronic-nose (e-nose)	Panida Larwongtragool et al.	Enables physiological measurement system where tracking of real-time health status or body hygiene is allowed.	Idea
The First Warning System	First Warning	Wearable sports bra format. Detects tissue growth and pattern changes in breasts at any stage of development.	In-the-market
FIT	BodyMedia	Core and display armband monitors - weight management, fitness tracking, sleep monitoring.	In-the-market
Fitness Band	Amiigo	Fitness bracelet for iPhone and Android - measures and tracks specific exercises, reps, sets, heart rate and calories burned.	In-the-market
Fitness Bracelet	Jawbone	Tracks movement and sleep, gives feedback in these areas.	In-the-market
Flex	FitBit	Tracks steps, calories burned, sleep hours and quality, active minutes, distance traveled - tracks goals online and on mobile devices.	In-the-market

Product	Company	Description	Status
Garment	Heapsylon	Body-sensing devices for the human foot. Activity type, body weight, contributes to prevent certain injuries or disease.	Developing
Google Glass	Google	Wearable technology in head-mounted, eye-glass format with computer capabilities. Used as a basis for health-related applications especially targeting physician-support and remote diagnostics.	In-the-market
Google Glass with Neural Input for Control	Kennesaw State University BrainLab (Adriane B. Randolph et al.)	Mobile, light-weight brain-computer interface (BCI) paired with Google Glass technology.	Developing
GOW Pack	GOW	SMART T-shirts with integrated sensors. Includes a heart rate monitor.	In-the-market
Invisibles	Karten Design, Intel	Implantable, microscopic sensor technologies.	Idea
Iris Scanning (wearable patch, eye-contact lenses, FiDELYS)	Apple, Google, IriTech	High-resolution image of the eye using near-infrared (NIR) light captured for use in a wearable patch, contact lens, and for authentication.	Developing
LUMOback	LUMO BodyTech, Inc.	Highly sensitive at measuring lower back spinal posture, help correct many cases of poor neck and upper back posture.	In-the-market
Metria Wearable Sensor Technology	Vancive (Avery Dennison)	Small disposable sensor worn on-the-body, collects heart rate and respiration to sleep duration and activity levels.	In-the-market
Motoactv	Motorola	Fitness Tracker, heart rate monitor, pedometer, GPS, MP3, FM tuner	In-the-market
nECG Platform	Nuubo	Wearable remote with E-textile technology, BlendFix sensor electrode technology, and cardiac remote monitoring.	Developing
NuMetrex Cardio Shirt for Men	NuMetrex	Cardio shirt heart rate monitor.	In-the-market
NuMetrex Heart Sensing Racer Tank	NuMetrx	Sleeveless tank top with shelf bra for electronic sensing to monitor heart rate.	In-the-market
NuMetrex Heart Sensing Sports Bra	NuMetrex	Heart Sensing Sports Bra – electrical sensing technology for heart's electrical pulse.	In-the-market
OpenGo Science	Moticon	System for measurement of plantar pressure distribution, wireless sensor insoles, ANT+ enabled USB flash drive.	In-the-market
Peeko Monitor	Rest Devices	Monitors baby respiration, body position, activity level, temperature and audio. Smartphone app allows view of breathing and sleep.	In-the-market
PERSmobile	Everon	Offers mobility and security to an ageing population, wearable alarm for emergency alerts.	In-the-market
Re-Timer	Re-Timer	Designed to realign your body clock to optimize sleep.	In-the-market
Smartphones (i.e. Android, Apple iOS, RIM, Blackberry, Simbian, Windows)	Apple, Samsung	Mobile phone with an operating system (handheld computer).	In-the-market
Smartwatches (Allerta, iWatch, Garmin Forerunner 910XT GPS Heart Rate Watch, G Watch, Samsung Gear)	Garmin, Imwatch, LG Metawatch, Motorola, Pebble, Samsung, and	Computerized wristwatch able to carry out functions other than timekeeping.	In-the-market

Product	Company	Description	Status
	Sony		
SleepShirt	Rest Devices	Records and diagnoses sleep for long periods.	In-the-market
T. Jacket	T. Ware	Developed to provide comfort, calm, and control to both people with sensory processing challenges and to their caregivers.	In-the-market
TmG-BMC	TmG	Monitors muscle fatigue while exercising using a muscle contraction (MC) sensor.	In-the-market
Vega	Everon	Aids safer walking for those with Alzheimer or other cognitive disorders.	In-the-market
Viiiiva	4iiii	Heart Rate Monitor that connects full suite of ANT sensors to iPhone.	In-the market
Wearable accelerometry-based technology	Dax Steins et al.	Wearable accelerometer motion sensing technologies used to assess mobility-related functional activities intended for rehabilitation purposes in community settings for neurological populations.	Idea
Wearable device for big data collection	Intel, Michael J. Fox Foundation for Parkinson's research	Use of wearable devices with big data analytic platform to measure Parkinson's disease progression.	Idea
Wearable monitoring systems in pre-term newborns	Politecnico di Milano, Comftech	Smart pajamas with monitoring device for pre-term newborns.	Developing
Wearable Power-Assist Locomotor (WPAL)	Shigeo Tanabe et al.	Motorized orthosis for patients with paraplegia - consists of wearable robotic orthosis and custom walker	Idea

Table 1. Wearable Technology used in Healthcare

In-the-Market Status Example: Google Glass by Google

Google Glass is a wearable technology in an eye-glass format that houses a micro-computer. Google is one of the first companies to create and offer this state-of-the-art technology. Since the official launch of the product, different versions have been implemented including the Explorer edition and various unique frames. Google has since introduced earbuds designed for Glass which are in-ear speakers that deliver full-range audio (https://www.google.com/glass/).

Google Glass has the ability to capture photos, record videos, Google search, and share what the user is viewing via messaging or Google+ Hangout. Concerning healthcare, "Google Glass is envisioned to provide unique benefits for communicating medical information to healthcare professionals (HCPs)" (Turbeville, S., Wells, D., &Wolfus, C., 2014). A benefit of Google Glass for HCPs is the head-mounted feature which frees the hands to take notes and conduct tasks conducive to their current element. There are many reported potential applications in medical information for Glass including HD recordings of office visits, direct access to patient support services, real-time information sharing to other hospital facilities, and physician-administered quality-of-life instruments (Turbeville, S. et. al., 2014).

Google Glass is in-the-market and has been available to the public as of May 15, 2014. Before, Glass was only being offered to qualified "Glass Explorers" in the U.S. and U. K. The technology is in continued development and is being tested for different task capabilities by its Explorers. An app has been created for Glass which takes pictures of diagnostic test strips and sends the data to computers that rapidly transmit a diagnostic report to the user; this is thought of as a way to help stop emerging public health threats around the world (ACS, 2014).

Developing Status Example: Iris Scanning by Apple, Google, and IriTech

Iris scanning seems to be on the brink and at the forefront of a few companies' newest innovations. Apple has increased its personnel for development of iris scanning in the form of a wearable patch and for incorporation into other products within their brand and Google has announced similar technology along the lines of iris scanning using eye-contact lenses (Gurman, M., 2014). IriTech recently introduced the world's first iris recognition-enabled smartwatch, FiDELYS. The company is one of leading iris-based identity management technology solutions companies as well as a member of the Texas Instruments Design Network (IriTech, 2014).

To perform an iris scan, a high-resolution image of the eye using near-infrared (NIR) light is captured and processed in a few different ways (South Carolina Law Review, 2012). The wearable patch designed by Apple is described as being sensor-laden, transdermal, painless and able to monitor everything on the basic metabolic panel including glucose levels, kidney function, and electrolyte balance; and the eye contact lenses by Google are slated to analyze glucose levels via a user's tears (Gurman, M., 2014). FiDELYS by IriTech (2014), authenticates users through its iris recognition algorithms, of a military grade, to enhance security and relevant to protecting healthcare information.

The wearable patch can already measure glucose and potassium levels as well as test up to a hundred different samples with 30-40% of today's blood diagnostics being compatible with the device. However, the wearable technology is still being developed to measure everything on the basic metabolic table and for finding ways of brand incorporation (Gurman, M., 2014). The contact lenses technology is reported as being "seemingly far from store shelves" due to hardware being housed within the eye, it likely poses several regulatory concerns (Gurman, M., 2014). FiDELYS is currently available for pre-order and thus is not completely accessible to the public (IriTech, 2014).

Ideas Status Example: Invisibles by Karten Design and Intel

Invisibles have emerged as a serious consideration as companies are already conducting research and development on the concept. They are described as implantable, microscopic sensor technologies believed to create a world in which technology is no longer seen but integrated into the human body.

Karten Design reports conducting research with Stanley Hearing Technologies on ways to make the traditional hearing aid disappear (Karten, S., 2014). Through their research, the companies found that ear-based wearables provide information more naturally than screens and according to design principles can essentially become invisible by reducing size and creating colors that blend with hair and skin tone. In addition, a partnership between Intel and the Michael J. Fox Foundation is relevant to find patterns in proposed data in to be collected by wearable devices that will monitor Parkinson's disease patients' symptoms. The plan includes collecting more than 300 observations per second for each patient while combining the data with a growing base of molecular data deployed in the cloud (Bolluyt, J., 2014). The novel, wearable electronic nose (e-nose), as proposed, will enable a physiological measurement system where tracking of real-time health status or body hygiene is allowed with long-term analysis (Panida, L., Swade, E., Matthapol, W., Baumann, R. R., & Teerakiat, K., 2014).

Invisibles for the most part are still an idea or concept for the future, with the exception of the hearing aid research currently underway. Karten (2014) believes, "to create invisibles, designers will have to start with wearables and start thinking about how to turn someone into a body computer" which is a vast statement that could be foretelling the future of wearables. Intel's partnership and ideas for wearables are well thought-out concepts and visions for the healthcare field and in particular, Parkinson's disease. Their aim is to demonstrate wearable devices as having potential to bring real diagnostic value to medical research and improve treatment of the disease while pioneering a new big data analytics platform to measure the disease's progression (Bolluyt, J., 2014). The idea for an e-nose underwent experiment and testing including the fabrication of chemical sensor array by inkjet-printing technique and the actual testing of the chemical sensor array (Panida et al., 2014).

CONCLUSION

This exploratory review was conducted to report wearable technologies that are being, can be, will be, or plan to be used in healthcare and provides categories to use as a basis for future investigations. Breakthrough technology as wearables in healthcare is available present-day and infiltrating general usage as indicated by products from consumer giants like Google and Apple. Sensor-based, invisible, and disposable technologies also have a significant presence in the market. Various wearable device types emerged related to healthcare including fitness, infotainment, and medical. In particular, the boundaries between fitness and medical types seemed to merge regularly.

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