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From A to Z: Wearable technology explained

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ABSTRACT

Wearable technology (WT) has become a viable means to provide low-cost clinically sensitive data for more informed patient assessment. The benefit of WT seems obvious: small, worn discreetly in any environment, personalised data and possible integration into communication networks, facilitating remote monitoring. Yet, WT remains poorly understood and technology innovation often exceeds pragmatic clinical demand and use. Here, we provide an overview of the common challenges facing WT if it is to transition from novel gadget to an efficient, valid and reliable clinical tool for modern medicine. For simplicity, an A–Z guide is presented, focusing on key terms, aiming to provide a grounded and broad understanding of current WT developments in healthcare.

1. Introduction

Wearable technology (WT, or wearable computing) encapsulates a plethora of devices worn directly on or loosely attached to a person. Commonly, the latter comprises smartphones, which have become integral to the popularity and functionality of WT [1]. Although there is a debate defining smartphones as WT, their existence has seen the demise and rebirth of WT as useful aids to assist daily living [2]. This is primarily due to the rise of third party applications (i.e. apps) which have nurtured innovation but at the expense of well-organised app development, leaving the end-user overwhelmed with choices. Indeed, the mobile computing power of smartphones is so influential that they will likely play a key role in ongoing WT innovations such as performing quick, robust and easy bioassays anywhere and at any time [3].

In short, WT can be subdivided into two categories: (i) primary, those operating independently and functioning as central connectors for other devices and/or information (e.g. wrist worn fitness tracker, smartphone) and; (ii) secondary, capturing specific actions or executing a measurement (e.g. heart rate monitor worn around the chest) offloading to a primary wearable device for analysis [4]. Additionally, those categories may include smart textiles where the physical properties of the material can measure or react to stimuli from the user or environment [2]. Smart textiles currently lay beyond the scope of normal daily use as the concept of wearing electronic or uncommon tailoring materials interwoven within clothes or directly on the skin remains the vernacular of technological idealists.

Nevertheless, fuelled by miniaturisation of electronic-based components, WT has experienced an evolution since first appearing as means to take traditional desktop computing on the go [1]. With the ability to gather and store data as well as perform complex permutations in any real-world environment it hasn't taken WT long to enter the healthcare domain, recognised as useful tools to aid patient assessment, treatment and management. Yet, the true utility of current WT (and associated communication infrastructures) remains lacking with development of novel WT usually exceeding pragmatic (clinical) use. Regulatory bodies and vendors hamper clinical adoption, struggling to differentiate between apps classified as medical devices requiring formal regulatory approval, versus wellness apps for general use by the consumer market. Qualification of device efficacy and safety, adoption of various standards for accurate analysis and device and communications interoperability are all interwoven, presenting further barriers to clinical adoption of WT. There is also a dearth of knowledge pertaining to the fundamentals of WT, e.g. outcomes generated and relevance to specific pathologies; suitable WT selection; appropriate data management and analysis. The aim of this review is to highlight key aspects of WT for those less familiar with their robust application in healthcare. Currently, there is a myriad of technologies and terminologies overwhelming those less familiar with this field. Here, we provide a concise overview for those aiming to familiarise themselves with WT.

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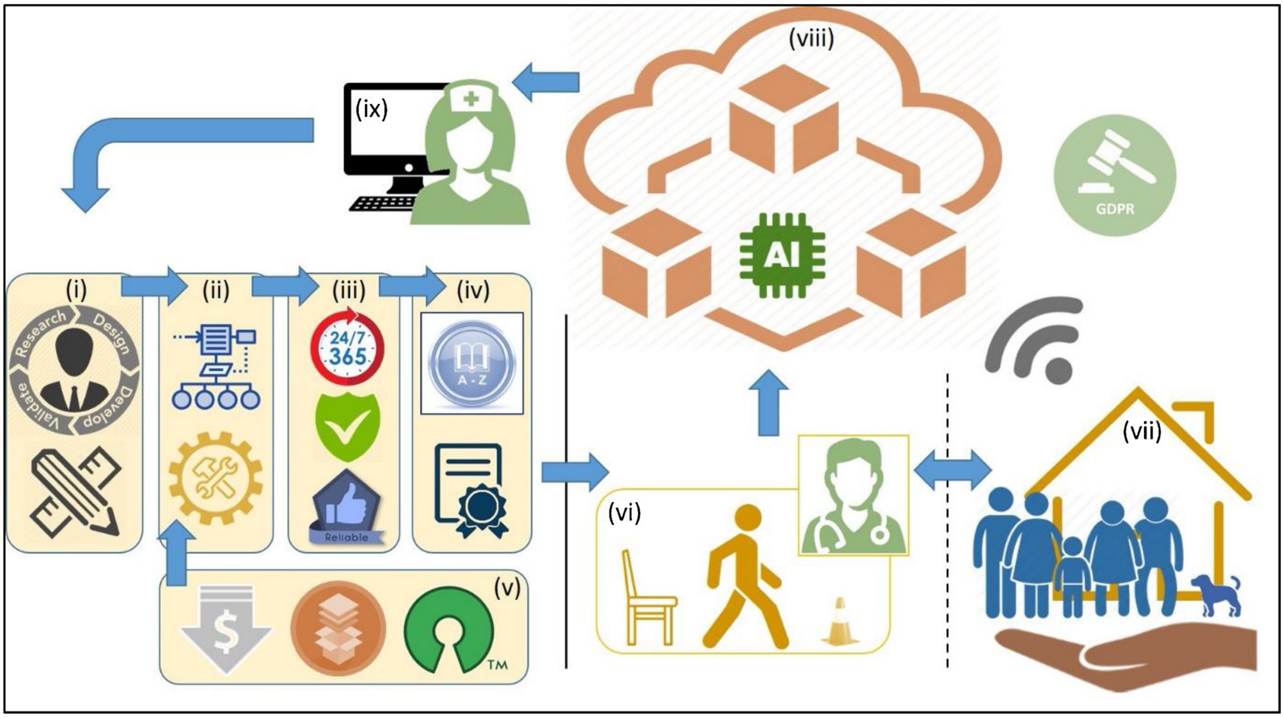

Fig. 1. A simplistic overview of the A–Z of wearables. (i, top-to-bottom) Co-creation with adults of all ages is paramount to the successful design of WT for continued daily use, influencing how WT is worn (ii) this will impact algorithm and hardware designs on how best to capture physiological measurements, (iii) once created WT will need to be efficient, valid/verified and reliable to robustly capture outcomes for longitudinal periods, (iv) adoption is simplified by translational/transparent terminology and implementing an expert consensus of standards, (v, left-to-right) the use of low cost technology including development kits and open source can facilitate novel and streamlined WT development, (vi) valid and reliable WT can better facilitate supervised patient assessment during instrumented testing in generic environments with more sensitive electronic-based data, (vii) WT (e.g. jewellery) can also provide habitual data on a range of generations facilitating self-care, (viii) WT connectivity to cloud computing, adhering to strict GDPR regulations, ensures ubiquitous sensing capabilities where embedded machine learning or artificial intelligence systems can decipher meaning from big data, (ix) WT data on the cloud can be accessed by healthcare professionals from any browser, facilitating ease of patient care. Feedback/involvement from those in the health services (or patient) should be used to inform design processes.

2. Wearables: an A–Z guide

The following details a selection of the most commonly used devices, terminologies and areas of interest. For simplicity, we present an *A–Z* guide (Fig. 1).

2.1. A is for algorithm

WT comprise different electronic-based sensors depending on measurement needs, e.g. electrocardiogram, blood glucose. For simplicity, sensors will generate an electrical signal when detecting physiological signs/responses, captured many times a second (high sampling frequency, SF) or every few minutes (low SF) depending on measurement needs. Subsequently, signals are stored as complex/raw time series data by acquisition electronics. Off-the-shelf commercial devices use proprietary software with embedded algorithms to download data, extract pertinent features and generate required outcomes (e.g. heart rate). Additionally, most WT facilitate access to raw data to allow the creation of bespoke algorithms via research tools (e.g. Matlab®, R) for more insightful patient assessment [5]. This aligns to trends in *open-source* development options, making algorithms transparent compared to black-box designs. Broadly, algorithms (within software/apps) are structured computer-based protocols to process and analyse sections of raw electronic signals/data to derive real world, meaningful outcomes. Algorithm syntax can be complex given the permutations of data interpretation needed but pseudo-code representations offer some insight to operations, like in eye tracking [6].

2.2. B is for big data

WT can continuously monitor many times a second for days or weeks. However, this will negatively affect running time between battery recharge/replacement and memory capabilities: increased data capture means reduced WT deployment time. Although WT can use large batteries or memory units, this will make WT impractical, too big and bulky to wear discretely. Thus, when deploying WT, data acquisition appreciation is required to ensure robust data collection procedures. For example; too little data and vital clues to diagnose or treat a patient may be missed; alternatively, mining/searching big data for clinically sensitive/relevant outcomes is complex. One common approach is to place WT in a low-power mode and only power up additional sensors when a possible event that is of interest has been detected [7]. Big data collected in free-living environments can offer insight to habitual behaviours such as seasonal trends, normally lacking under direct typically episodic clinical observation [8]. Yet, many obstacles exist for mainstream use of big data within healthcare such as choosing optimal architecture for storage (e.g. Structured Query Language, SQL) and analytical system (e.g. Apache HIVE), where one size does not fit all [9].

2.3. C is for cloud (computing)

Most WT is now part of the Internet of Things (IoT): connectable to digital communication infrastructures, facilitating rapid data transmission and storage. The latter is big business and growing, with overwhelming future estimates of 2.3 trillion gigabytes (GB) of IoT-based data produced daily by 2020 [10], reaching an accumulation of