

## Article

# On the Reliability of Wearable Technology: A Tutorial on Measuring Heart Rate and Heart Rate Variability in the Wild

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**Abstract:** Wearable sensors are quickly making their way into psychophysiological research, as they allow collecting data outside of a laboratory and for an extended period of time. The present tutorial considers fidelity of physiological measurement with wearable sensors, focusing on reliability. We elaborate on why ensuring reliability for wearables is important and offer statistical tools for assessing wearable reliability for between participants and within-participant designs. The framework offered here is illustrated using several brands of commercially available heart rate sensors. Measurement reliability varied across sensors and, more importantly, across the situations tested, and was highest during sleep. Our hope is that by systematically quantifying measurement reliability, researchers will be able to make informed choices about specific wearable devices and measurement procedures that meet their research goals.

**Keywords:** wearables; measurement reliability; heart rate; heart rate variability

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## 1. Introduction

A bathroom scale is a reliable measure of one's weight, provided one stands still on the scale for several moments. Yet, one is likely to discard the measurement shown by the scale if one is startled by a spider during these moments. Trying to measure cardiac signals with a wearable sensor is similar to trying to measure one's weight while dancing on the scale. The fidelity of the measurement will depend not only on the sensor's accuracy but also on the environmental conditions under which the measurement was taken.

The recent rapid proliferation of wearable sensing technology has been accompanied by many tests of their validity [1–7], usually by examining the correlation of the wearable's signal with that of trusted laboratory equipment [8]. A lot of effort has been put into developing hardware and processing algorithms to ensure high correspondence with benchmark equipment [9–14]; for latest reviews, see [15,16]. What is usually overlooked in these tests is that most laboratory measurement procedures severely limit participants' bodily movements and cognitive activities [17]. In sharp contrast, wearable devices promise to measure the same physiological signals across a wide variety of environments and bodily states. Yet, without further testing, there is no guarantee that wearables will yield accurate measurements in all contexts.

For example, Empatica's electrodermal activity (EDA) measurement showed high agreement with the EDA measurement taken under laboratory conditions. Yet, in a study that measured EDA with Empatica for 20 hrs per participant in their daily lives, 78% of the measurements were artifacts and no meaningful analysis could be performed with the remaining data [18]. In another study, which aimed to establish the validity of Empatica's HRV measurement against a Holter ECG monitor in 24-hour ambulatory monitoring, the

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**Business Publication Advertising Source** ,2001-10 *Wearable Technology: A Guide to the Revolution* Charles Nehme , In the annals of technological evolution few advancements have captured the imagination and transformed our daily lives as profoundly as wearable sensors From the humble beginnings of wristwatches to the sophisticated devices of today these tiny marvels have seamlessly integrated into our lives offering unprecedented insights into our health fitness and surroundings This book delves into the fascinating world of wearable sensors exploring their history underlying technologies and diverse applications We will examine the journey from early prototypes to the cutting edge devices that now grace our wrists fingers and even our clothing We will unravel the intricate mechanisms that power these sensors from their ability to measure heart rate and track steps to their potential to monitor environmental conditions and detect diseases Beyond their consumer appeal wearable sensors are revolutionizing industries ranging from healthcare to manufacturing They are empowering individuals to take control of their health enabling businesses to optimize operations and even reshaping the way we interact with the world around us As we navigate the pages of this book we will explore the challenges and opportunities that lie ahead We will discuss the ethical implications of collecting and analyzing personal data the importance of privacy and security and the ongoing quest for even more advanced and comfortable wearable devices I invite you to join me on this exciting journey as we uncover the incredible potential of wearable sensors and their transformative impact on our lives *Wearable Technology* Kevin Chen,2024-05 *Wearable Technology From Basics to Advanced Applications* is an indispensable guide that takes readers on an enlightening journey through the evolving world of wearable technology This comprehensive book demystifies the core concepts of wearable devices and delves into their transformative potential in various fields The book begins with an introduction to the fundamentals of wearable technology covering its history types and foundational principles It then transitions into a detailed exploration of advanced applications demonstrating the integration of wearables in healthcare fitness fashion and other sectors The book also offers insights into the technology s potential to revolutionize these fields providing a glimpse into the future of wearable devices *Wearable Technology From Basics to Advanced Applications* is a valuable resource for technology enthusiasts professionals and students With its balance of basic knowledge and advanced insights this book is an essential reference in understanding the impact and future of wearable technology Discover the world of wearables and how they shape our lives in this captivating read [Wearable Technology Show Complete Self-Assessment Guide](#) Gerardus Blokdyk,2018 *Wearable Technology Show Complete Self Assessment Guide*

**The Wearable Technology Handbook** Haider Raad,2017-01-26 The aim of this book as the title suggests is to provide a comprehensive guide to various components and applications of wearable technology in addition to its social psychological and market implications Moreover privacy security and health concerns will also be covered in this book The intended audience of this book includes but not limited to scientists in the Research and Development field university professors

practicing technologists in addition to all the enthusiasts interested in this fascinating technology Moreover the book serves as an extensive resource for both undergraduate and graduate students working on topics related to wearable technology

**Digital Health** Alan Godfrey, Sam Stuart, 2021-07-09 Digital Health Exploring Use and Integration of Wearables is the first book to show how and why engineering theory is used to solve real world clinical applications considering the knowledge and lessons gathered during many international projects This book provides a pragmatic A to Z guide on the design deployment and use of wearable technologies for laboratory and remote patient assessment aligning the shared interests of diverse professions to meet with a common goal of translating engineering theory to modern clinical practice It offers multidisciplinary experiences to guide engineers where no clinically advice and expertise may be available Entering the domain of wearables in healthcare is notoriously difficult as projects and ideas often fail to deliver due to the lack of clinical understanding i e what do healthcare professionals and patients really need This book provides engineers and computer scientists with the clinical guidance to ensure their novel work successfully translates to inform real world clinical diagnosis treatment and management Presents the first guide for wearable technologies in a multidisciplinary and translational manner Helps engineers design real world applications to help them better understand theory and drive pragmatic clinical solutions Combines the expertise of engineers and clinicians in one go to guide accessible to all

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