

# **The Necessity for Ubiquitous Motion Capture Among Athletes, Coaches, and Society**

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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## Introduction

Smart wearables that quantify athletic performance have become more widespread throughout the last decade. For reference, the athletic wearable market was at \$21 million in revenue in 2011 and has since grown to a projected \$14.91 billion in revenue in 2021 (Luczak et al., 2020). Companies such as Fitbit, Apple, and now WHOOP have developed consumer products that aim to provide users with lightweight devices that give users numbers behind what they are feeling as they workout, using various sensors that track things such as heart rate, distance traveled via GPS, and even sleep (*WHOOP*, 2021). Currently, companies are trying to crack the code in creating lightweight human motion capture wearables that can fully quantify users' movements whilst completing athletic training sessions. While still in the exploratory stage, this technology has the potential to provide feedback that improves an athlete's performance, allows coaches to make objective decisions, and reduce athletic injuries (Adesida, 2019). While there are many advantages to the advent of widespread motion capture within the world of athletics, there may be some unforeseen downsides.

With the prospect of any new technology, it is important to think about who will be the end-users and the actual customers who pay for it. Emerging technology is widely purchased when there is a strong necessity for it, but it must solve a consumer's pain point in order to be truly successful. For lightweight human motion capture, an important question that should be answered is: Is there a necessity for lightweight human motion capture in the space of athletics? To begin answering this question, this research will begin with analyzing both current wearable trackers and current motion capture technology in the sphere of sports. Currently, the most common reliable motion capture requires video set-up, and the data doesn't always make sense to coaches who want to focus on observing the actual players. There is also nothing that is

considered “ubiquitous”, or found everywhere. To predict how motion capture will play out among athletes, organizations, and society overall, the current wearable market and its impact is an important place to look.

With the increase of technology in sports sensing like heart rate monitors or WHOOP wearables, the extent to which such sensors are necessary has been questioned. While there are examples of innovation perhaps going too far, there are also studies that show close monitoring of athletes can decrease the rates of injury. Behaviors required of the users include the time to put on and set up the devices, which is highly dependent on whether the user experience was kept in mind when developing such devices. A big question that arises with the wearables is the athlete’s privacy, especially when the coaches are seemingly tracking every move and wielding control over the athlete. In addition, there is always the possibility that other actors with bad intentions may get access to such data considered to be private health information.

In this paper, I argue that there is a necessity for lightweight human motion capture that effectively trains athletes, doesn’t inhibit their performance or interpersonal relationships, and encourages them to be mindful of the moment instead of distracted by the technology itself should be developed to improve athletic performance, improve a coach’s ability to remain objective, and prevent costly injuries, enabling athletes to become the best they physically can be. As a founder of a company (known as Brave) with the purpose of creating and delivering lightweight human motion capture to the athletic space, this is a topic I think about every day and I am well-qualified to write about it.

## **Problem Definition**

Wearables in athletics have been increasing exponentially in popularity in the last decade. These technologies, in the form of wearable sensors, range from measuring physiological metrics such as an athlete's heart rate or respiratory rate to kinematic metrics such as an athlete's acceleration intensities. Companies in the space range from larger consumer technology firms such as Apple, Xiaomi, Samsung, and Huawei to other athletic specialized firms such as Zephyr, Catapult, Zebra, and Adidas (Vailshery, 2021). While athletic wearables are projected to continue their rapid growth, it is still "not fully understood the technology's usefulness or impact on athletic decisions about health and performance" (Luczak et al., 2020).

The data these devices collect are usually saved to the vendor's mobile or web applications, some with the option of being shared between platforms, and are readily available for the athlete, and when given permission, their coach to view. Previous research refers to such data as "Athlete Biometric Data" or "ABD", defined as the unique and permanent biometric information collectible and/or measurable from an individual (Garlewicz, 2020).

Within the space of athletic wearables are those used for human motion capture, which collects raw kinematic data about an athlete's movements. While not currently ubiquitous amongst athletes like a heart-rate monitor, human motion capture wearables will prove to become an emerging market this decade as the underlying technology becomes lighter, cheaper, and more accessible. Currently, human motion capture is primarily used for entertainment purposes, specifically animation (*3D Motion Capture System Market*, 2020). In addition, the motion capture technology is often in the form of an optical system, that requires both an external stationary camera system and the user to be wearing reference points on their body. While optical systems are not practical for athletes playing on the field, IMU (inertial

measurement unit) based systems can be worn completely on the body, and transmit the data wirelessly to an external receiver (Sell, 2020). This research refers to the lightweight wearable IMU form factor when discussing human motion capture in athletics.

The emergence of human motion capture in athletics includes ethical implications that cannot fully be realized until implementation, though they can be anticipated with sociotechnical system analysis. These include but are not limited to:

- Athlete Privacy and Autonomy
  - Data of an athlete's form (e.g. Tiger Wood's golf swing)
  - Time and Energy Spent on the Technology
  - How motion data should be stored and protected
  - Could athletes be abused or "commodified"
  - Are they willing to use the technology?
  - Gamification
  - Need to do studies – requires consent and extra privacy considerations
- Team Level – Interpersonal Relationships
  - Enhance or hurt an athlete-coach relationship
  - Coaches could see players as more of a data point rather than a person
- Society Level – lightweight human motion capture's impact on the outside world
  - Making everyone an athlete; teach anyone any sport
  - Data privacy would need to be medical grade
  - Adding Extended Reality/Mixed Reality to sports and athletics
  - Possible Virtual Reality adoption explosion

For the past two decades, technology for athletic tracking has taken sports into the new 21<sup>st</sup> century era. With the advent of lightweight human motion capture, automated recording, rendering, and replay will be available for an athlete's every move. While other athletic wearables are well understood at this point, light human motion capture wearables are not. There may exist unanticipated consequences as mentioned, though this research argues that the benefits outweigh the costs upon doing a sociotechnical analysis, and considering the necessity for such innovation through the discourse of inevitability and the discourse of design.

## **Research Methods**

The research method that this paper applies to answer the question of whether the athletic space necessitates ubiquitous lightweight human motion capture is based on the paper *Beyond Inevitability: Emphasizing the Role of Intention and Ethical Responsibility in Engineering Design* by Kathryn A. Neely and Heinz C. Luegenbiehl. This splits the discussion into two distinct hemispheres: the discourse of whether the development of such innovation is inevitable, and the discourse of developing such innovation in a way that is design-focused and ethically responsible (Neeley et al., 2008). While one could focus solely on arguing that the development of lightweight human motion capture is inevitable, building a company with the purpose of doing so is a much more fruitful endeavor when there is adequate customer discovery and co-creation with stakeholders that identifies and solves their pain points. This is key for design-focused engineering as well as building a successful business. After all, if no one wants the product you have developed, there is no money to be made.

The main basis behind *Beyond Inevitability* is that when engineers focus solely on the idea and discourse of technological development, there becomes a sense of inevitability that is abstracted away from personal and organizational responsibility (Neeley et al., 2008). That being

said, it is useful to research and identify the inevitability behind a potential innovation. From experience, there are generally two categories of ways that entrepreneurs select what product idea to create a venture around. One is that the entrepreneur identifies a problem either they have or someone else has and sets out to solve it. The other more calculated method is that an entrepreneur may take a hard look at market trends or the current state of technological innovations and seek to predict what the next most popular innovation will be. While no method is inherently better than the other, the second one falls more in line with the discourse of inevitability. Ideally, an entrepreneur sets out to create something that is backed both by inevitability and design-focused pull factors. In the Results section of this paper, the discourse of inevitability for lightweight human motion capture in athletics will be explored using data from both research and interviews.

The flip-side of the discourse of technological inevitability is the discourse of design, which enhances the perceptions of choice and individual responsibility, allowing for specific product considerations such as user experience and aesthetics, as well as environmental and societal implications (Neeley et al., 2008). This is much of what modern entrepreneurship education seeks to teach, that before ever even beginning to develop a potential technology, one should set out begin doing “customer discovery” (*The Customer Discovery Handbook*). Customer discovery is when founders go out and begin validating their idea for an innovation, with the primary objective of identifying their first customers. This often includes four phases that serve as a flywheel for innovation, beginning with stating hypotheses or core beliefs for an innovation, testing the hypotheses by seeking validation from potential customers, testing the product concept with potential customers, and then evaluating the customer feedback to iterate and ultimately determine next steps (*Value Proposition*). In the Results section of this paper, the

discourse of design for lightweight human motion capture in athletics will be explored using what my startup Brave has learned from the 100s of customer discovery interviews that we have done.

## **Results**

### Discourse of Inevitability

Data and data analytics have been a driving factor for many athletic teams' success in the 21<sup>st</sup> century. One of the first prominent examples of this is the 2002 Oakland Athletics season in which the baseball team, working with a comparatively small budget for player salaries compared to their competitors, selected players to recruit based on a mathematical system using statistical data, known as "sabermetrics" (Moneyball – book citation). That season, the team went on to have a 20-game winning streak and make it to the playoffs, paving the way for baseball and other sports teams to apply data analytics to their daily operations. This story became a book the next year and eventually a blockbuster movie, but the legacy of the 2002 Oakland Athletics changed the way athletic teams would recruit and manage athletes forever (Duquette et al., 2019).

The story of *Moneyball* and the 2002 Oakland Athletics is one in which wearable technology for athletes did not exist yet. Today, athletes have access to many different wearables, commonly heart rate sensors, but the options certainly do not end there. With the innovation of lightweight human motion capture, teams that choose to use such technology will provide their coaches, trainers, and data analysts with time-series data of their athletes' every move.



Current motion capture in athletics is mainly focused on highly repetitive sports such as golf, baseball, and softball, in addition to physical therapy. Not only is it expensive, but the current technology is primarily camera-based and limited to a fixed location (*Sports Performance*). With a trend in athletics to utilize as much possible data about an athlete's or team's performance, the proposition of more inexpensive and less cumbersome motion capture technology makes the necessity of such from a coach's perspective very obvious. An athlete's livelihood depends on their movement, making tracking it a valuable asset that can be used to maximize performance and prevent costly injuries.

### Discourse of Design

For my motion capture company Brave, we have completed more than 100 customer discovery interviews for our lightweight human motion capture product. The customer discovery flywheel ultimately is what lead us to begin developing motion capture, as we were originally developing a physical feedback system that enables touch interaction in virtual reality. What we began hearing was that there was a need for a subsystem of our potential innovation, the on-body motion capture component. Beginning in physical therapy, there were many hoops to jump through to comply with HIPPA and protect patient's data. Ultimately needing to complete medical studies and seek FDA certification, the potential market of athletics became more attractive.

The physical technology being specified in this analysis is a lightweight human motion capture wearable, requiring 10 nodes with IMUs for full-body data collection. This technology is the most minimally invasive form of human motion capture and allows the user to have the most mobility, making it an "attractive system" in sports (Van Der Kruk, 2018). From our interviews and tech demos with various golf instructors, football coaches, and experts in the space, the

biggest design hurdle is making the system lightweight such that it does not inhibit performance and quick to put on so that it does not take up any extra practice time to do so.

The data technology being specified in this analysis is the human motion capture data, which falls in the category of Athlete Biometric Data as per Garlewicz (2020). The importance of this classification is reflected by each state within the United States having its own laws outlining the scope of which data is officially considered private biometric data. Going forward, the data collected with Brave's lightweight human motion capture wearable will be both the company's biggest asset and biggest liability. A safe and secure platform should be a key design consideration, as leaking biometric data would be detrimental to the company and the individuals involved.

## **Conclusion**

There is a necessity in the athletics space for lightweight human motion capture wearables. Coach, trainers, and data analysts are the key stakeholders who would initially purchase and make use of the technology, though it would ultimately be for the well-being of the athletes, to help them reach the best possible version of themselves and prevent any costly injuries. As the technology improves and no longer requires the coach's guidance, athletes interested in gaining a competitive edge will likely adopt the technology as well, though this is more a discourse of inevitability. As my company Brave continues to develop and distribute lightweight human motion capture to the athletics space, we have a responsibility to take design considerations into account in order to make the best possible product that is both elegant and ethical.

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