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Wearable devices and workplace productivity: a bibliometric analysis of their integration into professional environments

Dispositivos vestíveis e produtividade no trabalho: uma análise bibliométrica da integração em ambientes profissionais

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Abstract
This study analyzes workers' perceptions and acceptance of the use of wearable devices in the workplace. A bibliometric review supported by complex network analysis was carried out, through which the driving themes of the area were identified. The results indicate the increase in the use of these technologies and the factors linked to employee acceptance or rejection. Workers' perceptions and the potential benefits of wearable technologies are also discussed. The findings reveal factors influencing technology acceptance and highlight organizational and technological characteristics that facilitate adoption for effective daily use. The study contributes to the literature by evaluating the feasibility and acceptance of wearable technologies within companies. It underscores that the lack of employee involvement in device selection is a significant barrier to adoption.

Keywords: Wearable technologies. Wearable devices. Internet of Things. Digital transformation.

Resumo
Este estudo analisa a percepção e a aceitação dos trabalhadores sobre o uso de dispositivos vestíveis no ambiente de trabalho. Foi realizada uma revisão bibliométrica apoiada por análise de redes complexas, por meio da qual foram identificados os temas motores da área. Os resultados apontam o aumento no uso destas tecnologias e os fatores atrelados a aceitação ou rejeição dos funcionários. A percepção dos trabalhadores e os benefícios potenciais das tecnologias vestíveis também são discutidos. Os achados revelam ainda os fatores que influenciam a aceitação da tecnologia e destacam características organizacionais e tecnológicas que facilitam a adoção para um uso diário eficaz. O estudo contribui para a literatura ao avaliar a viabilidade e aceitação de tecnologias vestíveis dentro das empresas e ressalta que a falta de envolvimento dos funcionários na seleção dos dispositivos é uma barreira significativa à adoção.

Palavras-chave: Tecnologias vestíveis. Dispositivos vestíveis. Internet das coisas. Transformação digital.

Graphical Abstract



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1. Introdução

Wearable devices are assistive portable technologies such as bracelets, watches, and smartphones that allow monitoring of human activities (Wang et al., 2019). These technologies have been gaining space for real-time monitoring and clinical support, enabling the prediction or prevention of health problems, and transforming the way people are monitored, diagnosed, and treated (Kristoffersson & Lindén, 2020). Wearable technologies are categorized in the literature as a branch of the Internet of Things.

The Internet of Things (IoT) features an ever-increasing variety of devices, and their numbers have been increasing dramatically since 2015 (Yildirim & Ali-Eldin, 2019). The portion of IoT related to wearable devices has also been growing, surpassing the number of devices existing in 2016 by 25 times in 2020 (Maltseva, 2020).

Thus, the use of this technology is projected to grow, particularly in work environments, aiming to ensure health monitoring and promote a more active lifestyle (Rowland, 2019), in addition to facilitating employee interactions with the work environment (Giddens et al., 2017).

As a result, wearable technologies are gaining space in various organizational sectors to help achieve results and promote workplace safety. Numerous studies have focused on understanding work-related accidents and using technology to identify and prevent causes and risk factors associated with accidents (Gope & Hwang, 2016).

According to Oswald et al. (2020), complying with worker safety requirements incurs costs for organizations, which may be associated with resources used to improve working conditions or reduce accident rates. Employee commitment to adopting new technologies is a concern for many organizational managers (Schall et al., 2018), leading to the use of practices such as financial incentives to motivate employees (Pink, 2009). In this context, it is important to analyze and consider human motivation as a more important allied factor than financial interest (Oswald et al., 2020), as motivation as motivation can drive employees for much longer than financial stimuli (Eriksson, 2011).

Wearable technologies can, among other things, monitor blood pressure, temperature, and heart rate, providing information that allows for better decision-making at behavioral, physiological, or environmental control levels (Mettler & Wulf, 2019; Swan, 2013).

Given the expansion of wearable technology use, several studies have explored the field concerning the intention to use it in the workplace (Yildirim & Ali-Eldin, 2019), employee acceptance (Choi et al., 2017; Jacobs et al., 2019), ergonomics (Brandt et al., 2018), and employee engagement (Kajiwara et al., 2019). Such research highlights the increasing use of wearables in work environments (Ailneni et al., 2019; Choi et al., 2019; Francés et al., 2019; Hwang & Lee, 2017; Schwambach et al., 2022).

Despite the growth of the study field, there is still a need for research exploring in-depth the relationships between wearable technologies and workers. To contribute to this gap in the literature, this paper aims to conduct a bibliometric analysis supported by complex network analysis to identify the main themes related to wearable technologies and workers, as well as to identify the greatest barriers regarding employee acceptance. For this purpose, SciMAT and VOSViewer software were used.

This study employs bibliometric and network analysis to uncover key themes and barriers associated with the acceptance of wearable devices in the workplace. Using SciMAT and VOSViewer software, we investigate trends in wearable technology adoption, analyze factors affecting employee acceptance, and perceived benefits.

2. Methodology

For the development of this research, two research questions were developed to guide the development of the work towards the objective, namely:

1. What are the key themes related to the use of wearable technologies by workers?

2. What challenges affect employee perception and acceptance of wearable technologies?

To find relevant documents, we used the following search string: **(TITLE-ABS-KEY (“wearable” AND “employee” OR “worker”))**.

The databases utilized were Scopus and Web of Science. Documents containing the search terms in the title, abstract, or keywords were selected. Filters were applied to include only articles and reviews published in English from 2015 to April 20, 2020. A total of 358 documents were exported, with 78 duplicates removed. The data were analyzed using SciMAT software, developed by Cobo et al. (2012).

The co-occurrence of keywords was analyzed, with synonymous terms such as “wearable technologies” and “wearable-technology” grouped, and unrelated or generic terms like “article” removed. This process resulted in 2,961 keyword clusters, which were used to generate a diagram highlighting the key themes in the field of study based on co-occurrence. **Fig. 1** illustrates the step-by-step methodological procedures.

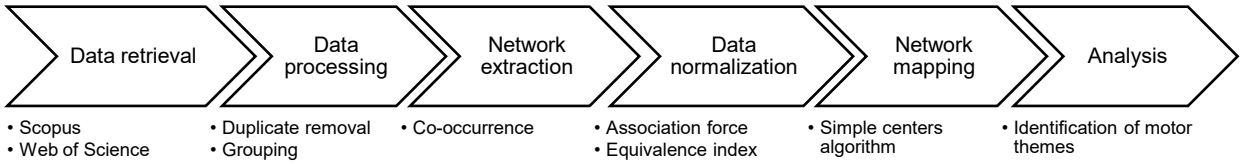


Fig. 1 Methodological steps used in the present study

For network analysis, the relationships between themes were calculated following the method of Callon et al. (1991). The Simple Center algorithm, as described by Coulter et al. (1998), was employed to create the network of links between clusters. The two-dimensional diagram displays the main themes of the field, with the 'x' axis representing the centrality of each theme relative to others, and the 'y' axis indicating the density of links between network clusters.

The clusters are distributed in the two-dimensional diagram based on their development and importance. Quadrant 1 (Q1) represents highly developed and important themes in the field during the study period. Quadrant 2 (Q2) includes basic and transversal themes that, despite having strong centrality, exhibit low density. Quadrant 3 (Q3) features emerging or declining themes, characterized by poorly developed clusters that require further qualitative analysis to determine whether they are emerging

or fading from the field. Finally, Quadrant 4 (Q4) consists of highly developed but isolated themes, which have a high density of connections but few relationships overall (Cobo et al., 2011). **Fig. 2** illustrates the distribution of clusters in the two-dimensional diagram.

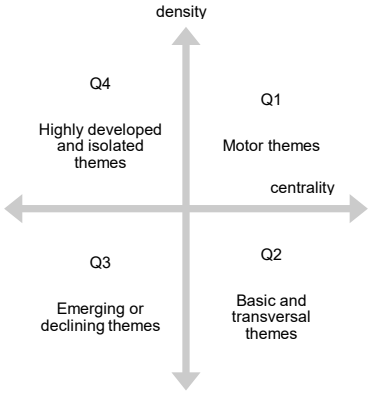


Fig. 2 Two-dimensional diagram exemplifying the themes addressed in this study

Additionally, VOSViewer software, developed by van Eck & Waltman (2012), was used to map the network of countries with the highest publication output in the field. This network analysis also reveals co-authorship relationships between countries and the research efforts dedicated to the field.

3. Results and Discussion

This section presents and discusses the research findings. It examines the development of the field by analyzing the number of published documents, the leading countries, and the journals with the highest publication rates on the topic. Additionally, the section addresses the theoretical framework of the field and explores the key themes identified through complex network analysis.

3.1 Wearable technologies

Wearable technologies are small electronic devices attached to an item or worn on the body that can collect and store information (Salah et al., 2014). Donati (2005) describes wearable computers (wearcomp) as devices that are worn on the body in a way that does not disrupt the user's daily activities. These devices need to be constantly on and accessible, providing full user control while supporting both motor and cognitive functions.

Wearable technologies can interact with the user's body in various ways, including implanted, wearable, or portable forms. All types have the capability to interact with other devices and store user information (Seymour, 2008).

These technologies also encompass accessories such as clothing that incorporate electronic and computational functions to generate information and provide feedback to users based on processed data (Fontana et al., 2014). Unlike other devices, wearable computers are designed to function as a second skin, and implants, genetic modifications, and specialized systems are excluded from this category (Donati, 2005).

The key distinction between wearable computers and mobile devices like smartphones is their ability to store and process information about both the user and their environment, enhancing interactivity. According to Mann (1996), wearable devices focus on the user and their characteristics, which can make the user seem passive. This is because the system's sensors can track the device's position, movement, and the user's vital signs, as well as detect nearby objects, people, and environmental conditions such as temperature and light (Donati, 2005).

With the potential to collect and analyze signals 24 hours a day, seven days a week, wearable computers can monitor their users and their health conditions, such as sleep, calories burned, heart rate and distance traveled. This data is available in real time, facilitating self-monitoring and enabling users to develop strategies for behavioral changes (Shin et al., 2019).

Daily life changes are influenced by various factors including technology, culture, routines, and interactions. According to Wen et al. (2017), wearable devices are increasingly capturing attention in modern lifestyles. With extensive applications, these devices are drawing significant interest from both industry and academic research (Zhang et al., 2017). Smart devices focused on health monitoring are particularly well-received, reflecting growing user concern for personal health.

To provide a comprehensive view of the field and identify literature gaps, studies from the databases were analyzed. Zhang et al. (2017) categorize current research into three main areas. They highlight the evaluation of users' intentions and behaviors regarding the adoption of wearable technology, noting that users are more likely to engage with these technologies when they perceive benefits outweigh the risks. This suggests that wearable technologies hold significant promise for future use.

Choi et al. (2017) highlight that wearable devices offer new opportunities for enhancing occupational health and safety. These devices can be used to locate employees in large industrial settings, identify associated risks, and monitor physiological conditions. The study emphasizes that factors such as perceived usefulness, social influence, and privacy concerns are crucial for the adoption of wearable technology by employees.

Despite the advancements, there are notable gaps in wearable technology research. Talukder et al. (2020) point out that there is limited data on the perceptions of older adults regarding the use and acceptance of wearables. Additionally, Distler et al. (2020) argue that the impact of this technology on user privacy and data reliability requires more attention.

Jacobs et al. (2019) identify acceptance and usage as primary concerns when integrating wearable devices into work environments. Talukder et al. (2020) further support the need for clear information about the technology's purpose and employee involvement in developing implementation programs to ensure effective use of wearable devices.

3.2 Bibliometric analysis

Since 2015, there has been exponential growth in the number of publications, reaching 110 documents in 2023 from a total of 280 documents.

The journals with the highest publication rates on this topic were identified. Automation in Construction leads with 25 articles, followed by Sensors (Switzerland) with 15 articles. Additionally, journals in the fields of construction, health, and technology have contributed notable publications. The high impact factors of these journals highlight the importance of the subject and the significant research efforts dedicated to wearable devices.

The VOSViewer software was used to identify the leading countries in terms of publication output. The United States is the foremost contributor, with the highest number of documents (100), citations (1,043), and extensive international research networks. This central position underscores the value of collaborative research networks in advancing the field. China, Italy, and South Korea also rank highly in terms of publication volume. **Fig. 3** displays the leading countries in this field and their respective co-authorship connections with other nations.

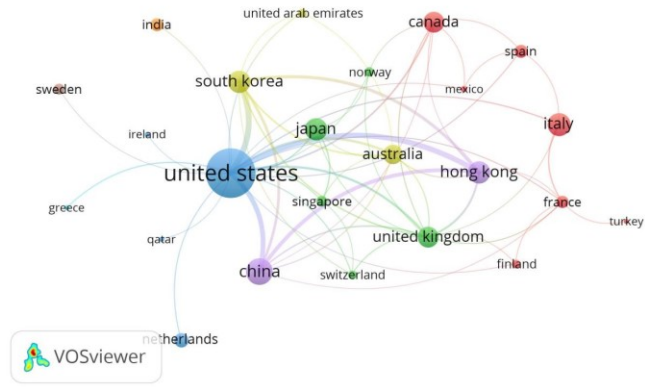


Fig. 3 Countries that publish the most on the study topic.

3.3 Driving themes of the field of study

Fig. 4 displays the strategic diagram highlighting the main themes associated with the use of wearable technologies in the workplace. The diagram is divided into four quadrants, plotting clusters/themes based on their density and centrality.

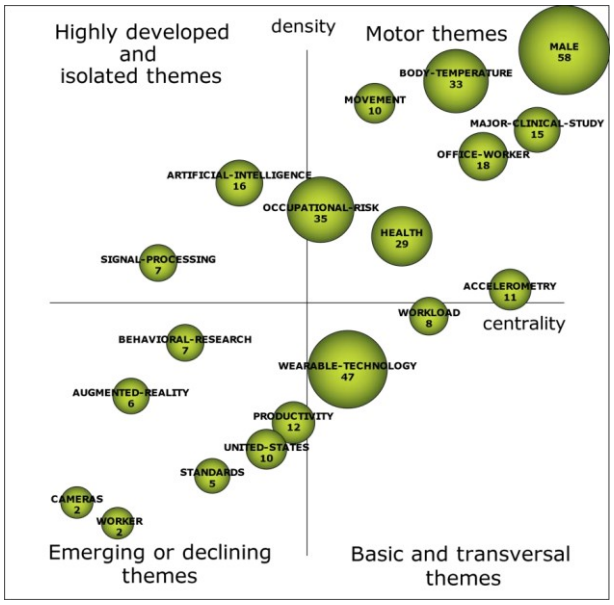


Fig. 4 Strategic diagram highlighting the main themes associated with the use of wearable technologies

The cluster with the highest density and centrality is "MALE," which includes 58 related works. This cluster has a high degree of development and numerous connections with other research topics, reflecting the substantial focus on studies concerning the use of wearable technologies by male individuals.

Other significant themes include "BODY-TEMPERATURE," which focuses on the monitoring and control of workers' body temperature in various work environments, as evidenced by studies such as Seo et al. (2016) and Buller et al. (2018). Similarly, the theme "MOVEMENT" is prevalent in research on tracking employee movements and postures in offices (Barkallah et al., 2017; W. Lee et al., 2017), walking and manual work movements (Sado et al., 2019), and musculoskeletal disorders (Valero et al., 2016).

The "OFFICE-WORKER" cluster is identified as a high-density, central theme discussing health issues related to office workers. It explores the use of wearable technologies for health monitoring, ergonomic improvements, and enhancing employee satisfaction.

Previous studies have explored various aspects of occupational time reduction through technology (Stephenson et al., 2020), body posture monitoring (Jun et al., 2019), and the movement of office workers (Hallman et al., 2019).

Additionally, research within the "MAJORCLINICAL-STUDY" cluster provides comprehensive insights into the development and application of wearable technologies in various contexts.

The "HEALTH" cluster addresses employee health concerns across different industries, emphasizing the benefits that wearable technologies can offer to both employees and employers (Boerema et al., 2016; Lee et al., 2015; Nedungadi et al., 2018; Valero et al., 2016).

The "OCCUPATIONAL-RISK" cluster examines occupational hazards in various work environments and how wearable technologies can aid in preventing and managing these risks, thus enhancing worker safety and providing organizational benefits (Podgórski et al., 2017; Schulz et al., 2018; Wang et al., 2015).

Other themes, as depicted in the strategic diagram in **Fig. 4**, are present and offer opportunities for further exploration in future research. **Fig. 5** illustrates the subthemes related to wearables, health, and occupational risk.

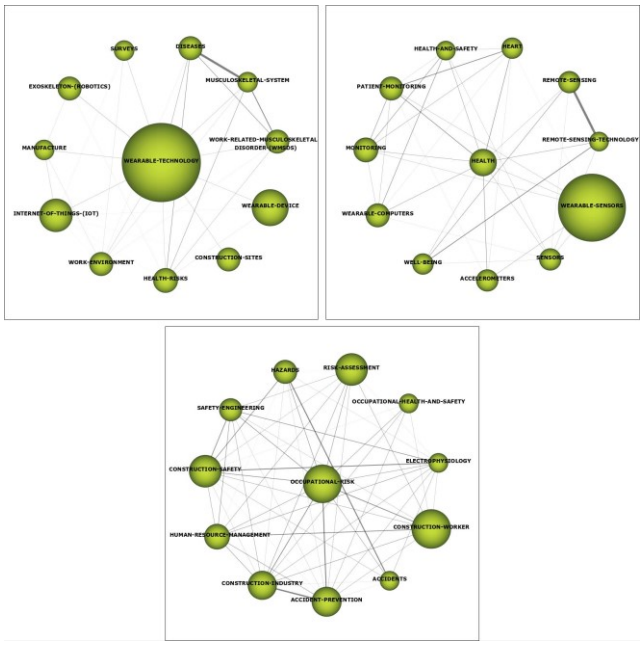


Fig. 5 Subthemes related to wearables, health, and occupational risk.

This study highlights that wearable devices are increasingly integrated into daily life, aiming to assist individuals both at home and in the workplace by reducing risk exposure and contributing to overall well-being (Kalantari, 2017). However, as noted by Flaherty (2014), the collection of data on users' routines raises privacy concerns, leading many employees to question how this information is managed and express resistance to its use.

Schall et al. (2018) emphasize that employee acceptance of wearable devices is a significant concern for managers and organizations worldwide. Hamblen (2015) highlights

that privacy issues, tied to social concerns, further complicate acceptance. Yildirim & Ali-Eldin (2019) note that the balance between privacy risks and the benefits of these devices heavily influences employees' willingness to use them in the workplace.

Jacobs et al. (2019) and Williams et al. (2015) discuss how behavioral expectations and social influence affect acceptance. Yildirim & Ali-Eldin (2019) and Abdolmohammadi & Baker (2006) underline those behavioral intentions, similar to privacy concerns, can vary among users and are crucial for technological adoption. Ethical and moral considerations also play a significant role.

According to Choi et al. (2017) and Schall et al. (2018), several factors impact the acceptance of wearable technologies by employees, including the type of device, data management practices, job position, cost, personal beliefs, and ethical considerations. Additionally, the acceptance of incentives to use these technologies is also a notable factor.

4. Conclusion

This article used a bibliometric review and complex network analysis to understand workers' perceptions and acceptance of wearable devices in the workplace. The findings reveal factors influencing technology acceptance and highlight organizational and technological characteristics that facilitate adoption for effective daily use. The study contributes to the literature by evaluating the feasibility and acceptance of wearable technologies within companies. It underscores that the lack of employee involvement in device selection is a significant barrier to adoption. Future research should explore the synergy between organizations and employees and develop strategies to mitigate the risks and costs associated with implementing wearable technologies. While this article addresses a gap in understanding wearable technology acceptance and perception, further research is needed. Future studies should investigate privacy concerns, the impact of organizational culture, and how workers' age affects acceptance. Additionally, exploring wearable device acceptance across various industrial sectors, such as manufacturing, retail, and agribusiness, is crucial.

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Authors' Contributions

G.C.S.S.; M.K.S.; R.E.S.; Data Curation, Writing-Original Draft Preparation; Editing, Reviewing, and Editing. All authors read and approved the final manuscript.

Conflict of Interest

The authors declare that they have no competing interests.

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