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Investigation of Scientific Studies on Wearable Technologies in terms of Security and Privacy

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Abstract: This research aims to present the general situation of scientific publications in the WoS database dealing with wearable technologies in terms of security and privacy from a comprehensive and holistic perspective. A total of 71 publications were reached within the scope of the research by going through various screening processes. Document analysis method was used to collect the data, and content analysis method was used for the analysis. The results of the research show that there has been a steady increase in the number of publications on this subject since 2015. In particular, it has been observed that 86.8% of the publications have been published in the last five years. In addition, it has been revealed that the most publications on the subject are in the fields of "Computer Science", "Engineering", "Telecommunications" and "Science Technology". On the other hand, it has been seen that the concept of Security is used more than the concept of Privacy in the fields of Computer Science, Telecommunications and Engineering. In addition, when the keywords of the publications are mapped, it has been seen that the words "Wearable Technologies", "Security", "Privacy", "Internet of Things", "Authentication" and "Attack" are used more frequently.

Keywords: Wearable technologies, Security, Privacy, Content analysis

Introduction

The popularity of wearable technologies has increased in the last few years with the latest improvements in technology and wearable technologies have now become a part of the daily life. Wearable technologies, which reach an important position in the market day by day with their wide product variety and are constantly developing, have a wide range of uses in terms of both individual and business needs (Bostanci, 2015; Ozguner Kilic, 2017). In the modern sense, it can be stated that the first wearable computer was designed in 1955. In the following years, there have been great developments in wearable technologies, especially in the fields of health, exercise, games, and entertainment (Demirci, 2018; Sağbas et al., 2016). In addition, the uses of wearable technology products include defense, communication, tourism, navigation and supporting services (Kalantari, 2017; Karamehmet, 2019). It can be said that these technologies have a rapidly growing impact in the field of education and offer significant opportunities.

Wearable technologies are smart digital devices or computers, often wirelessly connected, that can be integrated into pieces of clothing, worn on the body, or even tattooed on the skin, along with different types of accessories (Wright & Keith, 2014). Wearable technologies are a comprehensive concept that defines technologies that analyze and report the user's activities, behaviors, biological changes, emotions, environmental data, physical and psychological functions (Bozkurt, 2018). These technologies are electronic devices supported by

microprocessors, developed with the ability to send and receive data over the internet, have practical uses and are physically worn by individuals. Wearable technologies enable to perform multiple functions such as various types of communication, tracking personal data in real time with the help of various sensors, analyzing and transmitting this data.

Wearable technologies cover a wide variety of sensory devices such as smart watches, smart glasses, activity trackers, head-worn displays, smart optical lenses, smart clothing, smart jewelry, headbands, smart gloves, hearing aids, bracelets and wristbands (Kalantari, 2017; Wright & Keith, 2014). These technologies include a wide variety of sensors to measure mechanical data (position, displacement, acceleration, force), acoustic data (volume, pitch), biological and clinical data (heart rate, temperature, blood pressure, neural activity, sugar level, respiratory rate), behavioral data, (running, walking, climbing), optical data (refraction, light wave frequency, brightness, brightness) and environmental data (temperature, humidity) (Barfield & Caudell, 2001; Conderman et al., 2021; Lewy , 2015). Wearable technologies provide detection and monitoring features as well as many features that cannot be seen on mobile phones and computers, such as biological feedback and monitoring psychological conditions (Demirci, 2018).

It can be said that wearable technologies, which are among the products that consumers are most interested in, have many benefits that can significantly change the structure of societies and institutions. For example, the use of wearable technologies in the field of health can increase the success of medical procedures and patient safety by increasing the accuracy of clinical decisions with the obtained data. Also, wearable technologies can lead individuals to engage in healthier behaviors and significantly reduce health care costs. Wearable technologies can be used to monitor the safety and health of children and the elderly, reduce hospitalization and death rates, and alert health care providers about diseases of the elderly (Ferreira et al., 2021; Kekade et al., 2018; Lee & Lee, 2018). In addition, wearable technologies can be used to monitor personnel dealing with hazardous materials (Kalantari, 2017; Wilson, 2013). Moreover, the advantages of using these technologies over other devices include features such as easy portability, fast interaction, freedom of movement, providing feedback, increasing effectiveness, ergonomic and easy use (Bozkurt, 2018; Bower & Sturman, 2015). Fast interaction, ease of use, time and energy savings can be counted among the reasons why wearable technologies are preferred by users (Liu, 2014; Kuzu Demir & Demir, 2016). Due to the possibilities offered by wearable technologies, it can be considered that it will be beneficial in the long term in terms of enriching learning experiences (Bozkurt, 2018; Labus et al., 2015; Sezgin, 2016).

Despite the advantages offered by wearable technologies in the literature, it has also been determined that there are some disadvantages. Some educators believe that the constant use of wearable devices by students makes them dependent on this technology, thus preventing or reducing critical and independent thinking (Bower & Sturman, 2015). Long-term use of wearable technologies can also cause health problems that harm vision and hearing (Sivakumar, 2014). Furthermore, it should be noted that these technologies raise some concerns about data security and privacy in addition to concerns about users' intellectual property (Bostanci, 2015; Bozkurt, 2018; Resnick & Chircu, 2018). The main problems with wearable technologies are some of them require larger battery capacities, they are generally costly, some technical problems such as overheating occur, they distract students, may harm the privacy of users and users show resistance to change (Attallah & Ilagure, 2018; Bower & Sturman, 2015). In other studies, problems that may arise due to lack of infrastructure, social concerns, ethical factors, technical skills and compliance plus high prices have been identified (Bozkurt, 2018; Kuzu Demir & Demir, 2016; Sezgin, 2016).

The research aims to present the general situation of scientific studies dealing with wearable technologies in terms of security and privacy in the WoS database from a comprehensive and holistic perspective. In the literature, it has been observed that the number of scientific studies on the subject has increased and the studies have diversified. Due to the increasing importance of the subject, it is thought that it attracts the attention of researchers. It is thought that the results of the study will provide researchers and experts with a detailed perspective on the subject and will guide new studies to be done.

Method

In this study, which was carried out with the qualitative research method, a systematic review design was used. A systematic review is the synthesis of study findings with a holistic perspective by bringing together all published research related to the research question within the framework of predetermined criteria in order to answer a specific research question in general (Yilmaz, 2021). In this way, comprehensive assumptions about the trends of the researched subject can be obtained and this can guide the researchers about the current issues of

the research area for their future studies. In line with the general purpose of the research, answers to the following questions were sought:
Based on scientific studies on wearable technologies in the WoS database;

• What is the distribution by years?
• What is the distribution according to applied research areas?
• What is their distribution according to the scope of security and privacy in research areas?
• What is the distribution by keywords?

Data Collection Process and Analysis of Data

The data of the study were obtained from the Web of Science (WoS) database. In the data collection process, primarily, search criteria were determined to reach and examine scientific studies made with wearable technologies. As a search phrase ("wearable technolog*" OR "wearable device*" OR "wearable computer*" OR "fashion technolog*") AND ("privacy" OR "security" OR "crime" OR "legal" OR to find relevant studies "law" OR "violation" OR "malware" OR "hacking" OR "breach" OR "virus" OR "attack" OR "threat*" OR "injection" OR "ethical" OR "spam*" OR "DoS" OR "phishing") keywords are used. The scanning process was repeated at certain intervals until the end of January 2022. There was no restriction on the years of publication in the searches made. Books, research and lecture reports, and abstract or full-text papers found in the relevant searches were not included in the study. Only studies (articles, review articles and early access) written in English and scanned in SCI-E or SSCI indexes were included in the research. In the analysis, it is seen that a total of 68 studies that are suitable for the purpose of the research and that do not have access barriers have been accessed. The "Academic Publication Review Form" developed by the researchers was used as a data collection tool in the study. The form was developed considering similar compilation studies in the field. The form, which was prepared in accordance with the purpose and content of the research, was reviewed by three academicians who are experts in their fields, and its content validity was tried to be ensured. Data were analyzed using content analysis. Content analysis is coding the data, finding the themes, organizing the codes and themes, and defining and interpreting the results to reach relationships and concepts that can explain the data collected for studies in a specific field (Yildirim & Simsek, 2016).

Results and Discussion

Distribution of Publications by Years

In the study, primarily the distribution of scientific studies on wearable technologies by years was examined. The obtained results are given in Figure 1.

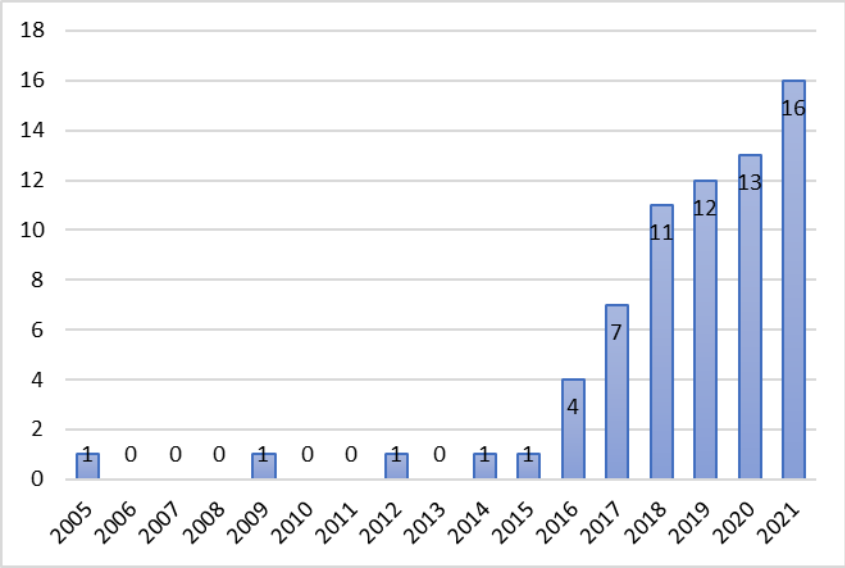

Figure 1. Numerical distribution of publications by years

When Figure 1 is examined, it is seen that only five publications on the subject were made until 2015. However, in the following years, a significant increase in the number of publications on the subject was noted. In particular, it has been observed that 86.8% (59 publications) of the publications were published in the last five years.

Distribution of Publications by Research Areas

In order to reveal the potential of wearable technologies in the field and to evaluate the results, it has also been determined in which research areas these applications are carried out. The top 10 research areas are presented in Table 1.

Table 1. Distribution of publications by research areas

Research Areas	(f)
Computer Science	41
Engineering	25
Telecommunications	22
Science & Technology	10
Business & Economics	7
Materials Science	7
Chemistry	5
Health Care Sciences & Services	4
Medical Informatics	4
Physics	4

When the data in Table 1 is examined, it is seen that the most publications on the subject are in the field of "Computer Science" (f=41). This is followed by publications in the fields of “Engineering” (f=25), “Telecommunications” (f=22) and “Science Technology” (f=10).

Distribution of Publications by Security and Privacy Scope in Research Areas

The distribution of publications in research areas according to the scope of security and privacy is presented in Table 2.

Table 2. Distribution of publications in research areas by security and privacy scope

Research Areas	Security (f)	Privacy (f)
Computer Science	32	15
Telecommunications	17	10
Engineering	15	9
Business & Economics	5	4
Medical Informatics	4	3
Health Care Sciences & Services	3	3
Science & Technology	4	2
Social Sciences	2	2
Chemistry	0	2
Communication	2	1
Information Science & Library	2	1
Automation & Control Systems	1	1
History & Philosophy of Science	1	1
Materials Science	1	1
Neurosciences & Neurology	1	1
Public Administration	1	1
Instruments & Instrumentation	0	1
Other Topics	1	0
Science Business & Economics	1	0
Mathematical & Computational Biology	1	0

According to Table 2, it has been determined that the concept of security (f=32) is used more often than the concept of Privacy (f=15) in Computer Science. In addition, similar findings were found in the fields of

Telecommunications and Engineering. However, there is no publication about Security in the fields of Chemistry and Instruments & Instrumentation. Another area outside of the research areas specified in Table 1 was included in the "other" category. When Table 2 is examined, it is seen that more than one research area is used in some publications. In addition, in some publications, the concepts of privacy and security are used together. It can be said that the main reason for this is the use of the concepts of privacy and security in more than one research area at the same time in some of the reviewed publications.

Distribution of Keywords Used in Publications

Keywords are very important in presenting the study content and outline. In this context, the keywords used in the publications were also examined. Key phrases that are very close to each other in terms of meaning were gathered under a single keyword in the research. The word cloud of the keywords used in the publications is presented in Figure 2.

Figure 2. Word cloud of keywords used in publications

As a result of the analysis, it was determined that in some of the publications, the keywords remained insignificant in reflecting the nature and content of the research, while in some of the publications, they fully explained the nature of the research. It was determined that a total of 249 different keywords were included in the studies discussed. When the keywords in the studies were examined, it was determined that the frequency of use of the keyword "Wearable technologies" (f=78) was higher than any of the other keywords. The most frequently used keywords after the “Wearable Technologies” are “Security” (f=96), “Privacy” (f=24), “Internet of Things” (f=16), “Authentication” (f=19) and “Attack” ” (f=7). The 204 keywords used in the studies took place only once. In addition, no keywords were used in four of the studies.

Conclusion

In this research, it is aimed to evaluate the current situation by examining the general situation of scientific studies dealing with wearable technologies in terms of security and privacy in the WoS database from a comprehensive and holistic perspective. Therefore, this study is a research based on document analysis. Based on this situation, it can be stated that the current study will constitute a source for new studies to be done in the future and may be a guide on current issues.

As a result of the research, it was concluded that the number of scientific studies on the subject increased steadily every year and a significant part of the studies were carried out in the last five years. Therefore, it can be said that the subject attracts the attention of researchers due to its increasing importance and studies on this subject will continue. It can be stated that the developments in wearable technologies in recent years have been an effective reason for the emergence of this situation.

In order to reveal the potential of wearable technologies in the field and to evaluate the results within the scope of the research, it has also been determined in which research areas these technologies are carried out. As a result of the analysis, it was seen that the most publications were in the field of "Computer Science". This is followed by publications in the fields of "Engineering", "Telecommunications" and "Science Technology", respectively. Focusing on these research areas can be expressed as the fact that wearable technologies are hardware that can communicate with other electronic devices and can transfer data, and that it is a common research area in which both computer sciences, engineering and telecommunication sciences work interdisciplinary. However, it is striking that the subject is relatively not preferred in fields such as "Social Sciences", "Chemistry" and "Sport Science". Despite this, the existence of studies related to these research areas draws attention. It can be said that the studies conducted outside the main research area are mostly qualitative or quantitative studies. In this context, it can be said that it would be beneficial to focus on studies in these fields in order to enrich the literature and support these research results.

Another result obtained in the research is that the concept of security is used more than the concept of Privacy in the fields of Computer Science, Telecommunications and Engineering. However, there is no publication on the concepts of Security in the fields of Chemistry and Instruments & Instrumentation. In the keyword analysis, it was determined that the words "Wearable technologies", "Security", "Privacy", "Internet of Things", "Authentication" and "Attack" were concentrated in accordance with the search criteria. It can be said that the keywords used in the studies are related to the subject and describe the characteristics of the research.

In this research, it is aimed to examine the scientific studies on wearable technologies in terms of security and privacy in various dimensions and to share the results with researchers. As a result of the content analysis, it has been determined that there are many research areas related to the subject that are very few in number. In order to better determine the benefit level of wearable technologies in terms of security and privacy, it is recommended to make academic publications in different research areas that are not examined or examined less.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

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