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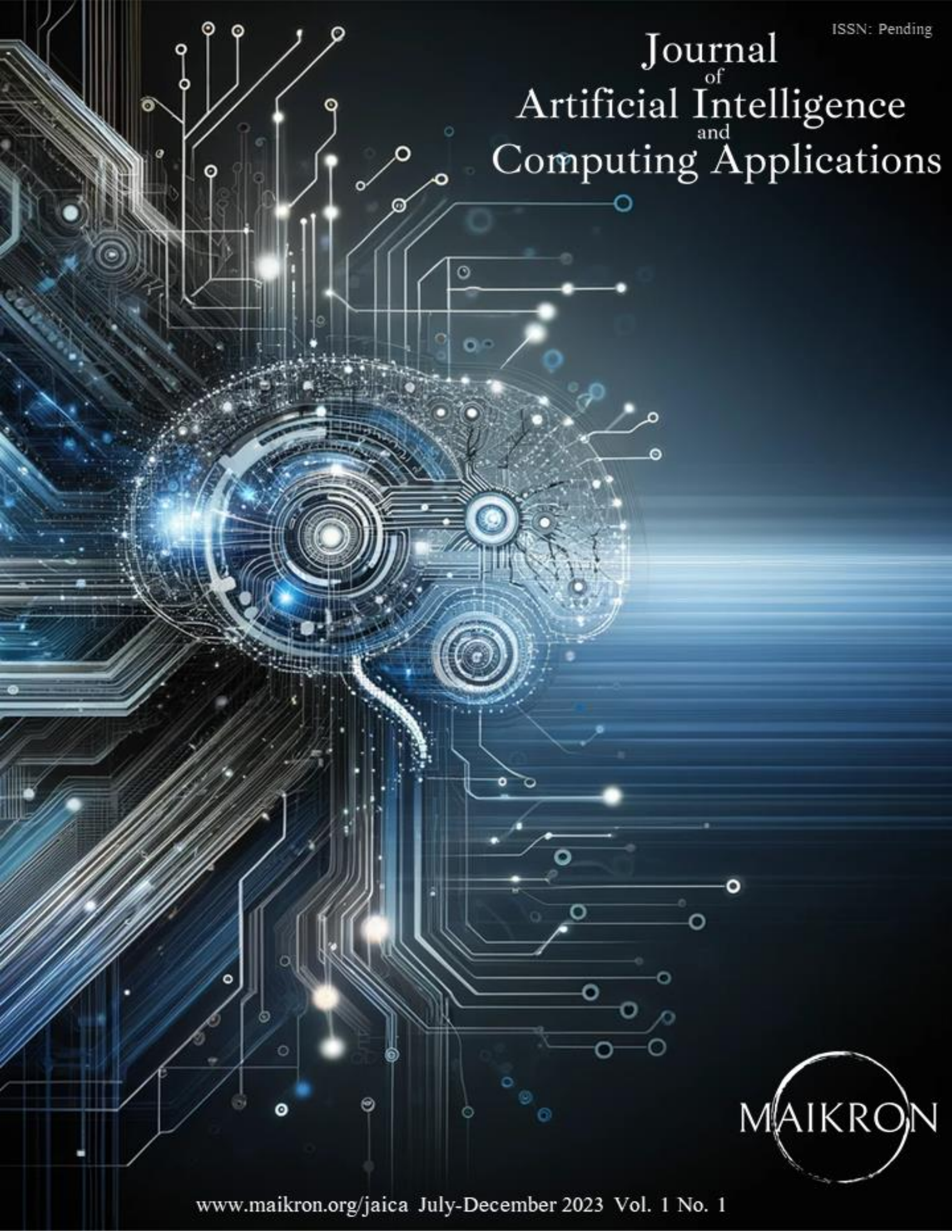

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Foreword

Dear Readers, Contributors, and Colleagues,

It is with immense pride and a profound sense of responsibility that I present to you the inaugural issue of the Journal of Artificial Intelligence and Computing Applications (JAICA). As the Editor-in-Chief, I am honored to embark on this journey, one that promises to chart new territories in the confluence of artificial intelligence and practical computing applications.

Founded under the auspices of Maikron, a visionary non-profit civil association (Association for the Advancement of Intelligent Applications and Technologies with Social Impact), JAICA aspires to be more than just a repository of scholarly articles. Our mission is to foster a vibrant community of scholars, practitioners, and enthusiasts who are united by a shared passion for the transformative power of AI and computing. We are dedicated to nurturing a diverse intellectual environment that welcomes a wide spectrum of contributions, from groundbreaking research to innovative software and hardware developments.

This first issue symbolizes the beginning of an exciting adventure, one that seeks to challenge the conventional boundaries of scientific publishing. By including categories such as Short Narrative Reviews, Applied AI Exploration Papers, and the Math for AI Capsules, as well as the more conventional Original Research Articles, we aim to offer a platform that accommodates the vast spectrum of intellectual curiosity and scholarly rigor within our community. Our inaugural issue features three insightful Short Narrative Reviews and one Math for AI Capsule, personally authored by me to exemplify the spirit of this section. Each piece has been carefully selected to represent the breadth and depth of research that JAICA strives to showcase.

Our vision for JAICA is ambitious. We aim to become a trustworthy source of not just groundbreaking research but also of thought-provoking articles that might not find a home in more traditional journals. This commitment to inclusivity and innovation is underscored by our rigorous, yet supportive, peer review process,

ensuring that every article we publish meets the highest standards of academic excellence.

In this issue, we delve into the multifaceted challenges of network security in smart cities, explore the therapeutic potential of custom-made video games for mental health, investigate the role of video games in vocabulary acquisition, and introduce a novel vector similarity measure for AI applications. Each article contributes to the rich tapestry of knowledge that JAICA aims to weave.

I would like to extend my heartfelt gratitude to our editorial team, the diligent reviewers, our dedicated technical staff, including members of the AAAIMX student chapter, our editorial sponsor Maikron, and, most importantly, our pioneering authors. Your collective efforts have brought JAICA from concept to reality.

As we look to the future, I am filled with optimism. I envision JAICA as a beacon of knowledge and innovation, guiding researchers around the globe. This is just the beginning of what I hope will be a fruitful and impactful journey.

Welcome to the inaugural issue of JAICA. Together, let's shape the future of technology.

Warmest regards,

Mauricio G. Orozco-del-Castillo

Editor-in-Chief

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Review article

Challenges in network security for smart cities: a short narrative review

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ABSTRACT

It is estimated that smart cities invest in the development of new technologies to improve the quality of life for citizens. By implementing these new technologies, issues of security and privacy have become a relevant challenge for the development of smart cities. Implementing traditional cybersecurity strategies to address these issues becomes obsolete, as contemporary threats are more complex. Motivated by these factors, we examine the current challenges, vulnerabilities, and threats present in smart cities regarding privacy and data protection to determine how these issues affect smart cities and their citizens. We begin this article with a description of the current situation of smart cities. Next, a compilation and selection of literature were carried out for the completion of this work, following certain selection criteria to obtain 20 articles. We then analyze the most recent challenges and threats regarding privacy and security present in smart cities. Subsequently, threats and challenges were compiled with a focus on how they affect smart cities and their citizens. Finally, we present gaps for future research and identify directions for future investigations.

Keywords: network security, smart cities, threats and vulnerabilities

1. Introduction

Nowadays, the term *smart city* is becoming increasingly crucial in response to the growth of the urban population. It is estimated that by the year 2050, almost two-thirds of the population will reside in smart cities [1]. Although the precise definition of a smart city is somewhat complex, it generally refers to places that invest in technology to improve the quality of life for residents, with the government playing a key role in managing natural resources [2]. In this modern context, smart cities have emerged as places where technology defines the way we live. These advanced urban centers seek to enhance efficiency, sustainability, and, above all, well-being. However, challenges to the development of smart cities exist, and one of the most prominent issues is network security, especially concerning security and privacy.

Security is not the only challenge for the development of smart cities; economic factors also come into the game. This has led to a decrease in investments in public services in such projects, hindering the flourishing of these cities in many cases [3]. The implementation of this smart urbanization faces various issues, including cyber attacks, mishandling of information, Denial of Service (DOS), and vulnerabilities in connected devices that are part of the cities' networks, known as the Internet of Things (IoT). These vulnerabilities are often linked to data collection and third-party service providers [1], posing significant risks in the smart urban environment. In addition to threats derived from data collection, there are potential attacks that can directly damage network infrastructure, such as Distributed De-

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nial of Service (DDoS) attacks [4], among many other vulnerabilities that greatly affect smart cities and their citizens.

However, there is an urgent need to update information on the challenges and cybersecurity threats present in smart cities. This need is based on the crucial importance of understanding these challenges to develop strategies and solutions, thus driving the progress of smart cities.

The purpose of this article is to review the literature and present an updated analysis of the most prominent and sophisticated cybersecurity threats, vulnerabilities, and challenges in smart cities. Given the recent advances in these urban areas, it is crucial to understand the cybersecurity risks affecting both infrastructure and citizens. In response to the challenges posed, we have formulated key questions to address these issues. We aim to explore in detail questions such as: What are the most prominent and advanced threats and vulnerabilities facing IoT networks in smart cities? Furthermore, how do these threats affect the security of citizens? These questions will be analyzed to gain a deeper understanding of the vulnerabilities and threats facing smart cities.

In the review, we highlight four key sections that we address: in Section 2, we define the parameters that guided our article selection; in Section 3, we broadly cover the central ideas of the established literature; in Section 4, we delve more specifically into the development of these key ideas; and finally, in Section 5, we summarize the ideas and justify the importance of compiling this information.

2. Methodology

In this section we describe the selection process, including our inclusion and exclusion criteria. We utilized Google Scholar and Semantic Scholar as our main search engines, recognized for their extensive repository of academic articles in various disciplines, including the field of computer science. These platforms were selected for their comprehensive indexing, search capabilities, user-friendliness, and integration with a wide range of academic journals from different years, making them highly suitable for conducting an extensive and high-quality literature search.

We initiated our search with a set of keywords such as “Network security”, “Smart city”, “Network security challenges”, “Smart security”, and “Security for smart home”, with the aim of gathering key information for our review. Our inclusion criteria were strict to ensure a high standard of quality and relevance. Each co-author undertook a thorough process to select the articles that would form the basis of our review.

In the initial phase of article searching, we encountered a considerable volume of literature (126 articles) that required careful organization and filtering by the co-authors. To carry out the exclusion process, we used the Mendeley management tool. On this platform, we conducted a thorough review and verification of duplicates, ensuring the uniqueness of each article. After this process, we obtained a total of 91 articles. In the same way, we used the same tool for detailed reading and inquiry of each document. We limited our scope to articles published between 2014 and 2023, ensuring contemporary knowledge. This left us with 77 articles. Continuing the literature reduction process, we focused solely on articles published in English, reducing our literature to 70 articles. Furthermore, we limited ourselves to journals indexed in the Journal Citation Reports (JCR), specifically those classified as Q1, representing superior quality in the field. However, in the presence of highly relevant information, we were willing to make exceptions, allowing the inclusion of a Q4 article, leaving us with 53 articles. Additionally, we focused on original research articles and reviews, resulting in 43 articles. Considering quality, we aimed for coverage of minimum 10 cites per year, discarding 11 articles. Finally, we conducted an initial reading, allowing us to discard articles that did not fit correctly with the theme of the review. As a result of this meticulous selection process, we obtained 20 articles for the review; Figure 1 describes our article selection process. This selection process allowed us to focus our review on the most valuable and relevant articles in the field of smart city security, ensuring that our review is based on the most pertinent literature. The final list of the selected articles is shown in Table 1.

A notable limitation of our review was the rigorous criteria which yielded only 20 articles. This choice was made among co-authors with the intention of maintaining a simplified narrative and exclusively focusing on research that met our selection criteria. While this strategy has the advantage of providing clarity, it also implies the exclusion of alternative or more nuanced perspectives, which yields clear disadvantages in comparison to other articles. It is important to note that these perspectives could be explored in future reviews, reflecting the constantly evolving nature of this field of study. Despite the shortcomings encountered during the conduct of this review, we have managed to acquire the essential information to carry out this work.

3. Thematic Overview

In this section, a detailed analysis of the findings extracted from the previously compiled literature is conducted. These results are organized into categories closely linked to the central theme of this review. The main objective of this approach is to provide a solid structure for a more in-depth discussion of the gathered information. The categorization not only facilitates a more precise analysis but also allows for an effective contextualization of the findings within the defined thematic framework.

3.1 Vulnerabilities in industries

Industries play a fundamental role in the progress of smart cities, serving as a primary source of sustainability for the production of goods and services that benefit

Table 1. The final list of articles used in this review, including information for title, journal, year of publication and citation.

Title	Journal	Year	Citation
Internet of Things for Smart Cities	IEEE Internet of Things Journal	2014	[3]
A Comprehensive Study of Security of Internet-of-Things	IEEE Transactions on Emerging Topics in Computing	2017	[5]
Deceptive Attack and Defense Game in Honeypot-Enabled Networks for the Internet of Things	IEEE Internet of Things Journal	2016	[6]
Smart home security: challenges, issues and solutions at different IoT layers	The Journal of Supercomputing	2021	[4]
An Accurate Security Game for Low-Resource IoT Devices	IEEE Transactions on Vehicular Technology	2017	[7]
Deep Abstraction and Weighted Feature Selection for Wi-Fi Impersonation Detection	IEEE Transactions on Information Forensics and Security	2018	[8]
Malware Propagation in Large-Scale Networks	IEEE Transactions on Knowledge and Data Engineering	2015	[9]
Security and Privacy in Smart Cities: Challenges and Opportunities	IEEE Access	2018	[1]
Security and Privacy of Smart Cities: A Survey, Research Issues and Challenges	IEEE Communications Surveys and Tutorials	2019	[10]
IoT Elements, Layered Architectures and Security Issues: A Comprehensive Survey	Sensors	2018	[11]
Security and Privacy in Smart City Applications and Services: Opportunities and Challenges	Cybersecurity and Secure Information Systems	2019	[12]
Internet-of-Things-Based Smart Cities: Recent Advances and Challenges	IEEE Communications Magazine	2017	[13]
The Need for Cybersecurity in Industrial Revolution and Smart Cities	Sensors	2022	[14]
An overview of security and privacy in smart cities' IoT communications	Transactions on Emerging Telecommunications Technologies	2019	[15]
Security for smart cities	IET Smart Cities	2020	[16]
Security and privacy challenges in smart cities	Sustainable Cities and Society	2018	[17]
Smart cities and cyber security: Are we there yet? A comparative study on the role of standards, third party risk management and security ownership	Computers and Security	2019	[18]
IoT-based smart homes: A review of system architecture, software, communications, privacy and security	Internet of Things	2018	[19]
Strategic Honeypot Game Model for Distributed Denial of Service Attacks in the Smart Grid	IEEE Transactions on Smart Grid	2017	[20]
Cyber security challenges in Smart Cities: Safety, security and privacy	Journal of Advanced Research	2014	[21]

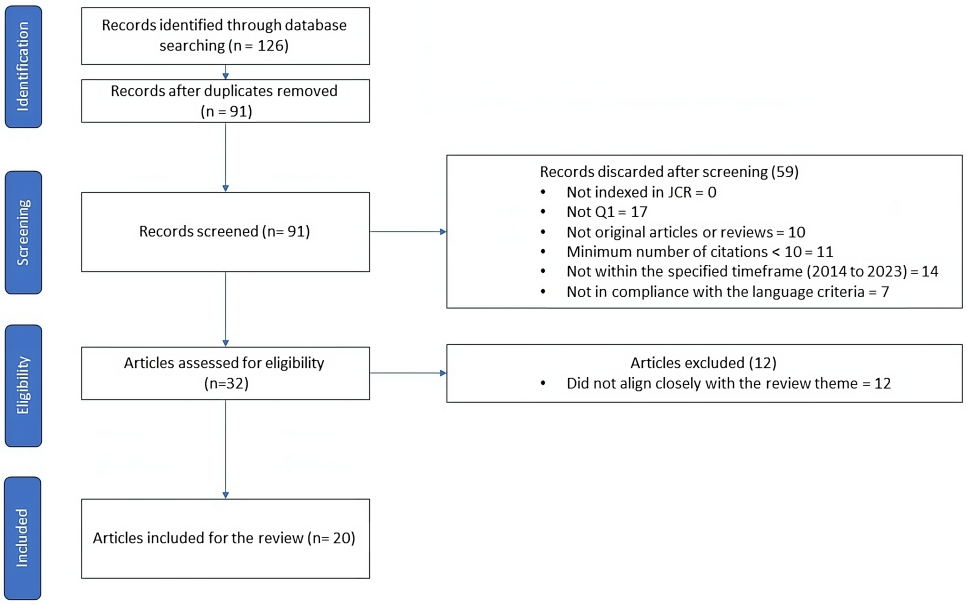

Figure 1. The selection process flowchart, illustrating the systematic screening and selection methodology used to determine the final set of articles included in the review. Starting with 126 records identified through database searching, the process details the removal of duplicates, screening for relevance, assessment of eligibility based on predefined criteria, and the final inclusion of 20 articles that closely align with the review theme.

the population [22]. Globally, industries have undergone evolution and incorporated the use of technologies to drive their activities more efficiently and facilitate their development, logistics, and production [14]. However, in the industrial realm, issues related to security arise, directly impacting the smart urban fabric.

One of the initial vulnerabilities is found in companies that maintain outdated infrastructure, which hampers security due to limited maintenance of their systems. Another present vulnerability is associated with the use of inadequately tested software, creating a security gap for attackers, as this software is established with unauthenticated configurations [4]. Additionally, a vulnerability is observed in the implementation of data encryption protocols, a critical aspect for the security of employees and the general population, both in industries and urban areas. These protocols turn out to be weak, exposing employees' systems [14]. This situation exposes personal data and company credentials, potentially leading to identity theft or impersonation attacks [4], causing conflicts and losses in the industrial sector and significantly affecting the development of smart cities.

3.2 Vulnerability in smart homes

Smart cities are composed of smart businesses and homes that host the entire population within these urban areas. In the context of smart homes, these are defined as IoT-connected applications, where physical components are linked to the internet [4], creating an intelligent ecosystem that enhances the quality of life for inhabitants in a smart city. However, these ecosystems are not exempt from the issues present in cities.

Security is one of the main challenges in IoT due to the wireless medium and the information present in devices [7]. It is crucial to consider the IoT layers in smart homes to ensure certain protection against potential malicious attacks. These layers include the perception layer, where sensors collect and process information before sending it to the network layer. The network layer is responsible for communicating this information to connected devices, using wireless sensors like Wireless Sensor Networks (WSN) and the internet [15, 11]. This layer is bounded by the instructions of the application layer, which provides services for users to interact with their environment.

At application level, common security issues include phishing and malicious code, originating from user imprudence [9]. Another threat is Ransomware, representing data hijacking through the use of encryption to obtain a ransom from the user for their own data [19]. Additionally, the possibility of intentional attacks by third parties seeking to compromise wireless devices for malicious purposes, such as data theft through malware or hacking of these devices, cannot be ruled out. A potential solution to IoT vulnerabilities is the use of the Honeypot method, based on using a decoy to detect malicious intruders attempting to harm IoT networks com-

prising a smart home [6] and, in turn, the infrastructure of a smart city. However, this does not guarantee invulnerability, as it can be detected by Anti-Honeypot, used by cyber attackers. These layers are vulnerable to attacks, especially due to the poor management of IoT wireless devices.

3.3 Challenges for the smart cities

Smart cities aim to become environments designed to meet the basic needs of the population. It is estimated that by the year 2050, approximately 66% of the population will reside in urban environments [10], driven by significant population growth and migration from rural to metropolitan areas. This demographic shift entails a considerable increase in crime rates, especially concerning attacks and vulnerabilities targeted towards smart city infrastructure [16], particularly in the network that connects various urban areas.

For the proper functioning of smart cities, various layers with specific functions are implemented. The detection layer employs various tools to collect data from the environment, while the data collection layer stores the information obtained, both from network traffic and smart homes. The data processing layer manages the stored information, and the application and intelligent processing layer facilitates data exchange between citizens and relevant users such as stakeholders [13]. The harmony of these layers allows the proper functioning of smart cities.

However, when managing large volumes of data, these layered systems become vulnerable to third-party attacks, which may aim at stealing or misusing information. If an unauthorized user accesses this information, confidentiality is compromised, leading to what is known as an interception attack [12], which poses a problem in the flow of information in intelligent environments.

For a smart city to develop based on IoT, it is crucial to address certain aspects. This includes privacy-conscious communication, the implementation of efficient security preventive measures, and the conduct of a risk assessment to identify security gaps or threats [23]. This approach underscores the importance of considering these aspects to successfully create a smart city. In this context, the Chinese government establishes key criteria for technological and population development in its cities [18], highlighting fundamental points for a smart city to be genuinely viable. Among these, the need for a resilient infrastructure, a secure cyberspace, and the establishment of strong international partnerships are emphasized.

3.4 Threats for the smart cities

In addition to the challenges present in smart cities, there are also threats that significantly impact them, causing damage to both infrastructure and citizens privacy. Malware is malicious software created by attackers with the goal of compromising infrastructure and exploiting systems, often for financial and political reasons. This stands out as a major threat in this environment, representing a substantial challenge and security risk [9]. A clear example of this is the Botnet, a network of compromised computers controlled remotely by malware that carries out attacks on Domain Name Systems (DNS) and Internet Protocol (IP) addresses, thereby creating vulnerabilities in privacy.

Another common threat is phishing, which generates spam with the intent of collecting information through enticing ads for the user. Additionally, there are threats focused on the system of devices, such as Hardware-Trojans [5], which are modifications of integrated circuits allowing attackers to remotely access data or software. Malware also affects mobile devices through networks like Bluetooth or Wi-Fi [9], posing a threat to both citizens and infrastructure.

A primary threat in urban environments revolves around the vulnerability of location data through devices with Global Positioning System (GPS) [21], which can be intercepted by third parties, compromising detailed location-based information. This risk addresses general aspects of prevention, detection, and recovery from security compromises. A clear example of this issue is observed in the United States, where GPS surveillance poses a legal problem [17], as these devices can collect large volumes of user data, raising concerns about potential theft or attacks on databases that would impact privacy.

Biometrics, often underestimated, poses a significant risk in the context of smart cities. From fingerprints to retinas, facial data, and electronic signatures, these biometric data become a treasure for intruders. They provide access to sensitive information, such as banking status, facilitating the execution of fraud and threatening privacy by gaining access to user's personal accounts [1]. This information, increasingly common today, can be a key component in the infrastructure and vital data of the citizenry in an intelligent environment. Furthermore, it is crucial to consider the use of these elements to prevent the leakage of private data.

Smart cities face various vulnerabilities that impact both industries and smart homes. In industries, outdated infrastructure and the use of inadequately tested software create security gaps, exposing data and credentials to potential attacks [22], additionally, the implementation of weak protocols in data encryption adds significant risks. In the realm of smart homes, security is challenged by vulnerabilities in IoT layers [6], where poor management of wireless devices exposes to phishing, malicious code, and possible intentional attacks. Despite the benefits, these layers are prone to malicious attacks compromising the privacy of citizens.

The management of large volumes of data in specific layers also presents vulnerabilities, with threats to the confidentiality, authenticity, and integrity of information. Moreover, trojans pose a specific threat to the device system, affecting both mobile devices and other devices through networks like Bluetooth or Wi-Fi [8], with identity theft being a common attack. In the case of Wi-Fi, it is crucial to implement protective measures

since it is essential for communication among various IoT devices. Wi-Fi security thus becomes one of the key considerations in this intelligent environment; to safeguard it, the use of control protocols like Mandatory Access Control (MAC) or the Wi-Fi Protected Access (WPA) protocol is necessary [16], providing more sophisticated data encryption.

Furthermore, the vulnerability of location data through GPS devices also stands out as a significant threat in this context. When comparing security factors and the approach to a smart city, there are many deficiencies regarding privacy and technological infrastructure [21], this poses multiple challenges to consider for potential threats that could jeopardize a general population, implying a restructuring of the plan for a smart city, taking into account the points raised in the theme of this review.

4. Discussion

When exploring vulnerabilities in industries within the context of smart cities, a complex network of challenges threatening urban sustainability and efficiency is revealed [24], posing a significant challenge for this environment.

In smart cities, security is challenged by crucial threats that compromise the infrastructure, data, and privacy of inhabitants. Both traditional crime and digital threats impact major industries, creating vulnerabilities in software due to inadequate maintenance. Furthermore, smart homes exhibit deficiencies in IoT device security [7, 9], exposing them to risks such as phishing and potential hacking.

Additionally, highlighted are additional dangers, such as the unauthorized use of biometrics, introducing significant risks [25], including banking fraud through the misuse of biometric data. This discovery not only resonates with the warnings from existing literature regarding the risks associated with outdated technology but also underscores the urgency for new cybersecurity research in the era of industrial digitization [20, 15]. Furthermore, vulnerabilities associated with the use of untested software and weak encryption protocols highlight the need to strengthen computer security. These findings not only broaden our understanding of current challenges but also align with the prevailing narrative, emphasizing the need for comprehensive approaches to bolster infrastructure in smart cities.

These issues highlight the vulnerability of these interconnected ecosystems, emphasizing the importance of user awareness and preventive measures. Our review not only provides a detailed insight into specific vulnerabilities but also seamlessly integrates into the overarching narrative of security in smart cities, underscoring the critical need for preventive measures in the layers of urban data processing.

This review, we believe, has implications in recognizing contemporary vulnerabilities and threats for smart cities. Examining vulnerabilities in both industries and smart home environments highlights the necessity of adopting more secure approaches to strengthen these areas in response to identified threats. The aforementioned findings support the importance of updates and maintenance in industrial infrastructures, along with the implementation of robust security protocols and strategies [26, 20], such as user awareness and preventive measures, including the use of Honeypots to enhance threat detection in smart environments. These results contribute to advance knowledge in the field of urban cybersecurity and to provide diverse strategies and solutions for the development of policies and practices that reinforce security in smart urban environments [1]. This plays a crucial role in the planning of a smart city by considering potential risks and vulnerabilities.

According to our findings, security is essential for all IoT devices. As smart cities provide internet connectivity to a wide variety of devices, security becomes a highly critical challenge. These findings are reinforced by analyzing previous research on the subject, as around 70% of IoT devices in a smart city were at risk of attacks [13]; this vulnerability stemmed from the inadequate software security and vulnerabilities in encryption within communication protocols.

It is important to acknowledge that our review may be affected by some bias stemming from the timing of the publication of the collected articles. This could lead to discrepancies between our interpretations and those obtained by other research, which, in turn, could contribute to potential errors in our analysis.

Furthermore, during the development of this work, we encountered several limitations that complicated the development process. Among them, the quantity of articles available for review, and the publication dates of some articles stand out. Additionally, we identified certain information gaps that our review could not fully address. For example, we could not include specific strategies applied to protect data in smart environments, as we focused exclusively on identifying threats and vulnerabilities present in smart cities. This limitation creates a gap in our review that could be the subject of future research: improving information organization and data collection, considering the search scope to obtain relevant and updated information.

Furthermore, our review has pinpointed literature gaps that deserve exploration in future research. We highlight some outstanding thematic areas: What could be viable solutions in the context of a smart city? What regulations could be adopted by governments to prevent risks in smart cities? How have technical challenges in cybersecurity in smart urban environments been addressed? What threats and solutions have emerged in the realm of smart vehicles? What are the most prominent threats to the development of smart cities? These questions represent valuable opportunities for future research.

In smart cities, security faces threats that compromise infrastructure and data, generating vulnerabilities [27, 15]; hence, efficient strategies are necessary to address these challenges. The review highlights com-

plex challenges in smart industries and homes, ranging from outdated infrastructures to weak encryption protocols. This implies adopting secure approaches and user awareness strategies to strengthen security [28]. These findings contribute to the knowledge in urban cybersecurity, enabling the development of security policies in smart cities. Furthermore, the need for future research is emphasized to address identified gaps and enhance understanding of security in intelligent urban environments.

5. Conclusion

During the elaboration of this article, we have compiled the most relevant and up-to-date research in the cybersecurity field, following our selection criteria. Subsequently, we conducted a literature analysis, allowing us to categorize the themes addressed in the articles to achieve a deeper understanding of the information. This process led to the discussion, where the previously exposed themes were thoroughly addressed, seeking a satisfactory consensus on the analyzed information. Finally, we will present our conclusions derived from the analysis and interpretation of the themes.

Our article highlights vulnerabilities in industries and smart homes, as well as challenges and threats for smart cities in general. In industries, the issue of outdated infrastructure, inadequately tested software, and weaknesses in encryption protocols [4] stands out, exposing data and credentials to potential attacks. In smart homes, IoT security is crucial, with layers vulnerable to attacks such as phishing and malicious code [6]. Additionally, demographic and criminal challenges in smart cities are prominent, along with the need to address data management security. Threats include malware, botnets, phishing, and the vulnerability of location data through GPS, as well as the risk of biometrics to citizens privacy. The most significant risk associated with citizens is information theft through data detection layer attacks [13, 12]; this could lead to a case of ransomware or identity theft, directly jeopardizing the security of the citizens.

It is expected that this article will emphasize security aspects in smart cities, considering significant issues such as privacy, infrastructure, and industry vulnerabilities, to develop a smart environment adequately, assuming citizen participation, and addressing the significant challenges of smart urbanization. Likewise, this review is estimated to emphasize future research covering observed gaps, favor future research with relevant information, and significantly contribute to an overall understanding of security and potential study objects contributing to new findings and advances in the field of cybersecurity for urban environments.

This review highlights various limitations in previous sections. One of the most prominent is the restriction on the number of citations per year in articles excludes those that could provide valuable or more updated information on the topics addressed in this article. Another limiting aspect was the absence of a central focus on possible solutions to threats and vulnerabilities in intelligent environments. Instead, we focused exclusively on addressing contemporary challenges related to vulnerabilities and threats impacting smart cities. All these limitations are essential elements to consider for future reviews, contributing to strengthening the identified weaknesses in this review.

Given the limitations that we have identified, gaps and openings have been revealed that offer opportunities for future research and valuable contributions to the study field. An example is the need to more comprehensively address possible solutions to the issues mentioned in this review, as well as delve into how cybersecurity challenges have been faced, especially in specific areas of smart city development. On the other hand, the emergence of new, more sophisticated threats could present an opportunity for further research. As can be seen, there are various areas of research to explore, with a crucial focus on security in the context of smart cities.

During the review, we have explored the current landscape of threats and vulnerabilities in network security in the context of smart cities. By identifying and analyzing the challenges and gaps in existing research, we have compiled detailed complexities and vulnerabilities inherent in this technological environment. Smart cities are a fascinating field full of potential, but they also present significant challenges that require a lot of attention. Our work not only highlights these critical issues but also describes possible directions for future research, paving the way for future research that will change the way we think and protect smart cities.

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Review article

Custom-made video games for mental health assessment and treatment in young adults: a short narrative review

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ABSTRACT

Throughout history, video games have been stigmatized and often linked to mental health issues due to their misunderstood nature as modern products. However, these limitations hamper its potential for broader applications. Our review delves into the use of serious and personalized video games, specifically aimed at improving mental health among young adults. Using a narrative approach, we synthesize studies showing the explicit use of video games in therapeutic procedures. As mental health concerns continue to rise, the once-dismissed notion of using video games for the treatment of mental disorders has gained credibility. The studies revealed promising results, particularly in the management of anxiety and depression, highlighting the potential of augmented reality and virtual reality technology. Casual games also showed promising results in therapeutic plans, gradually breaking the stigma associated with their use. The integration of video games into daily life is gradually changing perceptions, indicating a significant change in the therapeutic landscape.

Keywords: video games, mental health, young adults

1. Introduction

The influence of video games on mental health has been increasing over the years [1], thanks to numerous research studies on the subject, their constant evolution [1], the popularity they gained due to the COVID-19 pandemic [2], and their omnipresence in the lives of children and adolescents [1], which may persist into adulthood. Likewise, we cannot forget the mental health of young adults, which was affected by the loneliness they felt due to the confinement caused by the pandemic [3] and although those days are behind us, many have not recovered from these consequences [3].

However, few of them address the process of creating video games for their application in mental health; instead, they focus solely on the results obtained from their use [4, 5, 6]. This is an important gap to consider due to the relevance of game design in achieving positive outcomes [7]. These are referred to as "serious games" oriented toward teaching and learning, which limits their design and potential [7]. Custom-made video games indeed hold promising potential in the treatment and evaluation of mental health for children, adolescents, and adults, as they do not present the limitations of the aforementioned games. Although research is scarce, most yield promising results [6], which should be given the importance they deserve, being more acceptable to individuals than traditional treatments involving pharmaceutical products [8].

The aim of our review is to determine the feasibility of personalized video games for the assessment and treatment of mental health, particularly in young

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adults. During the COVID-19 pandemic, people were more inclined to seek psychological help due to concerns about their mental health [9]. It has also been established that video games, particularly aggressive ones, do not significantly impact the mental health of young individuals even when exposed to them at an early age [10]. With this, we intend to address questions such as: how should they be designed?, how viable are they for mental health treatment?

The methodology we follow is detailed in Section 2, where the process of searching, inclusion, exclusion and selection of articles for this review is described. Next, the thematic overview in Section 3 examines the themes and patterns found in the selected literature. The discussion continues in Section 4, where the results obtained during the review are analyzed and interpreted. Finally, the conclusion addresses the questions raised in the introduction and evaluates the hypothesis in Section 5.

2. Methodology

For the completion of this review, we employed a methodology allowing us to select the most relevant articles on the topic we are addressing. For article searching, we utilized the search engines Google Scholar and Semantic Scholar, which access databases such as Dialnet, CEPAL, DANE, SciELO, Redalyc.org, Dotec, Ideas, OpenLibra, DOAJ, Scopus, Latindex, ERIC, World Wide Science, and Refseek, aiming to obtain articles that meet our inclusion criteria. These platforms are recognized for their good reputation in providing articles of the highest quality.

We used the keywords "mental health", "custom-made", "video games", and "therapy", for example: "custom-made/video games/mental health", "custom-made/video games/therapy". For the initial screening of articles, we relied on the article being written in English and on a quick inspection of the title, abstract, and introduction, as these sections provide an overview of what the article will address. The quality of the articles we selected depended on whether the journals where they were published are indexed in the Journal Citation Reports (JCR) or Scopus, the number of citations, and their relevance in the field.

We utilized Mendeley as the software for article management and for the elimination of duplicates. The selection criteria for the articles included their quartile ranking, annual citations, and relevance to our topic. Initially, we screened 3,600 articles, discarding those published before 2008 or unrelated to our topic, which narrowed them to 200 articles. Further refinement involved excluding 99 articles not indexed in the JCR, 17 for not being in English, 34 for not ranking in the first quartile (Q1), 23 for having less than 15 citations per year, and 6 for lacking relevance after an in-depth review and unanimous agreement among the authors. For 2023 publications, the citation-per-year criterion was waived. In this category, one article was included for its relevance and rigor, according to the authors, despite having no citations. Ultimately, this process led to the exclusion of 179 articles, culminating in a final selection of 21 articles for review. The methodology of this selection process is depicted in Figure 1, while the complete list of reviewed articles is presented in Table 1.

Our methodology was limited by the number of articles selected for this review, leaving out a wide margin of existing literature. Our methodology, however, is rigorous enough to have articles of the highest quality, according to our previously mentioned criteria.

3. Thematic Overview

By exploring existing research, the aim is to identify emerging patterns and trends in the research of the use of video games in depression and anxiety therapy. Through thematic analysis, the goal is to understand how video games have been integrated into existing therapeutic practices and how they have given rise to new intervention modalities, known as serious games. Serious games were categorized into eight types according to the therapeutic approach they provide: 1) exercises, 2) computerized cognitive schema games, 3) biofeedback games, 4) attention distraction games, 5) brain training games, 6) social skills training games, 7) exposure therapy games, and 8) psycho-education games [17]. Although games and other electronic interventions can be created with specific therapeutic goals in mind, it has been shown that commercially available games provide a wide variety of interfaces and experiences that can be used as a complement to therapy, aiding in attitude change, relaxation, pain management, motivation, and increasing client-therapist interaction [20]. This analysis not only examines the efficacy of video games in terms of therapeutic outcomes but also identifies patterns regarding potential limitations and the discussion surrounding their implementation in clinical settings and the cost-benefit they represent. In the following paragraph, the identified themes will be presented.

The standout theme regarding the potential of therapeutic video games lies within augmented reality and virtual reality (AR/VR) technology. VR games demonstrated high acceptability among users, with players considering these formats authentic and realistic [16]. Simulating new experiences for patients through the immersive attributes of this technology, which equate to worlds spanning hundreds of square kilometers (digitally) and inhabited by individuals and places that offer the player numerous interaction possibilities [22], facilitates better engagement in therapeutic processes and emotional management. It is recognized that VR has proven particularly useful for eating disorders, phobias, and post-traumatic conditions [19].

Regarding the psychological outcomes achievable through video games, a pattern in their effectiveness was observed. While game-based interventions do not replace psychopharmacological treatment and psychotherapeutic follow-up foundations for managing de-

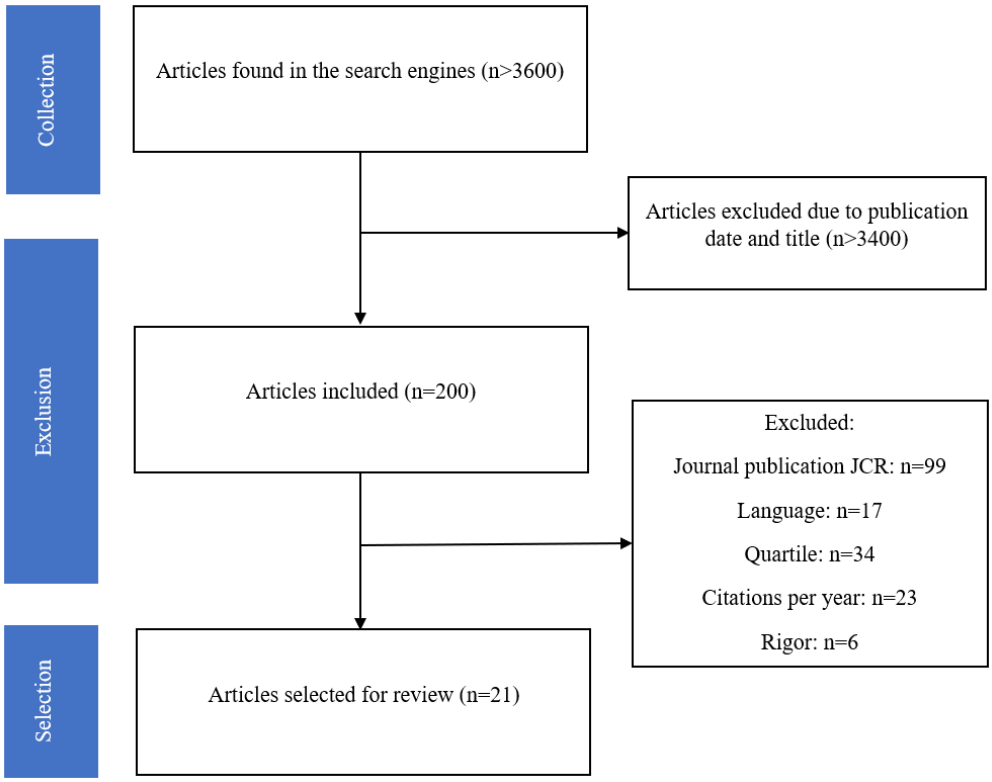

Figure 1. Diagram showing the process of collecting, excluding, and selecting articles for review.

pression [24], they can serve as a strong support due to their potential equivalence. A particularly promising game was Re Mission [4], which, in a study involving cancer patients, yielded results suggesting that an intervention using this video game targeted at behavior could enhance adherence to prescribed oral medication in young cancer patients [4]. Similarly, it was found that healthcare professionals might consider identifying a casual video game prescribed to complement existing medication or other treatment options [18].

One of the crucial yet scarce information areas is the design that therapeutic video games should have. It is known that aspects like design and management of stimuli within a game are vital for their acceptance. Subsequent studies on the use of video games as a therapeutic approach for mental health concerns could concentrate on two primary game categories: uncomplicated social games that are inclusive and enjoyable for individuals of all age groups, and online environments that provide a distinctive chance for narrative and immersive interaction with therapists and fellow patients [13]. However, the latter does not rule out the option of using horror or darker-themed video games.

A relevant gap in the analysis of the literature on this topic shows that there are neglected areas of research, such as the negative effects that video games can have on users. The COVID-19 pandemic caused mental distress to increase among a nationally representative group of American adults in late April 2020 compared to a similar sample in 2018 [9], causing many conservative researchers to continue to attribute all these negative emotions, stressful moods and emotional deficiencies to video games. It is true that the existence of Internet Gaming Disorder (IGD) among young people seems to be more prevalent every day. So it is vitally important to take care of the design of video games, because otherwise this can have a wide variety of consequences related to the users' health and relationships [25]. There is limited research addressing the attributes of video games for controlling negative emotions [15], reducing stress influence on individuals, and also failing to consider the existence of mixed emotions, thereby limiting our understanding of the range of emotions experienced while they play and how we can utilize it to our advantage.

Video games stand out as one of the most attractive technological approaches for creating programs aimed at alleviating stress and anxiety, given their motivating, immersive, and readily accessible nature [11]. Despite this encouraging information, video games do not seem to surpass conventional therapy but are also not defeated by it, possibly since younger patients might be familiar with this technology. One of the main obstacles preventing broader reach of custom-made video games is the involvement of non-experts in video game development. Consequently, they frequently develop products that neglect the fundamental element of engagement in games: enjoyment [1]. Added to stigma and resistance to learning, over time, individuals involved with

Table 1. The final list of articles used in this review, including information for title, year of publication and citation.

Title	Year	Citation
A video game improves behavioral outcomes in adolescents and young adults with cancer: A randomized trial	2008	[4]
Acceptance of Serious Games in Psychotherapy: An Inquiry into the Stance of Therapists and Patients	2016	[5]
Commercial off-the-shelf video games for reducing stress and anxiety: Systematic review	2021	[11]
Evaluating the Utility of a Psychoeducational Serious Game (SPARX) in Protecting Inuit Youth From Depression: Pilot Randomized Controlled Trial	2023	[6]
Mental distress among U.S. adults during the COVID-19 pandemic	2020	[9]
Mental health care for young people using video games: a pilot RCT on the development of a new intervention method toward Hikikomori and Futōkō	2022	[12]
Online Video Game Therapy for Mental Health Concerns: A Review	2008	[13]
Playing video games during the COVID-19 pandemic and effects on players' well-being	2021	[2]
Reach Out Central: a serious game designed to engage young men to improve mental health and wellbeing	2010	[14]
Serious Games for Psychotherapy: A Systematic Review	2017	[15]
Serious games, gamification, and serious mental illness: A scoping review	2020	[16]
The benefits of playing video games	2014	[1]
The Effectiveness of Serious Games in Alleviating Anxiety: Systematic Review and Meta-analysis	2022	[17]
The effects of casual videogames on anxiety, depression, stress, and low mood: A systematic review	2020	[18]
The Efficacy of Playing Videogames Compared with Antidepressants in Reducing Treatment-Resistant Symptoms of Depression	2019	[8]
The promise of the metaverse in mental health: the new era of MEDverse	2022	[19]
The Use of Electronic Games in Therapy: a Review with Clinical Implications	2014	[20]
Video Games in Health Care: Closing the Gap	2010	[21]
Video games, emotion, and emotion regulation: expanding the scope	2018	[22]
Videogames and Young People with Developmental Disorders	2010	[23]
Winning The Game Against Depression: A Systematic Review of Video Games for the Treatment of Depressive Disorders	2022	[24]

video games tend to see fewer drawbacks in using serious games in a psychotherapeutic setting [5]. Similarly, they remain a more comfortable option for patients who cannot overcome the stigma of psychological attention. Current studies on the connection between video games and emotions appear to adhere to a predictable and repetitive pattern, often failing to explore beyond the age-old inquiry of whether video games have positive or negative effects on children. However, those who do delve deeper establish that serious games are not only superior to a control condition in learning and behavior but also enhance knowledge about effective anxiety and anger management strategies, they also aid in dealing with symptoms of depression and stress [15]. Beyond the cheerful and colorful design that any game could easily adopt, the technology it employs is even more critical. Thus, the greatest bet continues to be on AR/VR technology, as its more immersive attributes have shown better results in patients with the aforementioned symptoms [19]. It has even become a game-changer for this medium, dispelling the notion that games must always have bright and stimulating designs.

On the other hand, video games implemented in the field of mental health are becoming an increasingly viable option [21], as they have aided in reducing mood disturbances, depression, and stress [22], helping certain patients regulate their emotions. It is worth noting that in the case of depression, while common discomforts were reduced, they did not disappear entirely [24], indicating that the implementation of serious games as a treatment would be more complementary [8]. There are other conditions for which these games can be implemented, such as in individuals on the autism spectrum, attention deficit hyperactivity disorder, and specific language impairment [23]. Additionally, it was noted that more appealing incentives are needed for research participants, as they easily lose interest when the concept does not seem relevant to them [14]. It has been demonstrated that younger individuals and those in their twenties find it unappealing to focus on their mental health due to various concerns that this may entail [12].

Broadly speaking, video games offer pleasure, greatly motivating chances for skill enhancement, and cognitive and imaginative stimulation. All of these represent particularly meaningful types of assistance for children dealing with developmental disorders [23]. One aspect that is being pursued and is more within the reach of science is the use of various platforms for diagnosing or monitoring patients who require services such as therapy [5].

4. Discussion

We reviewed research and articles on the use of video games in mental health treatment. Previous reviews have shown that the use of video games for mental health treatment, as well as the creation of video games for that purpose, have shown effective results [1].

The use of video games in the treatment of mental health has been proven to be effective and offers greater comfort compared to conventional methods [1]. Likewise, it has been shown that video games not only serve to entertain, but also have great potential in various psychological areas, ranging from learning to emotional control [22, 26, 27]. The focus extends beyond console and desktop gaming; AR/VR has also been implemented as a new experimental treatment that has shown very positive results [19]. Video games have been introduced to regulate emotional states due to their impact on emotions, suggesting that technology has the ability to satisfy psychological needs to some extent, which is why they could be a great tool [22, 26]. Our review illustrates how several investigations have previously shown that the use of video games and how others have previously investigated this topic arriving at the same point that is the efficiency and benefits it has, in different applications produced positive results [28] in the treatment of health mental, but unfortunately, they are not used as frequently as one would expect.

Review of the articles and findings show that there are numerous research studies and reviews that analyze the use of video games in mental health, how it can be used and how it is effective [28]. This has become a topic of great interest in both psychology and medicine, with the aim of facilitating and improving methods for mental health [1]. Several new strategies were identified that involve cutting-edge technologies used by video games for treatment, each one with different approaches.

A significant number of articles share certain similarities with our general findings. In general, we agree that experiments and studies have been carried out that have demonstrated their effectiveness and their way of acting with mental health; there are really many benefits they offer that can improve the way mental health is treated. Each article tends to focus on a specific topic or a more specific area. The articles present differences in themes; some illustrate how video games impact emotions [22], others highlight the positive impact of video games on mental health [1], emphasizing the importance of actively involving patients in the development of video games designed for mental health [1]. They suggest that a promising approach to improving the effectiveness of these games is to directly involve patients in the development process [1].

Due to the limited number of articles specifically addressing the creation of custom-made video games for the assessment and treatment of mental health, our article search had to focus more on the utilization of video games for mental health treatment and its findings. A question that remained unanswered was, "why are they not currently being used?". Most of the gathered documents discuss the usefulness of video games, but they do not specify the reasons for their limited utilization and integration alongside conventional treatments.

The significant potential demonstrated by video games in mental health is becoming an increasingly interesting topic for healthcare specialists. However, there are many uncertainties surrounding this. The most effective way to employ video games is a subject lacking sufficient research a relatively "new" treatment style, a definitive and straightforward method has not yet been identified to yield promising results. While a considerable portion of the population has accessibility to video games, certain new technologies like AR and VR are not accessible easily due to their high cost in the market. These technologies have proven to be valuable and functional tools in the mental health treatment [1]; efforts must be made to find new ways to make them more accessible to people.

Computer games, console games, and mobile games are feasible tools for mental health treatment and their effectiveness has been well demonstrated [27]. In some ways, they can make treatment easier and provide important help to people experiencing mental health issues. As mental health issues become more common, research on this topic is also trending in this area. Trying to find new treatments is one way to improve this situation and address the various mental health challenges.

5. Conclusion

Therapeutic video games are a good complement to the treatment of various psychological disorders or problems, since they can also relieve associated symptoms. Because mental health issues are very common globally, affecting 14% of the entire world population, it is necessary to reach a large number of patients, and one way to facilitate this is through these platforms or games [29]. On the other hand, the research also explores the use of other technologies, such as VR, to address these problems. Additionally, there are still unexplored areas and gaps in research, so it is expected that more will be learned in the coming years. It is also important to note that the lack of proper design of therapeutic video games and the involvement of non-experts in their development may hinder their wider use. The design of therapeutic video games must address different therapeutic methods such as exercise, cognitive programs, etc. Recognizing that commercially available video games can be useful as an adjunct to therapy emphasizes the importance of offering a variety of interfaces and experiences. Immersive technologies stand out for their ability to improve engagement and emotional management in therapeutic sessions.

The presented and explored results in the article stem from our analysis of the selected articles for review. Research on video games, their use, and influence in treating psychological disorders show promising results; it is known that video games influence the minds of players and can be used to guide their thoughts. The im-

plementation of these video games in young adults with various psychological disorders shows that, if used correctly, they can yield positive and promising responses. Patients demonstrate progress and improvements in certain areas affecting their daily lives, such as anxiety, depression, insecurities, difficulties in performing specific tasks, among others [30].

Managing psychological disorders with software, in this case, video games, has led many scientific areas to focus more on the subject. Both short and medium-term clearer answers are expected, and in the long term, programs or plans developed with a mental health professional are sought to optimize the quality of life and reduce the negative effects [17]. However, it is essential to remember that these video games are only a complementary tool for treatment and should not be considered a complete treatment or control for users. Consulting an expert is always necessary, as research is ongoing, and much remains to be clarified. It was also acknowledged that a high percentage of the population has easy access to video games due to the internet. Similarly, high percentages of the population experience different psychological disorders that could potentially be treated with favorable results. Considering the costs of this technology, which is quite expensive but has proven to be effective [31], it would be beneficial to explore ways to make it more accessible so that everyone has the same opportunity to access this new treatment modality for psychological disorders [32].

During the review of various articles on the use of video games, it was noted that most demonstrated the progress, achievements, and effectiveness of their use, but the reasons for not currently integrating them with existing mental health treatments were not found. This lack of information is probably causing a decrease in specialists' interest in the field, as there are very few articles specifically addressing the creation of custom-made video games for mental health, while those which do, have been conducted on a limited number of individuals. Interpreting results from small groups is not a statistically reliable information source. [17]. Similarly, it is unknown whether there will be long-term negative effects that may harm the patient's treatment [15]. Despite knowing that several benefits can be obtained from the use of custom-made video games, a simple and promising way to achieve this has not yet been definitively found.

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Review article

The use of video games in vocabulary acquisition: a short narrative review

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ABSTRACT

In the last few years, video games have started to become educational tools, particularly in language learning. Nevertheless, the usefulness of this method is often questioned. This article critically addresses their potential and effectiveness, focusing specifically on their ability to facilitate vocabulary learning with an emphasis on the teaching of English as a second language. Through a detailed analysis of a sample of the existing literature, we explore both the substantial benefits and limitations inherent to the use of video games in diverse educational contexts. This analysis goes beyond a simple assessment of their utility, highlighting the ability of video games to generate interactive and emotional immersion. However, our review also addresses the associated complexities, from digital barriers to challenges in cultural adaptation. We conclude that games are useful allies for vocabulary acquisition and provide recommendations for future research. These include the long-term persistence of the acquired knowledge, the creation of inclusive video games, and the exploration of music as a facilitator of vocabulary learning.

Keywords: video games, language learning, vocabulary

1. Introduction

In the globalized, modern era, English proficiency has become a necessity. As technology evolves and transforms our lives, video games have risen as educational tools with the potential to revolutionize the way in which a new language is learned [1]. These games encourage critical thinking, problem-solving and quick decision making. Some games are specifically designed to teach academic abilities and concepts such as science and mathematics [2]. Additionally, they offer a unique immersive experience in which language becomes an integral part of the entertainment and exploration [3]. This interactive environment mixes amusement with learning, thus becoming particularly attractive for the wide audience available in the growing digital world [4].

The ever-growing access to digital technology has brought on an avalanche of studies which explore the potential of video games and digital apps to improve linguistic abilities, especially reading and vocabulary skills [4]. Experts in the education and language fields have analyzed the efficacy of video games as learning tools for vocabulary, especially for students of English as a second language (ESL). This is due to the rich learning environment they provide from a linguistic standpoint [5]. Nevertheless, controversies requiring a greater analysis have arisen, as video games suffer from a bad reputation and are thus often discredited or dismissed as learning tools [2].

Therefore, this article aims to focus on the results

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of these studies and analyze the ways in which video games can be useful allies to the learning process. In the post-pandemic world, after a rapid switch to online learning, it is of vital importance to know all the tools at the disposal of educators, as well as their possible benefits and any consequences. The efficacy of video games and all their visual and auditory assets as resources to increase vocabulary acquisition among ESL learners is the guiding question of this review.

Digital learning is a broad field that has grown and developed greatly in the past couple of years [2]. This paper centers on a select few articles dedicated to shine a light on the influence of video games on English vocabulary acquisition and retention, as well as any major discoveries. Through these pages, we will examine their contribution to education and language learning in great detail and provide insight as to their importance.

In Section 2, our inclusion and exclusion criteria will be discussed, providing a thorough walk-through of our selection process. In Section 3, we will outline the key findings of our selected papers. These will then be discussed in-depth in Section 4. Lastly, we will share final thoughts and takeaways in Section 5.

2. Methodology

The selection method employed in this review marks the reach and depth of our investigation. Our main search engines were Google Scholar and Semantic Scholar, both recognized and trustworthy sources used by experts. These platforms were chosen due to their complete indexation and their simple yet effective usability, which made them both adequate for extensive literature compilation.

Papers for this review were found through the keywords "video games", "vocabulary", "vocabulary skills" expressed in the complete search requests "use of video games in vocabulary learning", "impact of video games in ESL vocabulary skills" and "effects of video games in vocabulary acquisition". This yielded a total of 4,530 papers. Those unrelated to our topic were discarded by agreement between the coauthors. This reduced our sample pool to 307 possible texts. Our selection criteria was strict to guarantee a high quality standard. We only considered papers written in English and further limited our search to papers published in journals indexed within the Journal Citation Reports (JCR). We excluded journals indexed in the JCR but classified as Q3 or Q4 within the Scimago catalog, as we aimed to work with the highest quality of papers in the field. Articles then had to reach a minimum of 5 citations per year to reflect their impact and recognition by academics.

In the beginning of our literature search, we were met with a substantial number of papers. Mendeley, a trustworthy reference management software, was used to exclude any duplicates. Papers were then filtered through our selection criteria. The aim was to extract only the most essential articles, taking their relevance into account. Additionally, each abstract was discussed by authors, and contentious disagreements were solved by vote; inclusion of a paper had to be unanimous. This method served to build a clear narrative around influential papers.

After a second read-through of abstracts, the 307 papers were reduced to 41. This sample was then refined by excluding those articles with a publication date further back than 2008 and non-indexed journals. This resulted in 27 articles. Eight more were excluded due to not meeting our citation per year requirement. One final article belonging to Q3 ranking was taken out of the sample after a mutual agreement between authors. The final sample consists of 18 articles considered to be the most relevant in the area.

This method, while efficient, has limits that may result in the omission of articles that at the moment of review did not meet our inclusion criteria. While our reduced number of papers allows us to have a simplified, focused narrative that centers on highlighting innovations in recent years, it is important to note that articles published in late 2022 and 2023 had fewer chances to reach our minimum citations requirement. This could mean some relevant discoveries are not discussed in this review. Therefore, it is highly recommended to carry out continuous and expansive research furthering on the topics this review covers. Despite these limitations, the methodology employed to collect our sample makes up a solid base for our thematic analysis and the critical evaluation and discussions that follow it.

3. Thematic Overview

The articles in this review feature a variety of aims and scopes. However, certain similarities exist between them which allows us to find and examine the trends of their fields. These common threads, as well as their goals and findings, are explored within this section. The select topics include the contributions of video games in vocabulary acquisition, the factors that affect the efficiency of video games as learning tools, and their limits and difficulties in application.

The effectiveness of video games in education is being explored. It is widely agreed upon that both players and spectators can recall vocabulary used in games, especially those focused on entertainment and adventure [4, 11]. These exert a positive influence in the incorporation of words and later recall [15]. The emotional connection and immersion fostered in an interactive environment have a significant role in this task, facilitating the process [13]. It has been highlighted that online learning has an emotional and motivational impact and that a correlation between enjoyment and learning capacity exists [11, 6]. This finding emphasizes the necessity to consider emotional factors when implementing educational video games. Games based on digital technology can often create a positive learning environment and, in some cases, surpass traditional learning methods [9].

Setting intentional learning goals leads to a higher retention rates among students [1]. It is necessary to

Table 1. The final list of articles used in this review, including information for title, journal, year of publication and citation.

Title	Journal	Year	Citation
Are Games Effective Learning Tools? A Review of Educational Games	Educational Technology & Society	2018	[6]
Digital game-based second-language vocabulary learning and conditions of research designs: A meta-analysis study	Computer & Education Journal	2018	[5]
Digital game-based vocabulary learning: where are we and where are we going?	Computer Assisted Language Learning	2021	[7]
Educational games as stand-alone learning tools and their motivational effect on L2 vocabulary acquisition and perceived learning gains	British Journal of Educational Technology	2017	[1]
Entertainment Video Games for Academic Learning: A Systematic Review	Journal of Educational Computing Research	2022	[2]
Exploiting adventure video games for second language vocabulary recall: a mixed-methods study	Innovation in Language Learning and Teaching	2017	[8]
Exploring the Potential of Digital Game-Based Vocabulary Learning: A Systematic Review	Systems	2023	[9]
Gamification in mobile-assisted language learning: a systematic review of Duolingo literature from public release of 2012 to early 2020	Computer Assisted Language Learning	2021	[3]
Gamified learning in higher education: A systematic review of the literature	Computers in Human Behavior	2018	[10]
Investigating the Impact of Integrating Vocabulary Exercises Into an Adventure Video Game on Second Vocabulary Learning	Journal of Educational Computing Research	2021	[11]
Motivating EFL students: E-learning enjoyment as a predictor of vocabulary learning through digital video games	Cogent Education	2016	[12]
Readers, Players, and Watchers: EFL Students' Vocabulary Acquisition through Digital Video Games	English Language Teaching	2017	[13]
Second language (L2) gains through digital game- based language learning (DGBLL): A meta-analysis	Language Learning & Technology	2022	[14]
The Effect of Interactivity with a Music Video Game on Second Language Vocabulary Recall	Language Learning & Technology	2010	[4]
The Effect of Multiplayer Video Games on Incidental and Intentional L2 Vocabulary Learning: The Case of Among Us	Multimodal Technologies and Interaction	2021	[15]
The effectiveness of digital game-based vocabulary learning: A framework-based view of meta-analysis	Language Learning & Technology	2018	[16]
The impact of adventure video games on foreign language learning and the perceptions of learners	Interactive Learning Environments	2012	[17]
Video-game based instruction for vocabulary acquisition with English language learners: A Bayesian meta-analysis	Educational Research Review	2020	[18]

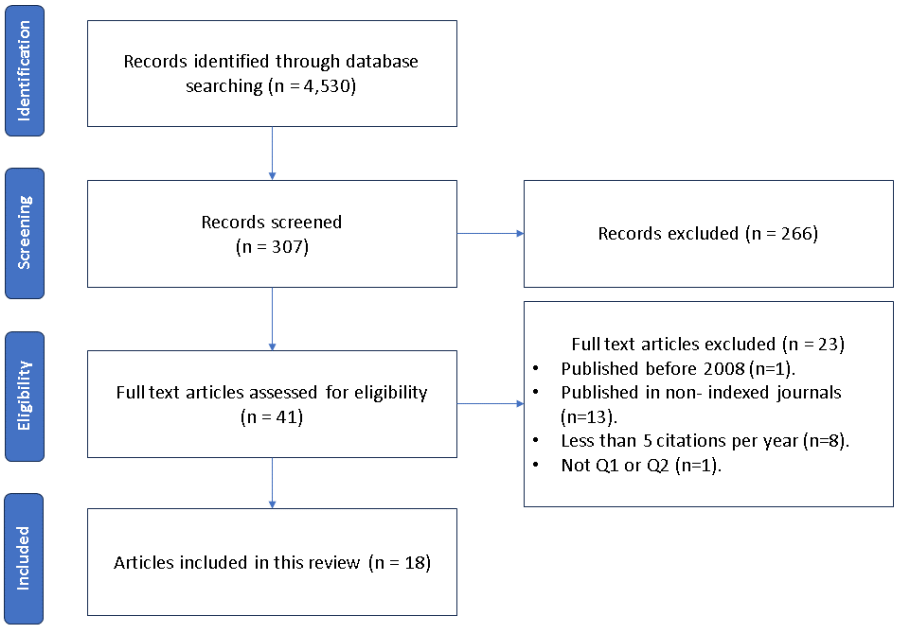

Figure 1. Selection process for the sample. Initial search engine results were then screened based on title before being put through our selection criteria. Final sample of articles consists of 18 texts.

ascertain that the video game in question is appropriate for the student level and that it has the adequate focus [8, 4]. Games designed for entertainment maintain student motivation and engagement at a higher rate. Single-player games allow for an individualized, autonomous learning experience. Multi-player games, on the other hand, encourage collaboration and interaction between students which results in more community practice [15]. Both the user actively playing, the player role, and the user watching the game-play, the observer role, receive their own benefits [4]. The player is provided with a more entertaining, active learning experience, while the observer can learn from others and analyze their strategies [14].

Serious video games, designed especially for educational purposes, showcase a higher efficiency once applied to learning practices regarding a specif academic topic [2]. However, this may not apply to vocabulary learning, as adventure video games tend to stimulate and interest players more than serious video games, which require a more significant cognitive load [19, 20, 16]. Adding a narrative does not increase the efficiency of serious games as their inclusion does not contribute any significant benefits [21].

Video games increase motivation among students and reduce their stress when compared to a traditional classroom. They can also innovate language learning in corporate settings [7, 12]. Video game-based learning promotes autonomy, allows them to take decisions and lets them make mistakes without pressure from an authority or attention from peers [9]. While traditional vocabulary learning causes boredom [15], various studies show that students have a positive attitude towards learning from video games [11, 8, 10]. This positive attitude improves memory [22]. However, it is possible for students to lose this motivation if the game requires a major cognitive load to play [9]. To avoid this, the use of lexical support tools is encouraged to facilitate the experience [11].

Game design is another key aspect to consider. Video games must be attractive and interesting. If the game is unattractive or does not generate any impact on the player, it will cause boredom and no learning will occur [3]. Game duration must also be taken into account, if a game is too long, it can generate exhaustion and result in poor short term memory [5]. Graphics and ease of use are all factors that influence the efficacy of the learning experience [9]. Likewise, the speed with which character speaks or text shows up onscreen and the availability of subtitles as support affects player interest [11]. Subtitles in particular are considered advantageous for students [8].

Music represents another motivational tool to aid in vocabulary retention [13]. Players and observers of a music video game have both been proven to retain vocabulary used within it [4]. The immersion born from a captivating soundtrack is associated with better listening, reading and a general improved attitude towards language learning [17]. Thus, music not only becomes a pedagogical support, but a way to encourage active student participation, creating a better learning environment [23]. The combination of these audio and vi-

sual elements with player interaction within music video games is an integral part of ESL learning [18].

Video games must adapt to player culture, including situations, characters and cultural references to their daily life [18]. They must have an objective language and go beyond simply showing off the words of phrases of the target language. Instead, it is preferable for them to involve the player in conversations and scenarios that allow them to interact with, understand and apply the language in a practical and significant manner [13]. A target audience must be selected, taking the age and level of the students into account [24]. The intended setting —formal classrooms or informal sessions, for example— has to be selected too, as different focuses will be needed for each. Achieving cultural relevance and authentic representation while guaranteeing accessibility for a wider audience is a great yet necessary challenge in cultural adaptation [18, 7].

When using video games for vocabulary acquisition, it is imperative to consider all aspects of their implementation. The words that will be included and how they will be tested must be outlined clearly from the beginning. Exercises within the game itself are recommended to help in this process as they provide lexical support and are the key to motivating the students and keeping their interest. To maintain said motivation, the video game must be selected carefully. The type of game is the first important factor, after which the student level must be evaluated. Its attractiveness, relevance to the student's cultural context and the time available for play, must also be taken into account. Having clear intentions when approaching game-based learning will result in better development, learning and retention.

4. Discussion

Video game-based learning represents a great advantage over traditional learning methods [11, 9]. However, it is necessary to consider aspects such as game focus, its cultural relevance and its design [3]. An effective implementation of games in language learning can only occur when differences between player style, ages and learning preferences are all taken into account [18]. Games offer a modern and attractive alternative for learning, but issues regarding the challenges of access and the technological gap must also be addressed [25, 26]. While the reviewed papers touch upon video games' efficiency, the question as to how to better adapt games to different learning contexts remains. In this section, we discuss the implications of our key findings and detail the limitations of current research, exploring possible areas for future development.

While incidental learning occurs in all aspects of education, such as reading, a deliberate, defined structure is the key to ensure the successful implementation of game-based learning [27, 9]. Digital learning often focuses on transmitting information to the student, but video games instead offer interactivity and entertainment [28, 4, 12]. They provide proper contextualization of the target words and naturally allow for repetition, which is essential in active learning [1, 29]. In this way, the selected texts have underlined the positive effect of video games in language learning, but there are very few games that combine the learning experience with the game-play [11]. Instead, games are mostly used as a language learning tool, and recall exercises are implemented later [15, 8]. This may occur because this integration is only available to education professionals with programming experience or who are not using off-the-shelf commercial video games [11, 8]. So, even though video games are seemingly effective tools for education that cover several of its principles, the technological gap exists for teaching professionals too [26], limiting their reach.

Practical application of video game learning is further complicated by the need for a proper cultural adaptation that nevertheless still allows for a large audience to benefit from it [7]. This would mean adjusting scenarios, characters and cultural references within video games, prioritizing making them enjoyable and avoiding the exclusion of certain demographic groups. If this is guaranteed, video games with interesting story lines and high entertainment value can help increase motivation and encourage autonomy [11, 1, 13, 9]. These positive effects can help promote the creation of education policies which innovate the education field and improve upon student participation and commitment [13]. Challenges regarding the technological gap remain, but fostering digital learning may incite institutions to address these disparities [9]. This would require investing in the corresponding infrastructure and the creation of strategies wherein all students, regardless of location or economic class, have access to game-based learning [21].

While not directly covered by the articles in our selection, the ethical implications of integrating video games into learning environments must be discussed. Gamified learning brings up questions as to the privacy of the student, access equality and the possibility of creating inclusive experiences that still respect fundamental values [9]. Video games are a valuable tool, but their effect on educational policies remains unexplored. How current educational policies can be broadened to cover this development and any attempted misuse is yet to be seen.

Among the findings identified while developing this review, and comparing it with other relevant reviews included in our bibliography, it is widely agreed upon that video games have become enriching learning tools, and can help specifically in reading and vocabulary skills [4, 2]. Nonetheless, this cannot be achieved without the proper implementation. A key point is ensuring the video game is attractive without exaggerating its design [3]. The technology, music, sounds and subtitles all must cooperate to help, not hinder, the player [11, 8]. The environment must contribute a pleasant atmosphere to create an enjoyable learning environment [9].

Agreements on what video games must not do were also common. They must not be of too long a duration and provoke fatigue or saturate the player with informa-

tion that creates a significant cognitive load [5, 4]. On the contrary, they must ensure motivating students and exalting their achievements is a goal at every step [3]. Another general agreement is the importance of teacher support and the appropriate game for the student level of the class [1, 7]. Games alone are not enough, interaction between the group and repetition of target words is greatly encouraged for proper understanding [6, 15].

Despite applying strict criteria to guarantee the quality and relevance of the literature, the possibility of having inadvertently excluded studies with new, innovative findings exists. Furthermore, a gap exists in the year 2023, where most studies published within the year did not meet our selection criteria. These articles may have provided additional perspectives or updates. It is also of utmost importance to recognize that, the methodological quality of individual studies may vary. This aspect must be be addressed to avoid biased interpretations based on heterogeneous research [18]. Although there is ample evidence supporting the effectiveness of video games in vocabulary learning, most studies in this field focus on video games in general and their lexical impact, but few dig deeper into variations of their effectiveness based on specific aspects of a game [16, 7]. Additionally, no standardized evaluation methods exist, which makes comparisons between them difficult and limits our abilities to draw concrete, definitive conclusions as to the better implementation methods overall.

Although the positive influence of adventure video games in incorporating and later recalling vocabulary has been highlighted [11], it must be recognized that effectiveness may vary depending on the specific nature and academic content. In particular, when it comes to vocabulary acquisition, serious video games may not be as efficient as adventure video games, as the latter tend to be more stimulating and interesting for students [19, 20]. This observation highlights the need to consider context and the intended learning goals while selecting the game to be used in vocabulary learning. The variability of the effectiveness of video games depending on the game mode (single or multiplayer) and the lack of significant differences between the player and the observer [4, 11] suggest the need for more specific studies that tackle the benefits and limitations of each method.

The inclusion of music as a tool for acquiring fluency in another language, although supported by several studies [13], also has limitations. The majority of studies focus on lyrics to English songs, which may limit the generalizing of results to other linguistic contexts. The lack of consensus as to how to best evaluate the musical effects on vocabulary learning brings forth challenges for a clear synthesis of the results.

Regarding game design, the need for attractive and interesting games presents challenges [3]. The positive impact of video games in motivation and stress reduction could be conditional to this attractiveness and cognitive load of the game [9]. However, the lack of consensus between what characteristics make a video game attractive and educational raises questions about the universal application of these findings [5]. Likewise, there is no general agreement on the ideal length of video games and the influence of technological factors highlights the need for specific considerations in each educational context [11]. The proper way of striking the balance between cultural authenticity and wide accessibility is another point of contention that limits the development of these findings [26].

While this review describes a narrative about the effectiveness of games and their impact in vocabulary acquisition and retention, it is fundamental to address and clarify our limitations in order for the field to advance towards more solid, universal conclusions that allow thorough integration into educational environments. A clear methodology and extensive consideration of the specific conditions are crucial to maximize the benefits of this innovative tool [11].

Due to the broad nature of this topic, several gaps within the available literature and unexplored areas still exist. Such areas include the long term impact of video games in vocabulary learning, and whether or not knowledge of the words learnt in these exercises persists overtime. Effects of gamified learning on academic success have not been thoroughly evaluated. While studies have been conducted across several cultures, more could yet be explored. Specifically, focusing on younger age groups or different socioeconomic classes could yield interesting findings where results may vary. Applying different game types to different cultures to find where preferences differ or coincide is another possible point of interest. Another one would be the use of video games in special needs education for specific disabilities, or the overlap between accessibility customization and effectiveness in language learning.

This review reveals the duality inherent to integrating video games in a learning context. While there are evident benefits, there exist crucial challenges when it comes to maximizing their potential. Addressing these challenges requires flexible, personalized strategies that have to also tackle the technological breach. The tension between amusement and learning emerges as another point of contention in the implementation of video games. It is essential to find the balance between an attractive game and an educational one to make any significant contribution to the students. This, and the application of games across different cultures and contexts in order to analyze their long-term effectiveness and other such variations, becomes incredibly important to overcome their current limitations and guarantee a global, fair application of this technology.

5. Conclusion

Although our review provides valuable insights into the use of video games in vocabulary acquisition, it is not without limitations. One of the challenges inherent in our review lies in the methodological diversity of the analyzed studies. It is difficult to directly compare the results due to differences in how the research is approached, the duration of the experiments, and the

evaluation metrics [30, 31]. Additionally, most studies focus on specific populations and controlled environments, limiting the possible generalization of the results to broader contexts [19, 32]. While this heterogeneity reflects the complexity of the topic, it also highlights the need for more uniform standards in future research.

The assessment of the effectiveness of video games is affected by the rapid evolution of technologies and the games themselves [32]. Our review, based on studies up to the 2022 cutoff date, may not capture recent developments in the video game industry that could influence their educational applicability [23].

The long-term persistence of knowledge acquired through video games emerges as a crucial area for future research. Most of the reviewed studies focus on short-term assessments, leaving unexplored the effective duration of the impact of acquired vocabulary [33]. Research addressing long-term retention and the maintenance of linguistic skills after exposure to video games will provide a more comprehensive insight into their long-term utility in educational settings.

The adaptation of video games for inclusive education is another avenue deserving further attention. The diversity of educational audiences suggests the need to design games that are accessible and effective for a variety of students, including those with different language abilities and learning styles. Research focused on adapting video games to address the diverse needs of students would be a valuable step.

Through the process of literature selection, debates, and reflections, the transformative potential of video games, especially those focused on adventure, to enrich vocabulary acquisition and its retention is highlighted. Emotional connection and immersion offer a powerful catalyst for learning, but this enthusiasm is challenged by practical and cultural challenges [30, 19]. According to our observations based on the sampled texts, video games have proven themselves effective allies for vocabulary acquisition, at least in the short term.

This analysis is not confined to classrooms; it transcends academic boundaries and projects into the broader landscape of culture, technology, and educational policies, emphasizing the need for innovation. Digital barriers, cultural adaptation, differing student needs present challenges that require careful and strategic attention [32, 19]. This review stresses the importance of a continued exploration and betterment of the integration of video games in language learning. This is an evolving field, and our research not only contributes to furthering the understanding of its current effect on education, but also guides us in the future practical implementation of this tool on diverse environments. Specific recommendations for future research include the importance of exploring the long-term persistence of knowledge acquired through video games, adapting these games for inclusive education, examining their impact in different cultural contexts, and delving into the effective integration of music in the educational design of video games [33, 23].

Ultimately, this review reveals the potential of video games as educational tools and allies; it raises crucial questions about overcoming challenges, adapting to diversity, and maximizing the positive impact of this technology on vocabulary acquisition for ESL students. May these reflections inspire future research and contribute to the ongoing evolution of education through the innovative use of video games.

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Math for AI Capsules

An element-wise contribution-based vector similarity measure for artificial intelligence applications: a brief exploration

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ABSTRACT

In Artificial Intelligence (AI), the ability to accurately assess the similarity between data points is fundamental to a myriad of applications, from recommendation systems and semantic analysis to case-based reasoning. Traditional similarity measures, however, often fall short in capturing the relationships inherent in complex data, particularly when the relevance of individual features varies or opposes. This article briefly introduces a novel element-wise contribution-based vector similarity measure that dynamically weighs the importance and directional relevance of features, offering a more refined approach to similarity assessment in AI. By normalizing vectors within specific ranges and employing a modulating vector to adjust feature contributions, our measure facilitates a more contextually aware and adaptable comparison process. The proposed measure is poised to have wide-ranging implications across diverse AI domains, suggesting its potential to enrich personalized, intelligent systems. This work contributes in similarity measurement, proposing a pathway for future research into AI methodologies that necessitate a personalised interpretation of data.

Keywords: similarity measure, element-wise analysis, feature importance modulation

1. Introduction

In the rapidly evolving field of Artificial Intelligence (AI), accurately quantifying the similarity between data points is foundational to the success of numerous applications, ranging from machine learning models, case-based reasoning and data clustering to information retrieval and pattern recognition [1]. These measures serve as critical components in algorithms that categorize, group, or differentiate data based on underlying patterns and relationships [2]. As AI systems handle increasingly complex datasets across diverse domains, the demand for more contextually aware similarity measures becomes fundamental [3]. This demand highlights the importance of developing similarity metrics that not only capture the essence of data relationships but also adapt to the unique requirements and dimensions of varied AI tasks.

Despite the widespread use of traditional similarity measures in AI, such as the Euclidean distance and cosine similarity, these methods often fall short when confronted with the intricate structure of high-dimensional data or when specific dimensions carry disparate significance [4, 5]. This limitation is particularly pronounced in domains where the relevance of features varies widely or explanation of such features is paramount, necessitating a more flexible approach to similarity assessment [6]. The inherent rigidity of conventional measures, which treat all dimensions uniformly, overlooks the underlying

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relationships and importance differentials among features, potentially leading to suboptimal performance in tasks such as clustering, classification, and recommendation systems [7, 8].

In response to these challenges, we propose a novel similarity measure that integrates element-wise contribution and directional relevance, leveraging a modulating vector to dynamically weigh the importance and oppositional alignment of features of two given vectors. This approach not only addresses the dimensional disparity but also introduces an understanding of 'opposite' directionality in vector similarity, thereby enriching the measure's applicability across a spectrum of AI tasks [4, 6].

2. Concept overview

The cornerstone of our proposed similarity measure is the interpretation of vector components within the context of their application domain. Specifically, the vectors $\mathbf{v}_1$ and $\mathbf{v}_2$, representing entities to be compared, are normalized to lie within the range of $[-0.5, 0.5]$. This normalization reflects the premise that elements within these vectors span opposite ends of a spectrum, allowing for a more balanced and interpretable comparison. Central to our formulation is the vector $\mathbf{v}$, with elements constrained within $[-1, 1]$, which serves as a modulator for the contribution of each corresponding feature in $\mathbf{v}_1$ and $\mathbf{v}_2$ towards the overall similarity score. This arrangement ensures that each feature's influence is not only accounted for in terms of magnitude but also in terms of its directional relevance, with negative values indicating an opposing contribution to the similarity measure.

The similarity measure is articulated through a formula that combines the normalized vectors $\mathbf{v}_1$ and $\mathbf{v}_2$ with the modulating influence of $\mathbf{v}$. The formula employs an element-wise operation modulated by $\mathbf{v}$, where each element's contribution is scaled according to its value in $\mathbf{v}$, signifying the feature's relative importance or oppositional alignment. This is achieved by adjusting the elements of $\mathbf{v}_2$ in accordance with the sign and magnitude of the corresponding elements in $\mathbf{v}$, thereby reflecting their directional contribution to similarity. The measure then calculates the absolute difference between the adjusted $\mathbf{v}_2$ and $\mathbf{v}_1$, which is subsequently weighted by the normalized version of $\mathbf{v}$, ensuring that each feature's significance is proportionally represented. The culmination of this process is a norm calculation, aggregating the weighted differences into a single scalar value that encapsulates the multidimensional similarity between the vectors, accounting for both magnitude and directional alignment of the constituent features. The formal expression of this measure is given by:

$$S = \left\| (1 - |\mathbf{v}_1 - (\mathbf{v}_2 \odot \text{sign}^*(\mathbf{v}))|) \odot \frac{\mathbf{v}}{\|\mathbf{v}\|} \right\|, \quad (1)$$

where $\odot$ denotes element-wise multiplication, and $\text{sign}^*(\mathbf{v})$ is an element-wise operation that maps positive elements and zero in $\mathbf{v}$ to 1 and negative elements to -1. This formula encapsulates the core principles of our similarity measure, taking into account the normalized differences between $\mathbf{v}_1$ and $\mathbf{v}_2$, modulated by the importance and directional relevance assigned by $\mathbf{v}$. The measure yields a value between 0 and 1, corresponding to low and high similarity, respectively.

3. Application in AI

The versatility of our similarity measure could be evidenced by its broad applicability across various AI domains, notably in areas where in-depth analysis and interpretation of data are paramount. In personalized recommendation systems, this measure could discern subtle user preferences from activity logs, significantly enhancing user experience by weighting features based on their relevance and directionality [9]. Our approach enables the identification of items that more closely align with a user's implicit preferences, even when not overtly expressed.

In semantic text analysis, our measure could facilitate the evaluation of thematic closeness among documents, where the normalization of $\mathbf{v}_1$ and $\mathbf{v}_2$ accommodates a comparison sensitive to the semantic scale of features. The modulation by $\mathbf{v}$ ensures that each term's specific importance is accurately reflected, aiding in the clustering or classification of texts based on underlying topics or sentiments [10].

Moreover, case-based reasoning (CBR) systems stand to benefit from our similarity measure. CBR hinges on the retrieval of relevant cases for problem-solving based on past experiences. By finely tuning the contribution of each feature in the comparison process, our measure offers a more adaptable and context-sensitive means to match new cases with the most pertinent historical instances, thereby optimizing the problem-solving process in CBR applications [11, 12].

4. Conclusions

In this work, we have introduced a novel similarity measure that leverages the nuanced contributions of individual vector elements $\mathbf{v}_1$ and $\mathbf{v}_2$, modulated by a third vector $\mathbf{v}$, to assess the similarity between two entities. This measure stands out by its ability to account for both the magnitude and directional relevance of features within vectors $\mathbf{v}_1$ and $\mathbf{v}_2$, thus offering a more sophisticated and contextually aware approach to similarity assessment. The normalization of vectors $\mathbf{v}_1$ and $\mathbf{v}_2$ within a defined range, alongside the modulation provided by $\mathbf{v}$, ensures that the similarity measure is adaptable to various domains and applications within AI, including but not limited to recommendation systems, semantic text analysis, and case-based reasoning.

The versatility and intuitiveness of our similarity measure could benefit AI systems. By providing a method to account for feature importance and oppositional alignment, our measure introduces a level of adaptability that is crucial for personalized, context-

aware AI solutions. Future work may explore the integration of this similarity measure into different AI methodologies or its adaptation to specific challenges within emerging domains of AI. Furthermore, empirical validation across diverse datasets and comparative studies with existing measures would provide deeper insights into its efficacy and applicability.

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