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Adoption of Human Augmentation Technologies for Non-Medical Applications: A Systematic Review of Empirical Literature

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ABSTRACT

The digitalization of society is driving adoption of human augmentation (HA) technologies beyond medical applications. While market size and public interest grow, empirical research on the adoption of non-medical augmentation technologies remains fragmented. This systematic review analyzes 61 empirical studies following PRISMA guidelines, using the Theories, Context, Methods-Antecedents, Decisions, Outcomes (TCM-ADO) framework to map theoretical, contextual, methodological characteristics, and research findings. Based on Diffusion of Innovations theory, we propose an integrated framework capturing the functional, affective, ethical, technological, and societal factors that influence the adoption process. Findings reveal contrasts between current and prospective users. Current users, often highly educated and aligned with the transhumanist movement, view augmentation technologies as tools to advance human evolution. In contrast, prospective users face barriers including limited access, regulatory uncertainty, and ethical concerns, with some expressing value-based opposition grounded in religious beliefs. This systematic review of empirical studies provides guidance for future research on non-medical HA and their adoption.

KEYWORDS

Human augmentation; systematic literature review; technology adoption; empirical studies

1. Introduction

The ongoing digitalization of society represents a profound socio-technical transformation encompassing the increasing datafication of life domains, the algorithmization of decision-making processes, and the platformization of new markets (Latzer, 2022, 2026). As digitalization expands, the human body also becomes a site of platformization (Pedersen, 2020). Devices that are worn, implanted, or integrated within the body monitor, collect, and analyze data on bodily functions and activities, forming what scholars variously refer to as cyborgization (Greguric, 2014), the Internet of Bodies (IoB) (Matwyshyn, 2019), or human–technology integration (Mullen, 2011). Social movements like Biohacking (Yetisen, 2018) and the Quantified Self (Lupton, 2016) provide early examples of how individuals use digital tools to monitor and enhance their bodies.

Non-medical applications of human augmentation (HA) technologies are both disruptive and innovative (Cohen, 2013; Gartner, 2019). In this article, we define HA technologies, following interdisciplinary consensus (Alicea, 2018; Gartner, n.d.; Guerrero et al., 2022; Raisamo et al., 2019), as digital systems that extend human physical, cognitive, or sensory capabilities through computational mechanisms, including AI features (Barfield & Williams, 2017; Guerrero et al., 2022; Ola & Legg-Jack, 2023; Renz et al., 2024). Non-medical applications refer to the use of HA technologies to augment human function beyond typical biological baselines. From a device perspective, this includes external and internal devices, referred to as wearables and insideables, respectively (Arias-Oliva et al., 2021; Barfield & Williams, 2017; Geddam et al., 2025). Insideables can be further classified as subcutaneous microchip

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implants and brain–computer interface (BCI) technologies (Barfield & Williams, 2017; Mueller et al., 2020).

The global HA market is projected to grow substantially, with industry estimates varying across forecasts but consistently indicating a sizable and rapidly expanding sector. Market size projections range from USD 725 billion in 2030 to USD 1.4 trillion in 2035 (Augmentation Market, 2020; Insights, 2023, 2024), underscoring the growing societal and economic impact. Consequently, public awareness and interest are rapidly rising. In the United States, 25% of respondents were aware of augmentation technologies in 2018 and 34% expressed interest in using them (Whitman, 2018). In Germany, 57% were open to use in 2021 (Schmid et al., 2021), and a 2025 survey in the United Kingdom shows that 80% of respondents expect widespread adoption within the next decade (El-Osta et al., 2025). However, public interest coexists with widespread privacy, safety, and cybersecurity concerns, reported by roughly 80% of respondents across several countries (Kaspersky, 2020; Latzer et al., 2023, 2025). Together, these findings reveal a rapidly expanding field that inspires both public interest and apprehension. However, systematic knowledge on the adoption process of non-medical augmentation technologies is currently missing.

Throughout this review, we use the term "adoption" as an umbrella term to refer to the innovation-decision process outlined in Rogers' Diffusion of Innovations (DoI) theory (Rogers, 2003). We refer to this innovation-decision process as the "adoption process," defined as a multi-stage progression encompassing initial individual awareness and attitude development, followed by an adoption decision that, if positive, culminates in actual use. This process is influenced by individual characteristics, societal context, and technological attributes, which affect how innovations diffuse over time, moving from innovators and early adopters to the early and late majority, and finally to laggards (Rogers, 2003). By situating the adoption process within the context of DoI, we emphasize the pivotal role of individual decision-making in understanding how non-medical HA technologies transition from emerging innovations to widespread societal integration. This focus aligns with extensive adoption research across domains (e.g., Kumar et al., 2023; Osrof et al., 2023; Page et al., 2018; Yao et al., 2012) and guides our interest toward studies examining individual attitudes, intentions to use, motivations for use, and the factors influencing adoption.

While initially focused on medical applications (e.g., Mosenia et al., 2017; Wu et al., 2022; Yao et al., 2012), non-medical applications of augmentation technologies are now being developed. Examples include the improvement of work-related performance (Gauttier, 2019b; Ho et al., 2022), facilitation of task-specific activities such as personal identification and payments (Jung & Lee, 2015), and augmentation for entertainment or personal enjoyment, such as sensory enhancement (Britton & Semaan, 2017; Gan et al., 2021; Gauttier, 2019a). In niche markets, technology enthusiasts in biohacker and transhumanist communities experiment with wearables and subcutaneous implants to enhance their capabilities for non-medical purposes (Britton & Semaan, 2017; Wexler, 2016). More advanced non-medical technologies, such as BCI implants (Cohen, 2013), are highly anticipated in early-adopter communities (Seyfried et al., 2023) and public discourse (Schmid et al., 2021). As applications expand, HA technologies hold transformative potential and spark discussions on individual and societal implications deriving from their widespread use.

The adoption of non-medical augmentation technologies has profound individual and societal implications. Ontologically, these technologies challenge traditional definitions of what it means to be human by blending biological and technological elements, suggesting a shift toward hybrid entities (Greguric, 2014). In response, the field of human–computer interaction has expanded to include human–computer integration (Mueller et al., 2020), reflecting a paradigm in which technologies become increasingly entangled with humans (Frauenberger, 2020). This hybridity fuels critical debates about personal autonomy and the safety of individuals (King et al., 2024). Personal autonomy may be affected by augmentation (Bavelier et al., 2019); for example, placebo effects of cognitive enhancement can increase risk-taking and alter decision-making (Villa, Kosch, Grelka, Schmidt, & Welsch, 2023). Safety concerns arise from technological challenges such as biocompatibility issues, hacking susceptibility, and data breaches (King et al., 2024; Mueller et al., 2020; Sharma et al., 2022). At the societal level, uneven availability of these technologies risks deepening existing inequalities by creating divides between augmented and non-augmented individuals (Allhoff et al., 2010; Bavelier et al., 2019; Raisamo et al., 2019). As non-medical augmentation technologies evolve and become more accessible, these theoretical discussions become pressing practical considerations requiring empirical insight.

Despite the growing variety of non-medical augmentation technologies, empirical research on their adoption was largely overlooked until 2016 (Reinares-Lara et al., 2016), after which a rapid increase in studies emerged (Chaudhry et al., 2023). Scholars note that debates on augmentation technologies are often too theoretical (Burwell et al., 2017; Sample et al., 2020). Béland et al. (2011) highlight that debates between transhumanist enthusiasm and humanist caution frequently stagnate due to their speculative nature. To overcome this stalemate, Gauttier (2019b) emphasizes the need for empirical research to complement theoretical discussions. Empirical studies are also critical for responsible innovation, as public perspectives are essential to ensuring that technologies align with societal expectations (Eden et al., 2013). Yet, public involvement in the design and testing of augmentation technologies remains limited (Record et al., 2013), suggesting that end-user concerns and expectations are often overlooked in development processes.

In response to these developments and their potential societal impact, this article presents a systematic review of empirical research on the adoption of non-medical HA technologies. The review maps existing relevant studies to structure the field, identify key influencing factors and research gaps, and support future interdisciplinary work among scholars, developers, and policymakers.

2. Related literature reviews

Despite growing interest in HA technologies, reviews summarizing empirical findings on their adoption for non-medical purposes remain scarce. Existing literature reviews cover subsets of enhancement technologies including nanotechnology, biotechnology, information technology, and cognitive sciences, highlighting the NBIC convergence driving the development of enhancement technologies (Latzer, 2022). We summarize key findings from related reviews, emphasizing insights relevant to HA technologies and the gaps our study addresses.

Dijkstra and Schuijff (2016) review 36 empirical studies on public opinion toward biotechnologies for non-medical enhancement, including CRISPR gene editing, reproductive technologies, and pharmaceutical cognitive enhancements. Although non-digital enhancement technologies like biotechnologies are outside the scope of our review, their findings reveal widespread public skepticism toward non-medical biotechnologies, contrasting with the optimism of theoretical debates. They also note that existing studies focus on limited cultural contexts and isolated technologies, limiting generalizability. The authors point out that an increased focus of the research community on empirical studies could mitigate the gap between negative public attitudes toward biotechnologies and optimistic theoretical debates.

Wolbring et al. (2013) examine empirical research on emerging technologies such as social robots, BCIs, and pharmaceutical cognitive enhancements. They find that traditional technology acceptance models fail to capture the distinctive psychological and social factors shaping adoption of enhancement technologies. Consequently, the authors suggest that it is necessary to design extensions to traditional technology acceptance models that integrate these additional dimensions.

Chaudhry et al. (2023) present a narrative review of 16 studies on non-medical HA technologies published between 2016 and 2023. They find that adoption patterns differ markedly between medical and non-medical contexts and that existing acceptance models must account for psychological, technological, and societal influences. Their findings point to the importance of integrating insights from social sciences and psychology, and they note that qualitative research could deepen understanding of how individuals interpret and adopt non-medical augmentation technologies.

3. Objectives

With this systematic literature review, we focus on the following research questions concerning the adoption of HA technologies for non-medical purposes:

> *RQ1*: What are the characteristics of empirical research on the adoption process of HA technologies for non-medical purposes?

RQ2: Which factors influence the adoption process of HA technologies for non-medical purposes, and how?

RQ3: What future research directions emerge from empirical literature on the adoption process of HA technologies for non-medical purposes?

The contribution of this systematic literature review is threefold: first, we examine both meta-level characteristics of empirical research, and related findings. Meta-level characteristics include an overview of populations and technologies, bibliometric trends, key publication venues, theoretical frameworks, and methodological approaches used in the studies. Findings highlight the key factors influencing the adoption of non-medical augmentation technologies.

Second, we design an integrated framework that maps empirical findings on the process of adoption of non-medical augmentation technologies, unifying them according to DoI theory (Rogers, 2003). Consistent with Rogers (2003) innovation decision process, we distinguish between antecedent factors, decision-related aspects, and outcomes to identify the most relevant factors and their role within the adoption process. The integrated framework provides a structured overview of the state-of-the-art findings from research in this field.

Finally, we identify gaps in the current literature and propose future research directions to address them. These insights are intended to structure the research field, and guide researchers and other stakeholders by identifying actionable areas for further exploration.

4. Methodology

4.1. Rationale

To this date, there is no systematic review of studies on the adoption of HA technologies for non-medical purposes. Literature reviews are fundamental for the development of research fields, and systematic review methodologies strengthen the relevance of their findings (Paul & Criado, 2020). Although "literature review" serves as an umbrella term that encompasses various research approaches such as narrative, scoping, systematic, and meta-analysis reviews, scholars highlight that the design of a review should align with the objectives of the study and fit the characteristics of the research field (Grant & Booth, 2009; Petticrew & Roberts, 2008). Systematic reviews, in particular, are distinguished by their structured and transparent methodology, including predefined inclusion criteria, comprehensive search strategies, and rigorous data analysis (Petticrew & Roberts, 2008).

We choose a systematic mapping approach for this literature review to prioritize the characterization of existing knowledge and the identification of research gaps rather than focusing on selectivity or quality appraisal based on predefined guidelines (Grant & Booth, 2009). This approach is appropriate because the adoption of augmentation technologies is an emerging field of research. In the absence of a systematic characterization of the guiding theories and methods in this area, it would be impractical to use approaches such as method-based or theory-based reviews, which include methodological or theoretical criteria in the study selection process (Paul et al., 2021). Furthermore, the diverse range of research topics and methodologies in this field limits the applicability of standard quality appraisal checklists (Petticrew & Roberts, 2008), as they are designed for studies using specific methodologies.

To ensure methodological rigor, this review follows a systematic approach through established processes and frameworks to document the study selection, and guide the analysis. We adhere to PRISMA guidelines (Moher et al., 2009) to document the selection process, and apply the Theories, Context, Methods-Antecedents, Decisions, Outcomes (TCM-ADO) framework (Lim et al., 2021) to structure the analysis. The TCM-ADO framework provides a structured approach to examine both "what we know" and "how we know" about the factors influencing adoption, thereby offering a comprehensive and systematized view of the current state of knowledge on non-medical HA technology adoption.

4.2. Selection process

We adhere to the PRISMA guidelines to document the identification, screening, and selection of relevant studies (Moher et al., 2009), detailing the rationale and significant steps in the selection process to ensure repeatability. The selection process involved the collaboration of the authors to refine search strategies, adjust query keywords and inclusion/exclusion criteria, and validate the selected set of studies. A PRISMA flow diagram (Figure 1) illustrates the selection process.

4.2.1. Database and source selection

A broad coverage of academic databases is necessary to collect relevant material for a systematic review. We conducted a thorough search across five academic databases and archives to cover a broad range of disciplines, including social sciences, economics, and computer science. The selected databases were ACM Digital Library, Scopus, Web of Science, Communication and Mass Media Complete, and Google Scholar. Google Scholar was included to locate gray literature and relevant peer-reviewed material which is not indexed in the selected databases (Haddaway et al., 2015). Additionally, relevant institutional reports were included when encountered. Due to the fragmented nature of the field and the use of specialized terminology across subfields, constructing a comprehensive database query posed significant challenges. Consequently, to ensure that all relevant studies were included, a complementary snowballing technique was employed (Wohlin, 2014). This involved screening the reference lists of the articles selected through database search, in order to locate additional relevant studies.

4.2.2. Research query

The choice of appropriate query strings and research filters is crucial to the success of a systematic literature review. An initial review of literature in the field allowed us to identify the appropriate time span, relevant fields of research, as well as the most relevant keywords. Paul and Criado (2020) point out that systematic literature reviews should consider a time span of at least 10 years for relevant publications. We limited the search to the years 2000–2025, a time frame in which technologies for HA were in development and potentially available to the public. An initial nonsystematic review of relevant studies allowed us to identify keywords that are frequently found in the context of adoption of technologies for HA. For the purposes of this review, we use the term "adoption process" as conceptualized in Rogers' DoI theory (Rogers, 2003), as an umbrella term encompassing attitudes, acceptance, and experiences related to augmentation technologies. It is important to note that studies in the field rarely address adoption holistically; instead, they typically focus on individual aspects of the adoption process, corresponding to a diverse range of keywords. We identified common keywords related to technologies (e.g., HA, cyborg, microchip implant, and BCI), specific aspects of adoption (e.g., acceptance, perception, attitudes, and opinions), or lastly present findings from reports and interviews of initial adopters (e.g., interview and biohacker). The final search query aggregates relevant keywords to capture a wide spectrum of studies related to the adoption of technologies for HA. A final query update was executed in the selected databases and Google Scholar on April 10 2025.

> **Title-Abstract-Keyword** *("human enhancement technolog*" OR "augmented human*" OR "human augmentation*" OR "human* 2.0" OR cyborg* OR "implant* technolog*" OR "microchip implant*" OR "biohack*" OR "brain-computer interface" OR "bci")* AND **Title-Abstract-Keyword** *(perception* OR view* OR acceptance* OR debate* OR opinion* OR trust OR attitude* OR interview OR survey OR expectation* OR report)*

4.2.3. Screening and eligibility

The selection process involved multiple phases to identify the final set of studies. All the databases were scraped, evaluating the query for matches in the Title, Abstract, and article keywords. The initial query results were filtered to include only peer-reviewed, final-version articles in order to ensure the reliability and consistency of the findings. Following recommended heuristics on the use of Google Scholar for systematic literature reviews (Haddaway et al., 2015), we included the first 250 results, sorted by relevance, in the screening phase. In the final database search conducted before submission, 126 additional articles were identified through Google Scholar and added to the screening phase. All identified records were exported to Zotero to remove duplicate, and filter irrelevant and inaccessible results. Despite the initial large dataset, most of the search results were irrelevant to our research interest and were excluded because the keywords were used in different contexts, unrelated to technologies

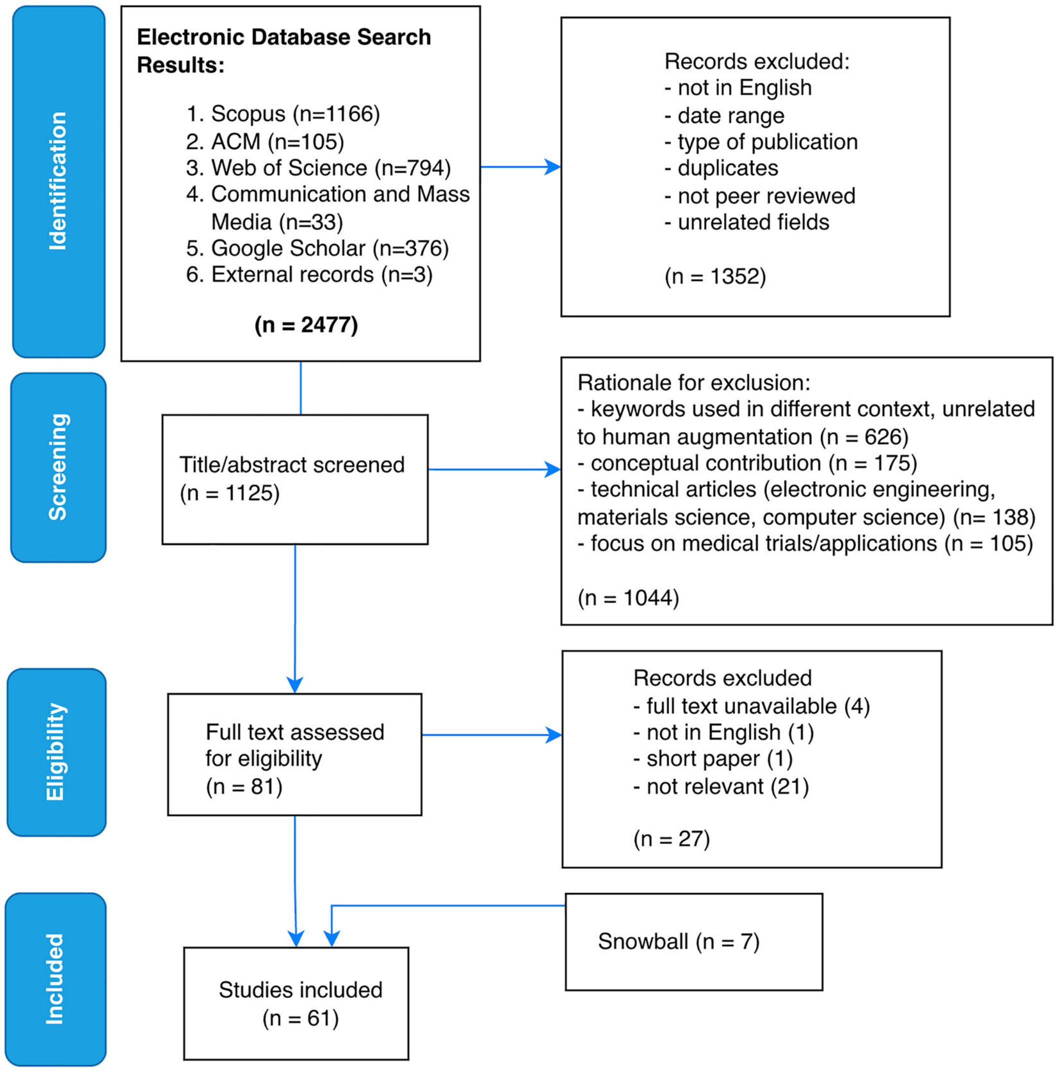

Figure 1. PRISMA graph for the selection of articles for the systematic review. Created by the authors.

for HA (626 records excluded). We adhered to the following criteria to ensure relevance of the remaining studies to our research questions:

- *C1*: The study must include empirical data on the personal use (current or prospective) of technologies for HA for non-medical purposes.
- *C2*: The study must not exclusively focus on technical details of the technologies for HA.
- *C3*: The study must not exclusively focus on (but can include information about) medical or specialized applications of technologies for HA, that exclude use among the general public.

Based on these criteria, 81 studies were selected for full-text analysis, and seven additional studies were identified through snowballing. Ultimately, a total of 61 studies were included, which is a suitable number for a systematic literature review (Paul & Criado, 2020). Figure 1 summarizes the steps of the selection process, including the rationale for exclusion of the remaining articles.

4.3. Analytical framework

4.3.1. Choice of the framework

We adopt the TCM-ADO framework (Lim et al., 2021) for this systematic review because it enables a comprehensive analysis of research characteristics, and a structured organization of findings.

This choice is also driven by the importance of repeatability in impactful systematic literature reviews (Paul et al., 2024). A variety of analytical frameworks are available for systematic literature reviews, including TCCM (Theories, Context, Methods, Characteristics) (Paul & Rosado-Serrano, 2019), ADO (Antecedents, Decisions, Outcomes) (Paul & Benito, 2018), TCM (Theories, Context, and Methods) (Paul et al., 2017), and TCM-ADO (Lim et al., 2021) (a combination of the previous two frameworks). Since this review aims to explore both the characteristics of the research landscape and the main findings of the selected studies, TCCM and TCM-ADO frameworks were identified as suitable options. Examples of systematic literature reviews on the adoption of emerging technologies can be found for both the TCCM (e.g., Kumar et al., 2023; Osrof et al., 2023) and TCM-ADO framework (e.g., Ambika et al., 2025; Dabas et al., 2023; Jain et al., 2024). However, the two frameworks provide different levels of granularity for analysis. TCCM defines "Characteristics" as the "elements of a construct and their relationship with other variables of interest" (Paul et al., 2024), offering an unstructured category to map findings. However, Paul et al. (2024) note that TCCM does not offer sufficient depth to structure and analyze a complex network of concepts. We therefore favor the TCM-ADO framework, that structures findings into a process-oriented framework of Antecedents, Decisions and Outcomes, offering a more granular approach to organize concepts (Lim et al., 2021). Applying the TCM-ADO framework in this systematic review enables a comprehensive analysis of research characteristics, and structures the findings in alignment with our definition of the adoption process of HA technologies according to DoI (Rogers, 2003). This approach allows us to identify antecedent factors, characterize the decision-making process, and structure the resulting outcomes. While the framework's comprehensive nature is challenging for systematic reviews with large sample sizes (Paul et al., 2024), it is well-suited for our review of 61 studies.

4.3.2. Coding and dataset

The TCM-ADO framework offers a structure to code and analyze the selected studies, guiding the creation of the initial codebook. The initial codebook was further developed through an inductive–deductive approach. Based on the findings, further categories of codes were defined to distinguish between individual, technological, and societal antecedent factors, as well as different aspects related to the decision process for the adoption of augmentation technologies. The analysis was conducted using the MaxQDA24 (VERBI Software, n.d.) software to ensure systematic and comprehensive coding of the data.

During the coding process, we identified six studies that use the same cohort population. In line with established guidelines for handling duplicate cohort data in systematic reviews (Wood, 2008), we included all studies in the content analysis while ensuring that duplicate findings were not reported multiple times. This approach captures the full range of insights provided by these studies without skewing findings due to duplicate counting. To focus on the most salient factors, we adopted frequency-counting practices used in prior reviews (Al-Emran et al., 2025; Giua et al., 2021; Osrof et al., 2023) and limited our discussion to factors reported in at least three different studies. The coded list of articles is available as supplementary material.[1] This approach ensures methodological rigor while accurately reflecting the scope and characteristics of the available research.

5. Results and discussion

This section presents the findings of our systematic review on the empirical research on the adoption of HA technologies for non-medical purposes, guided by the TCM-ADO (Lim et al., 2021) analytical framework. The findings are organized and discussed at two levels of abstraction: (1) meta-level characteristics of the research and (2) empirical findings on key factors influencing the adoption process. Additionally, this section provides an overview of future research directions in this field. The TCM portion of the framework guides the content analysis and discussion of RQ1, focusing on meta-level characteristics of the research. This includes contextual aspects such as bibliometric information (publication trends, venues, and leading authors), study populations, technologies examined, theoretical foundations, and research designs and methods used. To synthesize the findings for RQ2, we present an integrated framework based on DoI theory (Rogers, 2003), using the ADO structure. This framework maps key factors influencing the adoption of augmentation technologies. Finally, RQ3 addresses future research directions, synthesizing promising insights from the current literature and highlighting knowledge gaps suitable for further exploration in order to further develop the field.

5.1. RQ1: What are the characteristics of empirical research on the adoption of human augmentation technologies for non-medical purposes?

This research question seeks to identify the meta-level characteristics of empirical studies on the adoption of non-medical augmentation technologies, guided by the TCM analytical framework. We structure the discussion as follows: first, we examine key contextual characteristics, focusing on the populations studied, including distinctions between current and prospective users, as well as the types of technologies investigated. Contextual information on published research includes an overview of bibliometric information, highlighting publication trends, prominent publication venues, and the leading authors in the field. We also provide an overview of the theoretical and conceptual frameworks employed, along with the research methods used in the studies.

5.1.1. Context of research

The TCM-ADO framework broadly defines context as "circumstances shaping the research setting" (Paul et al., 2024). For our purposes, we consider the following aspects to be relevant contextual information: populations and technologies examined in the studies, as along with bibliometric information, including publication trends over time, key publication venues, and leading authors. Analyzing these elements allows us to understand the research landscape, assess the development of the research field over time, and identify potential gaps or trends that may inform future research directions.

5.1.1.1. Populations context. The empirical literature on the adoption of non-medical HA technologies distinguishes two primary populations: current and prospective users.

Current users are the initial adopters of augmentation technologies, typically found in niche communities such as biohacker collectives (Britton & Semaan, 2017; Gauttier, 2019a; Heffernan et al., 2016, 2021; Huberman, 2024; Ip et al., 2008a, 2008b; Michael & Michael, 2010, 2013; Orlowski, 2020; Schmid & Jox, 2021; Seyfried et al., 2023). A defining characteristic of these users is their alignment with transhumanist ideals, which advocate for the improvement of human capabilities and the transcendence of biological limitations through technology (Kurzweil, 2005; Moore, 2008). This ideological alignment is evident among current users included in the studies, as their use of augmentation technologies reflects both a philosophical commitment to these ideals and a practical exploration of the potential for human–technology integration (e.g., Britton & Semaan, 2017; Huberman, 2024). This characteristic positions them as influential actors in the adoption process, as their experimentation may influence societal attitudes and the broader acceptance of these technologies.

In contrast, studies on prospective users explore attitudes toward augmentation technologies among larger, more diverse population groups, investigating general public perspectives. Prospective user studies sample populations across various geographical and online contexts, with a notable concentration in European countries, particularly Spain (e.g., de Andrés-Sánchez, Arias-Oliva, & Souto-Romero, 2024; Pelegrín-Borondo et al., 2016, 2017; Reinares-Lara et al., 2016) and Germany (Sample et al., 2020; Sattler & Pietralla, 2022; Schmid et al., 2021). Despite access to larger population samples, these studies rely on non-representative data, with the exception of six studies (Gangadharbatla, 2020; Kaspersky, 2020; Prudhomme, 2020; Sattler & Pietralla, 2022; Schmid et al., 2021; Whitman, 2018). Among the reviewed studies, two notable clusters reuse the same underlying datasets. One consists of four single-country studies that draw on the same dataset of 600 survey responses from Spain (Olarte et al., 2015; Pelegrín-Borondo et al., 2016, 2017; Reinares-Lara et al., 2016). The second cluster comprises six studies that rely on the same dataset of 1563 survey responses spanning seven countries: Chile, China, Denmark, Japan, Mexico, Spain, and USA (Arias-Oliva et al., 2021, 2020; Cristina et al., 2021; de Andrés-Sánchez, Arias-Oliva, Souto-Romero, & Gené-Albesa, 2024; de Andrés-Sánchez et al., 2021; Pelegrín-Borondo et al., 2020). The reliance on non-representative data, combined with a limited

Table 1. Overview of human augmentation technologies examined in the reviewed studies.

Device type	Examples	Market availability	Study type	Common key findings
General HA technologies	Mixed or combined augmentation categories (cognitive, physical, sensory)	Mixed availability depending on the specific technology	Large cross-country surveys; mixed-method studies	Physical/therapeutic uses viewed more favorably than cognitive/emotional enhancement; privacy, inequality, and risk dominate concerns; younger and tech-positive individuals more supportive; cross-cultural differences.
Wearables	Smart glasses/lenses; cognitive enhancement wearables	Widely available consumer products	Primarily hypothetical adoption surveys; some experimental or comparative studies	Usefulness, enjoyment, and social influence increase acceptance; lower perceived risk than internal devices; preferred by older adults and women.
Insideables	Implanted digital devices	Limited availability in niche markets (biohacking, early adopters)	Hypothetical adoption studies, case studies, and interviews with current users	High privacy, safety, and ethical concerns; influenced by innovativeness, religiosity, and social norms; polarization between supporters and skeptics.
Microchip implants	RFID/NFC implants for access, payments, or identification	Niche availability in tech-forward workplaces and biohacker communities	Hypothetical adoption surveys; some studies with actual users	Convenience and utility strongly motivate adoption; high concern about surveillance and hacking; trust in institutions predicts willingness to adopt; strong cultural variation.
Brain–computer interfaces (BCIs)	Noninvasive BCIs; memory/cognitive enhancement implants	Not available for non-medical consumer use (experimental/emerging)	Hypothetical adoption surveys, vignette experiments, sentiment analyses	High moral, ethical, and identity concerns; strong preference for medical over enhancement uses; emotions, competitiveness, and religious beliefs influence acceptance; privacy concerns.

Examples and categories are derived from the empirical studies included in this review (see Supplementary Material).

geographic focus and the repeated use of the same datasets across multiple publications, may skew the understanding of general public attitudes and restrict the findings' applicability across cultural contexts.

5.1.1.2. Technological context. We define the technological context as the range of augmentation technologies examined in the studies. The empirical studies explore diverse HA technologies, including external devices (i.e., wearables), and internal devices (i.e., insideables), which are further divided into subcutaneous microchip implants and BCI implants. Because these categories vary substantially in terms of technological maturity and commercial presence, we provide a detailed overview in Table 1, which summarizes the types of technologies (with examples), availability, types of adoption studies, and key findings.

Differences in availability are analytically relevant because they influence whether researchers can study actual users or must rely on prospective, hypothetical, or vignette-based designs. This systematic review spans 17 years of technological development, with the focus of the articles reflecting the evolving novelty and availability of specific technologies. In earlier years, microchip implants were considered innovative technologies (e.g., Ip et al., 2008a, 2008b). More recently, there has been a shift toward BCI implants (e.g., Kablo & Arias-Cabarcos, 2023; Rousi & Renko, 2020; Schmid et al., 2021; Seyfried et al., 2023), signaling advancements in the development of augmentation technologies. Recent publications have introduced a novel focus on AI-based augmentation, including AI for cognitive enhancement and BCI implants, reflecting a growing interest in the role of artificial intelligence in HA, especially in light of the increased attention to generative AI (Oprea & Bâra, 2024; Oprea et al., 2024; Renz et al., 2024).

The studies in our systematic review focus on these technologies in two distinct ways. The first group of studies (eight in total) adopts a technology-agnostic approach, broadly examining user attitudes toward augmentation technologies without focusing on particular devices (Britton & Semaan, 2017; Kaspersky, 2020; Prudhomme, 2020; Stefański & Jach, 2022; Villa, Niess, Nakao, et al., 2023; Villa, Niess, Schmidt, & Welsch, 2023; Whitman, 2018; Zhang et al., 2025). The second group of studies, comprising the majority of our sample, is device-specific. Seventeen studies focus on subcutaneous microchip implants (Dragović, 2019; Gauttier, 2019a; Heffernan et al., 2016, 2021; Huberman, 2024; Ip et al., 2008a, 2008b; Michael & Michael, 2010, 2013; Niininen et al., 2023; Olarte et al., 2015; Orlowski, 2020; Sabogal-Alfaro et al., 2021; Shafeie et al., 2022; Werber et al., 2017; Žnidaršič et al., 2021, 2022), which, despite being available for applications like payment and identification in countries like Sweden (Alderman, n.d.), have yet to achieve widespread adoption. Ten studies expand from subcutaneous implants to include insideables in general (e.g., Arias-Oliva et al., 2020; de Andrés-Sánchez, Arias-Oliva, Souto-Romero, & Gené-Albesa, 2024; Gangadharbatla, 2020). Five studies (Arias-Oliva et al., 2021; Cristina et al., 2021; de Andrés-Sánchez et al., 2021; Murata et al., 2017; Reichel et al., 2024) specifically examine the differences in the adoption process between insideable technologies and commercial options such as wearables. Research on experimental technologies, including BCI implants (21 studies in total) (e.g., Ahadzadeh, Ong, Deng, & Ali, 2024; Castelo et al., 2019; Kablo & Arias-Cabarcos, 2023), highlights emerging trends and potential future applications.

Similarly to the findings of Dijkstra and Schuijff (2016) on biotechnologies, empirical research on augmentation technologies predominantly examines devices in isolation, rather than considering them as part of a cohesive trend toward non-medical HA. This isolated approach limits the ability to comprehensively characterize the adoption process of non-medical augmentation technologies. First, it hinders the understanding of the factors that cause differing adoption rates across technologies. Second, it makes generalizing findings across augmentation technologies difficult, as it overlooks the broader technological trend of non-medical augmentation that ties these devices together.

5.1.1.3. Publication trends. The evolution and increased interest in this area of research are illustrated in Figure 2, which shows the number of publications per year and highlights a notable increase in output, especially in the last decade. We distinguish between research clusters focused on current users (2008–present) and prospective users (2016–present) to highlight the increasing relevance of research on augmentation technologies for the general population. This shift from niche research on the biohacker community to broader studies of the general public reflects the rising importance of augmentation technologies, as they gain potential for widespread social adoption and impact. Notably, the surge in research since 2016 coincides with a growing interest from the business and marketing sectors (e.g., Arias-Oliva et al., 2020, 2021; Pelegrín-Borondo et al., 2016, 2017), which focus on identifying market segments for the adoption of augmentation technologies. This heightened interest aligns with both Gartner's identification, in 2019, of HA technologies as an upcoming disruptive innovation (Gartner, 2019), as well as the 2023 market projections of a significant increase in market capitalization for augmentation technologies (Augmentation Market, 2020), reinforcing their growing relevance and potential for widespread adoption.

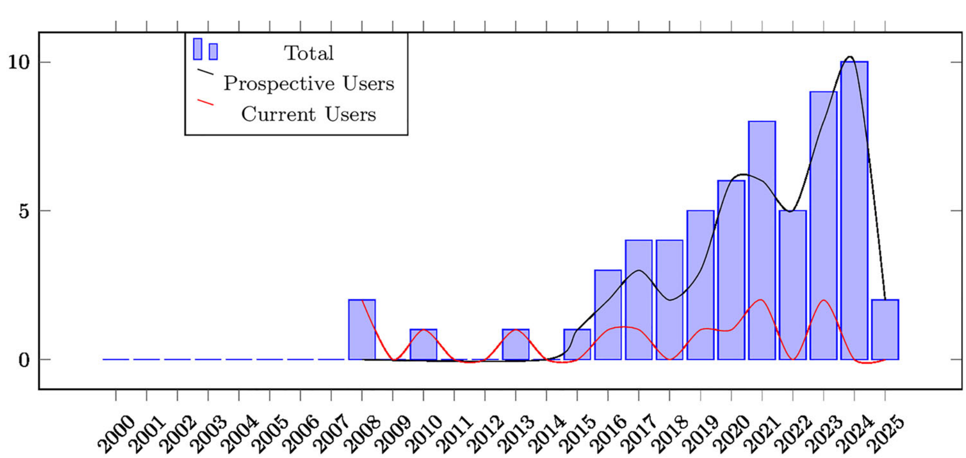

Figure 2. Total number of publications by year in the surveyed timespan, and distribution between current and prospective users. Created by the authors.

5.1.1.4. Leading authors and publication channels. An overview of contributing disciplines and publication venues (Table 2) reveals a concentration of research within specific regions and author groups, alongside a diverse but compartmentalized disciplinary interest in non-medical augmentation technologies. Data on author affiliations and research domains show that publications in the field are concentrated in a few key research centers. In particular, active research groups are prominent in Europe, particularly in Spain and Germany (e.g., Arias-Oliva et al., 2020, 2021; Kablo & Arias-Cabarcos, 2023; Pelegrín-Borondo et al., 2016), in Asia, including Malaysia (Ahadzadeh, Ong, Deng, & Ali, 2024; Ahadzadeh, Ong, & Veeraiah, 2024; Ahadzadeh et al., 2023; Ahadzadeh & Amini, 2024) and Japan (e.g., Murata et al., 2017, 2019), as well as in Australia (e.g., Ip et al., 2008a, 2008b; Michael & Michael, 2010), the USA (Shafeie et al., 2022; Whitman, 2018), and South America, specifically Chile and Colombia (e.g., Sabogal-Alfaro et al., 2021). Despite the strong growth in publication output since 2016, a limited number of authors and research groups account for the most publications. For instance, Pelegrín-Borondo coauthors 12 of the 61 publications included in this review, and in general European authors are frequently listed as first authors.

This concentration of publications not only highlights the reliance on a few leading contributors, but also reflects a skewed disciplinary focus of the field. Contributions from Business, Psychology, Informatics, and Social Sciences are notable, with particular emphasis on Business and Psychology. Much of business research focuses on market segmentation and consumer behavior (e.g., Arias-Oliva et al., 2020, 2021; Pelegrín-Borondo et al., 2016, 2017), while psychology-related studies often address personality traits that influence user acceptance and attitudes (Ahadzadeh, Ong, Deng, & Ali, 2024; Ahadzadeh, Ong, & Veeraiah, 2024; Ahadzadeh & Amini, 2024; Stefański & Jach, 2022). Although the field is expanding across various academic disciplines, there is a noticeable lack of interdisciplinary collaboration, with most studies addressing discipline-specific concerns rather than integrating diverse perspectives (e.g., Rousi & Renko, 2020).

The analysis of publication venues reveals the interdisciplinary nature of the field, with the 61 publications included in this review distributed across 45 different channels. Only four venues (CHI, Computers in Human Behavior, Human Behavior and Emerging Technologies, and Technology in Society) host more than one publication (examples are shown in Table 2).

Overall, while research on the adoption of augmentation technologies is expanding across disciplines, the field remains in its early stages of definition. Interdisciplinary collaboration is limited, and much of the published research is driven by a small number of contributors.

5.1.2. Theoretical frameworks

The TCM-ADO framework defines theories as "theoretical underpinnings and paradigms used to explain the inter-relationships between constructs" (Paul et al., 2024). This definition, with its focus on quantitative, model-oriented structures, does not fully capture the variety of theoretical approaches observed in the empirical literature on non-medical HA technologies. To better reflect the diversity of the literature, we categorize the studies into three overarching theoretical approaches: (1) exploratory and theory-building approaches, (2) behavioral description and prediction approaches, and (3) interpretive approaches through critical theories.

Table 2. Overview of the main contributing disciplines where research is disseminated.

Main contributing disciplines	Count	Examples of venues (and articles)
Interdisciplinary	16	International Symposium on Technology and Society (Michael & Michael, 2010), Technology in Society (Gauttier, 2019b)
Psychology and Cognitive Sciences	14	Human Behavior and Emerging Technologies (de Andrés-Sánchez, Arias-Oliva, & Souto-Romero, 2024), Computers in Human Behavior (Cristina et al., 2021), Current Psychology (Ahadzadeh et al., 2024)
Informatics	12	CHI (Villa, Niess, Nakao, et al., 2023), Informatics (Shafeie et al., 2022)
Business and Economics	10	International Journal of Consumer Studies (Žnidaršič et al., 2022), Developments in Marketing Science (Niininen et al., 2023)
Social Sciences and Humanities	5	Media, Culture and Society (Michael & Michael, 2013), Science, Technology and Human Values (Sample et al., 2020)
Independent Reports	3	AARP (Whitman, 2018), Kaspersky (Kaspersky, 2020), SIENNA project (Prudhomme, 2020)
Medical Sciences	1	JMIR Formative Research (Almanna et al., 2025)

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5.1.2.1. Exploratory and theory-building approaches. This category encompasses studies that do not explicitly adopt established theoretical frameworks but instead aim to generate preliminary insights and develop foundational understanding, often serving as a basis for future research. The absence of a theoretical framework in a study means that the research does not explicitly draw upon or align with an established set of concepts, paradigms, or models to guide its design, analysis, or interpretation of findings. In our sample, we identify 15 articles that do not specify a theoretical framework (Almanna et al., 2025; El-Osta et al., 2025; Heffernan et al., 2016, 2021; Ip et al., 2008a, 2008b; Kaspersky, 2020; Michael & Michael, 2013; Niininen et al., 2023; Prudhomme, 2020; Schmid et al., 2021; Schmid & Jox, 2021; Seyfried et al., 2023; Villa, Niess, Nakao, et al., 2023; Whitman, 2018). These studies provide preliminary insights into user attitudes, concerns, and expectations on technologies for HA, but lack the structured guidance of established theories. As a result, their conceptual definitions and rationales are often under-specified, increasing the difficulty to compare findings across studies. Among these, research by Schmid and Jox (2021) stands out by employing a grounded theory approach, aiming to build a theory on the motivations that drive users of non-medical augmentation technologies. However, the other studies in this category do not aim at constructing new theoretical frameworks. Instead, they focus on descriptive and exploratory objectives, offering valuable insights into key areas of interest such as user preferences for different applications of augmentation technologies (Heffernan et al., 2016; Prudhomme, 2020) and related societal concerns (Kaspersky, 2020; Whitman, 2018). These studies serve as useful groundwork for generating more hypotheses, providing direction for future research that can incorporate more robust theoretical frameworks.

5.1.2.2. Behavioral description and prediction approaches. This category covers 42 studies that aim to understand how individuals form preferences, attitudes, and intentions toward adopting HA technologies. While traditionally rooted in theoretical technology acceptance models like TAM (Davis, 1989), TAM2 (Venkatesh & Davis, 2000), UTAUT (Venkatesh et al., 2003), and DoI (Rogers, 2003), this category also includes studies that apply psychological, sociological, and ethical theories or concepts to explore behavioral drivers. These theories are frequently used to extend technology acceptance models to examine the process of adoption of augmentation technologies, and collectively contribute to understanding the influential factors, including demographic, contextual, and individual differences.

Psychological theories are used in studies that focus on the influence of personality traits, emotions, and personal values on the use of augmentation technologies. The Self-Discrepancy Theory (Higgins, 1987) is incorporated to explain how discrepancies between an individual's actual self and their ideal self can drive the desire to use augmentation technologies, explaining the role of personality traits like perfectionism and competitiveness in the adoption of augmentation technologies (Ahadzadeh, Ong, Deng, & Ali, 2024; Ahadzadeh, Ong, & Veeraiah, 2024; Ahadzadeh et al., 2023; Ahadzadeh & Amini, 2024). Furthermore, affective influences, such as users' emotional responses, and environmental factors, including social norms, have been shown to significantly impact users' adoption decisions for augmentation technologies (de Andrés-Sánchez, Arias-Oliva, Souto-Romero, & Gené-Albesa, 2024; Pelegrín-Borondo et al., 2016, 2017; 2020; Rousi & Renko, 2020). Similarly, value-based psychology constructs demonstrate that personal values influence the adoption process of augmentation technologies (e.g., Olarte et al., 2015; Shafeie et al., 2022; Stefański & Jach, 2022).

Theories that consider individual ethical judgment play a crucial role in expanding technology acceptance models, particularly in research focused on market segmentation. For example, the Multidimensional Ethics Scale (Reidenbach & Robin, 1990) has been successfully used to identify different market segments based on the perceived ethical judgment of augmentation technologies. This research reveals how varying perceptions of fairness, autonomy, and societal impact shape the adoption process (Ahadzadeh, Ong, Deng, & Ali, 2024; Arias-Oliva et al., 2020; Cristina et al., 2021). Moreover, ethical considerations are critical in specific applications, such as the use of augmentation technologies in the workplace where concerns about employee privacy and safety are highlighted (Gauttier, 2019b), and in relation to BCI technologies (Kablo & Arias-Cabarcos, 2023; Sample et al., 2020), which introduce unprecedented risks due to the sensitive nature of brain-related data.

5.1.2.3. Interpretive approaches through critical theories. Critical theoretical approaches offer a nuanced lens for examining the adoption of augmentation technologies. Despite being the smallest category of our sample, comprising only four studies, we identify two key research foci that relate to the individual experience and societal impact of non-medical augmentation technologies.

Phenomenological research investigates how individuals experience the integration of augmentation technologies with their bodies. Gauttier (2019a) and Orlowski (2020) examine how users perceive the transformation of their bodies as they adopt augmentation devices, and offer insight into the lived experience of integrating with technology in what the articles refer to as the "cyborg" body. Gauttier (2019a) shows that users of augmentation technologies conceptualize the cyborg body as a site of integration between human identity and technological innovation. Orlowski (2020) highlights that the cyborg body becomes a vehicle for self-expression and for challenging biological limitations of the human body.

The second research focus examines the societal and political impact of augmentation technologies. The feminist Science and Technology Studies perspective, drawing on Haraway's work (Haraway, 2013), is used to analyze how non-medical augmentation technologies can impact marginalized groups, examining the effect of augmentation technologies on issues related to gender and disability (Britton & Semaan, 2017). Huberman (2024) and Gauttier (2019a) examine the political activism enabled by augmentation technologies. Users of these technologies conceptualize them as tools to resist anthropocentric worldviews, and use them to foster deeper connections with nature and to challenge traditional human-centered perspectives of the world.

5.1.3. Research methods

The studies in this systematic review employ diverse research methods to explore the adoption of non-medical HA technologies. We categorize the methods into qualitative, quantitative, mixed, and computational methods, detailing the associated data collection and analysis methods within each category.

5.1.3.1. Qualitative methods. Qualitative methods are predominantly used in studies focusing on current users of augmentation technologies. These studies aim to provide in-depth insights into the motivations and experiences of initial adopters, and rely on methods such as case studies (Gauttier, 2019a, 2019b; Huberman, 2024; Michael & Michael, 2010), interviews (Heffernan et al., 2016; Ip et al., 2008a, 2008b), and ethnographic research (Britton & Semaan, 2017; Orlowski, 2020; Seyfried et al., 2023) for data collection. The data analysis process is guided by grounded theory (Charmaz, 2008; Strauss & Corbin, 1997) or thematic analysis (Blandford et al., 2016). Gauttier et al. (2024) examine the prospective users' ethical judgment of augmentation technologies using a qualitative Q-study methodology.

5.1.3.2. Quantitative methods. With the expansion of research to include the general population, a significant shift toward quantitative methods is evident. Studies that rely on quantitative methods typically employ survey-based methods to collect data from larger sample sizes, allowing for statistical analysis and generalization of findings. Within this category, some studies present descriptive statistics for their data analysis, mapping attitudes and perceptions toward augmentation technologies (e.g., Dragović, 2019; Kaspersky, 2020; Villa, Niess, Nakao, et al., 2023). Other studies (based on technology acceptance models) rely on regression or structural equation modeling (Ullman & Bentler, 2012) to assess the validity of models and relationships between constructs that have been adapted to fit the specific context of HA (e.g., Ahadzadeh, Ong, Deng, & Ali, 2024; Ahadzadeh, Ong, & Veeraiah, 2024; Ahadzadeh et al., 2023; Ahadzadeh & Amini, 2024; Pelegrín-Borondo et al., 2016, 2017, 2020). Our article sample includes three experimental studies (Castelo et al., 2019; Sattler & Pietralla, 2022; Zhang et al., 2025), which focus on the acceptance and intention to use cognitive enhancement technologies. The limited use of experimental research designs in research on the adoption of HA technologies can be ascribed to the emerging nature of the field, but should be encouraged as this approach is particularly useful for isolating specific factors that influence adoption decisions, providing evidence of causality.

5.1.3.3. Mixed methods. Although relatively recent in this field, mixed-methods research on non-medical augmentation technologies emerged in 2021 (de Andrés-Sánchez, Arias-Oliva, & Souto-Romero, 2024; Heffernan et al., 2021; Shafeie et al., 2022; Villa, Niess, Nakao, et al., 2023), allowing researchers to corroborate quantitative data with qualitative insights, and enhancing both the reliability and depth of findings.

5.1.3.4. Computational methods. Another methodological approach is found in Niininen et al. (2023), Oprea and Bâra (2024), and Almanna et al. (2025), all using computational techniques to analyze large datasets of online data. Niininen et al. (2023) and Almanna et al. (2025) use topic modeling to analyze online user attitudes toward microchip and BCI devices on X (Twitter). Oprea and Bâra (2024) propose a data analysis framework to examine public perceptions of BCI devices, integrating multiple computational methods.

5.2. RQ2: Which factors influence the adoption of human augmentation technologies for non-medical purposes, and how?

This section presents findings related to research question RQ2, focusing on the factors that shape the adoption process for non-medical HA technologies. We use the ADO portion of the TCM-ADO framework to guide content analysis. The field's methodological diversity, encompassing ethnographic studies, experimental designs, large-scale surveys, and phenomenological investigations, reflects the complexity of the adoption process. Therefore, our analysis focuses on thematic aggregation of factors rather than effect sizes, providing a comprehensive map of influential factors across diverse methodological approaches. This thematic synthesis approach allows us to identify patterns while acknowledging the field's methodological pluralism.

We structure this section by first presenting a categorization of factors within a taxonomy of antecedents, decision-related aspects, and outcomes according to the ADO framework. Using practices seen in previous systematic reviews on similar topics (Al-Emran et al., 2025; Giua et al., 2021; Osrof et al., 2023), we only discuss factors that appear in at least three different studies. A coded table of articles is available as supplementary material. We begin with an introduction of the measured outcomes that can be highlighted in the empirical literature reviewed; we then discuss findings related to how antecedent factors and decision-related aspects affect the outcomes. Finally, these factors are mapped in an integrated framework, based on Rogers (2003) DoI process, that aggregates findings and offers a unified perspective on the categories of factors shaping the adoption of non-medical augmentation technologies.

5.2.1. Outcomes

We frame outcomes using Rogers (2003) DoI model, which conceptualizes adoption as a multi-stage process. Following the ADO framework's definition of outcomes as "consequences arising from performance or non-performance of a behavior" (Paul et al., 2024), our content analysis identified three measurable outcomes in augmentation technology adoption studies: attitudes, intention to use, and current use. These outcomes represent sequential stages in Rogers' adoption process.

5.2.1.1. Definition and categorization of outcomes. We code as "Attitudes" all the outcomes that the studies identify as attitudes, opinions, concerns, and expectations. Attitudes represent the first evaluative stage in the adoption process, corresponding to the Knowledge and Persuasion stages in the DoI model (Rogers, 2003). We code as "Intention to Use" the individual's active evaluation of their personal willingness or intention to use augmentation technologies. Intention to Use is the result of the Decision stage identified by Rogers (2003), where potential adopters consider different aspects related to technology adoption, resulting in an intention to use augmentation technologies. Among prospective user studies, Intention to Use is the most advanced stage in the adoption process. Finally, we code as "Current Use" all reported cases of individual use of augmentation technologies. Current Use corresponds to Rogers (2003) Implementation and Confirmation stages, which represent continued use of the technology.

5.2.2. Antecedent and decision-related factors

We categorize factors affecting adoption outcomes based on Rogers' innovation-decision process (Rogers, 2003), and differentiate between preexisting antecedents and factors related to evaluative decision using the definitions of the TCM-ADO framework (Paul et al., 2024). Antecedents are "drivers behind involvement or non-involvement in a behavior," existing independently of the adoption process. Decisions are defined in the TCM-ADO framework as "types of behavioral performance/dimensional structure of a construct" (Paul et al., 2024). In this context, decision-related factors are different aspects of decision-making that emerge during the individual's adoption decision. Our analysis accounts for duplicate findings from repeated population samples (Wood, 2008), which could artificially inflate the importance of certain factors.

5.2.2.1. Categorization of antecedents. We identify three primary categories of antecedents affecting non-medical HA adoption: individual, technological, and societal. Each of these categories includes relevant sub-categories based on thematic overlap. Individual antecedents include socio-demographic factors and personal characteristics (Table 3). Technological antecedents cover device type, augmentation type and goal, and lastly the cost of the device (Table 4). Societal antecedents encompass social context,

Table 3. Categorization of individual antecedent factors.

Category	Antecedent	Findings	Count
Socio-demographic	Age	(1) Young individuals have more positive attitudes toward HA technologies (2) Young individuals have higher intention to use HA technologies	(1) *N*=8 (2) *N*=5
	Gender	(1) Male individuals have more positive attitudes toward HA technologies (2) Male individuals have higher intention to use HA technologies	(1) *N*=8 (2) *N*=6
	Education level	(1) Low education levels are associated with negative attitudes toward HA technologies (2) High education levels are associated with current use of HA technologies	(1) *N*=3 (2) *N*=3
Personal characteristics	Health and wellbeing	(1) Individuals with a lower health status, such as physical disabilities or high stress levels, have more positive attitudes toward HA technologies. (***contradictory result*)	(1) *N*=4
	Technological expertise	(1) High technological expertise is associated with positive attitudes toward HA technologies (2) High technological expertise is associated with intention to use HA technologies (3) High technological expertise is associated with current use of HA technologies	(1) *N*=3 (2) *N*=3 (3) *N*=3
	Personal and religious beliefs	(1) Religiosity is associated with negative attitudes toward augmentation technologies (2) Progressive beliefs are associated with positive attitudes toward HA technologies (3) Progressive beliefs are associated with intention to use HA technologies (4) Belief in free will (internal locus of control) versus fatalistic determinism (external locus of control) affects intention to use HA technologies (5) Transhumanist beliefs are associated with current use of HA technologies	(1) *N*=10 (2) *N*=1 (3) *N*=2 (4) *N*=2 (5) *N*=6
	Personal traits	(1) Perfectionism and competitiveness are associated with positive attitudes toward HA technologies (2) Perfectionism and competitiveness are associated with intention to use HA technologies (3) Personal innovativeness and curiosity are associated with intention to use HA technologies (4) Higher neuroticism trait is associated with intention to use HA technologies (5) Temporal orientation on present and future is associated with higher intention to use HA technologies (6) Personal habits affect the intention to use HA technologies (7) The desire to be a pioneer motivates current use of augmentation technologies	(1) *N*=1 (2) *N*=3 (3) *N*=3 (4) *N*=1 (5) *N*=1 (6) *N*=2 (7) *N*=3

The table includes information on the associated findings (numbered), and relevant count of studies for each finding. Created by the authors.

Table 4. Categorization of technological antecedent factors.

Antecedent	Findings	Count
Type of device	External devices (wearables): (1) Relate to better attitudes (2) Generate higher intention to use (3) Invasive devices are preferred by current users, due to their convenience and the association with cyborg identity	(1) N=3 (2) N=5 (3) N=2
Type of augmentation	(1) The type of augmentation (cognitive, sensory, physical) influences attitudes toward HA technologies (2) The type of augmentation (cognitive, sensory, physical) influences the intention to use HA technologies	(1) N=3 (2) N=1
Goal of augmentation	The goal of augmentation (medical, task-specific, or superhuman): (1) Influences user attitudes (2) Influences intention to use (3) Motivates current users to adopt HA technologies	(1) N=9 (2) N=5 (3) N=2
Cost of device	(1) The cost of the augmentation device affects attitudes toward HA technologies	(1) N=3

The table includes information on the associated findings (numbered) and relevant reference count for each finding. Created by the authors.

Table 5. Categorization of societal antecedent factors.

Antecedent	Findings	Count
Social context	Social context: (1) Affects attitudes toward HA technologies (2) Affects the intention to use HA technologies (3) Belonging to biohacking communities facilitates the use of HA technologies	(1) N=3 (2) N=8 (3) N=4
Regulatory framework	(1) Prospective and current users believe augmentation technologies should be regulated	(1) N=9
Country or regional differences	(1) Attitudes toward HA technologies vary across countries and regions (2) Intention to use HA technologies differs by country	(1) N=7 (2) N=2

The table includes information on the associated findings (numbered) and relevant reference count for each finding. Created by the authors.

regulatory frameworks, and country differences. Table 5 presents the complete categorization of related findings.

Overall, findings on antecedent factors suggest that, beyond basic sociodemographic characteristics like age and gender, additional antecedent factors such as technological expertise, personality traits and social influences (e.g., belonging to biohacking communities) are crucial in shaping the individual adoption process. Despite contextual, theoretical, and methodological differences, findings are largely consistent across studies. The association between age, gender, and technology adoption is consistently confirmed (e.g., Gangadharbatla, 2020; Sattler & Pietralla, 2022), with younger males emerging as the most supportive demographic. Technological expertise is also associated with positive attitudes toward adoption of non-medical augmentation technologies (e.g., Toker et al., 2025). Furthermore, the relevance of individual beliefs and social context is confirmed across current and prospective user populations. First, while progressive personal beliefs are associated with technology use (Huberman, 2024; Murata et al., 2019), religious beliefs are linked to negative attitudes toward augmentation (e.g., Sample et al., 2020; Whitman, 2018). Gauttier et al. (2024) further confirm this contrast, showing that progressive and religious beliefs respectively drive acceptance and rejection of non-medical augmentation technologies. Second, the effect of a supportive social context is highlighted in both prospective user studies (e.g., Pelegrín-Borondo et al., 2016, 2017; Reinares-Lara et al., 2018) and current user studies which highlight the supportive role of biohacking communities (e.g., Britton & Semaan, 2017; Seyfried et al., 2023), which also facilitate access to augmentation technologies (Seyfried et al., 2023). Current users appear undeterred by regulatory gaps (e.g., Britton & Semaan, 2017), while prospective users view limited regulation as a barrier (e.g., Schmid et al., 2021; Shafeie et al., 2022).

The main inconsistent results relate to the effect of the individual health status. Although two studies suggest that lower health status may positively impact individual attitudes (Sample et al., 2020; Shafeie et al., 2022), Whitman (2018) shows the opposite effect. The comparison between these studies is difficult since they are based on population samples of different countries (USA, Canada, Spain, and Germany), and use quantitative (Sample et al., 2020; Whitman, 2018) and qualitative (Shafeie et al., 2022) methods, so further research is needed to explore the inconsistency. While the lack of further inconsistencies is encouraging, the limited number of studies on the topic, and their theoretical, methodological, and contextual characteristics, warrant caution. For example, the reliance on non-representative student populations can significantly skew findings toward younger, higher educated individuals. Further contextual variations between studies arise from the different types of augmentation technologies examined, as highlighted in RQ1. The focus on different technologies across the selected studies implies that the influence of specific technological characteristics cannot be explicitly quantified.

These findings collectively show that individual, technological, and societal antecedent factors all contribute to shaping the adoption process of augmentation technologies.

5.2.2.2. Categorization of decision-related considerations. We identify five categories of decision-related considerations that influence the adoption of non-medical augmentation technologies: functional, affective, ethical, technological, and societal. These categories are derived from thematic overlaps across studies. Detailed findings for each category are reported in Table 6. Functional considerations relate to perceived usefulness and ease of use. Affective considerations involve emotional responses,

Table 6. Categorization of decision-related considerations for the adoption of augmentation technologies.

Category	Factor	Findings	Count
Functional	Usefulness considerations	Usefulness considerations: (1) Affect attitudes toward HA technologies (2) Affect intention to use HA technologies (3) Affect the current use of HA technologies	(1) $N=11$ (2) $N=13$ (3) $N=6$
	Ease of use considerations	Ease of use considerations: (1) Affect attitudes toward HA technologies (2) Affect intention to use HA technologies (3) Affect current use of HA technologies	(1) $N=6$ (2) $N=11$ (3) $N=3$
Affective	Positive emotional response	Positive emotions (such as excitement and curiosity): (1) Affect attitudes toward HA technologies (2) Affect intention to use HA technologies (3) Affect current use of HA technologies (4) Personal enjoyment impacts intention to use HA technologies (5) Personal enjoyment impacts current use of HA technologies	(1) $N=1$ (2) $N=6$ (3) $N=3$ (4) $N=4$ (5) $N=3$
	Negative emotional response	(1) Negative emotions (such as fear and anxiety) affect attitudes toward HA technologies (2) Negative emotions (such as fear and anxiety) affect intention to use HA technologies	(1) $N=2$ (2) $N=5$
Ethical	Ethical considerations	The individual's ethical judgment: (1) Affects attitudes toward HA technologies (2) Affects intention to use HA technologies (***duplicate results*) (3) Activism in support for bodily autonomy motivates current users to adopt HA technologies	(1) $N=12$ (2) $N=10$ (3) $N=7$
Technology-related	Technological risk considerations	Concerns for invasive implant procedures: (1) Affect the attitudes toward HA technologies (2) Affect the intention to use HA technologies (3) Concerns for invasive implant procedures are acknowledged but dismissed by current users of HA technologies	(1) $N=12$ (2) $N=5$ (3) $N=2$
	Privacy considerations	Concerns for cyberhacking or privacy infringement: (1) Affect attitudes toward HA technologies (2) Affect intention to use HA technologies (3) Are mentioned but dismissed by users of HA technologies	(1) $N=16$ (2) $N=3$ (3) $N=5$
Society-related	Societal impact considerations	(1) Perceived societal impact of HA technologies affects attitudes toward HA technologies (2) Perceived societal impact affects intention to use HA technologies (3) Perceived societal impact motivates current use of HA technologies	(1) $N=6$ (2) $N=1$ (3) $N=7$
	Expectations of negative perceptions	Expectations of negative perceptions of augmented individuals (e.g., stigma, fear, dehumanization): (1) Affect intention to use HA technologies (2) Are highlighted by current users of HA technologies	(1) $N=5$ (2) $N=1$
	Personal trust in institutions	(1) Trust in institutions influences attitudes toward HA technologies (2) Trust in institutions influences intention to use HA technologies	(1) $N=2$ (2) $N=3$

The table includes information on the associated findings (numbered), and relevant reference count for each finding. Created by the authors.

including excitement, enjoyment, fear, and discomfort. Ethical considerations reflect individual judgments on fairness, responsibility, and moral acceptability. Technological considerations concern risks associated with the technology itself, such as privacy, security, invasiveness, and health. Societal considerations include perceptions of broader societal impact, trust in regulation, and concerns about stigma or dehumanization.

This categorization of decision-related aspects aligns with Chaudhry et al. (2023) taxonomy of technology acceptance models for augmentation technologies, confirming the presence of cognitive, affective, ethical, technological, and societal considerations in the adoption process. While their work focuses solely on technology acceptance models, our review includes both acceptance studies and exploratory or qualitative research involving current and prospective users. This broader scope reinforces the validity of the categorization by showing that similar considerations emerge across diverse user groups and research designs.

Functional considerations on usefulness and ease of use remain central to adoption decisions, consistent with traditional technology acceptance models (e.g., Davis, 1989; Venkatesh et al., 2003). Current users particularly emphasize the comfort and convenience of augmentation technologies compared to external devices like ID cards or credit cards (e.g., Ip et al., 2008a, 2008b). For prospective users, perceived usefulness varies significantly by application domain, with medical and task-specific enhancements viewed more favorably than superhuman augmentations (e.g., Sattler & Pietralla, 2022; Whitman, 2018). However, the adoption process also incorporates novel dimensions beyond functionality, including affective, ethical, technological, and societal considerations.

Affective considerations reveal that prospective users often experience a mix of excitement, curiosity, fear, and discomfort, reflecting both the allure and uncertainty of augmentation technologies (e.g., Pelegrín-Borondo et al., 2017; Reinares-Lara et al., 2016). In contrast, current users describe their adoption experiences as enjoyable and fulfilling, often emphasizing the personal satisfaction derived from technological integration, regardless of its utility (e.g., Ip et al., 2008a, 2008b).

Ethical considerations shape the adoption process differently for prospective and current users. Prospective users express concerns about fairness and the potential misuse of augmentation technologies (e.g., Cristina et al., 2021; Murata et al., 2017). On the other hand, current users often frame their adoption as an expression of autonomy and empowerment, with beliefs in individual control over their bodies serving as a significant motivator (e.g., Britton & Semaan, 2017; Orlowski, 2020).

Technological considerations, such as concerns about invasive implant procedures and privacy risks related to continuous data collection, present significant barriers for prospective users (e.g., Kablo & Arias-Cabarcos, 2023; Žnidaršič et al., 2021). This contrasts with the experience of current users, who report an easy integration of augmentation technologies into daily life (Gauttier, 2019a; Heffernan et al., 2016; Ip et al., 2008a).

Finally, societal considerations highlight the tension between personal gains and collective implications of augmentation technologies. Prospective users voice fears about inequality, misuse, social exclusion, and discrimination (e.g., Kaspersky, 2020; Shafeie et al., 2022; Villa, Niess, Nakao, et al., 2023; Villa, Niess, Schmidt, & Welsch, 2023; Zhang et al., 2025). Current users on the other hand, have a more optimistic perspective, viewing augmentation technologies as tools for societal improvement and progress (e.g., Gauttier, 2019a; Huberman, 2024), and as a way to achieve the next step in human evolution (Britton & Semaan, 2017; Heffernan et al., 2016).

5.3. An integrated framework for the adoption of augmentation technologies

Based on the findings of the studies included in this systematic review, we propose an integrated, twofold framework that aggregates them within the context of DoI theory (Rogers, 2003). The first component of the framework, based on Rogers (2003) conceptualization of the innovation-decision process, presents a mapping of factors that influence the adoption process. The second component of the framework, based on Rogers' DoI curve (Rogers, 2003), contextualizes the adoption process of different augmentation technologies at a societal level. This twofold framework answers RQ2 by connecting individual, technological, and societal factors into a comprehensive understanding of the adoption process of non-medical augmentation technologies.

5.3.1. Contributing factors to the adoption process

The first component of the framework, depicted in Figure 3, organizes factors in key categories of antecedent, decision-related considerations, and outcomes, mapping them in the process of adoption of non-medical augmentation technologies. This mapping visualizes how antecedent, decision-related, and outcome factors interconnect within the adoption process. Antecedents (e.g., sociodemographic traits, technological attributes, and societal context) feed into decision-related considerations (functional, affective, ethical, technological, and societal), which in turn shape successive adoption outcomes from attitudes to use. Since the framework is an adapted version of Rogers (2003) innovation-decision process, we represent the outcomes from our ADO framework as sequential steps in the adoption process, with Attitudes, Intention to Use, and Current Use representing stages from initial awareness to technology use. A notable finding emerging from our framework is the prominence of ethical, technological safety, privacy, and societal concerns which contribute to the adoption process of non-medical augmentation technologies, adding nuance to the original DoI innovation-decision process. This mapping

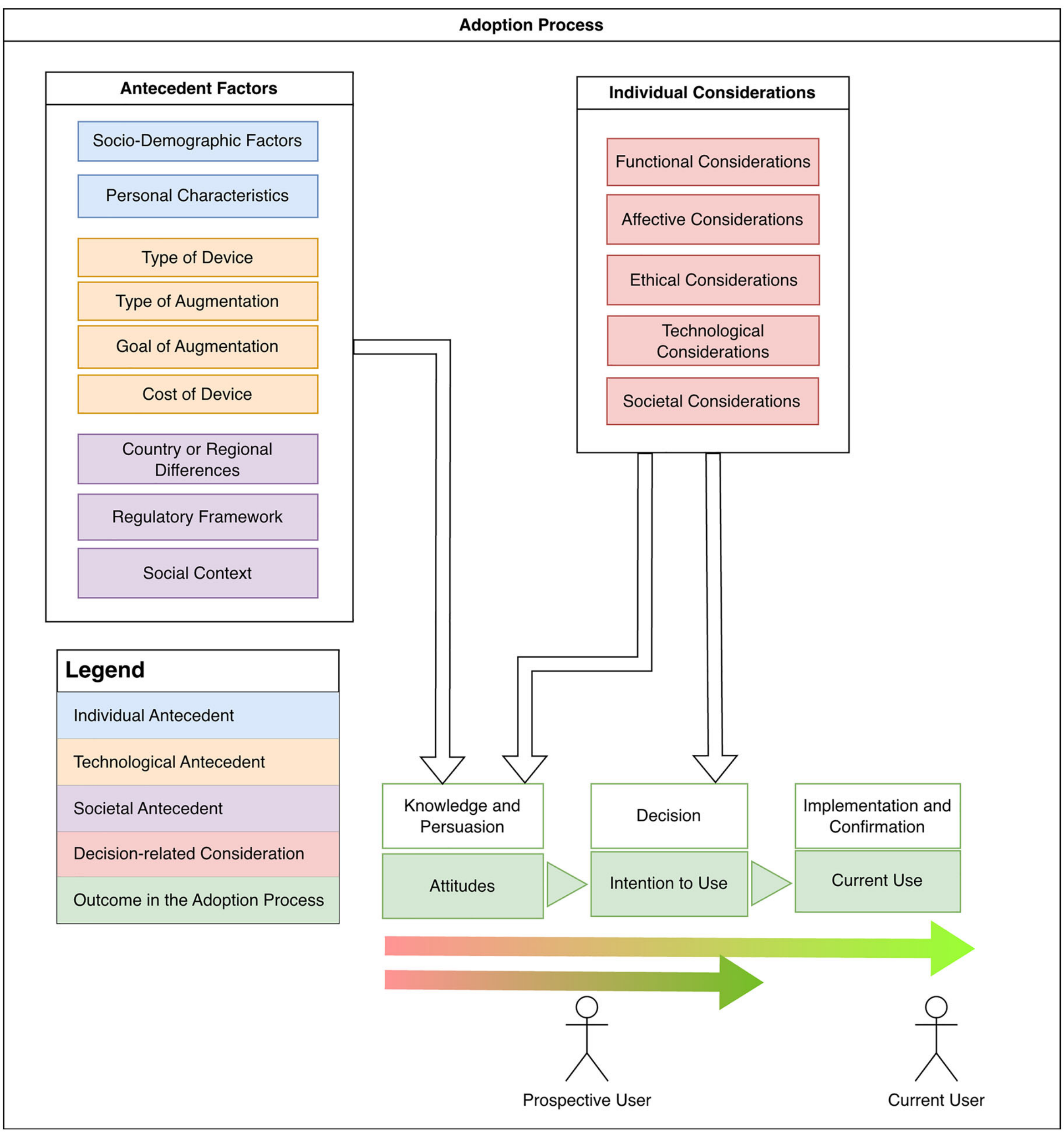

Figure 3. Integrated framework of factors affecting the adoption process of non-medical augmentation technologies. The adoption process is adapted from Rogers' innovation-decision model (Rogers, 2003). Created by the authors.

provides a comprehensive overview of which factors shape adoption decisions, based on current empirical evidence.

5.3.2. Emerging patterns in the diffusion of non-medical augmentation technologies

The second component of our integrated framework explores how non-medical augmentation technologies diffuse through society. Drawing on Rogers (2003) DoI curve, it maps user groups along the adoption curve and integrates technological and contextual factors that shape this process (Figure 4).

We acknowledge that these connections are partly inferential. Current empirical research seldom examines how antecedent, decision-related, and contextual factors interact, as most studies analyze

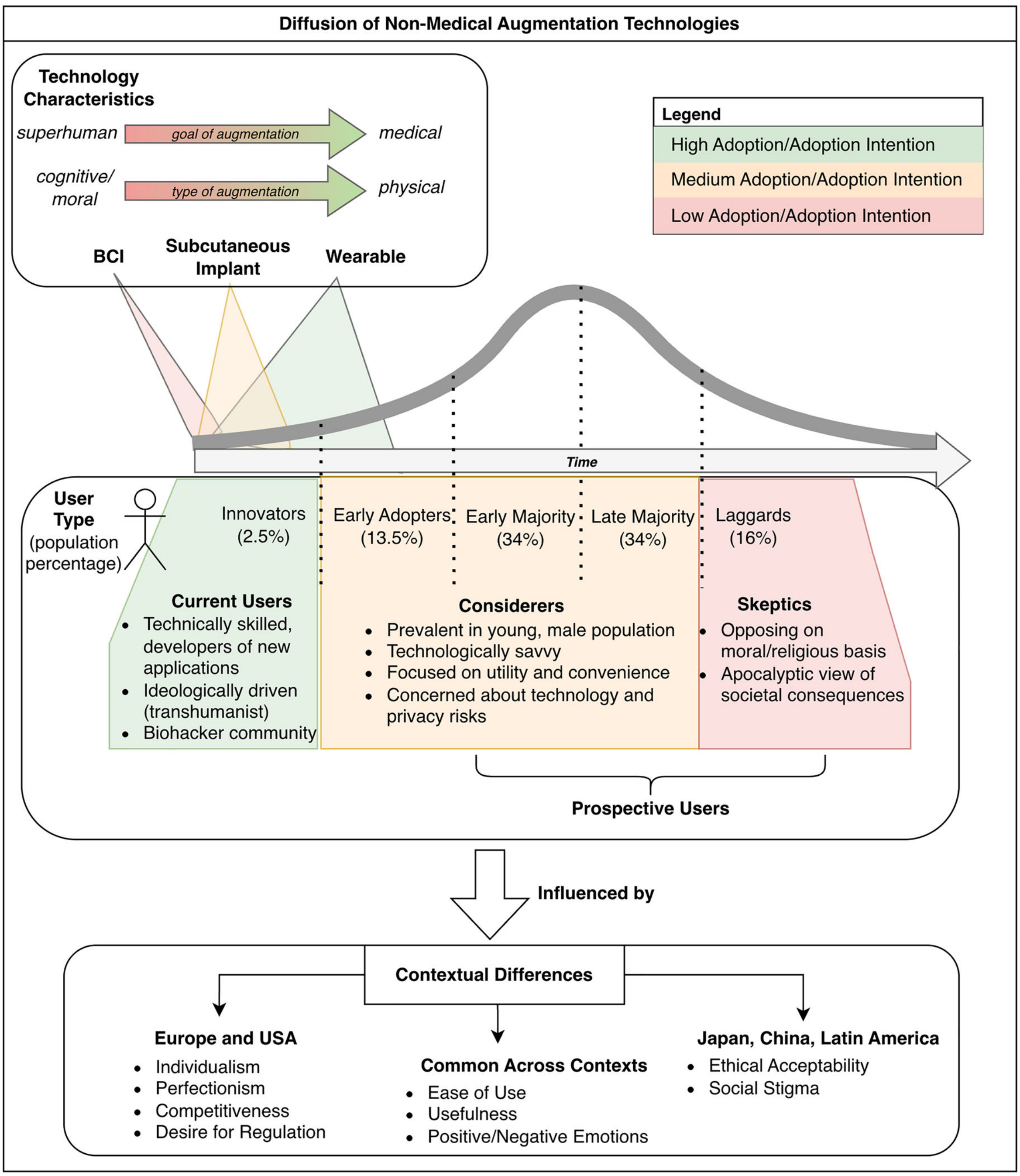

Figure 4. Diffusion of non-medical human augmentation technologies across technology types, user groups, and contexts. The figure positions current and prospective users along adoption stages, from innovators to laggards, and illustrates how different forms of augmentation correspond to varying levels of acceptance and diffusion. Adapted from Rogers (2003). Created by the authors.

subsets of these factors. Our synthesis integrates recurring patterns across studies to propose plausible links and temporal dynamics, which should be interpreted as hypotheses for future empirical testing.

At the technological level, adoption patterns are primarily differentiated by the type of technology, as wearable augmentation technologies receive the broadest acceptance and have the highest diffusion (Arias-Oliva et al., 2021; Murata et al., 2017; Žnidaršič et al., 2021). In contrast, implanted technologies spur more hesitation, with BCI technologies being at a speculative stage with no real use in non-medical applications (Almanna et al., 2025; El-Osta et al., 2025). Acceptance is highest for physical and sensory enhancements (Kaspersky, 2020; Villa, Niess, Nakao, et al., 2023) and declines for cognitive, moral, and emotional forms of augmentation, which remain the most controversial (Koverola et al., 2022; Zhang et al., 2025). Across studies, therapeutic or task-specific augmentations are viewed more favorably than elective or superhuman enhancements, suggesting that perceived necessity can legitimize use (Prudhomme, 2020; Sattler & Pietralla, 2022; Whitman, 2018).

At the individual level, empirical findings derive from studies on two populations of current and prospective users. However, findings further detail the user profiles allowing us to identify three recurring adoption profiles of current users, considerers, and skeptics (Olarte et al., 2015; Oprea & Bâra, 2024). Current users operate within niche experimental communities and develop prototype applications for these technologies (e.g., Britton & Semaan, 2017; Orlowski, 2020; Seyfried et al., 2023), ideologically driven by transhumanist values, demonstrating high tolerance for invasiveness and risk, and viewing augmentation as a form of self-expression and empowerment. Considerers, by contrast, are prospective users, typically younger, male, and technically literate, who prioritize convenience, esthetics, and personal benefit, favoring external augmentations such as AR glasses or smart wearables, and expressing concerns about privacy and technological risks (Arias-Oliva et al., 2021; Gangadharbatla, 2020; Heffernan et al., 2021). Skeptics adopt a precautionary stance, often grounded in moral, religious, or philosophical reasoning, emphasizing societal risks of augmentation technologies (Gauttier et al., 2024; Sattler & Pietralla, 2022; Whitman, 2018).

Cross-cultural patterns reveal notable variation in the factors influencing the adoption of augmentation technologies. While ease of use, perceived usefulness, and emotional reactions consistently appear across contexts, additional factors emerge depending on cultural setting. In Europe and the United States, individualism, perfectionism, and competitiveness appear as antecedents influencing adoption (Ahadzadeh, Ong, Deng, & Ali, 2024; Ahadzadeh, Ong, & Veeraiah, 2024; Ahadzadeh & Amini, 2024). These traits reflect Western societies' broader focus on autonomy and personal achievement (Brewer & Venaik, 2011). At the same time, Western contexts are also where stronger calls for regulation emerge, potentially reflecting the more advanced diffusion of these technologies and the resulting urgency to govern their use (Schmid & Jox, 2021; Whitman, 2018). In contrast, studies from Latin America, Japan, and China emphasize ethical acceptability and social stigma as central considerations in adoption decisions (e.g., Cristina et al., 2021; de Andrés-Sánchez et al., 2021; Zhang et al., 2025). Taken together, these findings suggest that cultural contexts, particularly the balance between individualist and collectivist orientations, may shape how users evaluate HA, with Western settings emphasizing self-driven enhancement and non-Western settings prioritizing social and moral acceptability.

Based on the 61 studies, four high-level patterns can be highlighted. (1) Across types of users, technology, and context, five categories of decision considerations emerge, as functional, affective, ethical, technological, and societal considerations shape technology adoption. (2) Adoption varies strongly by technology type, with wearables receiving broad acceptance, subcutaneous implants receiving mixed reactions, and BCIs remaining speculative and controversial. (3) Three user profiles recur across contexts. Current users are technology experts and enthusiasts, and are motivated by experimentation and ideology. Considerers are a portion of prospective users, with statistical associations emerging for male and young individuals with high technological expertise, which prioritize convenience and safety. Lastly, skeptics emphasize moral/religious concerns and societal risks. (4) Cultural contexts modulate these patterns, with Western settings emphasizing self-improvement and competitiveness, while East Asian and Latin American contexts highlight ethical acceptability and social harmony.

The integrated framework can be a valuable resource for academics, developers, and regulatory actors. Its summary of current empirical evidence could serve as a guiding tool for future research, product development, and public policies. As the field of HA continues to develop, this framework should evolve to represent the advances in our understanding of how non-medical augmentation technologies are adopted and integrated into society.

5.4. RQ3: What future research directions emerge from the literature on the adoption of human augmentation technologies for non-medical purposes?

This section aggregates and discusses the future research directions highlighted by the studies included in our systematic review. Adhering to the TCM-ADO framework of analysis, the discussion is divided into two main perspectives. The TCM perspective refers to overarching characteristics of the research including theoretical foundations, research methodologies, and research context (i.e., populations and technologies). The ADO perspective addresses future research directions related to empirical findings. In addition, we include practical implications for the design and development of augmentation technologies, as well as implications for policymakers.

5.4.1. TCM perspective

5.4.1.1. Theoretical foundations. The surveyed studies reveal promising directions and important gaps related to theoretical foundations. First, studies suggest that further research is needed for the development of technology acceptance models that are tailored to incorporate unique aspects of augmentation technologies such as ethical considerations, personal traits, and societal impact considerations (Gangadharbatla, 2020; Gauttier et al., 2024; Pelegrín-Borondo et al., 2016, 2017). Second, while technology acceptance models provide valuable insights into the adoption of augmentation technologies in the general population, a separate approach could be used to characterize motivations of early adopters. While much of the existing research on this group has been ethnographic, exploratory, or descriptive (e.g., Gauttier, 2019a; Ip et al., 2008a; Seyfried et al., 2023), further investigation and theorization of early adopters' motivations and their evolution over time could enhance our understanding of the adoption process.

5.4.1.2. Research methodologies. The surveyed studies identify several considerations that could improve research methodologies. The predominance of cross-sectional designs is frequently cited as a limitation of current findings (e.g., Ahadzadeh, Ong, Deng, & Ali, 2024; Ahadzadeh, Ong, & Veeraiah, 2024; Ahadzadeh & Amini, 2024), leading researchers to recommend experimental approaches to better establish causal relationships between factors (Reichel et al., 2024; Rousi & Renko, 2020). Similarly, based on the evolving nature of augmentation technologies, researchers propose longitudinal studies to capture changes in attitudes and behaviors over time, particularly as HA technologies become more accessible (Ahadzadeh et al., 2023; Ahadzadeh & Amini, 2024; Oprea & Bâra, 2024; Reichel et al., 2024). The reliance on self-reporting scales across the field also presents challenges, as authors highlight that these scales are susceptible to biases and potential inconsistencies based on how participants interpret questions (Kablo & Arias-Cabarcos, 2023; Koverola et al., 2022; Renz et al., 2024). To address this issue, researchers have suggested exploring alternative or supplementary methods of data collection. Both qualitative and quantitative studies suggest exploring mixed-method approaches to compensate for their shortcomings. For example, Gauttier et al. (2024) suggest validating their framework, developed through qualitative research, through quantitative approaches. Conversely, Koverola et al. (2022) suggest using in-depth qualitative research to explore individual motivations for cognitive enhancement, based on their quantitative findings. Finally, three studies (Almanna et al., 2025; Niininen et al., 2023; Oprea & Bâra, 2024) exemplify the value of deploying computational research methods, which could be further used to garner insights from online discussions and discourse around augmentation technologies, to e.g., explore online discussions using topic modeling (Almanna et al., 2025; Niininen et al., 2023) or to profile users through clustering algorithms (Oprea & Bâra, 2024).

5.4.1.3. Population contexts. Existing research highlights limitations that derive from the selection of populations in empirical studies, suggesting opportunities for a broader representation in future studies. The majority of studies included in this review present results based on young, digital-native populations (usually university students), and recommend diversifying samples across age groups, educational backgrounds, and economic conditions in future research (e.g., Ahadzadeh, Ong, & Veeraiah, 2024; Arias-Oliva et al., 2020, 2021; Murata et al., 2019; Sabogal-Alfaro et al., 2021). Additionally, researchers emphasize the importance of addressing the Western-centric scope of current research by incorporating perspectives from underrepresented cultural contexts (e.g., Kablo & Arias-Cabarcos, 2023; Sample et al., 2020; Žnidaršič et al., 2021). Comparative analyses across countries and cultural contexts have also been suggested to explore the impact of local factors on technology adoption (Reinares-Lara et al., 2018; Sattler & Pietralla, 2022). Given the observed influence of religious beliefs on technology adoption (e.g., Oprea et al., 2024; Sattler & Pietralla, 2022), Zhang et al. (2025) propose investigating the role of Eastern philosophies and religions, which feature distinct conceptions of bodily integrity, in shaping attitudes toward augmentation technologies. In addition to these considerations, a methodological limitation lies in the frequent reliance on repeated cohort studies, which can constrain the generalization of findings. Expanding research to include new survey samples, rather than reusing prior respondent data, could provide new insights and strengthen the reliability of findings.

5.4.1.4. Technological context. Future research on HA can advance in two complementary directions, (1) by deepening analysis of individual technologies and (2) by broadening scope toward the wider landscape of enhancement technologies. On one hand, examining specific technologies such as BCIs or subcutaneous microchip implants (Arias-Oliva et al., 2020, 2021; Cristina et al., 2021) may help clarify how features like invasiveness and usefulness shape user attitudes and behaviors. Authors also suggest comparing technologies at different stages of diffusion, distinguishing between widespread wearable devices and niche insideables (Cristina et al., 2021; de Andrés-Sánchez et al., 2021; Pelegrín-Borondo et al., 2017). On the other hand, future research could extend beyond digital augmentation to encompass the broader NBIC convergence (Roco & Bainbridge, 2003) of enhancement technologies, bringing this strand of research into dialogue with related domains such as biotechnology (Dijkstra & Schuijff, 2016), robotics (including exoskeletons) (Warwick & Gasson, 2004), and non-digital sensory augmentation devices like magnetic implants (Harrison, 2015). Studies of existing user communities already highlight overlaps between these areas, suggesting that investigating them together could yield a more comprehensive understanding of how diverse enhancement technologies are perceived, adopted, and integrated into everyday life.

5.4.2. ADO perspective

Our proposed integrated framework (Figure 3) maps the factors currently known to be influential in the adoption of augmentation technologies, but additional key directions for future research can reinforce it by (1) consolidating research on individual factors and (2) examining interrelationships between them.

First, while many factors have been identified, their impact remains underexplored. For example, the exploration of the role of personal beliefs surrounding free will and determinism is recent, with authors recommending a more in-depth characterization of this role (Ahadzadeh & Amini, 2024). Interestingly, concerns about the cost of augmentation technologies, which might be expected to play a prominent role in adoption decisions, do not appear in the quantitative predictive models included in this review. However, such concerns are mentioned in exploratory and qualitative studies (El-Osta et al., 2025; Shafeie et al., 2022; Villa, Niess, Nakao, et al., 2023), particularly in discussions about the accessibility of augmentation technologies. Consequently, researchers interested in examining the influence of technology pricing on the adoption of augmentation technologies could explore whether cost serves as a potential barrier to adoption, particularly as these technologies move toward broader commercialization.

Second, in addition to examining the influence of individual factors in the adoption process, researchers suggest analyzing how these factors interact and influence each other through moderating effects (Castelo et al., 2019; Pelegrín-Borondo et al., 2016; Rousi & Renko, 2020). For example, existing literature suggests that age and gender influence attitudes and intentions to use augmentation technologies (e.g., Gangadharbatla, 2020; Kablo & Arias-Cabarcos, 2023; Reichel et al., 2024). However, further research is needed to explore how these demographic factors interact with other variables. Correlations suggest that different age groups tend to prefer different types of augmentation (Kaspersky, 2020; Whitman, 2018). Additionally, women's attitudes toward augmentation technologies may be influenced by factors such as emotional responses, which affect genders differently (Rousi & Renko, 2020), and the varying impact of perfectionism on men and women (Ahadzadeh et al., 2023).

To facilitate more rigorous and comparable studies of these interrelationships, researchers could utilize recently developed measurement instruments. The validated scale proposed by Villa, Niess, Schmidt, and Welsch, (2023), as well as the questionnaire presented by Stefański and Jach (2022), provide tools specifically designed to investigate the adoption of HA technologies.

5.4.3. Implications for design and development

The empirical literature offers several practical implications for the design and development of HA technologies. We highlight key areas, particularly relating to preferred applications, safety and security, and societal acceptance.

5.4.3.1. Applications. First, since research highlights the importance of usefulness considerations in shaping adoption intentions, authors suggest that companies involved in the development of augmentation technologies could focus on clearly demonstrating the practical benefits of these technologies to appeal to a larger public (Gangadharbatla, 2020; Pelegrín-Borondo et al., 2017). This implies prioritizing noninvasive, convenient, and easily reversible augmentations that provide immediate and visible utility. Developers could focus on small, lightweight devices that integrate seamlessly into everyday life such as AR glasses, smart rings, or wearable sensors, which improve task efficiency or comfort without radically altering the body. Such designs better align with users' focus on convenience and perceived usefulness, while reducing apprehension linked to invasiveness or permanence of the device.

5.4.3.2. Safety and security. Second, the biocompatibility of materials, sustainable device upgrades and maintenance, rigorous safety testing, and cybersecurity emerge as critical factors in empirical studies (Britton & Semaan, 2017; Dragović, 2019; Gangadharbatla, 2020; Heffernan et al., 2021). Accordingly, the development of new devices could prioritize durable and modular components, with long-term support and upgrades. Integrating privacy-by-design principles, including user-controlled data permissions, local data processing, and transparent information flows can further strengthen user trust and acceptance.

5.4.3.3. Design for societal acceptance. Findings in the empirical literature highlight persistent user concerns about social stigma and discrimination toward users of augmentation devices (e.g., Castelo et al., 2019; Zhang et al., 2025). Building on design frameworks for augmentation technologies, several studies suggest that fostering social visibility and shared experience among users could help normalize these technologies and reduce perceived stigma. Developers could therefore consider the social dimension of design, creating devices that not only integrate functionally and visually with the human body but also encourage positive forms of social sharing or identification among users (De Boeck & Vaes, 2021, 2024). Devices that are discreet, customizable, and esthetically noninvasive can promote acceptance by aligning with individual preferences while blending naturally within everyday social contexts.

Together, these insights encourage a user-centered design orientation in HA research and development by emphasizing convenience, device maintenance, noninvasiveness, and aesthetic appearance as practical enablers of societal acceptance and broader adoption.

5.4.4. Implications for policymakers

The surveyed studies highlight several practical implications for policymakers and regulators overseeing HA technologies. Findings indicate a persistent gap between public expectations for regulation and existing policy frameworks.

5.4.4.1. Desire for regulations. In general, given the novelty of the technologies, regulations are not yet tuned to HA technologies. Schmid et al. (2021) report that, while the European Union lacks specific regulations governing the use of augmentation technologies by healthy individuals, this clashes with user expectations. Consistent with other studies, the general public identifies the absence of regulation as a key barrier to adoption (e.g., Castelo et al., 2019; Shafeie et al., 2022; Villa, Niess, Nakao, et al., 2023; Whitman, 2018).

5.4.4.2. Balancing innovation and regulation. While the population expresses a desire for regulation, excessive regulation may hinder innovation, making the balance between technological progress and public trust a challenge. Greater collaboration between developers and policymakers is recommended to address this tension, ensuring that safety testing, data governance, and user welfare are systematically integrated into development and oversight processes (Oprea & Bâra, 2024).

5.4.4.3. Existing top-down efforts. Emerging regulatory efforts indicate that well-articulated governance frameworks can both reassure the public and enable responsible innovation. In the United States, several states have enacted laws prohibiting employers from mandating subcutaneous microchip implantation in workers, setting a precedent for protecting bodily autonomy and informed consent in augmentation practices (Smith, 2024). At the global level, debates increasingly center on the concept of neurorights, i.e., legal principles designed to safeguard cognitive liberty, mental privacy, and psychological integrity in response to neurotechnologies such as BCIs (Ienca, 2021). These initiatives seek to prevent unauthorized access to, or manipulation of, neural data (Guzmán, 2022; Santalu, 2025). Chile's constitutional amendment explicitly recognizing mental privacy and cognitive liberty as fundamental rights represents the first codification of neurorights (Guzmán, 2022). In the European Union, parallel debates explore integrating similar protections within instruments like the EU AI Act (Santalu, 2025). Together, these developments mark a transition from ethical debate to enforceable governance, which may be instrumental toward building public trust in the governance of augmentation technologies.

5.4.4.4. Community-led development. Complementing top-down initiatives, bottom-up approaches emphasize the role of citizens and user communities in shaping regulation. Researchers highlight the need for participatory policymaking to ensure that governance reflects social values and public priorities (Oprea et al., 2024). Educational programs and awareness campaigns are likewise essential to dispel misconceptions and enable informed decision-making to engage with augmentation technologies (Oprea et al., 2024). Such participatory mechanisms can align regulatory outcomes with societal expectations, reinforcing both transparency and trust.

5.4.4.5. Cultural sensitivity. We encourage culturally sensitive approaches when developing regulatory frameworks and governance mechanisms for HA technologies. While our review identifies substantial cross-cultural variation in how augmentation technologies are evaluated, existing regulatory discussions and public policy initiatives remain heavily driven by Western perspectives (Schmid & Jox, 2021; Shafeie et al., 2022; Villa, Niess, Nakao, et al., 2023; Whitman, 2018). Empirical studies from East Asian, Latin American, and other non-Western contexts show distinct ethical priorities, including stronger emphasis on social acceptability, moral obligations, and collective well-being (e.g., Zhang et al., 2025). Future research and policy development should therefore incorporate diverse cultural perspectives to ensure that regulatory frameworks reflect heterogeneous values, expectations, and societal priorities.

6. Limitations

This systematic review synthesizes empirical research on the adoption of non-medical HA technologies, identifying key influencing factors and proposing a meta-framework for future research. As a rapidly evolving, interdisciplinary field, research in this area spans diverse terminologies and databases. Despite a comprehensive search strategy, relevant studies may have been missed due to variations in terminology and indexing. Snowballing helped mitigate this, though some omissions remain possible.

The review reflects the state of the field up to the final database search, and recent studies may not be included. Additionally, while the analysis followed PRISMA guidelines and employed the TCM-ADO framework, the inductive–deductive coding process may reflect some degree of subjectivity. Despite these limitations, this review offers a foundation for ongoing research and discussion on the adoption of HA technologies.

7. Conclusions

This systematic review of 61 empirical studies on non-medical HA technologies makes three main contributions: (1) providing the first comprehensive mapping of research using the TCM-ADO framework, (2) synthesizing an integrated adoption framework based on DoI theory, and (3) identifying future research directions. Our analysis reveals an emerging field characterized by limited interdisciplinary engagement and non-representative sampling. This reflects a fragmented research landscape that requires broader, more representative, and theoretically diverse approaches.

Through the ADO framework, we identify individual, technological, and societal antecedents, decision factors and outcomes ranging from attitudes and usage intentions to current use. Across the 61 studies, four high-level patterns emerge. (1) Decision factors recur across users and technology types and can be grouped into functional, affective, ethical, technological, and societal considerations. (2) Wearables receive consistently higher acceptance than implanted or neural interfaces, (3) current users, considerers, and skeptics form user profiles with distinct motivations, and (4) cultural contexts shape evaluation criteria, with Western settings emphasizing personal enhancement and non-Western settings prioritizing social acceptability. These cross-study patterns illustrate a complex and layered adoption landscape that cannot be understood through functional factors alone. Our integrated framework, grounded in DoI theory, synthesizes how these factors contribute to the adoption decision.

The findings demonstrate that prospective users are hindered by unresolved ethical, technical, and societal concerns, while current users view augmentation technologies more positively, often embracing them as enablers of transhumanist ideals and human evolution. This highlights a significant divergence in risk and opportunity perception between user groups.

Beyond academic insights, the review also provides practical implications for both the design and development of HA technologies, such as prioritizing noninvasive, secure, and socially acceptable devices, as well as for policymakers, who must address persistent public demand for clear governance frameworks without stifling innovation.

By identifying key factors, research gaps, and possible future directions in the field of non-medical augmentation technologies, this review informs and guides future research and development efforts, ultimately facilitating the responsible development and integration of augmentation technologies into society.

Note

1. https://figshare.com/s/d7c7aab3a5f66698c29c.

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CRediT: **Giulia Frascaria**: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing; **Daniela Jaramillo-Dent**: Conceptualization, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing; **Michael Latzer**: Conceptualization, Project administration, Supervision, Writing – review & editing.

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Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials.

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