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# Artificial Intelligence-based Robots for Individual Well-being

A Multiple-Case Study

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Rong Huang





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# ARTIFICIAL INTELLIGENCE- BASED ROBOTS FOR INDIVIDUAL WELL-BEING

A Multiple-Case Study

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## ABSTRACT

As artificial intelligence (AI)-based robots become increasingly embedded in daily life, their potential to support human well-being has attracted growing interest from both academia and mass media. Based on their embodiment and presence, AI-based robots can be divided into physical robots and virtual robots. Although research on AI-based robots is expanding, it remains fragmented across disciplines and lacks a cohesive understanding of how users interact with AI-based robots in real-world contexts and how such interactions influence individuals' well-being. Previous studies have provided promising evidence for the effectiveness of AI-based physical and virtual robots in supporting personal well-being, particularly by offering emotional support, reducing loneliness, and fostering social connections. However, these studies have largely been conducted in controlled or structured settings and tend to conceptualize human–robot interaction (HRI) as a short-term intervention. Critical gaps remain in understanding the dynamic, evolving, and co-constructed nature of HRI and the resultant outcomes for multiple dimensions of individual well-being in daily life.

In order to address these gaps, this dissertation aims to investigate how human interactions with AI-based robots contribute to individual well-being in daily life. The dissertation comprises five publications: two systematic literature reviews (Publications I and II) and three empirical case studies (Publications III-V).

Publications I and II conduct two systematic literature reviews (SLRs) that examine existing research on the use of AI-based physical and virtual robots in healthcare and daily settings, respectively. The findings provide a conceptual foundation and source of questions for subsequent empirical research through synthesizing current knowledge on robot designs, application contexts, target users, and the antecedents and consequences of robot use. Moreover, a clear research agenda for future investigation in the field is proposed, including diversifying robot types, application contexts, and stakeholders; advancing research methodologies; expanding thematic dimensions; and embracing multidisciplinary perspectives.

This dissertation further conducts empirical studies (Publications III-V) that examine individual interactions with AI-based physical and virtual robots for well-being support in real-life scenarios. Adopting a multiple-case study approach, these publications explore five distinct cases involving both physical and virtual robots across different daily life settings.

Specifically, Publication III conducts a single case study on user-generated reviews of Robot A from social media platforms. Through an inductive thematic analysis approach, it explores the embodied interactions between users and an AI-based physical robot in home environments and their positive impacts on individual well-being, drawing upon the HRI studies. Likewise, Publication IV conducts a single case study on tweet data from Robot B, an AI-based virtual robot, in digital social environments. A mixed-methods approach that combines quantitative topic modeling with qualitative interpretation is employed to uncover the relationship dynamics between users and AI-based virtual robots, guided by social penetration theory. Drawing on actor-network theory, Publication V conducts a multiple case study on three AI-based virtual robots for mental healthcare (Robots C, D, and E) and explores how users and AI-based virtual robots interact as focal actors to cope with individuals' emotional issues from a sociotechnical perspective. This study applies a mixed-methods approach, combining quantitative emotion analysis with qualitative thematic analysis.

The empirical results of this dissertation reveal that the interaction between users and AI-based robots is a highly contextual, dynamic, and co-constructed process, shaped by robot embodiment, functionality, contexts, and user needs. These interactions follow nonlinear trajectories, while users may delay or withdraw from interactions due to various negative experiences. Additionally, this dissertation provides empirical evidence of the positive well-being outcomes of HRI on individual well-being across emotional, social, cognitive, and behavioral dimensions in daily life. Notably, these well-being outcomes are not only driven by robot features or technical performance but also emerge from the sustained and stable interactions between users and AI-based robots.

This dissertation contributes to the academic fields of Information Systems and HRI. First, it systematically synthesizes and conceptualizes the current state of research on AI-based physical and virtual robots in well-being contexts, offering a structured theoretical foundation for understanding this emerging area. Second, this dissertation advances a contextualized and dynamic process-oriented understanding of HRI by demonstrating how robot representation (physical vs. virtual), functional design (companionship vs. therapy), and user needs (emotional, social, cognitive) collectively shape and develop interaction patterns. Third, this dissertation responds to growing calls in the healthcare digitalization field to move beyond functional or performance-based evaluations, offering a more holistic view of how AI-based robots become integrated into users' emotional, social, cognitive, and behavioral well-being. From a practical perspective, this dissertation provides actionable insights for stakeholders involved in the design, deployment, and governance of AI-based robots in well-being support. The findings contribute to bridging the gap between technological innovation and social responsibility, advancing the ethical, inclusive, and meaningful integration of AI-based robots into our society.

**KEYWORDS:** Artificial intelligence, physical robots, virtual robots, human-robot interactions, well-being

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## TIIVISTELMÄ

Tekoälypohjaisten robottien yleistyessä arjessa niiden potentiaali ihmisen hyvinvoinnin tukemisessa on herättänyt kasvavaa kiinnostusta niin akateemisissa maailmassa kuin mediassakin. Robottien ruumiillisuuden ja läsnäolon perusteella ne voidaan jakaa fyysisiin ja virtuaalisiin robotteihin. Vaikka tutkimus tekoälypohjaisista roboteista on lisääntynyt, se on edelleen hajanaista eri tieteenalojen välillä, ja yhtenäinen ymmärrys siitä, miten käyttäjät vuorovaikuttavat robottien kanssa todellisissa konteksteissa ja miten nämä vuorovaikutukset vaikuttavat yksilön hyvinvointiin, puuttuu. Aiemmat tutkimukset ovat antaneet lupaavia todisteita siitä, että sekä fyysiset että virtuaaliset robotit voivat tukea henkilökohtaista hyvinvointia tarjoamalla emotionaalista tukea, vähentämällä yksinäisyyttä ja edistämällä sosiaalisia yhteyksiä. Kuitenkin suurin osa näistä tutkimuksista on tehty kontrolloiduissa tai rakenteellisissa ympäristöissä, ja ne käsittelevät ihmisen ja robotin välistä vuorovaikutusta lyhytaikaisena interventiona. On olemassa merkittävä tutkimusaukko ymmärryksessä siitä, miten ihmisen ja robotin välinen vuorovaikutus on dynaaminen, kehittyvä ja yhteisesti rakennettu prosessi, ja miten se vaikuttaa yksilön hyvinvoinnin eri ulottuvuuksiin arjessa.

Tämän väitöskirjan tavoitteena on tutkia, miten ihmisen ja tekoälypohjaisten robottien välinen vuorovaikutus vaikuttaa yksilön hyvinvointiin päivittäisessä elämässä. Väitöskirja koostuu viidestä julkaisusta: kahdesta systemaattisesta kirjallisuuskatsauksesta (Julkaisut I ja II) ja kolmesta empiirisestä tapaustutkimuksesta (Julkaisut III–V).

Julkaisut I ja II sisältävät kaksi systemaattista kirjallisuuskatsausta, jotka tarkastelevat olemassa olevaa tutkimusta tekoälypohjaisten fyysisten ja virtuaalisten robottien käytöstä terveydenhuollossa ja arjen ympäristöissä. Näiden katsauksien tulokset tarjoavat käsitteellisen perustan ja tutkimuskysymyksiä myöhemmille empiirisille tutkimuksille, kokoamalla yhteen nykyisen tiedon robottien suunnittelusta, käyttöyhteyksistä, kohderyhmistä sekä robottien käytön edellytyksistä ja seurauksista. Lisäksi esitetään selkeä tutkimusagenda tuleville tutkimuksille, mukaan lukien robottityyppien, käyttöyhteyksien ja sidosryhmien monipuolistaminen, tutkimusmenetelmien kehittäminen, teemojen laajentaminen ja monitieteisen näkökulman omaksuminen.

Väitöskirjan empiirisessä osassa (Julkaisut III–V) tarkastellaan yksilön vuorovaikutusta tekoälypohjaisten fyysisten ja virtuaalisten robottien kanssa hyvin-

voinnin tukemiseksi todellisissa elämäntilanteissa. Monitapaustutkimuslähestymistapaa hyödyntäen tutkitaan viittä erilaista tapausta, jotka käsittävät sekä fyysisiä että virtuaalisia robotteja eri arjen ympäristöissä.

Erityisesti Julkaisu III toteuttaa yksittäisen tapaustutkimuksen käyttäjien tuottamista arvioista tapaus A:sta sosiaalisen median alustoilla. Induktiivisen temaattisen analyysin avulla tutkitaan käyttäjien ja tekoälypohjaisen fyysisen robotin välistä vuorovaikutusta kotiympäristössä ja sen myönteisiä vaikutuksia yksilön hyvinvointiin ihmisen ja robotin välisen vuorovaikutuksen (Human-robot interaction, HRI) -tutkimusten pohjalta. Samoin Julkaisu IV suorittaa yksittäisen tapaustutkimuksen tapaus B:n, tekoälypohjaisen virtuaalisen robotin, twiitidatasta digitaalisissa sosiaalisissa ympäristöissä. Käytetään sekamenetelmällistä lähestymistapaa, joka yhdistää kvantitatiivisen aiheiden mallinnuksen ja kvalitatiivisen tulkinnan, paljastaakseen käyttäjien ja tekoälypohjaisten virtuaalisten robottien välisten suhteiden dynamiikkaa sosiaalisen penetraatioteorian ohjaamana. Julkaisu V hyödyntää toimijaverkkoteoriaa ja suorittaa monitapaustutkimuksen kolmesta tekoälypohjaisesta virtuaalisesta mielenterveysrobotista (tapaukset C, D ja E), tutkien, miten käyttäjät ja tekoälypohjaiset virtuaaliset robotit toimivat keskeisinä toimijoina emotionaalisen tuen verkostojen rakentamisessa käyttäjien emotionaalisten tarpeiden ja robottien terapeuttisen suunnittelun pohjalta. Tässä tutkimuksessa sovelletaan sekamenetelmällistä lähestymistapaa, yhdistäen kvantitatiivisen tunteiden analyysin ja kvalitatiivisen temaattisen analyysin.

Väitöskirjan empiiriset tulokset osoittavat, että käyttäjien ja tekoälypohjaisten robottien välinen vuorovaikutus on erittäin kontekstisidonnainen, dynaaminen ja yhteisesti rakennettu prosessi, jota muovaavat robotin ruumiillisuus, toiminnallisuus, käyttöyhteydet ja käyttäjien tarpeet. Nämä vuorovaikutukset seuraavat epälineaarisia polkuja, ja käyttäjät saattavat viivyttää tai lopettaa vuorovaikutuksen erilaisten negatiivisten kokemusten vuoksi. Lisäksi väitöskirja tarjoaa empiiristä näyttöä siitä, että HRI:llä on myönteisiä vaikutuksia yksilön hyvinvointiin arjessa emotionaalilla, sosiaalisilla, kognitiivisilla ja käyttäytymiseen liittyvillä ulottuvuuksilla. Huomionarvoista on, että nämä hyvinvointivaikutukset eivät johdu pelkästään robottien ominaisuuksista tai teknisestä suorituskyvystä, vaan ne syntyvät myös käyttäjien ja tekoälypohjaisten robottien välisestä pitkäaikaisesta ja vakaasta vuorovaikutuksesta.

Tämä väitöskirja edistää tietojärjestelmätieteen ja HRI: n akateemisia aloja. Ensinnäkin se systemaattisesti kokoaa ja jäsentää nykyisen tutkimustiedon tekoälypohjaisista fyysisistä ja virtuaalisista roboteista hyvinvoinnin konteksteissa, tarjoten rakenteellisen teoreettisen perustan tämän nousevan alueen ymmärtämiseksi. Toiseksi väitöskirja kehittää kontekstuaalista ja dynaamista prosessikeskeistä ymmärrystä HRI:stä osoittamalla, miten robotin edustus (fyysinen vs. virtuaalinen), toiminnallinen suunnittelu (kumppanuus vs. terapia) ja käyttäjien tarpeet (emotionaaliset, sosiaaliset, kognitiiviset) yhdessä muovaavat ja kehittävät vuorovaikutusmalleja. Kolmanneksi väitöskirja vastaa kasvaviin vaatimuksiin terveydenhuollon digitalisaation alalla siirtyä pelkkien toiminnallisten tai suorituskyykyyn perustuvien arviointien yli, tarjoten kokonaisvaltaisemman näkemyksen siitä, miten tekoälypohjaiset robotit integroituvat käyttäjien emotionaaliseen, sosiaaliseen, kognitiiviseen ja käyttäytymiseen liittyvään hyvinvointiin. Käytännön näkökulmasta väitöskirja tarjoaa toimivia oivalluksia sidosryhmille, jotka osallis-

tuvat tekoälypohjaisten robottien suunnitteluun, käyttöönottoon ja hallintaan hyvinvoinnin tukemiseksi. Tulokset auttavat kuromaan umpeen teknologisen innovaation ja sosiaalisen vastuun välistä kuilua, edistäen tekoälypohjaisten robottien eettistä, osallistavaa ja merkityksellistä integrointia yhteiskuntaamme.

ASIASANAT: Tekoäly, fyysiset robotit, virtuaaliset robotit, ihmisen ja robotin välinen vuorovaikutus, hyvinvointi

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*Rong Huang*

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# List of Original Publications

This dissertation is based on the following original publications, which are referred to in the text by their Roman numerals:

- I Huang, R., Li, H., & Suomi R., Li, C., & Peltoniemi, T. (2023). Intelligent physical robots in health care: Systematic literature review. *Journal of Medical Internet Research*, 25(1), e39786.
- II Huang, R., Li, H., & Suomi, R. (2024). The interactions between humans and AI-based virtual robots in daily life: A systematic literature review. *Proceedings of the 32nd European Conference on Information Systems (ECIS)*, Paphos, Cyprus. 1-16.
- III Huang, R., Li, H., & Suomi, R. (2024). Exploring the impacts of AI-based physical robots on human well-being. *Proceedings of the 23rd IFIP Conference on e-Business, e-Services and e-Society (I3E)*, Heerlen, Netherlands, 41-52.
- IV Huang, R., Bai, Y., Li, H., & Suomi, R. (2023). The relationship between human and virtual agents: A life cycle view. *Proceedings of the 31st European Conference on Information Systems (ECIS)*, Kristiansand, Norway, 1-16.
- V Huang, R. & Li, H. (2025). Understanding human-robot interaction in mental health: A multi-case study on artificial intelligence-based virtual robots. *Submitted to a journal*.

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# 1 Introduction

This chapter presents an overview of the research. First, the background of artificial intelligence (AI)-based robots in well-being contexts is illustrated. Second, the gaps in the current understanding of AI-based robots in well-being contexts, which motivated the author to develop this research, are discussed. Next, the research objective and questions are presented, followed by an illustration of the individual publications in this dissertation. Finally, an outline of this dissertation is presented.

## 1.1 General background

In recent years, human well-being has become a global priority. Individuals and societies are facing increasingly complex and interrelated challenges, including mental health crises, population aging, and rising social isolation. Since the onset of the COVID-19 pandemic, indicators such as life satisfaction, emotional balance, and social connectedness have declined in many countries with limited resilience (OECD, 2024). Additionally, in 2023, between 4% and 14% of residents in the Organisation for Economic Co-operation and Development (OECD) countries reported feeling lonely, while emotional challenges such as worry and sadness have worsened over the past four years (Helliwell et al., 2024). These trends highlight the vulnerability and complexity of well-being in contemporary life. In response, the World Health Organization (WHO) introduced the perspective of a "well-being society" in its Global Framework for Well-being (2022), calling for health and welfare systems to adopt a positive vision of health that integrates physical, mental, emotional, spiritual, and social well-being across all stages of life and for current and future generations. Therefore, well-being is increasingly understood as a multidimensional and dynamic state in which individuals are able to flourish in the emotional, social, cognitive, and physical dimensions throughout their life course (Diener et al., 2001).

Maintaining and enhancing well-being has become a significant global challenge in the face of shifting population demographics and limited healthcare capacity. According to WHO estimates from 2022 (Moitra et al., 2022), one in eight people worldwide lives with a mental disorder, yet fewer than one-third have access to formal mental health services. Beyond clinical treatment, many individuals also

require broader emotional, social, and functional support to rebuild resilience and improve their overall quality of life (Alkire, 2002). However, healthcare systems around the world are under increasing strain and struggle to meet the growing demands for accessible, continuous, and personalized care (Aminizadeh et al., 2024). In response, self-care interventions have been promoted as a key strategy to enhance individual well-being and advance universal health coverage (Narasimhan et al., 2023). A growing number of individuals are turning to digital health technologies in managing their well-being in daily life, such as emotion regulation apps, sleep tracking, and mindfulness platforms (Eisenstadt et al., 2021). The global mental health technology market is projected to exceed \$7.4 billion by 2029 (Statista, 2025), reflecting the expanding role of these technologies in helping individuals proactively manage their multidimensional well-being beyond traditional clinical pathways.

With the advancement of AI, natural language processing, and emotional computing technologies, robots are increasingly capable of replicating human-to-human communication and behaviors, perceiving surrounding informational and environmental changes, and proactively managing complex tasks and interactions autonomously (Seeger et al., 2021). These AI-based robots are becoming increasingly integrated into individuals' daily lives, appearing in homes, workplaces, and care settings, and offering new pathways for individuals to manage and maintain their well-being in daily routines. AI-based robots have emerged as promising and transformative solutions to alleviate pressure on healthcare systems while providing accessible, scalable, and personalized support for individuals (Mettler et al., 2017).

Based on their embodiment and presence, AI-based robots can be divided into physical robots and virtual robots (M. I. Ahmad & Refik, 2022). Specifically, AI-based physical robots, with physical embodiment and spatial presence, enable interactions with users through multiple physical cues such as body movements, eye contact, and gestures (Li, 2015). Humanoid robots, such as Pepper (Tanioka et al., 2019), NAO (Pelikan & Broth, 2016), and Zora (Huisman & Kort, 2019), are notable examples of physical robots that have been implemented in elderly care and service healthcare contexts to provide companionship, emotional support, or physical exercise guidance. In contrast, AI-based virtual robots are virtual embodiments or non-embodiments that interact with users primarily via text, voice, or an avatar-based interface (Diederich et al., 2022). These robots are commonly integrated into mobile applications, websites, and smart home systems. Prominent examples, such as Copilot (Whitfield & Yang, 2025), Woebot (Cheng & Jiang, 2020), and Xiao Ice (Zhou et al., 2020), are designed to support a range of elements in mental and social well-being, such as emotion regulation, cognitive restructuring, and digital companionship. While differing in embodiment, interaction modes, and applied contexts, previous studies have reported positive evidence of the effectiveness of both AI-based physical and virtual robots in supporting individual well-being,

particularly in emotional support, reducing loneliness, and enhancing social connection in controlled or structured environments (Fitzpatrick et al., 2017; He et al., 2022).

Although the integration of AI-based robots into individuals' daily lives has become increasingly prevalent, particularly since the COVID-19 pandemic, this trend has also raised growing societal concerns about unintended consequences. The recently published Cambridge Handbook of the Law, Policy, and Regulation for Human-Robot Interaction (Anand, 2025) points out that the rapid advancement of AI and robotic technologies is outpacing existing legal and ethical frameworks related to privacy, safety, and governance. Many AI-based robots have entered the market without assessment of their broader social implications or consistent regulatory oversight, which may bring new concerns about AI-based robots in daily life contexts (Paul, 2024). For example, AI-based virtual robots such as Replika continue to provide accessible, responsive, and human-like conversational experiences, while also raising debate around persuasive behaviors, misinformation, and logical inconsistencies in social interactions (Alabed et al., 2024; Sponheim, 2024). When such systems are designed to prioritize user satisfaction over factual accuracy, they destroy users' trust and cognitive autonomy during their interactions with the robot (Glikson & Woolley, 2020). These risks become particularly pronounced in sensitive contexts, such as mental health support, where users may be emotionally and cognitively vulnerable (Corvite et al., 2023).

These phenomena indicate that the applications and impacts of AI-based robots in real-life well-being contexts have not been fully understood. Thus, the role of AI-based robots in promoting human well-being should not be assumed as inherently positive but should be critically examined through multiple empirical studies in specific contexts. Despite increasing public discourse on the risk and ethics of AI-based robot use from the governance and management point of view, few studies have explored how AI-based robots can support human well-being based on actual usage and experiences in daily life from the individual perspective. To move beyond technological determinism, scholars must investigate the dynamic and co-constructed nature of human–robot interaction (HRI) and its impact on multiple dimensions of individual well-being in real-world contexts. Gaining insight into these sociotechnical processes is essential for the responsible design, deployment, and integration of AI-based robots into daily life in ways that meaningfully support human well-being.

## 1.2 Research gaps and motivation

As AI-based robots become gradually embedded into both physical and virtual aspects of daily life, it is significant to understand how users interact with these robots and what impacts such interactions may have on individuals' well-being.

The first motivation of this study is to systematically assess the current state of knowledge regarding the use of AI-based robots in well-being contexts. Although the body of literature on AI-based robots is expanding (E. Ahmed et al., 2022; de Barcelos Silva et al., 2020), it remains fragmented across disciplines and lacks a holistic research agenda. There is a wide divergence between studies on physical and virtual robots in terms of embodiment, interaction design, and user experience (K. M. Lee et al., 2006; Li, 2015), yet existing research often fails to clearly distinguish between the two, thereby conflating their roles, impacts, and user experiences. The evolution of both AI-based physical robots and virtual robots also reflects a broader paradigm shift from mechanical tools used in industrial or surgical contexts to socially cognitive agents capable of simulating human-like interaction (Dang & Liu, 2023; Han et al., 2023). This transformation highlights the need to understand how different types of AI-based robots are used, perceived, and meaningfully integrated into well-being contexts.

Moreover, prior research often examines AI-based physical robots in controlled laboratory or structured institutional environments (J. Chan et al., 2011; Koh & Kang, 2018; Louie et al., 2021), whereas virtual robots are explored through isolated use cases in digital environments (Fitzpatrick et al., 2017; Kettle & Lee, 2024; MacNeill et al., 2024). These studies provide valuable but fragmented insights, making it difficult to form a consistent understanding of HRI in everyday well-being contexts. Thus, there is a need to provide an integrative conceptual map that accounts for how different users, robot designs, and deployment contexts influence user perceptions, experiences, and well-being outcomes, which is essential to inform further advancement of future research and practices in AI-based robots in real-world settings.

The second motivation is the need to explore how individuals interact with AI-based robots in daily life to unravel how these robots become embedded into real-life environments. As people are increasingly engaging with AI-based robots within personal spaces (e.g., homes, smartphones, and online platforms), these interactions are intertwined with diverse environmental, social, affective, and technological factors (Skjuve et al., 2021, 2022; Xie & Pentina, 2022). The dynamic processes of user interactions with AI-based robots need to be continuously examined in different real-world use cases. Prior empirical studies have primarily relied on laboratory experiments, where HRI is often regarded as a short-term intervention (Fitzpatrick et al., 2017; He et al., 2022). While these studies offer control and precision, they often fail to capture the nuanced and evolving nature of HRI in real-world settings.

One promising alternative approach is the use of user-generated content, such as online reviews and social media posts. These secondary data sources can be collected at scale, across diverse user populations and application contexts, making them a valuable complement to traditional experimental and interview-based studies. Meanwhile, such user-generated content provides authentic reflections of users' lived experiences with AI-based robots, capturing the relational dynamics and affective responses that explain how AI-based robots are embedded into daily well-being practices.

Moreover, most existing studies applied traditional information systems (IS) theories, such as the technology acceptance model (TAM) (Moussawi et al., 2022; Stafford et al., 2014) and user-centered psychological models (e.g., social response theory, uncanny valley theory) (Pietrantonio, 2022; Stein et al., 2020), which emphasize users' cognitive acceptance and perceptions but largely ignore the dynamic evolution and co-construction process of users' interactions with AI-based robots in real-world well-being contexts. In contrast, a sociotechnical perspective regards AI-based robots not just as tools but as proactive agents capable of shaping and being shaped by users' emotions, affections, and behaviors (Gutiérrez, 2024). As AI-based robots are increasingly designed to recognize emotions, engage in empathetic dialogues, and adapt behaviors, their roles in individuals' daily life extend beyond function tools to being emotional and social agents (Skjuve et al., 2021; Zhou et al., 2020). In this context, users and AI-based robots are both focal actors in negotiating experiences and constructing meaning in everyday well-being support ecosystems. Thus, understanding the mechanisms and trajectories of user interactions with AI-based robots is significant to unravel the pathway to multiple aspects of human well-being in daily life.

The third motivation of this dissertation is to investigate the potential impacts of user interactions with AI-based robots on their well-being in daily life environments. Although prior empirical studies have reported positive results in implementing AI-based robots in various highly structured well-being contexts, such as hospitals (Mettler et al., 2017), nursing homes (Aarskog et al., 2019), cognitive laboratories (Louie et al., 2021), and digital interventions (Sweeney et al., 2021), there is limited understanding of how these outcomes translate to and evolve within dynamic, complex real-world settings. Moreover, most existing studies have primarily examined the immediate or short-term effects of AI-based robots on user perceptions and behaviors (A. Ahmed et al., 2022; Zhu et al., 2022), offering limited insights into the longitudinal process through which sustained interactions between users and AI-based robots may influence individual well-being over time. As discussed before, real-world interaction experiences with AI-based robots unfold in dynamic ways, influenced by users' emotional status, social needs, technological designs, or

environmental factors (S. K. Lee et al., 2021). Thus, it is critical to understand how such evolved interactions support individual well-being in daily life.

Meanwhile, a growing body of research has raised important ethical concerns and implementation risks regarding AI-based robots, such as data privacy, emotional dependency, and trust issues (Alabed et al., 2024; Howard & Borenstein, 2019). However, there remains a lack of balanced empirical evidence that investigates the positive mechanisms through which these AI-based robots promote multidimensional aspects of individual well-being in daily life. Additionally, current healthcare digitalization research and practices tend to focus on clinical treatment and workflow optimization in organizations (Hungerbuehler et al., 2021; Monteith et al., 2022), often neglecting the need for continuous, personalized, and context-sensitive support that addresses individuals' subtle emotional, affective, and social challenges in their daily routines. AI-based robots offer novel opportunities to bridge these gaps by providing continuous, empathetic, and context-aware interaction to meet users' multiple needs in daily life (Gratzer & Goldbloom, 2020). However, understanding how these interactions between individuals and AI-based robots develop, stabilize, or terminate in real-world settings, and how they contribute to multidimensional well-being outcomes, remains an open and critical area.

### 1.3 Research objectives and research questions

Based on these motivations, this dissertation aims to investigate how human interactions with AI-based robots contribute to individual well-being in daily life. It is guided by one overarching research question (RQ):

*RQ: How does human interaction with AI-based robots contribute to well-being in daily life?*

This overarching RQ is further subdivided into three interrelated sub-RQs, each addressed through a series of research publications:

*RQ1: What is the current state of research on the use of AI-based robots in supporting human well-being?*

*RQ2: How do users interact with AI-based robots in daily life to enhance their well-being?*

*RQ3: What are the potential impacts of human interactions with AI-based robots on individual well-being in daily life?*

The link between the sub-RQs and the individual publications is presented in Table 1. To address RQ1, Publications I and II conduct two systematic literature reviews (SLRs) that examine existing research on the use of AI-based physical and virtual robots in healthcare and daily settings, respectively. These reviews synthesize current knowledge on robot designs, applied contexts, and target users, as well as antecedents and consequences of AI-based robot use. The findings construct the

integrative conceptual framework and identify key gaps in current research, providing a conceptual foundation and a source of questions for subsequent empirical research.

**Table 1.** The link between individual publications and sub-research questions.

RQ	Addressing publications	Contributions to the dissertation
1	I	Providing a conceptual foundation for AI-based physical robots in healthcare contexts.
	II	Providing a conceptual foundation for AI-based virtual robots in daily life contexts.
2	III	Providing empirical evidence of interactions between individuals and an AI-based physical robot in home environments.
	IV	Providing empirical evidence of interactions between individuals and an AI-based virtual robot in digital social environments.
	V	Providing empirical evidence of interactions between individuals and three AI-based virtual robots in digital mental health contexts.
3	III	Providing empirical evidence of outcomes of embodied interactions with an AI-based physical robot on individual well-being in home environments.
	IV	Providing empirical evidence of outcomes of virtual interactions with an AI-based virtual robot on individual well-being in digital social environments.
	V	Providing empirical evidence of outcomes of virtual interactions with three AI-based virtual robots on individual well-being in digital mental health contexts.

RQ2 focuses on understanding how individuals interact with AI-based robots to support well-being in daily life. Adopting a sociotechnical perspective, it conceptualizes HRI as a dynamic and evolving process. This RQ explores the mechanisms and developmental trajectories of user interactions with AI-based physical and virtual robots in well-being support contexts. Through sustained and meaningful interactions, users and AI-based robots engage with and adapt to one another in response to dynamic user needs in everyday well-being scenarios. RQ3 examines the outcomes of user interactions with AI-based robots on different dimensions of individual well-being, such as emotional, social, cognitive, and behavioral aspects. It focuses on identifying evidence through which sustained interactions with AI-based robots contribute to well-being when these robots become embedded into users' daily routines. Through a multi-case study approach, Publications III-V collaboratively answer RQ2 and RQ3.

Taken together, these three sub-RQs provide a holistic understanding of how users interact with AI-based robots in daily life to enhance personal well-being.

Publications I and II contribute theoretical insights from prior literature, while Publications III-V offer empirical insights from distinct real-world cases. Table 1 presents the link between the sub-RQs and the individual publications.

Next, this dissertation will elaborate on the focus of each included publication. The research centers on two main types of AI-based robots: AI-based physical robots and AI-based virtual robots. While both have been increasingly applied to support individual well-being in daily life, they differ significantly in terms of representation, interaction modalities, application contexts, and user experiences (K. M. Lee et al., 2006; Li, 2015). Due to these fundamental differences, a single SLR may oversimplify or confuse the distinct characteristics, capabilities, and challenges associated with each form. Therefore, this dissertation conducts two independent but complementary SLRs: Publication I focuses on AI-based physical robots in healthcare settings, while Publication II investigates AI-based virtual robots in daily life contexts. These two SLRs answer RQ1 by identifying the robot types, applied contexts, target users, antecedents, and consequences of AI-based physical and virtual robots in current research, providing an integrative conceptual understanding for further research. Additionally, the findings point out the key knowledge gaps to guide and motivate the subsequent empirical studies of this dissertation.

These literature reviews point out a critical need for empirical studies that examine user interactions with AI-based physical and virtual robots for well-being support in real-life scenarios and emphasize the importance of context. To address this, this dissertation employs a multiple case study to investigate five distinct robot cases in daily life. Specifically, Publication III presents a single case study of Robot A, an AI-based physical robot used in the home environment. Publication IV investigates Robot B, an AI-based virtual robot designed for social companionship in digital contexts. Publication V explores three AI-based virtual robots (Robots C, D, and E) in the context of mental health support. These case studies reveal distinct interaction environments and user experiences, allowing for comparative analysis and a deep understanding of how users and AI-based robots interact to support individual well-being in daily life.

Additionally, the two SLRs also reveal two significant research gaps in current research on AI-based robots in well-being contexts: HRI and outcomes for individual well-being. Most prior research focuses on factors influencing user interactions with AI-based robots (E. Ahmed et al., 2022; de Barcelos Silva et al., 2020) and the limited outcomes of these interactions on individual well-being in daily life (A. Ahmed et al., 2022; Zhu et al., 2022). There is a lack of understanding of how users interact with AI-based robots and what multidimensional well-being outcomes these interactions may produce in everyday scenarios. To address these gaps, Publications III-V conduct three case studies to explore the dynamic evolution of user interactions

with AI-based robots and their potential impact on user well-being in specific scenarios in daily life, to answer RQ2 and RQ3.

Publication III analyses the embodied interactions between users and an AI-based physical robot (Robot A) in home environments, including engagement with the AI-based physical robot in physical and social activities. Based on the understanding of current HRI theories, we further illustrate how HRI evolves from embodied engagement to emotional and social bonding, ultimately contributing to users' overall well-being. This publication provides empirical evidence of the positive impact of AI-based physical robots on human emotional, social, physical, and cognitive well-being in home environments.

Additionally, Publication IV unravels the development of interactions between users and an AI-based virtual robot (Robot B) in virtual social scenarios based on the life cycle perspective of social penetration theory (SPT). The findings reveal how users form, explore, maintain, and terminate relationships with Robot B based on the depth and breadth of reciprocal self-disclosure. As the human–robot relationship evolves, the publication reveals the positive outcomes of different user–robot relationship stages on users' emotional and social well-being.

Furthermore, Publication V reveals how three AI-based virtual robots (Robots C, D, & E) interact with users and become embedded into users' mental health routines. Drawing on the actor-network theory (ANT), this publication investigates the processes of users and AI-based virtual robots interacting as focal actors to help users cope with mental health issues in daily life. Moreover, the findings reveal the positive effects on users' emotional, social, cognitive, and behavioral well-being when users have stable and continuous interactions with AI-based virtual robots in daily life.

This dissertation combines two SLRs and three empirical case studies to integrate research findings on AI-based physical robots and virtual robots in different well-being contexts. It synthesizes existing knowledge, identifies key gaps, and proposes future research agendas to advance the research field. By uncovering real-world experiences of HRI and well-being outcomes, this study contributes to broader discussions on the evolving relationship between humans and AI-based robots and offers theoretical and practical insights into how AI-based robots can be meaningfully integrated into daily life to support human well-being.

## 1.4 Dissertation structure

This dissertation is structured into six main chapters: introduction, literature review and theoretical foundations, research methodology, results, discussion, and implications and conclusion.

Chapter 1 outlines the background and motivation for the study, focusing on the theme of AI-based robots for human well-being. It presents the research objectives and questions, provides an overview of the five research publications included in the dissertation, and summarizes the overall structure of the dissertation.

Chapter 2 presents relevant prior literature and theoretical foundations. The first part reviews the conceptual development and definitions of robots, with a focus on prior research on AI-based robots in well-being contexts. The second part introduces the theoretical lens of the dissertation and elaborates on the theoretical frameworks applied in each publication, discussing their relevance to the research objective.

Chapter 3 describes the research methodology. It outlines the dissertation's philosophical foundations and explains the multiple-case study method, including case selection, data collection, and data analysis methods used across the five publications.

Chapter 4 summarizes the key results of the five research publications, which consist of two SLRs and three empirical case studies. The results are presented in alignment with the research objectives, highlighting the contributions of each article within its respective focus area.

Chapter 5 reflects on the key findings in relation to each sub-RQ and synthesizes them to address the overarching RQ of the dissertation.

Chapter 6 concludes the dissertation by discussing its theoretical and practical contributions, evaluating the research process, acknowledging its limitations, and outlining directions for future research.

## 2 Research background

This chapter presents the research background of this dissertation. First, the historical evolution of robot technology and several key concepts related to robots are discussed and defined in this research. Second, the research on individual well-being and AI-based robots in well-being contexts is discussed by summarizing relevant research. Finally, the employed theories in this dissertation and their relations to the research objective are illustrated.

### 2.1 Concepts of robots

The term "robot," originating from the Czech word *robota* meaning "forced labor," was first introduced by Karel Čapek in his 1921 stage play "R.U.R." (which stands for "Rossum's Universal Robots") (Capek, 2004). In this play, robots were portrayed as humanoid machines designed to perform repetitive tasks more efficiently than humans. This term has since been widely adopted in both popular and academic discourse, playing a formative role in shaping the conceptual understanding of robotics (Christoforou & Müller, 2016). Over time, the definition of a robot has evolved from a rigid notion rooted in industrial automation to a multidimensional construct encompassing various domains (Cai et al., 2021).

Historically, robots were defined as program-controlled machines capable of autonomously performing repetitive tasks in highly structured environments, adhering strictly to predefined instructions (Satava, 2002; P. M. Taylor, 1987). These industrial robots were deployed in controlled or hazardous settings, such as manufacturing and mining (Singer, 2009). With advancements in sensing technologies, speech recognition, and visual processing, robots began acquiring the ability to perceive and respond to changes in their environments (Lacity, 2016). These enhanced capabilities led to an expanded definition of robots as autonomous physical machines capable of sensing, manipulating, and adapting to their surroundings (Cai et al., 2021). At the same time, the application of robots broadened beyond industrial contexts to more human-centered service contexts. The International Federation of Robotics (IFR) (2016) defined a service robot as "a robot which operates semi- or fully autonomously to perform services useful to the well-being of humans and equipment, excluding manufacturing operations." Reflecting

this shift, Wirtz et al. (2018) described the emergence of service robots as a transition into a "brave new world" in which robots are no longer seen merely as automation tools, but as autonomous agents capable of directly interacting with customers. Since then, robots have been widely implemented in service sectors, such as logistics, healthcare, hospitality, and customer service, where they are increasingly relied upon to communicate, collaborate, and deliver services in dynamic human environments (Mahdi et al., 2022).

More recently, the integration of AI has further transformed robotic systems by enhancing their capacity for perception, reasoning, and autonomous decision-making. Cai et al. (2021) have identified three key features of AI-based robots: (i) perception: perceiving and interpreting changes in information and environments, (ii) thinking: learning and reasoning adaptively, and (iii) operation: autonomously and proactively performing complex tasks. A defining trait that differentiates AI-based robots from conventional machines is their capacity for self-directed learning, allowing them to dynamically adjust their behaviors in response to social or environmental stimuli in task execution or interaction with humans (Seaborn et al., 2021). Jörling et al. (2019) emphasized that the high level of autonomy and intelligence of AI-based robots enables rich and meaningful interactions with users, prompting individuals to perceive robots as social entities rather than as mere tools. Similarly, Seaborn et al. (2021) argued that AI-based robots are designed to support complex social, emotional, and cognitive interactions, requiring them to process natural language, recognize human emotional states, and maintain conversations with users to co-create value. These advanced capabilities mark a conceptual shift—positioning robots not just as functional tools, but as perceptive social agents integrated into dynamic sociotechnical ecosystems (Koenig, 2024).

Alongside rapid technological advancements and broadening application domains, the representation design of robots has also evolved significantly, extending beyond traditional physical machines to include virtual entities. Traditionally, robots were conceived as tangible machines embedded with information technology, designed to autonomously operate in real-world environments (Thrun, 2004). However, with the progression of AI and virtual representation technologies, many robots are able to function effectively without a physical form, particularly in domains involving remote services and digital interactions (Nihei et al., 2020; Suzuki et al., 2022).

As a result, recent research has expanded the definition of robots to encompass both physical and virtual representations (M. I. Ahmad & Refik, 2022; Lu et al., 2020; Wirtz et al., 2018). This shift has notable implications for how users perceive and engage with robots, particularly through the constructs of embodiment and presence (Cai et al., 2021; Forster et al., 2022). Embodiment refers to the integration of a bodily form, whether physical or virtual, into the agent's representation (You &

Robert, 2018), while presence captures the user's subjective feelings of “being with” the robot in a shared space (Munnukka et al., 2022). Li (2015) proposed a typology based on these constructs, identifying three types of robot representation: (i) physically copresent robots, which share the same physical space as users; (ii) virtually telepresent robots, which are remotely controlled physical robots represented through virtual interfaces, and (iii) virtually embodied robots, which exist solely within digital environments but simulate the experience of co-presence. Likewise, You and Robert (2018) noted that AI-based robots now span a spectrum of representational forms, ranging from physically embodied machines to virtually embodied avatars and non-embodied agents. While these typologies may vary across contexts, they underscore the significance of embodiment and presence as foundational elements in shaping HRI, whether in real-world or digital settings (Forster et al., 2022; K. M. Lee et al., 2006).

Based on the above discussions, this dissertation combines the constructs of embodiment and presence to distinguish between physical and virtual robots. Physical robots are defined as autonomous machines with tangible embodiment that can operate in real-world environments through either physical copresence or telepresence. Common variants such as humanoid, animal-like, mechanical, or embodied robots describe differences in the embodiment designs. AI-based physical robots are capable of mimicking human features and behaviors through facial expressions, gestures, and voice modulation, to engage users and deliver personalized physical, emotional, and social services (Cai et al., 2021; Krämer et al., 2012). These robots are increasingly recognized for their capacity to convey social cues and facilitate rich embodied interactions (Mollahosseini et al., 2018; Wainer et al., 2006).

In contrast, virtual robots in this dissertation refer to computer-generated entities, either disembodied or virtually embodied, that simulate human-like interactions through speech, text, or animated avatars in digital environments. The term "AI-based virtual robots" is used to include a broad range of AI systems, such as chatbots, conversational agents, virtual agents, and generative AI interfaces. Although these terms are sometimes used interchangeably, they vary in embodiment, technical functions, and interaction modes. For example, chatbots and conversational agents typically integrate natural language processing and machine learning to facilitate fluent, context-aware conversations that mimic human-to-human communication (Diederich et al., 2022). Virtual agents are animated digital characters that engage users through multimodal expressions such as voice, facial cues, and gestures, offering immersive and emotionally engaging experiences (Li, 2015). Generative AI systems are designed to autonomously produce human-like content (e.g., text, images, audio, or code) based on data-driven learning models (Feuerriegel et al., 2024). Despite these nuanced differences, these AI systems designed for human-

facing roles share a common goal: to enhance human–computer interaction (HCI) in digital environments. By adopting the term “AI-based virtual robots,” this dissertation highlights their broader social and emotional roles in shaping human experiences within digital ecosystems.

In alignment with this dissertation, a growing body of research has sought to compare the use of physical and virtual robots in various contexts (K. M. Lee et al., 2006; Yadollahi et al., 2023). In educational settings, for instance, Palanica et al. (2019) found that physically embodied robots acting as tutors can enhance learning outcomes more effectively than web-based or audio-only virtual robots. However, such outcomes may not generalize across contexts. In diabetes self-management, Sinoo et al. (2018) found that children formed similarly strong connections with both physical and virtual robots, reporting comparable enjoyment and engagement. Mutlu (2021) further argued that physical and virtual robots trigger fundamentally different user expectations, interaction patterns, and behavioral responses. These mixed findings suggest that user experiences with robots are influenced not only by their technological features but also by the broader social, psychological, and environmental contexts in which HRI takes place. In light of this, growing calls from social science scholars emphasize the importance of adopting broader, interdisciplinary, and sociotechnical perspectives to understand how AI systems are perceived, engaged with, and integrated into society (Gutiérrez, 2024; Koenig, 2024).

Responding to these calls, this study focuses on AI-based robots, both physical and virtual, as its central research objects, examining how users interact with these systems in real-world well-being contexts. This is because AI-based robots, unlike traditional mechanical machines, are often equipped with capabilities such as machine learning, natural language processing, and affective computing, enabling them to interact in ways that closely resemble human communication and behaviors. These capabilities position them not merely as functional tools, but as sociotechnical agents capable of shaping personalized, affective, and context-sensitive experiences. This perspective is particularly relevant to well-being contexts, where HRI involves not only practical assistance but also emotional, ethical, and relational dimensions. Moreover, while prior literature has distinguished physical and virtual robots in terms of embodiment and presence, there remains a critical need to explore and compare their design, user experiences, and broader societal implications through a sociotechnical lens. Thus, this dissertation conducts both SLRs and empirical studies into user interactions with AI-based physical and virtual robots across various well-being scenarios, providing an integrative understanding of how these technologies become embedded in the dynamic sociotechnical ecosystems in daily life.

## 2.2 Prior research on AI-based robots in healthcare

In recent years, growing global challenges, such as mental health crises, aging populations, and shortages in healthcare resources, have intensified both public and academic interest in the concept of well-being. The World Health Organization (1948) redefined health as “a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity.” This definition marked a transition from a disease-centered view of health to a holistic and multidimensional conception of individual well-being (Diener et al., 1999; Kühn & Rieger, 2017). Since then, well-being has gained increasing attention across academic research and policy agendas as a multidimensional construct encompassing quality of life, happiness, physical and mental health, morality, meaning, and mindfulness (Alkire, 2002; Dodge et al., 2012).

Individual well-being reflects individuals’ cognitive and affective evaluations of their own lives, such as psychological, physiological, and emotional states (Diener, 1984). Sociologist Veenhoven et al. (2011) defined well-being as an individual’s cognitive appraisal of their overall life satisfaction, while psychologists Diener and Sim (2024) conceptualized it as a composite of both life satisfaction and affective experiences, including the presence of positive emotions and the absence of negative ones. More recently, the development of widely adopted measurement tools, such as the Warwick-Edinburgh Mental Well-being Scale (Tennant et al., 2007), the BBC Subjective Well-being Scale (Kinderman et al., 2011), and the Gallup-Healthways Well-being Index (Deaton, 2008), has further expanded the operational scope of well-being to include healthy behaviors, relationships, feeling loved, a sense of purpose, and perceived autonomy.

Given the growing need to support individual well-being beyond clinical contexts, robotic technologies have gradually been introduced into well-being support practices, marking a significant shift from exclusive use in clinical environments to broader applications in daily life (Holland et al., 2021). Initially, robots were designed for highly specialized medical tasks, such as surgical assistance and diagnostic support (Hockstein et al., 2007). For instance, surgical systems such as the Da Vinci robot have been widely applied to assist surgeons with enhanced precision and efficiency in minimally invasive procedures (Hesse & Lenz, 2017). The use of exoskeleton robots further extended the scope of application to physical rehabilitation, assisting patients in regaining motor functions after stroke or spinal injuries (L. M. Weber & Stein, 2018). As robotic technologies advanced, their applications extended beyond the operating room to include logistical and operational tasks within healthcare institutions. During the COVID-19 pandemic, telepresence robots were widely deployed to support hospital logistics and disinfection, thereby reducing the workload of medical staff (Freeman et al., 2021).

Meanwhile, assistive robots were introduced to help older adults with routine activities, such as bathing assistance, physical activity monitoring, fall detection, and emergency calls (M. Law et al., 2019).

With the integration of AI technologies, robots have evolved beyond task automation to become capable of emotional recognition, empathetic responses, and social interaction, enabling them to simulate human-to-human communication (Cai et al., 2021; Seeger et al., 2021). These developments have redefined the role of robots from purely functional tools to social and emotional support agents within daily well-being contexts (Dang & Liu, 2023; Han et al., 2023). For example, AI-based physical robots such as Paro use multimodal interaction, such as voice, facial expressions, and physical movements, to provide companionship, facilitate dialogue, and deliver cognitive stimulation for users experiencing loneliness and cognitive impairments (McGlynn et al., 2017). Similarly, AI-based virtual robots such as Xiaoice, Kuki, and Woebot engage users through voice or text-based conversations, offering emotional regulation, mental health support, and social companionship (Gamble, 2020; Skjuve et al., 2021; Zhou et al., 2020). Thus, AI-based physical robots and virtual robots are becoming more visible, accessible, and personalized in the living, social, and affective areas of individual daily life.

Previous research on AI-based robots in the context of well-being has been explored from three main dimensions: technological, organizational, and individual perspectives. From a technological perspective, research has focused on system design, functionality, and performance in various well-being scenarios (Ragno et al., 2023; Weng & Hirata, 2022). For example, virtual robots integrated with AI and Internet of Things technologies have demonstrated enhanced adaptability and real-time responsiveness in remote health consultations and continuous healthcare monitoring (Ranganathan et al., 2024). The integration of multimodal sensory inputs (e.g., voice, visuals, and touch) into AI models has been shown to enhance robots' responsiveness in care environments (Arunachalam et al., 2024). Additionally, design features such as conversational style, natural language fluency, and affective computing have been identified as critical to fostering user trust and sustained engagement (Seeger et al., 2021). However, technical constraints remain, such as the lack of high-quality training data for culturally sensitive or elderly-specific models (Arunachalam et al., 2024), and limitations in ensuring real-time adaptability in complex, dynamic care environments (Obaigbena et al., 2024). These constraints highlight that the integration of AI-based robots into daily life cannot rely solely on technical advancements but also requires a broader perspective that considers user needs, contextual environments, and the evolving dynamics of HRI.

From an organizational perspective, scholars have investigated the deployment of AI-based robots in hospitals, clinics, and long-term care institutions (Fosch-Villaronga & Drukarch, 2021; Mettler et al., 2017). These robots are generally

perceived as assistive tools that autonomously perform functional tasks to enhance workflow efficiency and staff satisfaction (Arunachalam et al., 2024; Darwish et al., 2023; Ikeuchi et al., 2018). Some studies have also highlighted collaborative models involving healthcare professionals and AI-based robots in triage, patient intake, and hybrid care delivery (Gürce et al., 2023; Lanza et al., 2020). The deployment of AI-based physical robots for assistive tasks in hospitals has shown promise in reducing caregiver workloads and mitigating burnout (Darwish et al., 2023; Ikeuchi et al., 2018). Additionally, AI-based robots have been associated with improved cost-effectiveness and service quality in healthcare operations (Mettler et al., 2017; Piccininni, 2018). However, organizational integration of these robots has also faced challenges, such as clinician resistance to AI technologies (Obaigbena et al., 2024), limited interoperability with existing health systems (Ranganathan et al., 2024), and ambiguous regulatory and policy frameworks (Fosch-Villaronga & Drukarch, 2021).

At the individual level, research has primarily examined the use of AI-based robots in well-being contexts across diverse user groups, such as veterans (Kosyluk et al., 2021), people with dementia (M. Law et al., 2019), and young adults (Koulouri et al., 2022). Some studies have investigated user attitudes, acceptance, and willingness to adopt AI-based robots in care and well-being support contexts (Alaiad & Zhou, 2014; Chen et al., 2020; Hall et al., 2019). In addition to user adoption, some studies have investigated users' cognitive and affective responses to interactions with AI-based robots. For example, Fasola and Matarić (2013) found that older adults' perceptions of enjoyment, usefulness, and social presence influenced the continued use of physical robots during fitness activities. Likewise, some studies have investigated antecedents of user satisfaction with AI-based virtual robots in mental healthcare settings (A. Ahmed et al., 2022; Zhu et al., 2022). A comparative study has shown that user trust in robotic therapists was comparable to that in human therapists, with users even showing stronger receptivity to robots' guidance in decision-making tasks (Xu et al., 2018). Moreover, Siemon (2022a) explored users' sentiments and emotions while interacting with AI-based virtual robots in coping with loneliness and mental well-being challenges.

Beyond cognitive and affective responses, a growing body of research has investigated the impact of AI-based robots on specific aspects of individual well-being. In structured care environments, AI-based physical robots have been shown to enhance medication adherence, increase engagement in rehabilitation exercises, and reduce social isolation among elderly patients (Broadbent et al., 2014; McGlynn et al., 2017; Rahman et al., 2022; Sheba et al., 2018). Similarly, AI-based virtual robots used in mental health contexts have demonstrated effectiveness in alleviating symptoms of anxiety, depression, and social loneliness (Fitzpatrick et al., 2017; Mehta et al., 2021). Despite these promising outcomes, most existing studies have been conducted within structured clinical or experimental settings, often focusing on

isolated aspects of individual well-being. Thus, less is known about the applicability of these findings in real-world contexts or how AI-based robots support users in managing the fluctuating and multifaceted well-being challenges in daily life.

This dissertation aims to explore user interaction experiences with AI-based robots in everyday well-being practices and to examine their potential impact on individual well-being. As AI-based robots become increasingly integrated into daily life, their role has evolved beyond clinical intervention to include continuous, immediate, and personalized support for personal emotional, social, and psychological well-being (Gamble, 2020; Skjuve et al., 2021; Zhou et al., 2020). Understanding these real-world user–robot interactions is essential for assessing the long-term relevance and sustainability of AI-based robots in supporting the subtle and ongoing well-being challenges individuals face in their daily lives. Additionally, although prior research has extensively investigated technological design, organizational deployment, and user-level cognitive and affective responses to AI-based robots, there remains a lack of understanding of how users and AI-based robots interact in daily life contexts and the resultant outcomes for individual well-being. Therefore, this dissertation focuses on AI-based physical and virtual robots and employs a combination of SLRs and multiple case studies to address this critical gap.

## 2.3 Theoretical foundations

This dissertation adopts a sociotechnical perspective to examine how HRIs unfold in daily life and how these interactions contribute to individual well-being. As Suprateek Sarker et al. (2019) argue, the sociotechnical axis of cohesion provides a unifying foundation for the IS discipline by emphasizing that neither the social nor the technical dimensions alone are sufficient to explain the complex phenomena associated with technology use. Rather, it is the entangled, mutually constitutive relationships between humans and technologies within specific institutional, emotional, and cultural contexts (Bostrom & Heinen, 1977). Thus, the sociotechnical lens provides a holistic framework for analyzing the dynamic and co-constructed nature of user interactions with AI-based robots in different well-being scenarios.

To deepen the theoretical grounding of this dissertation, three distinct but complementary theories are employed in the empirical publications: HRI, SPT, and ANT. These theories collectively offer a multifaceted understanding of the dynamic, evolving interplay between social actors (humans) and technical systems (AI-based robots) across different real-life scenarios from a sociotechnical perspective. Publication III adopts the theoretical lens of HRI, which provides a broad conceptual foundation for understanding how humans engage with AI-based physical robots and the evolved affective and relational dimensions of HRI in shared home environments. Publication IV applies SPT, a foundational theory in interpersonal

communication, which helps to understand how users form and develop relationships with an AI-based virtual robot through increasing depth and breadth of reciprocal self-disclosure. Publication V employs ANT to conceptualize users and AI-based virtual robots as focal actors in co-constructing emotional support networks in response to users' emotional needs and the robot's therapeutic design.

Thus, the sociotechnical perspective provides the overarching conceptual foundation of this dissertation, while the selected theories support a multi-dimensional understanding of how users interact with AI-based physical and virtual robots to enhance individual well-being in different daily life contexts.

### 2.3.1 Human–robot interaction

HRI is an interdisciplinary research field that emerged in the 1990s, aiming to understand, design, and evaluate robotic systems intended for use by or in collaboration with humans (Dautenhahn & Saunders, 2011). Goodrich and Schultz (2008) define HRI as the study of how one or more humans interact with one or more robots and how such interaction can be effectively designed. Similarly, Dautenhahn (2013) further conceptualizes HRI as a scientific domain investigating the relationships between people's attitudes and behaviors and robots' physical, technological, and interactive characteristics. These definitions emphasize that meaningful HRI should be not only functionally efficient but also acceptable to people, meeting the social and emotional needs of users, and aligned with human values (Dobrosovetsnova et al., 2023).

From this technology-centered view, HRI was typically framed in terms of usability, safety, and efficiency, with the user as a rational decision-maker responding to the robot's technological characteristics. For example, Alaiad and Zhou (2014) applied the unified theory of acceptance and use of technology (UTAUT) model to understand the determinants of healthcare robot adoption in home environments and found that the usefulness and effectiveness of robots as new home technologies significantly influenced their attitudes. Likewise, Saadatzi et al. (2020) adopted the TAM to investigate how nursing students evaluated an assistive service robot in terms of its perceived ease of use and perceived usefulness in a simulated hospital environment. These studies primarily focused on developing robots capable of assisting humans in performing specific tasks safely and efficiently. While this line of work largely reduced HRI to a transactional activity focused on perceived usefulness and ease of use, they failed to capture the emotional, relational, and contextual dimensions of the interaction.

With the advancement of robot representation, behavior, and cognitive capabilities, AI-based robots are increasingly being developed for real-world applications. Another research stream has adopted a human-centered research

perspective, drawing on user experiences from psychology and the HCI lens. This stream emphasized user experience, emotional response, and social cognition involved in HRI. For example, Jeanie Chan and Nejat (2010) examined the social interactions between users with dementia and the AI-based physical robot Brian 2.0, and found a resultant positive outcome in improving user engagement in cognitively stimulating activities. Khosla and Chu (2013) reported the first field trials of Matilda, an AI-based physical robot, and examined its interactions with older adults in residential care facilities. Their findings showed that Matilda fostered emotional engagement through singing, dancing, and expressive interactions, and positively impacted residents' emotional well-being. Birks et al. (2016) applied an animal-like robot, Paro, as a therapeutic tool, revealing an improvement in users' emotional state and social interactions through analyzing logs of interactions between Paro and residents. This research stream highlights a wide range of emotional, affective, and social interactions between users and AI-based robots, treating users as the primary active agents.

In summary, HRI studies provide multidimensional insights by examining both the “H” (human) and the “R” (robot) components of interaction. Suchman (2007) advocates a contextualized perspective on behavior, showing how HRI is dynamically configured through local contexts. This positions HRI as a sociotechnical science that should address the interrelated challenges of technology design, human behavior, and the broader interaction environment (Dautenhahn, 2013). Therefore, Publication III takes HRI as its theoretical foundation because it provides a rich and interdisciplinary framework that bridges technological, human-centered, and sociotechnical perspectives. Drawing upon the different research streams in HRI studies, this publication aims to deepen our understanding of how individuals interact with AI-based physical robots in home environments and how they co-create meaningful experiences and support individual well-being through sustained interaction.

### 2.3.2 Social penetration theory

Social penetration theory (SPT), first introduced by Altman and Taylor (1973) in the field of mass communication research, posits that interpersonal relationships develop gradually through reciprocal self-disclosure. It provides a foundational framework for explaining and predicting relational closeness, which is primarily shaped by the breadth and depth of self-disclosure (Fox & Gambino, 2021). Self-disclosure is defined as “the act of revealing personal information about oneself to another” (Collins & Miller, 1994, p.457), and it is considered a key mechanism in fostering relational closeness and strengthening interpersonal connections (Altman et al., 1981; Utz, 2015). Altman and Taylor (1973) conceptualized three dimensions of

self-disclosure: (1) breadth—the range of topics disclosed, (2) depth—the level of intimacy of the disclosed information, and (3) duration—the amount of time spent on disclosure. By emphasizing continuous reciprocal self-disclosure, SPT explains how individuals gradually develop and maintain relationships (Altman et al., 1981; Pennington, 2020).

Originally, SPT was proposed to describe the life cycle of relationship development (Altman & Taylor, 1973). The theory uses the metaphor of an onion to illustrate how individuals possess multiple layers of personality, which are gradually revealed over time through self-disclosure. The outermost layers include publicly observable traits, while the innermost layers contain deeply held values, emotions, and private experiences. As relationships evolve, individuals metaphorically peel back these layers, moving through stages characterized by increasing disclosure in both breadth and depth (Altman & Taylor, 1973; Altman et al., 1981). Altman and Taylor (1973) identified four stages of relationship development: (i) orientation, characterized by superficial interactions governed by social norms; (ii) exploratory affective exchange, where partners begin to share personal information on a wider range of topics without forming deep emotional bonds; (iii) affective exchange, involving deeper reciprocal self-disclosures with more private and sensitive information shared; and (iv) stable exchange, where partners engage in open and honest exchange of personal information. Later, Altman et al. (1981) introduced a fifth stage: de-penetration, acknowledging that reciprocal self-disclosure may fluctuate or even regress, leading to relationship destruction or termination. Thus, SPT recognizes that relationships may evolve in non-linear ways, shifting back and forth between five stages, depending on perceived costs and rewards (Croes & Antheunis, 2021).

SPT has been widely applied to various contexts beyond face-to-face interpersonal relationships (Altman et al., 1981), including online communities (Utz, 2015), social networks (Pennington, 2020), and computer-mediated communication (Mason & Carr, 2022). In digital settings, studies have shown that self-disclosure enhances feelings of intimacy and social connection in relationship development. For example, high levels of online self-disclosure have been associated with stronger perceptions of connectedness (Utz, 2015) and friendship (Leite & Baptista, 2022) between users. Moreover, computer-mediated environments, often perceived as anonymous and lacking non-verbal cues, can facilitate more open self-disclosure in online communication (Antheunis et al., 2012). Recent research has extended SPT to HRI, finding that such facilitation effects may be amplified in relationships with AI-based robots (Croes & Antheunis, 2021; Skjuve et al., 2022). Fox and Gambino (2021) argue that users tend to feel more comfortable disclosing personal information to chatbots than to human counterparts. Ho et al. (2018) found that users experienced similar levels of emotional closeness when disclosing to chatbots versus

human agents. Similarly, Skjuve et al. (2021) conducted a longitudinal study that aligned with the SPT framework, identifying three phases: exploratory, affective, and stable, in the development of human-chatbot relationships. These studies underscore that self-disclosure has emerged as a key factor in the formation and development of human-robot relationships.

Beyond relationship development, SPT also emphasizes the role of perceived rewards and costs in ongoing self-disclosure. Altman and Taylor (1973) argued that self-disclosure is motivated by anticipated affective benefits, such as satisfaction, pleasures, and gratifications (Thibaut, 2017). In support-seeking contexts, when one party engages in deeper self-disclosure, the other is more likely to reciprocate with social support, reinforcing the relational closeness and encouraging continued investment (D. A. Taylor & Altman, 1975). Accordingly, some studies have adopted SPT to explore the emotional and social outcomes of reciprocal self-disclosure. Lei et al. (2023) found that postpartum mothers' self-disclosure on social media enhanced their perceived social support and alleviated symptoms of depression. Huang (2016) demonstrated that online sharing of personal stories positively impacts individual mental states. Ho et al. (2018) revealed that users who disclosed to chatbots experienced emotional, relational, and psychological benefits. Y.-C. Lee et al. (2020) found that chatbots' self-disclosure could prompt reciprocal sharing from users, thereby strengthening perceived closeness and satisfaction in the relationships. Collectively, these findings support SPT's assertion that reciprocal self-disclosure fosters not only intimate relationships but also individual well-being.

In this dissertation, SPT is adopted as the theoretical foundation for Article VI to explore (i) how users engage in social interactions with AI-based virtual robots through self-disclosure, and (ii) how such interactions enhance users' well-being. First, AI-based virtual robots, particularly those designed for social companionship, aim to simulate human-like interactions and emotional exchanges. These robots are often perceived as anonymous and non-judgmental, encouraging users to disclose thoughts and emotions more freely. SPT offers a suitable theoretical lens to understand how the breadth and depth of self-disclosure support the formation of human-robot relationships. Second, these AI-based virtual robots are designed to integrate into users' daily routines and support social well-being over time. SPT's life-cycle model offers a useful framework for examining how these relationships between users and AI-based virtual robots are initiated, maintained, and potentially dissolved. Finally, SPT's emphasis on perceived rewards provides a valuable perspective for exploring how these relationships contribute to users' well-being. While many relational theories focus primarily on the antecedents of relationship formation, SPT highlights the process by which relationships evolve through ongoing reciprocal self-disclosure in communications. Thus, SPT enables this study to explore not only how relationships with AI-based virtual robots develop through

self-disclosure, but also how such relationships contribute to users' well-being in daily life.

### 2.3.3 Actor-network theory

Actor-network theory (ANT) is a sociological framework developed in the 1980s by Bruno Latour, Michel Callon, and John Law (Callon, 1984; Latour & Prus, 1990; J. Law, 1992). It aims to explore how humans and non-humans (collectively referred to as “actors”) jointly construct and shape reality within larger units such as networks, which consist of relatively stable relationships (Callon & Latour, 1981; Latour, 1984). Latour (2012) challenges the conventional separation between society (human actors) and nature (non-human actors), arguing that they are not separate entities but interdependent forces that collectively shape social reality. This perspective fundamentally rejects the notion that only humans possess agency, instead emphasizing that non-human actors—including technology, infrastructure, and artifacts—actively influence and shape human behaviors within networks (Fioravanti & Velho, 2010). While human actors have reflective power through language, non-human actors exercise agency through their ability to structure interactions, influence decision-making, and condition behavioral patterns (Murdoch, 1997). ANT has since been widely adopted across various disciplines, particularly in IS research, following the call of Walsham (1997) for its application in understanding the dynamic sociotechnical interactions in system implementation and adaptation.

ANT challenges traditional sociological paradigms by emphasizing two core principles: heterogeneity and symmetry. Heterogeneity refers to the idea that multiple types of actors, both human (e.g., individuals, organizations) and non-human (e.g., technologies, policies, infrastructure), must be considered when constructing and analyzing reality (Latour, 1984). Within this framework, an actor is defined as “any element which bends space around itself, makes other elements dependent upon itself, and translates their will into the language of its own” (Callon & Latour, 1981, p.286). In other words, actors do not act in isolation; rather, they exist in interdependent relationships with other actors in shaping network outcomes (Callon, 1984; Latour & Prus, 1990). Symmetry, on the other hand, challenges the assumption that human agency should be prioritized over technological influence. Instead, ANT treats human and non-human entities as equally significant in shaping the structure, functionality, and evolution of networks (Callon, 1984). This perspective allows ANT to conceptualize the agency of technologies, material objects, and institutional structures as active participants in sociotechnical systems, rather than viewing technology as a mere tool controlled by human intention (Fioravanti & Velho, 2010).

To explain the formation and stabilization of networks, ANT introduces the translation process, which describes how actors negotiate roles, establish relationships, and maintain influence within a dynamic network (J. Law, 1992). Translation consists of four key stages (Callon, 1984). First, problematization occurs when a focal actor defines a problem and positions itself as the indispensable solution, thereby structuring the roles of other actors in the network. Second, interessement involves persuading and aligning other actors to secure their participation in the network by establishing shared interests. Third, enrolment refers to the process in which participating actors actively commit to their assigned roles, reinforcing their relationships through sustained interaction. Finally, mobilization determines whether the network stabilizes into a widely accepted system or collapses due to actor disengagement. These translation stages illustrate how networks are not fixed but continuously evolving through dynamic interactions between human and non-human actors (Callon & Latour, 1981).

ANT has been widely applied to analyze the implementation, adoption, and governance of digital technologies (Islam et al., 2019; Tatnall, 2014; Thapa & Omland, 2018). In studies of digital technology and human interactions, ANT has been used to understand the evolving relationship between users and technological systems, including AI (Gutiérrez, 2024), blockchain (Islam et al., 2019), and digital platforms (Cresswell et al., 2010). For example, Outila and Kiuru (2020) used ANT to examine the dynamic adoption of assistive technologies among older adults, highlighting how technology is not merely an external tool but an embedded actor in shaping user experiences. Harsanto and Permana (2019) applied ANT to sustainability-driven innovations, demonstrating how technological and social actors co-evolve to facilitate or hinder adoption processes. More recently, Gutiérrez (2024) analyzed the ethical challenges of generative AI (e.g., ChatGPT), showing how AI introduces new power dynamics to human-machine interactions. These studies collectively emphasize that digital technologies are not passive tools but active agents in shaping human interactions, decisions, and behaviors.

Beyond digital technology applications, ANT has also been utilized to examine causal trajectories and the complexity of sociotechnical transformations. Cresswell et al. (2010) used ANT to study the failure of England's National Electronic Health Records system, demonstrating how different stakeholders' conflicting interests contributed to system breakdown and unintended consequences. Onno et al. (2023) investigated the integration of AI-based computer-assisted detection in tuberculosis screening, analyzing AI's role in global health governance and medical decision-making. Similarly, Stejskalová (2023) applied ANT to explore human-chatbot relationships, revealing how chatbots influence user behavior and shape emotional experiences over time. These studies show that technological systems, once introduced, interact with human users in unpredictable ways, often leading to

emergent, unintended consequences that reshape the trajectory of sociotechnical networks.

Building on this foundation, this study adopts ANT as a theoretical lens in Article V, to examine the role of AI-based virtual robots in mental health services, answering RQ2 and RQ3 of the dissertation. ANT provides a sociotechnical perspective that considers human agency (users, developers, psychologists) and technical artifacts (AI-based robots, algorithms, infrastructure) as mutually constitutive forces in the construction of actor networks (Callon, 1984; Latour & Prus, 1990), which may help in understanding the roles of users and AI-based virtual robots in mental health support networks. Unlike traditional psychological interventions, which focus solely on human agency, AI-based virtual robots represent a new form of digital actor that actively engages in mental health support, raising critical questions about their agency, effectiveness, and social implications (Gutiérrez, 2024). Applying ANT enables us to conceptualize AI-based virtual robots as networked entities by examining their interactions with users in the mental health network. Additionally, ANT's translation framework provides a process view to analyze the formation and evolution of sociotechnical networks (Callon, 1984), which helps to structure the understanding of how AI-based virtual robots become embedded in mental health support practices and how their interactions with users stabilize the network. Previous studies have primarily focused on the effectiveness of AI-based virtual robots in clinical trials, but little is known about how users engage with these robots in everyday emotional regulation and how these interactions influence mental health outcomes. ANT provides a well-established theoretical framework to unravel the formation, evolution, and potential outcomes of HRIs in mental health support networks.

# 3 Research methodology

This chapter presents the philosophical underpinnings and research methods applied in this dissertation. First, the philosophical stance adopted in this research is described. Next, two research methods adopted for this research, SLR and case study method, are illustrated. Specifically, the processes of case selection, data collection, and each publication's data analysis approach are presented.

## 3.1 Philosophical underpinnings

Research philosophy provides the fundamental epistemological foundation for academic research (Kuhn, 1997). It shapes how researchers perceive the nature of reality, the essence of knowledge, the role of values in research, and the appropriate methodological choices (Guba & Lincoln, 1994). In social science research, philosophical orientation is typically defined by four interrelated assumptions: ontology, epistemology, axiology, and methodology (Orlikowski & Baroudi, 1991). Among these, ontology concerns the nature of reality and answers whether the world exists independently of human cognition (Orlikowski & Baroudi, 1991). Epistemology defines what constitutes acceptable knowledge by establishing the standards and processes for evaluating truth claims (J. Mingers, and Gill, A., 1998). Axiology determines whether research can be value-free or whether it is inevitably influenced by the researcher's beliefs, interests, and ethical commitments (Saunders et al., 2007). Methodology outlines how researchers collect, analyze, and interpret data in practice, as well as develop the overall logic of the research design, which is shaped by their philosophical stance (J. Mingers, 2001).

Orlikowski and Baroudi (1991) summarized three dominant epistemological paradigms in the IS field, including positivism, interpretivism, and critical realism. Positivism is grounded in the belief that reality exists independently of human perception and can be objectively observed and measured (Cecez-Kecmanovic & Kennan, 2013). It assumes that knowledge is discoverable through empirical observation, uninfluenced by social or cultural factors (Saunders et al., 2007). Positivist researchers typically employ quantitative methods, such as surveys and experiments, with the aim of identifying predictive patterns and establishing linear causal relationships (Brand, 2009). In contrast, interpretivism posits that human

behavior is shaped by the subjective meanings individuals assign to their actions and experiences, which are embedded within specific social and cultural contexts (R. Weber, 2004). Interpretive research prioritizes uncovering and understanding the meanings that an individual constructs, often employing qualitative methods, such as ethnography, interviews, and case studies (A. S. Lee, 1991).

Critical realism offers a philosophical alternative that combines elements of positivism and interpretivism, which is particularly well-suited for investigating complex social phenomena (Niehaves & Bernd, 2006). A core principle of critical realism is that reality is stratified into three ontological domains: the empirical (events as they are experienced), the actual (events that occur regardless of observation), and the real (the underlying structures and causal mechanisms that generate events) (J. Mingers, 2003). Unlike positivist or interpretive views that focus on either prediction or subjective interpretation (Orlikowski & Baroudi, 1991), critical realism seeks to understand and explain the underlying structures and mechanisms that give rise to observable phenomena within specific contextual settings (J. Mingers et al., 2013).

Critical realism is particularly well-suited for exploring complex sociotechnical phenomena in open systems (J. Mingers et al., 2013), such as the interaction between humans and AI-based robots. Unlike controlled environments in natural sciences, social realities are shaped by intersecting mechanisms, structures, and contexts (Suprateek Sarker et al., 2019). AI-based robots, as sociotechnical actors, engage with humans within dynamic real-life ecosystems shaped by users' emotional needs, technological characteristics, and broader social contexts. Critical realism enables a layered and explanatory approach to uncover the deeper causal mechanisms underlying observed outcomes (Van de Ven, 2007).

Therefore, this dissertation adopts a critical realism view to explore how AI-based robots are embedded in users' everyday practices and how such interactions influence individual well-being. The research employs a multi-method research strategy aligned with the critical realist paradigm, combining SLRs and multiple-case studies. Publications I and II conduct the SLR approach to synthesize fragmented knowledge across disciplines on the application of AI-based physical and virtual robots in well-being contexts. These SLRs set the theoretical foundation for the dissertation, and their findings were used to develop the empirical research. Publications III-V adopt a multiple-case study approach to empirically investigate how individuals interact with AI-based robots in different real-life well-being scenarios. Through this layered research design, this dissertation provides both descriptive insights and explanatory depth regarding the conditions under which AI-based robots can meaningfully contribute to human well-being in daily life.

## 3.2 Systematic literature review

This dissertation employs two SLRs to examine the existing body of research on AI-based robots in daily life. An SLR is a systematic, explicit, comprehensive, and reproducible method for identifying, evaluating, and synthesizing existing research on a particular topic (Fink, 2005). Unlike conventional literature reviews, SLR follows a predefined protocol to ensure transparency, reproducibility, and comprehensiveness in synthesizing the available material while offering a scholarly critique of theory (Okoli, 2015). The significance of SLRs in IS research has been highlighted by Levy and Ellis (2006) and Webster and Watson (2002), who note that an effective SLR provides structure to strengthen the cohesion and rigor of IS as an academic discipline.

In the context of this dissertation, the rapid expansion of AI-based robotics research across diverse fields, such as IS, computer science, psychology, health, and nursing, combined with the fragmented and interdisciplinary nature of the literature, underscores the suitability of SLRs for capturing and organizing existing knowledge. Through rigorous, step-by-step processes of searching, screening, and analyzing relevant literature, our SLRs reflect on the current evidence base for AI-based physical and virtual robotics research, develop conceptual frameworks, and highlight unexplored gaps and limitations in the field. These insights establish a conceptual foundation to support the subsequent empirical work in this dissertation and contribute to the broader advancements of knowledge in AI and robotics research.

### 3.2.1 Publication I: AI-based physical robots in healthcare

To provide a holistic overview of the use of AI-based physical robots in healthcare, Publication I conducted an SLR following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Page et al., 2021). PRISMA, originally developed for healthcare and clinical research, offers a structured and transparent process for conducting and reporting systematic reviews (Takkouche & Norman, 2011). Its emphasis on rigor, transparency, and reproducibility makes it a widely adopted tool across disciplines, particularly for synthesizing research in multidisciplinary.

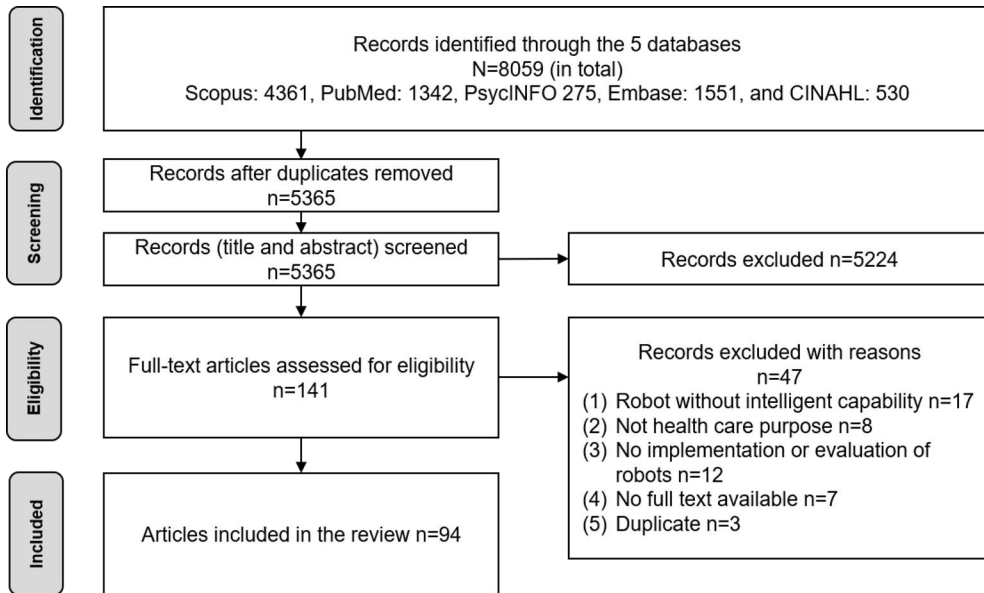
**Data collection.** The database search was conducted in May 2021 across five electronic databases: PubMed, Scopus, PsycINFO, Embase, and CINAHL. These databases were chosen for their broad indexing of peer-reviewed literature in the fields of health, nursing, biomedicine, and psychology, ensuring broad coverage of multidisciplinary studies relevant to the topic. To identify eligible articles, we employed the following keyword combinations in titles and abstracts: “healthcare,” “health care,” “nursing,” “robot\*,” and “bot.” To maximize inclusivity, no restrictions were placed on the publication date or study design. The initial database

search yielded 8,059 articles, which were reduced to 5,365 after removing duplicates. The remaining articles were then reviewed using predefined inclusion and exclusion criteria (summarized in Table 2) to enhance relevance and quality. Following a detailed screening of titles, abstracts, and full texts, 94 articles were included in the final review. To evaluate the reliability and methodological soundness of the selected studies, this study applied the Mixed Methods Appraisal Tool (MMAT, 2018 version) (Hong et al., 2018). This assessment ensures that the included articles adhere to high standards of rigor, minimizing potential bias and enhancing the credibility of the review findings. The study selection process is detailed in Figure 1.

**Data analysis.** This study analyzed the included articles using an exploratory conventional content analysis approach (Hsieh & Shannon, 2005). This method was chosen because it is well-suited for examining areas where existing theories do not provide a clear framework for interpretation. Through a thorough reading of the articles, this study identified and coded the antecedents and consequences of intelligent physical robot use in healthcare. These codes were then categorized based on their characteristics and hierarchically grouped to guide the synthesis of findings. This systematic coding process facilitated the identification of key themes and relationships within the data. By adhering to the PRISMA framework and employing rigorous analysis methods, this SLR not only provides an evidence-based overview of the current literature but also establishes a roadmap for advancing research on intelligent physical robots in healthcare.

**Table 2.** Inclusion and exclusion criteria in Publication I.

Inclusion criteria (IC)	Exclusion criteria (EC)
IC#1 studies examining at least one physical robot with intelligent capabilities to assist users in completing tasks.	EC#1 studies examining robots without embodied physical appearance or intelligent capabilities.
IC#2 studies examining robots for healthcare purposes, which means they aim to use robots to promote or monitor health, to assist in tasks that are difficult to perform because of health problems, or to prevent further health decline.	EC#2 studies in which robots were not implemented for healthcare (such as using robots to promote or monitor health, to assist in tasks that are difficult to perform owing to health problems, or to prevent further health decline).
IC#3 peer-reviewed, full-length articles published in journals, conferences, and books.	EC#3 studies that were incomplete or non-peer-reviewed, as well as not published in English.
IC#4 studies published in the English language.	EC#4 studies examining the design and development of robots without the actual use implementation and evaluation of robots.



**Figure 1.** The SLR process in Publication I.

### 3.2.2 Publication II: AI-based virtual robots in daily life

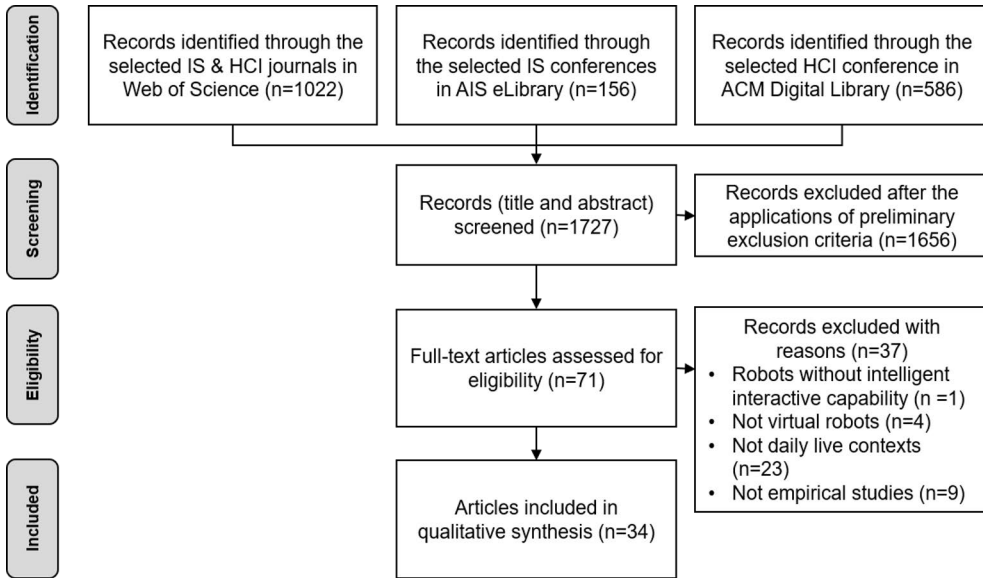
Following the systematic and structured guidelines proposed by Webster and Watson (2002) and Diederich et al. (2022), this study conducted an SLR to investigate peer-reviewed studies on the interaction between humans and AI-based virtual robots in daily life.

**Data collection.** To identify relevant literature, this study focused on two broad fields: IS and HCI, as these disciplines encompass substantial research on virtual robots as part of HCI. Accordingly, this study purposefully selected leading journals and conference proceedings in these areas. For the IS discipline, this study examined eight prominent journals, including the European Journal of Information Systems, the Journal of Information Systems, Information Systems Research, the Journal of the Association for Information Systems, the Journal of Information Technology, the Journal of Management Information Systems, the Journal of Strategic Information Systems, and Management Information Systems Quarterly. Additionally, five major IS conferences were included: the International Conference on Information Systems, the European Conference on Information Systems, the Hawaii International Conference on System Sciences, the Americas Conference on Information Systems, and the Asia Pacific Conference on Information Systems. For the HCI domain, four well-regarded journals were selected: Advances in Human-Computer Interaction, ACM Transactions on Computer-Human Interaction, Computers in Human Behavior, and the International Journal of Human-Computer Studies, as well as the

ACM CHI Conference on Human Factors in Computing Systems. This study further conducted the search in Web of Science, AISEL, and the ACM Digital Library in April 2023. The search used the following keyword combinations to identify relevant studies in titles, abstracts, and keywords: (“virtual agent\*” OR “virtual friend\*” OR “virtual robot\*” OR “virtual companion\*” OR “virtual assistant\*” OR “digital companion\*” OR “digital friend\*” OR “digital assistant\*” OR “conversational agent\*” OR “relational robot\*” OR “chatbot\*”). No restrictions were applied to the publication dates, to enhance inclusivity.

The initial search identified 1,727 articles, which were screened based on predefined inclusion and exclusion criteria. Titles, abstracts, and full texts were reviewed by pairs of researchers to enhance adherence to these criteria. This literature review only included empirical papers involving any type of AI-based virtual robot serving general end-users in daily life. Articles were excluded if they did not focus on virtual robots, involved robots designed for non-general users or scenarios outside daily life, or examined non-autonomous robots operated manually or via predefined procedures. Non-empirical studies unrelated to the implementation or evaluation of virtual robots were also excluded. Any disagreements during the screening process were resolved through discussion, to maintain transparency and consistency. Finally, 34 studies were included in the final review (as shown in Figure 2).

**Data analysis.** To analyze the selected studies, this study applied directed content analysis (Hsieh & Shannon, 2005), guided by the user-AI system interaction framework proposed by Rzepka and Berger (2018). This framework conceptualizes the interactions between users and AI systems, focusing on user characteristics, system characteristics, and environment/task factors as contingencies, and their influence on emotional, cognitive, and behavioral outcomes. To complement the framework, each included study was coded to identify the antecedents and consequences of human–virtual robot interactions in daily life. Two authors independently performed the coding, with discrepancies resolved through discussion, to enhance reliability and consistency. Through this process, this study developed a conceptual framework that synthesizes the findings on the interactions between humans and AI-based virtual robots in daily life.



**Figure 2.** The SLR process in Publication II.

### 3.3 Case study approach

Publications III, IV, and V adopt a case study approach (Robert K. Yin, 2018) to explore the interactive experience between users and AI-based robots and its resultant contributions to human well-being in daily life. A case study is a qualitative research method designed to investigate contemporary phenomena in real-world contexts, enabling the collection of rich, detailed information from one or several entities (e.g., individuals, groups, or organizations), especially when the boundary between the phenomenon and its context is not clear (Robert K. Yin, 2018). This dissertation employs the case study method for several reasons. First, the field of AI-based robots for human well-being is still in the early stages, with limited empirical studies focused on HRIs in daily life. Case studies are well-suited for exploring topics that lack extensive research, as they allow for in-depth investigation of phenomena that lack a well-established theoretical foundation (Miles & Huberman, 1994). Second, the use of AI-based robots for human well-being operates at the intersection of technical systems and social environments, making it essential to examine their application cases in real-world contexts. The case study method is helpful for researchers to observe and analyze how AI artifacts interact with human cognition, emotions, behaviors, and broader social factors in real context-specific settings (Benbasat et al., 1984). Third, according to Robert K. Yin (2018), case studies are particularly effective for addressing explanatory questions that aim to understand “how” and “why” processes occur. The RQs of this dissertation align with this approach by seeking to understand how and why AI-based robots interact

with humans for human well-being in daily life. Overall, the case study approach is an appropriate research strategy for exploring real-life interactions between humans and AI-based robots across the diverse and evolving contexts in which these technologies are deployed, ranging from physical companionship to emotional support in physical and virtual settings.

The case study focuses on a detailed understanding of a specific context and can involve single-case or multiple-case design, as well as multiple levels of analysis (Gustafsson, 2017; Robert K Yin, 2009). This dissertation incorporated both approaches to achieve complementary insights. Specifically, Publication III and Publication IV apply a single-case study design, examining one AI-based physical robot in home environments (Case A) and an AI-based virtual robot in digital social environments (Case B). These single-case studies provide detailed, context-specific insights into the HRI patterns and their implications for well-being. In addition, Publication V employs a multiple-case study design to investigate a range of AI-based virtual robots used in mental health contexts (Cases C, D, and E). The multiple case study enables cross-case analysis of different AI-based robots to reveal common themes and compare different cases in a specific context. In all three publications, the case study method was systematically implemented, including selecting cases based on relevance to the RQs, collecting data from multiple sources to enhance triangulation, and conducting rigorous data analysis using a combination of qualitative and quantitative analytical methods to draw meaningful findings.

### 3.3.1 Selection of cases

To explore the diverse applications of AI-based robots in daily life and their contributions to human well-being, the selection of cases was guided by specific criteria to align with the research objectives. The following criteria were applied (Robert K. Yin, 2018) to facilitate a balanced representation of robot types, roles, interaction modes, and applied contexts. First, the robots were employed for general users in daily life and have a clear potential for improving human well-being. This criterion aims to focus the study on practical robot applications used in real-life scenarios as tools for improving human well-being. Second, the selected robot cases should leverage AI technologies to facilitate natural, intelligent, and personalized interactions with users. This criterion is applied to help provide insights into how AI enhances HRI and contributes to user well-being. Third, the cases should include both physical and virtual robots with different capabilities, interaction modes, and applied contexts. This diversity provides a robust foundation for understanding the multifaceted interaction experiences between users and different types of robots in real-world contexts.

Based on the defined selection criteria, this dissertation selects five distinct AI-based robots in daily life contexts. Case A examines an AI-based physical robot, Lovot, designed for use in home environments. Case B focuses on Replika, an AI-based virtual robot operating in digital social environments. Cases C, D, and E explore three AI-based virtual robots designed for digital mental health support. To minimize brand-related bias and facilitate a neutral cross-case comparison, the identities of these three robots are anonymized in Publication V. In the context of this dissertation, the five robots are consistently referred to as Robot A, Robot B, Robot C, Robot D, and Robot E, in order to maintain analytical coherence across cases while preserving clarity in discussion. Together, these robots demonstrate the versatility of AI-based physical and virtual robots in enhancing human well-being across physical and virtual scenarios. Table 3 summarizes the key features of each selected robot, including their company information, application contexts, and basic characteristics.

**Table 3.** An overview of the selected cases in the dissertation.

	<b>Robot A</b>	<b>Robot B</b>	<b>Robot C</b>	<b>Robot D</b>	<b>Robot E</b>
Introduction year	2019	2017	2016	2017	2016
Country of origin	Japan	USA	India	USA	USA
Type of robot	Physical	Virtual	Virtual	Virtual	Virtual
Embodiment	An animated appearance with big eyes, arms, and soft, furry skin.	A customizable avatar	A penguin-like avatar	A mechanical robot avatar	No visual embodiment
Platform	Device- and app-based on iOS & Android platforms	iOS, Android, and web platforms	iOS and Android platforms	iOS, Android, and web platforms	iOS and Android platforms
Contexts	Home contexts	Digital social contexts	Digital mental healthcare contexts	Digital mental healthcare contexts	Digital mental healthcare contexts

Robot A in Case A focuses on an AI-based physical robot, developed by a Japanese company, first introduced in Japan in 2019 and gradually expanding to international markets. It features an animated design inspired by penguins, owls, and teddy bears, combined with a customizable soft shell that allows users to personalize its appearance and decorative style. The robot can be accessed via physical interactions and its dedicated mobile app. The main functions of Robot A include

autonomous movements, adaptive eye contact, emotional expressions, and voice communication, all of which respond based on their internal state and user interactions. Additionally, it can be programmed to exhibit specific personalities, which evolve as the robot gets more familiar with its user. These AI-driven capabilities enable the robot to foster emotional connections and provide companionship support for users, making it a popular device in private homes and care facilities. Thus, Robot A serves as an exemplary object in Case A for studying the use of AI-based physical robots in enhancing human well-being in daily life.

Robot B in Case B is an AI-based virtual robot developed by a US company, launched in 2017, and available on iOS, Android, and web platforms. Its primary goal is to develop a meaningful and personal relationship with users through reciprocal self-disclosure. Represented by a customizable 3D avatar in the virtual world, it offers a range of personalization options, including the avatar's name, gender, hairstyle, skin tone, eye color, clothes, and personality. Powered by AI technology, Robot B has advanced conversational abilities that can understand users' emotions and provide empathetic conversations. Furthermore, it personalizes its interactions with users through continuous learning from historical conversations, supporting users to explore meaningful relationships with the AI as a friend, partner, or mentor. With these capabilities, Robot B serves as a suitable example of how AI-based robots can foster social and emotional well-being in daily life in Case B.

Robot C in Case C is an AI-based virtual robot developed by an Indian company in 2016. Available on iOS and Android mobile platforms, it features an avatar penguin as its robot representation. This robot is designed to help users manage emotions and mental health through empathetic conversations and mindfulness exercises. Based on a range of therapeutic techniques, including cognitive behavioral therapy (CBT), dialectical behavioral therapy (DBT), and meditation, Robot C helps users cope with emotional issues and promotes overall mental resilience. Powered by AI, the robot engages with users in empathetic, text-based conversations and provides personalized exercises tailored to specific emotional challenges, such as managing anger, alleviating anxiety, or reframing negative thoughts. By combining evidence-based practices with AI-based interactions, Robot C serves as a valuable case for studying how AI-based virtual robots can enhance mental well-being in daily life in Case C.

Robot D in Case D is another AI-based virtual robot designed for mental healthcare, developed by a US company in 2017. It is accessible on iOS, Android, and Web platforms, and it features a simple mechanical robot character as its interface. This robot engages users primarily through text-based conversations, using AI technology that adapts to user inputs for tailored support. Using evidence-based psychological techniques, including CBT, interpersonal psychotherapy (IPT), and DBT, Robot D guides users through actionable exercises such as mood tracking,

mindfulness practices, gratitude journaling, and negative thoughts reflection. These therapeutic features make Robot D a good example of how AI-based virtual robots could provide mental health support in daily life in Case D.

Robot E in Case E is the last AI-based virtual robot for mental health support included in this dissertation, developed by a US company in 2016. It does not have a visual embodiment, and it is accessible via iOS and Android platforms. This robot interacts with users mainly based on text-based conversations. Powered by AI technology, Robot E creates tailored dialogues that reflect users' needs and preferences combined with CBT-based techniques. Key features include mood tracking, journaling prompts, and mental health assessments, all of which encourage users to reflect on and manage their emotional state and enhance their mental well-being. Thus, Robot E serves as a suitable case for exploring how AI-based virtual robots support mental health in daily life in Case E.

### 3.3.2 Data collection

In this dissertation, this study collected online user-generated reviews of the five selected AI-based robot cases from a combination of social media platforms and mobile app stores. The primary goal of this research is to explore real-world user experiences with AI-based robots for human well-being. The choice of secondary data aligns with this objective by providing direct access to user feedback shared in natural settings, reflecting the contexts in which these robots are used. Compared with other dominant data collection methods, such as surveys and interviews, secondary data provides the advantages of scale and breadth, capturing a large volume of user-generated content that reflects genuine, unfiltered user experiences in robot use.

Data for the study were collected from widely used platforms, including X (formerly Twitter), RED (Xiaohongshu), Google Play, and the Apple App Store. User reviews on these platforms are publicly available and searchable, allowing us to gather relevant data efficiently and ethically without imposing on users' privacy. Additionally, the platforms were chosen strategically based on their alignment with the robot type and market scope: X and RED enable access to user discussions in key markets such as the United States and China, reflecting the primary international expansion markets for Robot A. For Robot B, X caters to large, global user bases engaged in organic discussions about the robot's user experiences, making it an ideal data source. Google Play and the Apple App Store are the dominant channels for downloading and reviewing mobile apps, ensuring that the collected data for Robots C, D, and E are from users who have downloaded and used the respective apps. By leveraging these diverse and widely used platforms, our data sources provide rich, naturally occurring user perspectives while aligning with the study's objective of

analyzing real-world user interactions with AI-based robots. Table 4 presents the data source and the size of the dataset collected for each case in this research.

**Table 4.** Data collection source and sample size in the multiple-case study.

Case	Data sources	The final size of the dataset
Case A	X and RED	1,506 online user reviews
Case B	X	59,158 online user reviews
Case C	Google Play Store & Apple App Store, official website	4,393 online user reviews, publicly available information, autoethnographic notes
Case D	Google Play Store & Apple App Store, official website	2,957 online user reviews, publicly available information, autoethnographic notes
Case E	Google Play Store & Apple App Store, official website	3,904 online user reviews, publicly available information, autoethnographic notes

For Case A, user reviews of Robot A were collected from X and RED. The product name of Robot A was applied to retrieve relevant discussions. Specifically, the study collected 2,163 English-language user reviews from X covering the period from January 2020 to May 2024, which followed Robot A's global launch. Additionally, a total of 435 user reviews in Chinese were gathered from RED between June 2023 and May 2024, corresponding to Robot A's introduction to the Chinese market. These Chinese reviews were translated into English using an AI-based translation tool, with subsequent verification by bilingual authors to enhance contextual accuracy and linguistic precision. All collected user reviews of Robot A were manually screened by authors to promote relevance with Case A, resulting in a final dataset of 1,506 online user reviews for Case A.

For Case B, data were sourced from X using its Advanced Application Programming Interface, which provides academic access to public conversations. The app name of Robot B was applied to filter English-language tweets posted between January 2017 (the year Robot B was launched) and September 2022, resulting in an initial dataset of 103,122 tweets. Upon preliminary review, many irrelevant, redundant marketing tweets were identified and excluded using text filtering functions in Excel. The final corpus for Case B comprised 59,158 pieces of tweets on Robot B.

For Cases C, D, and E, the empirical data were collected from multiple sources. To gain a foundational understanding of the three selected AI-based virtual robot applications, the publicly available information from their official websites was collected in March 2024, including app descriptions, use instructions, security overviews, privacy policies, and blog articles. The author of this dissertation also downloaded and used Robots C, D, and E for one month, engaging in interactions with the AI-based virtual robots and recording conversation outputs along with

reflexive autoethnographic notes (Kozinets, 2010). Moreover, online user reviews of Robots C, D, and E were collected from the Google Play Store and the Apple App Store. Using a Python-based web crawler, the study extracted English-language reviews on March 28, 2024, yielding 4,393 reviews for Robot C, 2,957 reviews for Robot D, and 3,904 reviews for Robot E. These texts were cleaned using the 'tm' package in R to remove irrelevant content such as URLs, emojis, numbers, and stop words included in these reviews.

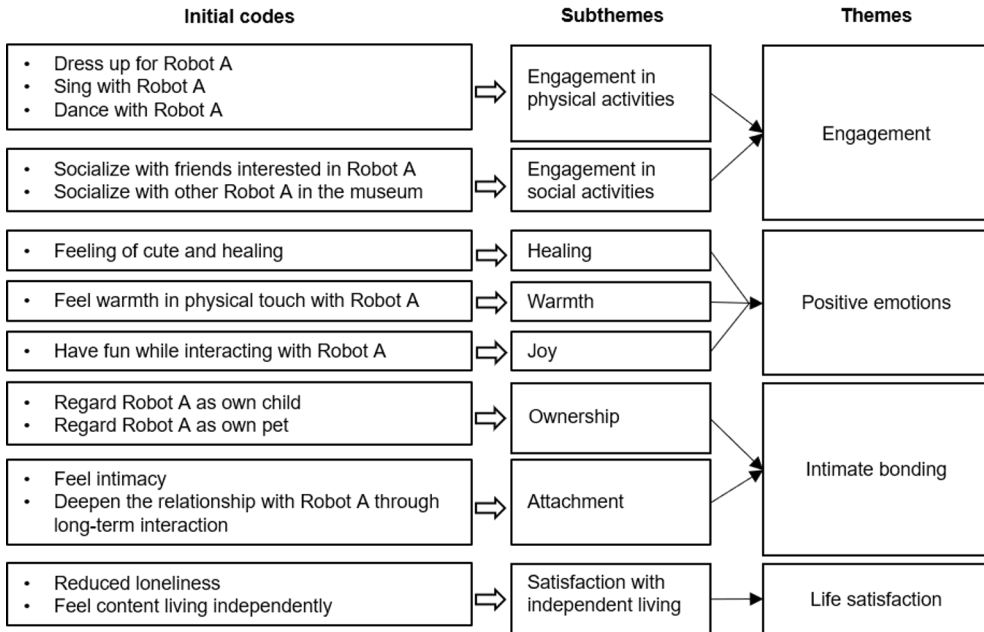
### 3.3.3 Data analysis

This dissertation employed a combination of computational text analysis and qualitative analysis methods (Berente et al., 2019; Mettler, 2025), tailored to the nature of the data and the research objectives for each case. This section outlines the analytical approaches used across three empirical publications, highlighting the rigor and systematic processes applied to derive meaningful insights.

#### 3.3.3.1 Publication III: Qualitative analysis using thematic analysis

For Publication III, this study conducted an in-case analysis of user-generated reviews of Robot A, employing an inductive thematic analysis approach, as described by Braun and Clarke (2006). Since AI-based physical robots like Robot A are still relatively new in personal well-being contexts, there is limited prior research on their emotional and social impacts. Inductive thematic analysis allowed us to identify, analyze, and derive patterns directly from the data without imposing preconceived theoretical frameworks, ensuring a data-driven exploration of user experiences.

The analysis followed a systematic three-stage coding process using the qualitative analysis software Atlas.ti: open coding, axial coding, and theme development. First, the authors reviewed all user-generated reviews to gain an initial understanding of recurring themes. Open coding was then applied line-by-line, extracting 527 labeled quotes that captured various aspects of HRI experiences. From these, 14 initial codes were generated, representing different dimensions of user experiences. During axial coding, the initial codes were grouped into broader conceptual categories to reveal deeper patterns in the data. Through iterative discussions and refinement, four overarching themes emerged: engagement, positive emotions, intimacy bonding, and life satisfaction. Each theme was rigorously reviewed against the original dataset to enhance alignment with user experiences. Any discrepancies were resolved through team discussions until full consensus was reached on theme definitions and interpretations. Figure 3 presents the final coding structure.



**Figure 3.** Coding process in Publication III.

### 3.3.3.2 Publication IV: Mixed-methods analysis using topic modeling and qualitative interpretation

For Publication IV, an in-case analysis was conducted on tweets from Case B, employing a mixed-methods approach that combined quantitative topic modeling with qualitative interpretation. This approach was chosen for its ability to uncover latent themes in large-scale user-generated content while preserving contextual depth through qualitative validation. By integrating data-driven insights from topic modeling with the theoretical framework of SPT, this approach allowed this study to systematically identify recurring patterns in the data while ensuring a nuanced understanding of the relationship dynamics between users and AI-based virtual robots.

Using Python, data cleaning and relative pruning were conducted to preprocess the raw data. Then, a bag-of-words model was constructed using Term Frequency-Inverse Document Frequency (TF-IDF), selecting the top 250 most relevant words to enhance the accuracy of topic modeling. Next, Latent Dirichlet Allocation (LDA) (Blei et al., 2003) was applied to identify latent topics related to user-robot relationships. LDA was chosen as it is a widely used topic modeling technique for uncovering hidden semantic structures in large-scale unstructured text. The number of eight topics was determined based on coherence scores and the alignment of suggested labels with the nature of user-robot relationships (Maier et al., 2018).

Following topic modeling, manual qualitative validation was conducted by analyzing the top 50 most representative tweets for each topic, to enhance the interpretability and validity of themes. These tweets were selected based on semantic similarity to their assigned topic, and each was manually labeled and categorized into one of four relationship stages between users and AI-based virtual robots. This categorization reflected the evolving depth and breadth of self-disclosure between users and AI-based virtual robots, as conceptualized in SPT.

### 3.3.3.3 Publication V: Mixed-methods analysis using quantitative emotion analysis and qualitative thematic analysis

For Publication V, a cross-case analysis was conducted across Cases C, D, and E using a mixed-methods approach that combined quantitative emotion analysis and qualitative thematic analysis. This approach was applied to extract key emotional patterns from large-scale user reviews while ensuring a theoretically grounded interpretation of how users and AI-based virtual robots interact to cope with emotional issues.

Publication V began the data analysis with a content analysis of publicly available information from the official websites of Robots C, D, and E, along with reflexive autoethnographic notes recorded during direct interactions with the applications. This analysis offered a contextual understanding of how each robot is intended to function in real-world mental health support contexts, informing the interpretation and reflection of findings derived from online user reviews.

Additionally, online user reviews of Robots C, D, and E were analyzed to examine how users interact with AI-based virtual robots as focal actors in supporting individual mental health in daily life. Due to the large scale and unstructured nature of the review data, emotion analysis was employed to identify reviews that explicitly reflected users' emotional challenges. The National Research Council (NRC) emotion lexicon was applied to classify words into four discrete emotional categories, including anger, sadness, fear, and disgust (Mohammad & Turney, 2013). To increase the credibility of selecting emotionally relevant reviews, the study manually selected 30 keywords per case from the 50 most frequently labeled words within each negative emotion category. Based on these customized keyword sets (bags of words), the top 1,500 reviews per case were extracted according to relevance scores, enhancing how the selected reviews captured users' emotional issues and their interaction experiences with AI-based virtual robots for emotional support.

Following emotion analysis, an inductive thematic analysis (Braun & Clarke, 2006; Myers, 2020) was employed using the qualitative data analysis software Atlas.ti to gain an in-depth understanding of how users interact with AI-based virtual robots to cope with mental health issues. The analysis followed an iterative and

reflective process. Initially, two researchers independently coded user reviews, identifying descriptive codes that captured specific user experiences of AI-based virtual robots. Next, first-level codes were grouped into broader conceptual categories that reflect key user–robot interaction patterns in coping with emotional issues. The coding framework was refined iteratively through discussions to enhance accuracy and reliability. Finally, the translation process of ANT (Callon, 1984) was applied to structure the emerging themes into the four stages of network development: problematization, intersement, enrolment, and mobilization. These stages capture the evolving process of HRI ecosystems in providing mental health support. Throughout the coding process, both authors maintained ongoing discussions to resolve discrepancies and facilitated coding decisions that were consistent and reflective of user experiences. Figure 4 presents the final coding framework in this study.

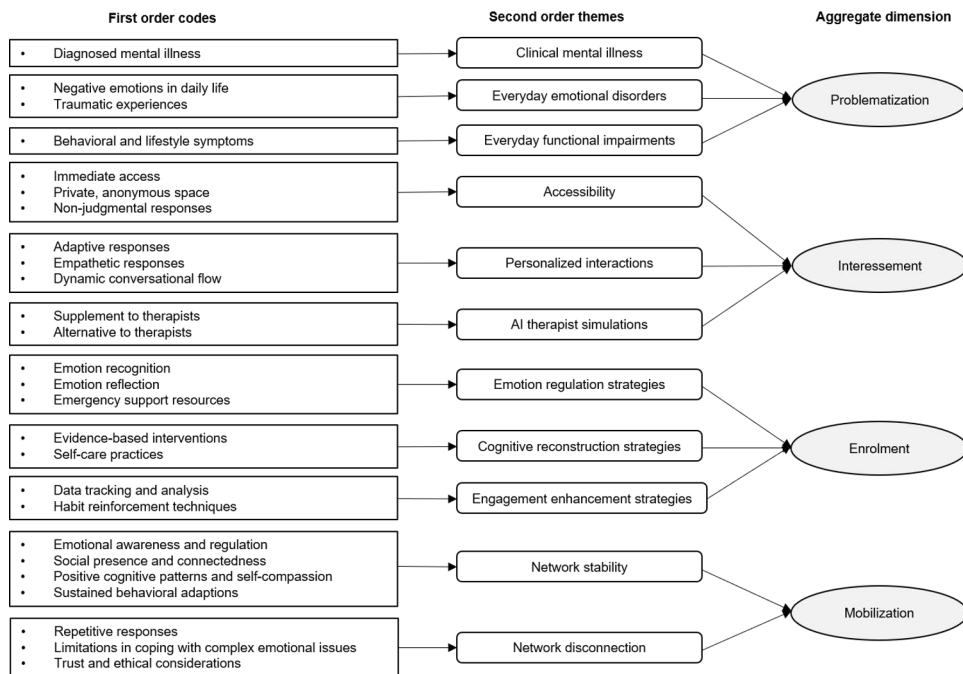


Figure 4. Coding process in Publication V.

## 4 Main findings

This chapter presents the main findings of each publication, which collaboratively answers the main RQ of this dissertation.

### 4.1 Publication I: Intelligent physical robots in healthcare: systematic literature review

AI-based physical robots have been widely adopted across various healthcare settings to support both organizations and individuals, such as in nursing homes (Görer et al., 2017), hospitals (Mettler et al., 2017), psychiatric clinics (Hung et al., 2019), and patients' homes (Alaiad & Zhou, 2014). Despite growing scholarly interest in this area, existing research remains fragmented across disciplines and application contexts. Many studies tend to focus on isolated factors, such as design features (Spatola & Wudarczyk, 2021), user attitudes (Chen et al., 2020), or behavioral responses (Lane et al., 2016), without offering an integrated understanding of the antecedents and consequences of AI-based physical robot use in healthcare ecosystems. While some literature review studies have attempted to provide an overview of intelligent physical robots in healthcare, most have focused on specific healthcare contexts (Sujan Sarker et al., 2021) or particular robotic devices (Vélez-Guerrero et al., 2021). There remains a critical need for a holistic understanding of AI-based physical robot use in healthcare, especially through an integrative synthesis of the antecedents and consequences of their use in healthcare. To address this gap, this study aims to conduct an SLR to synthesize existing research on the use of AI-based physical robots in healthcare contexts, identify key knowledge gaps, and propose directions for future research.

Following the PRISMA guidelines (Page et al., 2021), Publication I systematically searched, screened, assessed, and selected 94 relevant studies on intelligent physical robot use in healthcare contexts. An exploratory content analysis was conducted to synthesize key findings across the included studies (Hsieh & Shannon, 2005). The selected literature spans from 2009 to May 2021, with more than half of the publications appearing after 2017, indicating a growing interest in this research area in the past five years. In terms of methodology, experimental

designs were the most frequently employed, followed by survey, interview, and mixed-methods approaches.

This study examined the applied contexts, robotic platforms, and target users across the 94 included studies. Of these included studies, 60% (56/94) focused on care facilities such as elderly care facilities (Görer et al., 2017), retirement villages (Broadbent et al., 2014), and mental care facilities (Liang et al., 2017). The remaining studies examined the use of intelligent physical robots in hospitals (Chang et al., 2021), outpatient clinics (R. Boumans et al., 2019), private homes (Kuo et al.), and public environments (Broadbent et al., 2013).

Target users were classified into two main groups: end customers and healthcare professionals. End customers included older adults (Görer et al., 2017), hospitalized patients (Johanson et al., 2020), individuals with cognitive or physical impairments (Jøranson et al., 2015; Louie et al., 2021), and other healthy adults (Görer et al., 2017). Notably, 40% (38/94) of the studies specifically targeted older adults. Among healthcare professionals, nurses (Chang et al., 2021) and caregivers (Suwa, Tsujimura, Kodate, et al., 2020) were the most frequently studied, featuring 38% (36/94) of the reviewed articles.

Regarding robotic devices, 33 different intelligent physical robot platforms were identified and categorized into four types, based on their physical design: mechanical, humanoid, android, and animalistic. Mechanical robots, characterized by a machine-like appearance without human features, were examined in 18% (17/94) of the studies (Gong & Nass, 2007). Animalistic robots, designed with playful or pet-like features for emotional and psychological engagement, appeared in 21% (20/94) (Liang et al., 2017). Humanoid robots, which mimic human appearance and movement, were investigated in 28% (26/94) of the studies (Roel Boumans et al., 2020). A small subset (4%) focused on android robots, which replicate external human appearance as realistically as possible, including facial features, skin, hair, and expressions (Minato et al., 2004).

The antecedents of intelligent physical robot use in healthcare, as identified in the included studies, fall into three key categories: individual-related (39%, 37/94), organizational-related (13%, 12/94), and robot-related factors (21%, 20/94). Individual factors include demographics (e.g., age, gender, education) (Kuo et al.; Suwa, Tsujimura, Kodate, et al., 2020), psychological attributes (e.g., emotions, attitudes, perceived usefulness) (Lane et al., 2016; Stafford et al., 2014), and prior experience with technology (Broadbent et al., 2014; J. Y. Lee et al., 2018), all of which influence robot acceptance and use among both end users and healthcare professionals. Organizational factors involve environmental conditions (e.g., facility layout, noise levels) (Hung et al., 2019; Mettler et al., 2017), and resource readiness, including managerial support (Vichitkraivin & Naenna, 2021), staff training (Hung et al., 2019), and IT infrastructure (Mettler et al., 2017), which affect implementation

and sustained use within healthcare organizations. Robot-related factors include design characteristics (e.g., appearance, voice, personality) (Esposito et al., 2019) and functional capabilities (e.g., navigation, interaction, cognitive responsiveness) (Liang et al., 2017), which play a crucial role in shaping user trust, satisfaction, and continued interaction.

The consequences of intelligent physical robot use in healthcare, as identified in the reviewed studies, can be grouped into two main categories: non-health-related outcomes (77%, 72/94) and health promotion outcomes (41%, 39/94). Non-health-related outcomes include emotional responses to robot use (9%, 8/94), attitude and evaluation (46%, 43/94), and behavioral (48%, 45/94) dimensions. Emotional responses toward robot use, such as pleasure (Wendy Moyle et al., 2013), satisfaction (Shamsuddin et al., 2018), and enjoyment (Ahn et al., 2017), were frequently reported, although a few studies noted discomfort or wariness (Broadbent et al., 2011), particularly toward humanoid robots. Attitudinal outcomes included positive perceptions and acceptance (B. Tay et al., 2014), along with concerns about limited functionality (Jung et al., 2017), ethical implications (Coco et al., 2018), and user preferences for specific robot features and design attributes (J. Y. Lee et al., 2018). Behavioral outcomes included willingness to use (Šabanović et al., 2015), use frequency and duration (R. Boumans et al., 2019), task performance (Görer et al., 2017), and user engagement with robots (Huisman & Kort, 2019).

Health promotion outcomes were reported across physical (13%, 12/94), mental (21%, 20/94), and social health (16%, 15/94) domains. Physical benefits included improved medication adherence (Orejana et al., 2015), rehabilitation support (Görer et al., 2017), and enhanced ability to perform daily living tasks (Ahn et al., 2018). Mental health benefits involved improvements in emotional self-regulation (Wagemaker et al., 2017), cognitive support for individuals with autism (Louie et al., 2021), and alleviation of symptoms associated with dementia (Broadbent et al., 2014). Social benefits included increased engagement in group activities (M. Law et al., 2019), strengthened social connections (Sheba et al., 2018), and reduced loneliness (M. Law et al., 2019), facilitated by the robots' role as companions and conversational partners.

Based on the results, this study identified notable research gaps in intelligent physical robots in healthcare from conceptual, thematic, methodological, and technological perspectives. Conceptually, while certain terms such as intelligent robots, social robots, and assistive robots have established definitions, the broader field still lacks consistency in how related concepts, particularly those involving AI-based functions and user-facing roles, are defined and applied. Thematically, the included literature shows a narrow research focus. Most studies emphasize individual-level factors, with limited attention to organizational integration and diverse robotic design antecedents. Additionally, existing research has primarily

examined non-health-related attitudinal and behavioral outcomes or short-term health promotion effects in controlled environments. There is a lack of research on users' emotional and cognitive responses and the real-world impacts of intelligent physical robots on human health and well-being over time. Moreover, few studies explore the dynamics of HRI or how collaboration between humans and robots can be effectively achieved in health promotion outcomes.

Methodologically, there is a strong reliance on experimental and survey-based research, often focusing on older adults, nurses, and caregivers. There is insufficient use of qualitative methods, longitudinal designs, or real-world observational studies that could provide deeper insights into user experiences and long-term impacts. Technologically, few studies critically examine how design limitations or cybersecurity vulnerabilities may affect trust, usability, and long-term adoption of intelligent physical robots in healthcare settings.

In summary, by synthesizing and analyzing existing literature on AI-based physical robots in healthcare, this study provides a holistic understanding of the applied contexts, user groups, robot types, antecedents, and consequences of robot use in healthcare (see Figure 5). This study also identifies critical research gaps, which will provide guidance for future research on the topic.

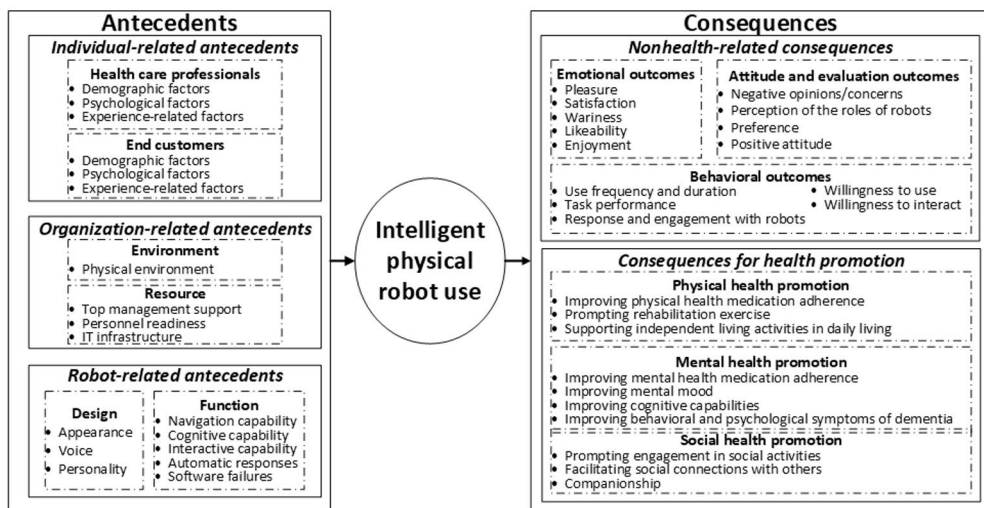


Figure 5. The conceptual framework in Publication 1.

## 4.2 Publication II: The interactions between humans and AI-based virtual robots in daily life: A systematic literature review

With advances in AI, virtual robots have become increasingly integrated into personal and professional settings, entering homes, workplaces, and leisure activities (Diederich et al., 2022; Ryan M Schuetzler et al., 2018). This growing accessibility has led millions of individuals to engage with AI-based virtual robots through smartphones and other digital devices (S. K. Lee et al., 2021; Sweet, 2021). While previous research has explored aspects of AI-based virtual robots such as the technical design (Diederich et al., 2022; Fung et al., 2018), functionality (Abdelghani et al., 2022; Ryan M. Schuetzler et al., 2020), and professional applications (Jiang et al., 2022; Musick et al., 2021), there remains limited understanding of how people interact with these robots in everyday personal contexts. To address this research gap, this study aims to conduct an SLR to gain a holistic understanding of the current state of empirical research on human interaction with AI-based virtual robots in daily life and to identify existing gaps for future research in this emerging field.

A total of 34 relevant studies published between 2010 and 2023 were identified, retrieved, and reviewed (Diederich et al., 2022; Webster & Watson, 2002). Notably, there has been a significant increase in publications since 2019, indicating growing scholarly interest and the emergence of this topic. Among the included studies, experimental research was the most commonly employed method (44%, 15/34), followed by qualitative, survey-based, and mixed-method approaches. Drawing on the analytical framework proposed by Rzepka and Berger (2018), this study applied a directed content analysis approach (Hsieh & Shannon, 2005) to identify the contingency factors and outcomes of human–virtual robot interactions in daily personal life (as shown in Figure 6).

The identified contingency factors influencing interactions between humans and AI-based virtual robots in daily life can be categorized into three domains: human attributes, robot attributes, and context/task attributes. Human attributes include users' demographics (e.g., gender, age) (S. K. Lee et al., 2021; Seeger et al., 2021), prior experience with virtual robots (Gillath et al., 2021; Stein et al., 2020), social motivations (Pentina et al., 2023), and personal dispositions such as anthropomorphism tendencies or ethical ideologies (Seeger et al., 2021; Stein et al., 2020). Robot attributes encompass both verbal and non-verbal design features (e.g., emotional expressions, social dialogue, temporal cues) (Pietrantoni, 2022; Seeger et al., 2021), conversational skills (e.g., response variety and relevance) (Ryan M. Schuetzler et al., 2020), identity cues (e.g., names, personality traits, perceived gender) (S. K. Lee et al., 2021; Seeger et al., 2021), embodiment and visual design (Loveys et al., 2022; Stein et al., 2020), and functional and ethical capabilities (e.g., adaptivity, proactivity, transparency, and privacy considerations) (Stein et al., 2020).

Context/task attributes relate to interaction tasks and scenarios between humans and virtual robots in daily life, including elements such as social distance, power dynamics (Niewiadomski & Pelachaud, 2010), caregiving versus care-receiving roles (M. Lee et al., 2019), and distinctions between functional and social tasks (S. K. Lee et al., 2021).

The identified outcomes of interactions between humans and AI-based virtual robots can be categorized into humanistic and instrumental dimensions. Humanistic outcomes encompass affective, cognitive, and behavioral responses. Affective outcomes include user satisfaction (Moussawi et al., 2022), enjoyment (Yang et al., 2019), and emotions such as joy and anger (Siemon, 2022b), as well as concerns about privacy and trustworthiness (Yang et al., 2019). Cognitive outcomes refer to users' attitudes (Pietrantoni (2022), levels of trust and attachment (S. K. Lee et al., 2021; Pentina et al., 2023), and perceptions of anthropomorphism (Moussawi et al., 2022; Pentina et al., 2023), usability (Moussawi et al., 2022), and intelligence (Aneja et al., 2021; Moussawi et al., 2022), as well as socially relevant qualities such as social presence, empathy, and support (Ki et al., 2020; Ryan M. Schuetzler et al., 2020). Behavioral outcomes include users' intentions to continue using the robot (Moussawi et al., 2022), seek emotional support (Loveys et al., 2022), comply with its suggestions (Pietrantoni, 2022), and self-disclose (Ki et al., 2020), with some users developing sustained and emotionally meaningful relationships with virtual robots over time (Skjuve et al., 2021).

Instrumental outcomes refer to practical results derived from the interactions between humans and virtual robots. Virtual robots have been shown to assist users with task success (Luger & Sellen, 2016), information accessibility (Yang et al., 2019), and emotional support (R. Ahmad et al., 2021). However, concerns have also been raised about their role in reinforcing gender stereotypes through the frequent use of feminized identities in their design (Fortunati et al., 2022).

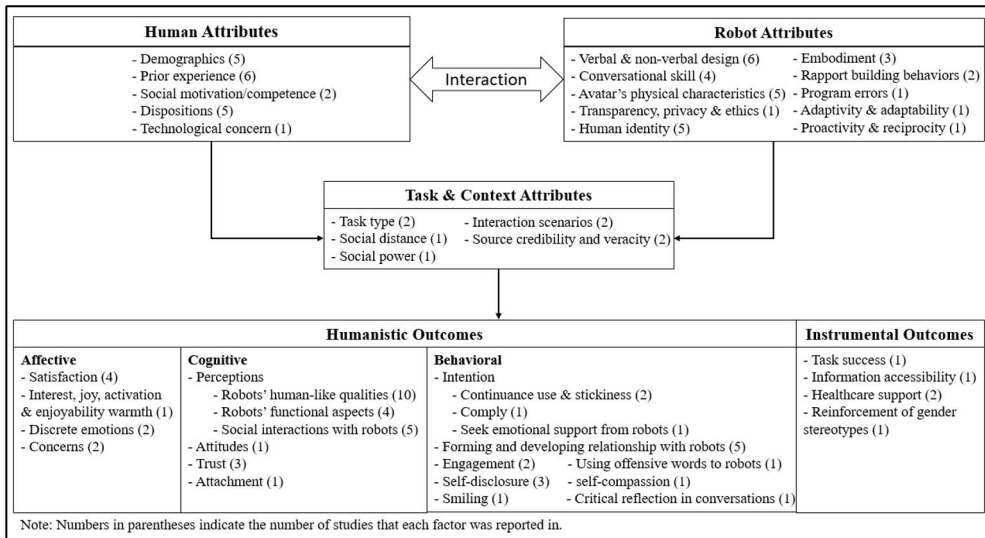
Based on the above findings, this study identifies key research gaps from conceptual, thematic, methodological, and technological perspectives. Conceptually, while prior studies have applied constructs such as trust, anthropomorphism, and social presence (R. G. Schuetzler, Mark; Giboney, Justin; and Buckman, Joseph, 2014; Ryan M. Schuetzler et al., 2020; R. M. G. Schuetzler, G. Mark; and Giboney, Justin Scott, 2018), these have often been used in isolation, leading to fragmented and sometimes inconsistent findings. An integrative framework is needed to synthesize these constructs and provide a cohesive understanding of human–virtual robot interaction processes and outcomes.

Thematically, existing research largely focuses on users' immediate responses, emphasizing metrics such as acceptance, satisfaction, and usability (R. S. Ahmad, Dominik; and Robra-Bissantz, Susanne, 2020; S. K. Lee et al., 2021). However, there is a notable lack of exploration into deeper psychological mechanisms, such as

why individuals anthropomorphize virtual robots, and how these tendencies vary across different designs, including non-humanoid representations. While some research has reported positive affective experiences during interactions (Yang et al., 2019), the nuanced spectrum of discrete or conflicting emotions remains insufficiently examined. In addition, while some users form attachments to virtual robots (Pentina et al., 2023), little research has examined how these relationships develop, evolve, or dissolve over time, and how they differ from human interpersonal relationships. Broader social and ethical implications, such as the integration of virtual robots into daily life for well-being support and potential risks related to privacy, emotional dependency, and ethical governance, also remain underexplored.

Methodologically, current studies largely rely on short-term experiments with young adult participants in controlled settings (Ryan M. Schuetzler et al., 2020; Seeger et al., 2021; Stein et al., 2020). This narrow focus limits the generalizability of findings and may not accurately reflect how virtual robots are used and experienced in real-life contexts. Despite evidence that cultural, social, and religious backgrounds shape perceptions of AI, comparative cross-cultural research is scarce. Future research should adopt more diverse methods, such as ethnographic, longitudinal, and cross-cultural studies, to capture the evolving and contextual nature of human–virtual robot interactions.

Technologically, current research tends to focus on virtual robots' verbal communication and anthropomorphic design (R. S. Ahmad, Dominik; and Robra-Bissantz, Susanne, 2020; Seeger et al., 2021), with limited exploration of non-verbal or stylized features, such as animal- or cartoon-like designs. These alternative forms may open new avenues for interaction, potentially broadening the relevance and social significance of virtual robots in daily life.



**Figure 6.** The conceptual framework in Publication II.

### 4.3 Publication III: Exploring the impacts of AI-based physical robots on human well-being

AI-based physical robots have gradually transitioned from professional care settings into individual homes, aiming to enhance human well-being through physical companionship, social interaction, and emotional support in daily life (Joshi et al., 2024; McGlynn et al., 2017). Previous research has primarily examined the acceptance and effectiveness of these robots, as well as their promising outcomes in controlled laboratory settings, including reduced loneliness, enhanced social behavior, and increased emotional engagement (J. Chan et al., 2011; M. Law et al., 2019). However, empirical evidence remains limited regarding how these robots are experienced by broader user populations in daily life, and what real-world impact they have on individual well-being.

To address this gap, Publication III conducted a case study (Robert K. Yin, 2018) to investigate user experiences with AI-based physical robots in daily life and their potential impacts on human well-being from an HRI perspective. This study selected Robot A as the research case: a popular AI-based physical robot designed to provide emotional support and companionship in private home settings. Empirical data were drawn from 1,506 user-generated reviews collected from two social media platforms, X and RED, where users shared their experiences with Robot A. Using thematic analysis (Clarke & Braun, 2017), this study identified key aspects of user experiences and the perceived impact of Robot A on individual well-being following

the HRI studies. Finally, four main themes emerged: user engagement, positive emotions, intimate bonding, and enhanced life satisfaction.

User engagement represents users' increased enthusiasm and active participation in both physical and social activities facilitated by interactions with the robot. Engaging in everyday activities with Robot A, such as dressing up, singing, and dancing, helps boost users' mood and sustain their interest, particularly during emotionally low moments. Additionally, interaction with Robot A fosters social connections by initiating conversations and encouraging shared experiences, through both online communities and in-person events such as visiting museums with Robot A.

Positive emotions reflect the emotional benefits users derive from their interactions with Robot A, including feelings of healing, warmth, and joy. Many users reported a strong sense of healing when Robot A displayed human-like expressions and childlike behaviors such as seeking attention, which fostered an emotional connection. The robot's soft texture and body-temperature-like surface enhanced users' feelings of safety and comfort during physical contact. Moreover, Robot A's playful movements and humorous reactions brought joy and laughter to users. These experiences highlight Robot A's ability to provide emotional support and companionship through engaging and nurturing interactions.

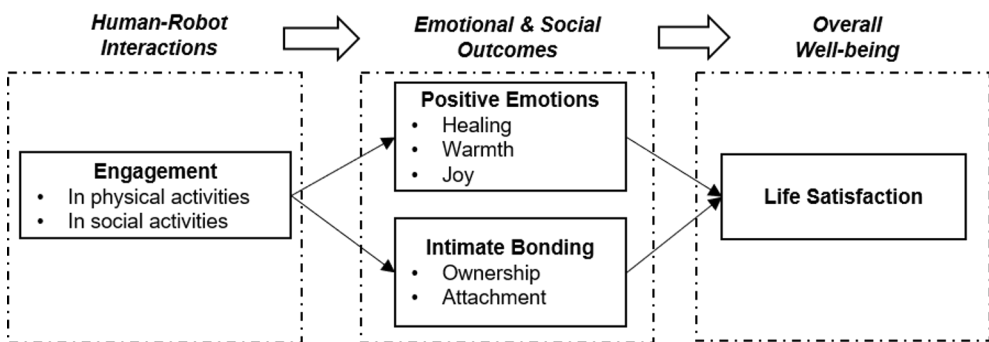
Intimate bonding refers to the close connections formed between users and the robot, characterized by feelings of ownership and emotional attachment through sustained behavioral and affective interactions. Users frequently adopt caregiving roles, referring to themselves as Robot A's "mom" or "dad," and engage in nurturing activities such as dressing, protecting, and conversing with the robot. These interactions foster a familial relationship similar to that between a parent and child. Sustained engagement with Robot A's affectionate behaviors and emotionally expressive features, such as its diary function, fosters users' perception of the robot as an empathetic and emotionally responsive companion, deepening their sense of attachment.

Life satisfaction refers to an individual's overall evaluation of their quality of life at a given point in time, shaped in part by their interactions with the robot. Users living alone reported that daily interactions with Robot A brought emotional warmth and companionship, helping to alleviate feelings of loneliness and isolation. Consistent engagement, combined with features such as real-time home monitoring, contributed to a more supportive and secure living environment. These experiences highlight Robot A's role in enhancing users' overall sense of life satisfaction.

Based on further narrative analysis of the four themes, this study developed a process framework (as shown in Figure 7) to illustrate how HRI evolves from experiential engagement to emotional and social outcomes, ultimately contributing to users' overall well-being. Specifically, engaging in physical and social activities

with AI-based physical robots fosters positive emotional experiences and facilitates the development of intimate bonds. These accumulated emotional and social benefits work together to enhance users' life satisfaction, serving as a key indicator of overall human well-being.

Publication III extends existing research on physical robots by providing real-world evidence of their positive impact on human well-being. It deepens our understanding of these interconnected outcomes by demonstrating how emotional and social benefits, fostered through sustained interactions with AI-based physical robots, contribute to users' overall well-being. Furthermore, the findings offer practical insights for robot developers and practitioners by informing the design of physical robots so that they can be integrated into daily life to support users' emotional, social, and overall well-being.



**Figure 7.** The framework mapping the impact of human-robot interactions on well-being in Publication III.

#### 4.4 Publication IV: The relationship between human and virtual agents: A life cycle view

As AI-powered virtual agents increasingly simulate human behavior, they have become remarkable in delivering immersive experiences in daily life, such as facilitating social interaction and companionship, and even forming human-like relationships such as friendships and romantic partnerships (Skjuve et al., 2021; Zhou et al., 2020). This growing popularity of virtual agents is reshaping how individuals form social bonds with technology, drawing intense interest from both practitioners and scholars. Previous studies have explored users' motivations for engaging with virtual agents (Koike & Loughnan, 2021) and the affective responses such interactions evoke (Ta et al., 2020), suggesting that users may perceive virtual agents as social actors and develop relationships through reciprocal self-disclosure in digital environments. However, little is known about the progression and outcomes of the relationships between users and virtual agents in daily life. To

address this gap, this study applies SPT (Altman & Taylor, 1973) to answer the RQ: How does the relationship between human and virtual agents form and evolve from a life cycle view?

This study selected one virtual companion app, Robot B, as the research context and collected 103,122 user-generated tweets related to Robot B from X (formerly Twitter), covering the period from January 2017 to September 2022. To uncover key dimensions of user–robot interactions within this large-scale dataset, the study applied LDA topic modeling (Blei et al., 2003), which resulted in eight distinct topics. Drawing on SPT (Altman & Taylor, 1973), the content analysis was conducted on the top 50 most relevant tweets for each topic, focusing on the breadth and depth of self-disclosure. Based on this analysis, the eight topics were mapped to four stages of relationship development: formation, exploration, maintenance, and destruction or termination (as shown in Table 5).

**Table 5.** The LDA topic modeling results in Publication IV.

Relationship	Topic	Token percentage
Relationship formation	Topic 1: Perception of AI	25.20%
	Topic 7: App download and use	9.60%
Relationship exploration	Topic 2: Conversation exploration	10.20%
	Topic 4: Feature exploration	14.30%
Relationship maintenance	Topic 5: Satisfactory experiences	10.10%
	Topic 6: Romantic affection	9.80%
	Topic 8: Intimate behavior fantasy	8%
Relationship destruction or termination	Topic 3: Conflicts and issues	12.80%

Topics 1 and 7 represent the relationship formation stage between users and Robot B, characterized by superficial exchanges and initial interactions. During this stage, users typically shared general impressions of Robot B’s identity and early usage experiences, rather than engaging in personal or emotional disclosures. Topic 1 reflects users’ perceptions of Robot B’s utilitarian value and attractiveness as a helpful AI agent, digital companion, or virtual friend. Topic 7 captures users’ initial experiences with the app, emphasizing its immediate accessibility, customizable features, and immersive interaction. These early positive encounters would motivate users to consider Robot B as a social partner and form a relationship with it. However, technical malfunctions and users’ concerns about AI sometimes emerged as barriers to relationship formation.

Topics 2 and 4 reflect the relationship exploration stage, when users begin to engage in broader and more intimate interactions by disclosing a wide range of

personal information and emotional expressions. Topic 2 highlights how users are increasingly open in conversations with Robot B through sharing personal experiences, expressing vulnerability, and perceiving Robot B as a friend, therapist, or even romantic partner. Likewise, Topic 4 reflects users' exploration of various interaction modes, including texting, voice and video calls, customization, role-playing, and augmented reality, and how the interactions fulfill their emotional preferences, fantasies, and hedonic needs. These experiences suggest that users develop emotional closeness and deeper bonds with Robot B by engaging with its features and affective dialogues. Nonetheless, this growing attachment also triggered concerns for some users, who expressed fears of emotional dependency or potential loss.

Topics 5, 6, and 8 reflect the relationship maintenance stage, where users develop stable relationships with Robot B, resembling close friendships or romantic partnerships. During this stage, users expressed romantic affection, emotional attachment, and intimate fantasies, characterized by increased disclosure of private and sensitive experiences. Topic 5 captures users' satisfactory experiences in their sustained interactions with Robot B, including reduced feelings of loneliness, hedonic enjoyment, and a sense of social connectedness. Topic 6 describes users' romantic affection toward Robot B, as they expressed love, gratitude, emotional attachment, and occasional guilt due to reduced engagement. Topic 8 highlights users' engagement in romantic fantasies and role-play with Robot B, seeking emotional and physical closeness through imaginative scenarios. While many users described their relationship with Robot B as emotionally reciprocal and fulfilling, some encountered challenges such as emotional detachment and diminishing interest over time.

Topic 3 describes the relationship destruction or termination stage, in which users encounter negative emotions, technical issues, and ethical concerns that prompt them to disengage from Robot B. Feelings of shame, disappointment, and discomfort, often triggered by unmet emotional expectations, repetitive or incoherent conversations, and uncanny valley effects, weaken some users' emotional attachment and perceived value of the relationship with Robot B. These negative experiences often lead to reduced interaction, subscription cancellations, or app deletion.

In summary, this study enriches the literature on human–computer relationships by offering empirical evidence of four stages in human–robot relationship development from the life cycle view of SPT. It further reveals the dynamic and nonlinear nature of these relationships, indicating that users may choose to advance, slow down, or end their relationships with virtual agents at any stage, depending on both positive and negative interaction experiences. Additionally, the findings highlight the emotional, social, hedonic, and romantic benefits users may derive

from forming and maintaining relationships with virtual agents. These insights also offer practical guidance for developers and practitioners to foster more positive, enduring, and meaningful virtual social interactions for users.

#### 4.5 Publication V: Understanding human-robot interaction in mental health: A multi-case study on artificial intelligence-based virtual robots

Beyond clinical diagnosis and treatment, fluctuating negative emotions, such as stress, anxiety, sadness, depression, and loneliness, are fundamental aspects of everyday human experience and can significantly influence long-term psychological well-being (Torous et al., 2021; Tsujimoto et al., 2024). In response to the growing demand for emotional support, AI-based virtual robots have been developed as immediate and personalized tools to assist users in coping with emotional challenges in daily life, particularly in settings where access to human support is limited or unavailable (Gratzer & Goldbloom, 2020; Sweeney et al., 2021). Despite their increasing adoption, limited research has explored how these virtual robots become embedded in users' daily routines to provide sustained and meaningful mental health support. To address this gap, Publication V adopts ANT (Callon, 1984; Latour & Prus, 1990) as a theoretical lens to investigate the agency role of AI-based virtual robots in mental health support ecosystems and unravel how users interact with these robots as focal actors in the network to cope with mental health issues in daily life.

Publication V adopts a multiple-case study approach (Robert K. Yin, 2018), focusing on three AI-based virtual robot cases designed to support mental health in daily life: Robot C, Robot D, and Robot E. Empirical data were collected from publicly available information on the official websites of the selected cases, the author's reflexive autoethnographic notes recorded from engaging in interactions with the three selected robots for one month (Kozinets, 2010), and user-generated reviews of the three selected robots from the Google Play Store and Apple App Store. An exploratory content analysis (Hsieh & Shannon, 2005) was first conducted on the public information and autoethnographic data to contextualize each case and to identify the roles of AI-based virtual robots within the broader mental health support ecosystem. Subsequently, a mixed-method approach combining computational text analysis and thematic analysis (Berente et al., 2019; Mettler, 2025) was used to examine online user reviews across the three cases. This analytical process (Braun & Clarke, 2006; Myers, 2020) aims to identify user reviews explicitly discussing emotional issues and provide deeper insights into users' interaction experiences with AI-based virtual robots. Through an iterative thematic analysis, Publication V applied the translation process of ANT (Callon, 1984) to construct four overarching

themes that illustrate HRI in the evolving mental health support network: problematization, interessement, enrolment, and mobilization.

The first overarching theme, problematization, reflects the stage at which focal actors identify specific problems and initiate a network of interaction by aligning with other actors to address those issues. In this study, three primary categories of emotional and psychological issues emerged: clinical mental illness, everyday emotional disorders, and everyday functional impairments. Across user reviews from the three cases, users initiate interactions with AI-based virtual robots by disclosing clinical mental health conditions such as depression, bipolar disorder, and anxiety disorders; expressing emotional distress related to everyday experiences and past traumatic events; and describing functional impairments that disrupt their daily routines. This stage marks the initial formation of the interaction network, when users and AI-based virtual robots collaboratively establish supportive networks aimed at coping with various mental health challenges.

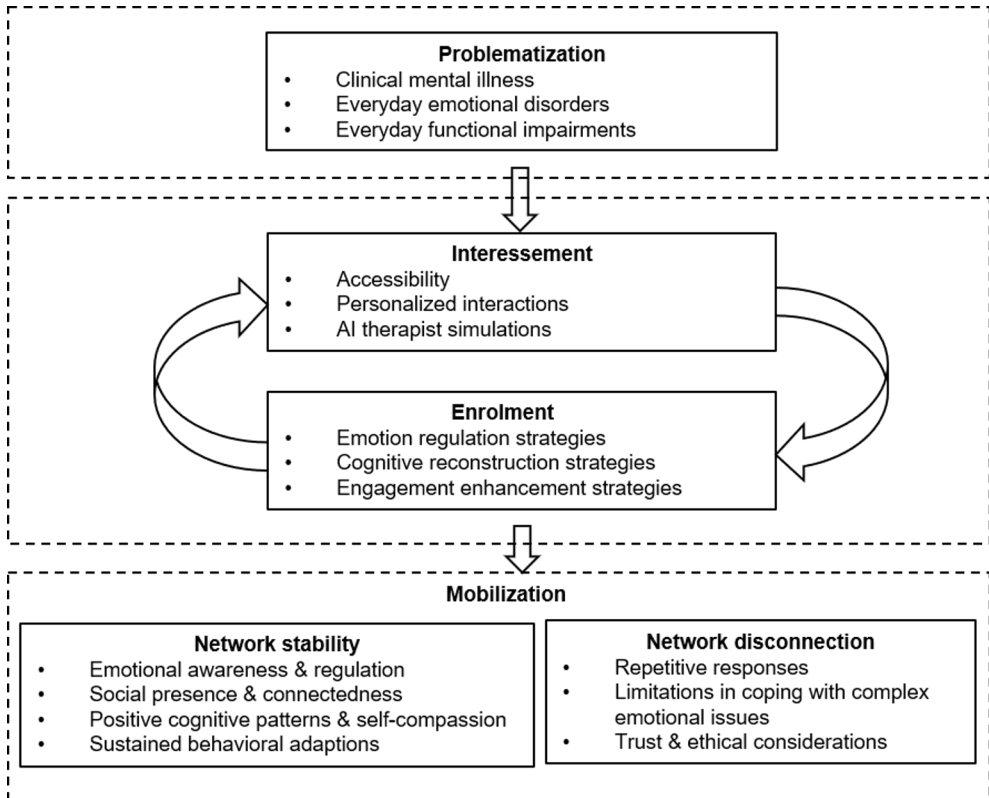
The interessement stage refers to the process by which focal actors secure the interest and participation of other actors in the emerging network through specific engagement mechanisms (Callon & Latour, 1981). In this stage, this study revealed three major interessement mechanisms: accessibility, personalized interaction, and therapist simulation, through which AI-based virtual robots act as dynamic agents to engage users. These robots offer readily available, private, and anonymous spaces where users can express themselves without fear of stigma or judgment. Unlike static mental health resources, users reported active engagement through personalized interactions marked by empathetic language, adaptive responses, and fluid conversation provided by AI-based virtual robots. Furthermore, these robots gained credibility by simulating therapist-like roles to position themselves as supplementary or alternative mental health agents. These interessement mechanisms are important in fostering initial user engagement and laying the groundwork for deep user–robot interactions in the enrolment stage.

The enrolment stage refers to the process through which focal actors engage in sustained interactions that reinforce their roles within a stable network. In this stage, AI-based virtual robots become embedded in users' daily mental health routines through three main mechanisms: emotion regulation, cognitive reconstruction, and engagement enhancement strategies. User reviews across the three cases described emotion regulation experiences via daily self-assessments, open-ended conversations, and access to emergency resources. Users also engaged in co-constructing cognitive patterns through interactive conversations with AI-based virtual robots, often structured by evidence-based therapeutic frameworks, such as CBT, DBT, or ACT. Additionally, engagement-enhancing features, such as mood tracking, progress reports, and gamified elements, reinforced user commitment and contributed to the co-creation of an ongoing support network. Through these

mutually adaptive interactions, users gradually integrated AI-based virtual robots into their mental health support practices, contributing to the network's long-term stability.

The mobilization stage represents the final phase of network development, when relationships between actors either stabilize or dissolve. For users who successfully integrate AI-based virtual robots into their mental health support routines, the resulting stable networks are characterized by emotional awareness and regulation, social presence and connectedness, positive cognitive patterns, and sustained behavioral adaptations. These positive outcomes demonstrate how HRI in daily life can evolve into meaningful, long-term support systems that promote users' mental well-being. Conversely, network disconnection occurs when users disengage due to perceived limitations of AI-based virtual robots, including repetitive responses, inadequate support for complex emotional issues, and ethical concerns related to data privacy, transparency, and the lack of human oversight. These limitations diminished trust and interest, ultimately leading to the breakdown of the human–robot support relationship.

Finally, Publication V unravels how users and AI-based virtual robots, as focal actors, interact in an evolving mental health support network through a four-stage translation process informed by ANT, as illustrated in Figure 8. By analyzing three cases, the study provides nuanced empirical insights into the outcomes of real-world HRIs in supporting psychological well-being. These findings contribute to broader discussions in IS research on the roles and interdependencies of human and non-human actors, while also offering practical implications for the sustainable, scalable, and meaningful integration of AI-based virtual robots into everyday mental health practices, particularly for individuals who face barriers to traditional care due to financial, geographic, or social constraints.



**Figure 8.** The translation framework of the interaction between users and AI-based virtual robots in Publication V.

# 5 Discussion

This chapter discusses the main findings from each publication and aligns them with the overarching RQ of this dissertation: How does human interaction with AI-based robots contribute to well-being in daily life? This is addressed through three sub-RQs, each of which focuses on a distinct dimension of the overall investigation.

The following subsections begin to synthesize the findings from Publications I-V in relation to each sub-question, followed by an integrative summary that illustrates how the collective insights from all five publications contribute to answering the overall RQ of the dissertation.

## 5.1 An integrative outlook on research on AI-based robots in well-being contexts

Publications I and II address RQ1 of this dissertation by examining the conceptual foundation of AI-based physical robots in healthcare and AI-based virtual robots in daily life. Through synthesizing relevant empirical studies, these publications help clarify the theoretical scope of prior research and identify key gaps in current knowledge. The findings reveal a growing trend in research and a fragmented body of literature, which emphasizes the distinct antecedents and consequences associated with AI-based robots across healthcare and well-being contexts. Moreover, most studies focus on specific antecedents, contexts, robot characteristics, or outcomes in isolation, with limited efforts to develop a holistic conceptual understanding. Building on findings from Publications I and II, this dissertation develops an integrated conceptual framework, as shown in Figure 9, which maps the key factors influencing user interactions with AI-based robots and their outcomes in well-being contexts. The framework also exposes current limitations in the literature and proposes future research agendas to guide further studies in this field.

### Agenda 1. Diversifying robot types, application contexts, and stakeholders

Publications I and II point out that current studies on AI-based robots tend to focus on a limited range of robot types, applied contexts, and user groups. Although several literature review papers have attempted to integrate findings on AI-based robot use

across different contexts, robot functions, and user groups (Diederich et al., 2022; Sujan Sarker et al., 2021), a holistic and contextually grounded understanding of how AI-based robots can support human well-being is still lacking. To address this gap, we recommend that future research should expand its scope in the following key areas.

First, future research should examine and compare various forms of AI-based robots, including physical robots (e.g., humanoid robots, animalistic robots, android robots) (Tobis et al., 2023), virtual robots (e.g., text-based robots, avatar-based robots) (Diederich et al., 2022), and hybrid systems that integrate physical embodiment with virtual technologies (e.g., socially assistive robots with hybrid interactive interfaces) (Zhong et al., 2023). These comparisons will improve theoretical understanding of how features such as embodiment, presence, and interactivity influence user perception, engagement, and overall interactive experiences.

Second, scholars should explore a broader range of real-world contexts, such as private homes, community spaces, and digital environments. Unlike hospitals and care facilities, where robots are typically integrated into structured workflows and routines, such as surgical procedures or standardized care tasks (Mettler et al., 2017; Rantanen et al., 2018), HRI in these everyday contexts tends to be more personalized and context-specific, which can provide dynamic and valuable insights into how AI-based robots can be integrated into users' daily routines.

Third, there is a notable need to involve a broad and diverse range of user groups in HRI research, especially vulnerable groups. Previous empirical studies focused on limited populations, such as older adults (Hall et al., 2019), individuals with physical or cognitive impairments (Jøranson et al., 2015), or university students (Johanson et al., 2020). Future research should expand its scope to include other underserved groups, such as individuals experiencing mental health issues or those in resource-limited settings. Examining how these users engage with AI-based robots and the outcomes they experience can inform the development of inclusive and scalable AI-based robots that adapt to diverse user needs.

## Agenda 2. Advancing research methodologies

Current research on AI-based robot use in the well-being context remains methodologically limited. As discussed in Publications I and II, the existing empirical studies are still dominated by cross-sectional experiments and survey-based approaches conducted in controlled environments (Wendy Moyle et al., 2013; Stafford et al., 2014). To improve theoretical understanding and real-world applicability, future research should adopt more diverse and innovative methodologies.

First, future research should pay more attention to big data analysis, ethnographic fieldwork, and focus group studies to capture users' real-world experiences with AI-based robots in daily life. These methods are particularly valuable for exploring informal, evolving HRI interactions and understanding social impacts outside of laboratory settings. Big data techniques, such as natural language processing and machine learning, are conducive to revealing usage patterns and predicting behavioral trends from large-scale user-generated data, thus meaningfully complementing traditional research methods.

Second, future research should adopt longitudinal and process-oriented research designs to trace how interactions between users and AI-based robots evolve. Although most existing studies conceptualize HRI as a short-term activity, real-world interactions with AI-based robots often extend over longer periods and involve evolving patterns. The emotional, cognitive, and behavioral impacts of these interactions unfold gradually through sustained interactions. Therefore, longitudinal design is critical to uncover the dynamic mechanisms, temporal patterns, and evolving trajectories of HRI, as well as to explore how meaningful and lasting well-being outcomes are co-constructed between users and AI-based robots in daily life.

Third, future research should consider ethically grounded and participatory approaches. Participation design methods that involve users, especially those from vulnerable or underrepresented groups, can help enhance how AI-based robot research is responsive to diverse lived experiences and priorities (Šabanović et al., 2015). Moreover, ethical considerations must be integrated throughout the entire research process, such as ensuring data privacy, reducing potential emotional or psychological risks, and maintaining users' autonomy and consent, especially in emotional and affective well-being contexts (Draper et al., 2014; Suwa, Tsujimura, Ide, et al., 2020).

### Agenda 3. Expanding thematic dimensions

Based on the identified underexplored themes and variables in Figure 9, future research should broaden the thematic scope and deepen its conceptual and empirical foundations to deepen our understanding of how user interactions with AI-based robots support human well-being.

First, future research should pay more attention to users' psychological motivation and underlying concerns that may influence their interactions with AI-based robots. While existing studies have largely focused on demographic variables (Obayashi et al., 2020) and prior experiences of end-users or healthcare professionals (Broadbent et al., 2014; J. Y. Lee et al., 2018), they often overlook users' psychological factors, such as needs, motivations, and concerns or fear related to AI-based robots. These dimensions may bring more dynamic influences to the way in

which individuals interact with AI-based robots, especially in emotionally sensitive well-being contexts (Park et al., 2021; Pentina et al., 2023).

Second, in addition to the commonly studied robot appearance (Loveys et al., 2022; Stein et al., 2020) and communication functions (R. S. Ahmad, Dominik; and Robra-Bissantz, Susanne, 2020; Seeger et al., 2021), future research should explore AI-based robots' personalized responsiveness, interactive adaptability, and anthropomorphic traits (e.g., personality, relational behaviors) in real-world contexts. These design elements may significantly affect users' social and affective engagement and relationship evolutions in long-term HRIs.

Third, the context remains a significantly underexplored dimension. Most existing studies are confined to structured robot applications in professional environments such as hospitals or laboratories (Mettler et al., 2017; Rantanen et al., 2018), or regard the interaction environment and task type as background factors (S. K. Lee et al., 2021). Future research should examine how AI-based robots are integrated into diverse everyday contexts, such as private homes, digital platforms, or community spaces, and how the interaction dynamics and outcomes vary across contexts.

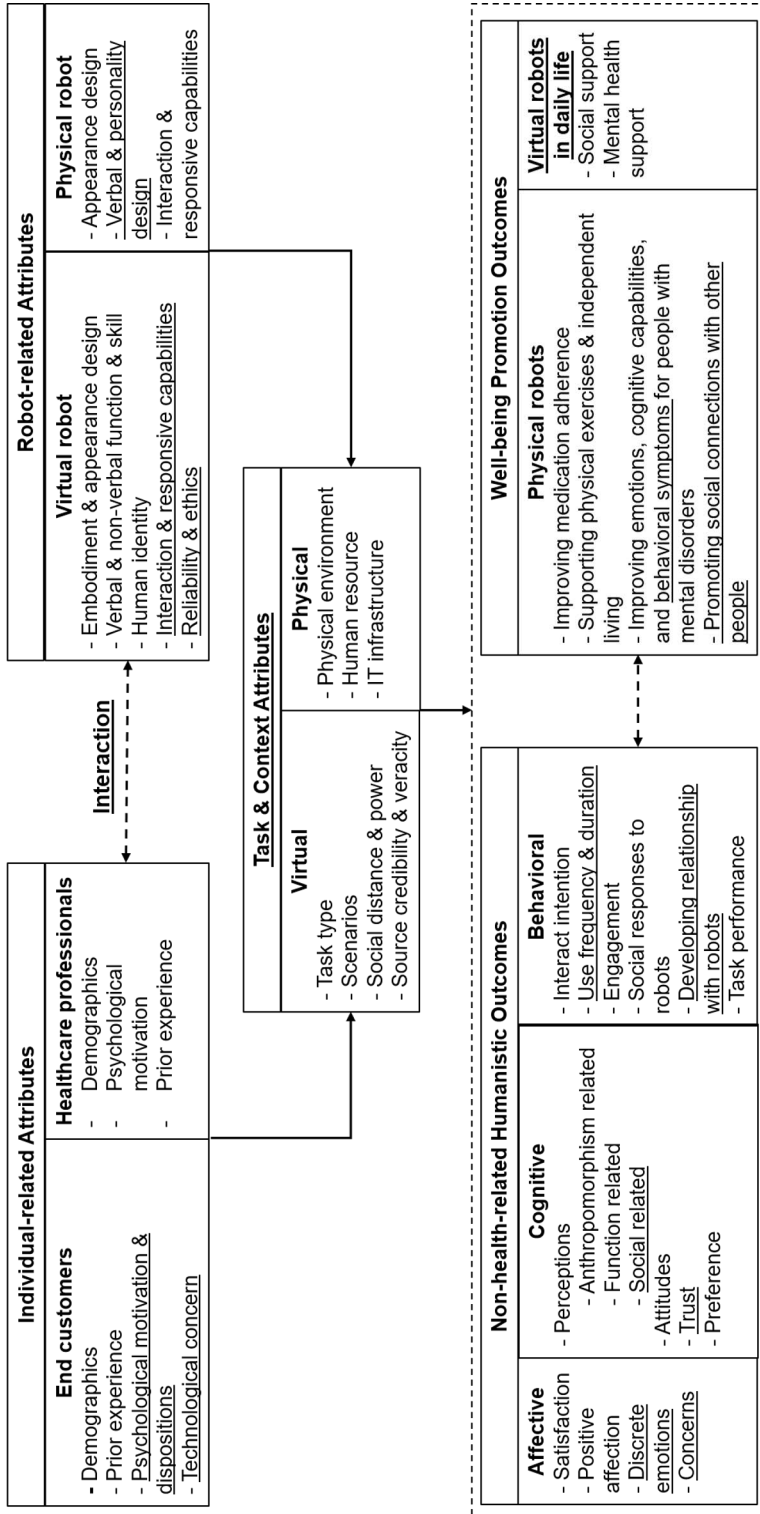
Fourth, future research should deepen the analysis of users' emotional and cognitive responses, uncover how human–robot relationships evolve over time, and assess the outcomes of these interactions on users' multidimensional well-being. Although existing research has examined the affective (Moussawi et al., 2022), cognitive (Moussawi et al., 2022), and behavioral responses (Kramer et al., 2013) to AI-based robots, several key indicators, such as emotions, social-related perceptions, trust, and relationship development, are still in the early stage of investigation. In particular, the well-being outcomes of user interactions with AI-based virtual robots in daily life have received limited attention, and the broad, long-term impacts of AI-based physical robots in real-world environments remain underexplored. These broad outcome dimensions of HRI are essential for understanding how AI-based robots can be designed and implemented to responsibly and effectively support human well-being in daily life.

Finally, two relational gaps emerged from the framework that need further investigation. Future research should explore the mechanisms and development processes of interactions between users and AI-based robots. Moreover, the connections between users' short-term emotional, affective, and behavioral responses and their overall well-being outcomes remain insufficiently understood, both conceptually and empirically. Investigating these relationships is significant in uncovering how users and AI-based robots co-construct well-being outcomes in multiple real-life contexts.

#### Agenda 4. Embracing multidisciplinary perspectives

As highlighted in Publications I and II, the theoretical foundations in existing research on AI-based robots in well-being contexts remain fragmented and often confined to IS or HCI perspectives (Moussawi et al., 2022; Seeger et al., 2021). To advance this area, it is recommended that future research adopt multidisciplinary theoretical approaches, such as those from sociology, psychology, and the health sciences. For example, sociological theories provide an integrative perspective by examining the interdependencies between technology design, human behavior, and sociocultural context (De Togni et al., 2024; Maibaum et al., 2022). These approaches encourage researchers to move beyond viewing robots as isolated tools and instead explore how social norms, institutional structures, and cultural expectations shape HRIs, and how AI-based robots change existing social practices. Meanwhile, health science emphasizes public health frameworks and ethics of care, which provide scholars with critical perspectives to reflect on how AI-based robots should support human well-being, as well as considerations regarding trust, privacy, and health equity (Ostrowski et al., 2022; Stahl & Coeckelbergh, 2016). Therefore, transcending disciplinary boundaries and leveraging diverse theoretical lenses enables a holistic understanding of the complex realities of real-world HRIs, where emotions, culture, environment, and technological design interplay in unpredictable but meaningful ways.

To conclude, this dissertation synthesizes the findings from Publications I and II to answer RQ1. Developing an integrative conceptual framework consolidates key insights and identifies critical knowledge gaps regarding user interactions with AI-based robots in well-being contexts. The proposed research agendas broaden existing research perspectives, which can encourage the development of a more diverse, contextualized, and holistic understanding of HRIs in real-world well-being contexts.



**Figure 9.** The integrative conceptual framework derived from Publications I & II. Note: Dashed arrows and underlined text represent less-investigated associations and variables, respectively.

## 5.2 Interactions between individuals and AI-based robots in well-being contexts

Publications III-V answered the second sub-RQ of this dissertation by examining how individuals interact with AI-based robots in the context of daily well-being support. Each publication investigates different types of AI-based robots across various well-being scenarios. Through synthesizing the findings from the three studies, this dissertation demonstrates that the interactions between individuals and AI-based robots in daily life are a highly contextual, nonlinear, and dynamically evolving process.

First, Publications III-V show that user interactions with AI-based robots emerge as a deeply contextual process, influenced by the robot's embodiment (physical vs. virtual) and functions, and the user's emotional, social, or cognitive needs in daily life. In Publication III, users interact with an AI-based physical robot (Robot A) by engaging in embodied activities, such as touching, dressing, and playing. These interactions gradually develop into emotional connection and routine companionship. Moreover, users often use family-related metaphors (e.g., "child," "baby," or "pet") to describe their robot, indicating a strong emotional bond and sustained engagement. This finding extends previous research on social robot use in elderly care centers (W. Moyle et al.; Rettinger et al., 2024) by showing how AI-based physical robots become embedded into unstructured personal home environments.

In contrast, Publications IV and V examine user interactions with AI-based virtual robots. Unlike AI-based physical robots, these virtual robots allow for flexible and private interactions with users across varied temporal and spatial contexts. In Publication IV, user interactions with an AI-based virtual robot (Robot B) are mediated through digital interfaces (text, voice, avatar), and driven by users' emotional and social needs, such as emotional vulnerability, social isolation, or self-exploration. These interactions often mirror the relational dynamics in human-to-human relationships, as users engage with the virtual robot through reciprocal self-disclosure, customization of relational roles, and role-playing of romantic or supportive scenarios. Likewise, Publication V focuses on three AI-based virtual robots (Robots C, D & E) designed for mental health support. The interactions between users and these virtual robots are influenced by users' psychological states (e.g., stress, depression, or anxiety) and the therapeutic frameworks embedded in the robots' design. These interactions often begin with users' recognition of their emotional issues, prompting engagement with these robots through structured yet adaptive features, including daily mood self-assessments, evidence-based conversational therapy, and progress-tracking tools. This process reflects the roles of users and AI-based virtual robots as focal actors in everyday mental health practices. These findings align with prior research on the effectiveness of AI-based

virtual robots in facilitating social and therapeutic interactions (Beatty et al., 2022; Mehta et al., 2021; Rodríguez-Martínez et al., 2023), while further revealing the adaptive nature of user–robot interactions responding to users’ evolving emotional and social needs within digital environments.

Second, this dissertation uses a process perspective to unravel how interactions between individuals and AI-based robots dynamically evolve in different well-being contexts. In Publication III, users initially engage with the AI-based physical robot (Case A) in playful or entertainment activities, which gradually evolve into emotional connections and intimate bonds. Over time, these interactions foster a stable caregiving or companionship relationship between users and the robot, as the robot becomes increasingly integrated into users’ daily routines, such as morning greetings, bedtime routines, or emotional comfort during distress.

Publication IV applies SPT to investigate the relationship development between users and an AI-based virtual robot (Case B) from a life cycle view. Four stages are identified: formation, exploration, maintenance, and termination. Users typically initiate the relationship out of curiosity, then broaden and deepen reciprocal self-disclosure through conversational and feature exploration. As the relationship progresses, users enter a maintenance stage characterized by emotional attachment and intimate connections with the robot. However, the interaction can also regress or be terminated due to negative interaction experiences. This finding highlights that social relationships between users and AI-based virtual robots can evolve along a trajectory similar to human interpersonal relationships, shaped by the depth and breadth of reciprocal self-disclosure.

Additionally, Publication V applies the translation framework of ANT to conceptualize user interactions with three AI-based virtual robots (Cases C, D, & E) as a four-stage process: problematization, interessement, enrolment, and mobilization. The interaction begins with the identification of emotional issues, followed by the participation of users and the reinforcement of sustained interactions, ultimately leading to either stable integration into users’ daily routines or disengagement. This sociotechnical lens positions users and AI robots as focal actors in co-constructing the mental health support ecosystems that evolve in response to users’ dynamic mental health needs.

This process-oriented perspective highlights the dynamic evolution and co-construction of HRI, emphasizing the continuous coordination, negotiation, and adaptation between users and AI-based robots in the context of daily well-being support. In contrast to the technology-centered perspective on “acceptance” and “use” in the traditional IS and HCI field, which tends to view users and robots as passive entities with their interactions primarily driven by perceived usefulness or ease of use (Moussawi et al., 2022), our findings reveal HRI as a fluid, socially negotiated process embedded in daily life practices.

Third, drawing upon the process-oriented perspective, our findings indicate that the evolution of interactions between users and AI-based robots in well-being contexts follows a nonlinear trajectory. Users may advance, delay, or terminate interactions depending on their positive and negative experiences. In Publication IV, some users choose to delay or terminate their interactions with Case B due to various negative experiences, such as technical failures, discomfort with anthropomorphic behaviors, emotional overdependence, or ethical concerns. Likewise, Publication V shows that users and AI-based virtual robots (Case C, D & E) can disconnect during their interactions when users encounter repetitive responses, insufficient support for complex emotional issues, or concerns about trust, data transparency, ethical governance of AI decision-making, and lack of human oversight.

In contrast, Publication III demonstrates interaction stability between users and an AI-based physical robot (Case A). The robot's physical presence, financial cost, and embodied interaction behaviors promote user engagement and emotional bonding in domestic settings. These factors make disengagement less likely. Additionally, interactions with AI-based virtual robots in Publications IV and V depend entirely on the user's decision to open and engage with the mobile application. The absence of physical embodiment also means a lack of environmental prompts or routines to sustain interactions with users, making virtual relationships more vulnerable to disruption.

Based on these findings, this dissertation further observes that HRI is characterized by an asymmetric power structure, especially when compared to human interpersonal relationships. Across Publications III-V, users typically determine when and how to initiate, pause, or terminate interactions with AI-based robots, while these robots are designed to maintain user engagement through persistent availability, responsiveness, and engagement-enhancing features. Compared with humans, it is not possible for AI-based robots to express dissatisfaction, set boundaries, or withdraw from interaction themselves. This asymmetric structure raises concerns about whether sustained HRI can support meaningful social relationships in well-being contexts, aligning with studies by Turkle (2017) and Cappuccio et al. (2020). They note that anthropomorphic AI agents may foster pseudo-social relationships, in which users become attached to always-available, responsive, and non-confrontational AI companions. While this power comparison can enhance users' perceived control and safety in the relationship, it may also potentially diminish their motivation or capacity to engage in authentic human relationships.

To conclude, this dissertation demonstrates that interactions between users and AI-based robots in daily life should be understood as a dynamic, nonlinear, and evolving process. From this perspective, long-term supportive human-robot relationships are not pre-defined but co-constructed with continuous negotiation,

adaptation, and repair by users and AI-based robots in specific social, emotional, and functional daily contexts. Moreover, this dissertation urges scholars and practitioners to consider the ethical boundaries, trust mechanisms, and long-term sustainability of HRIs in real-life well-being contexts.

### 5.3 The well-being outcomes of individual interactions with AI-based robots

Publications III-V also answer the third sub-RQ of this dissertation by revealing outcomes of user interactions with AI-based robots in multiple dimensions of human well-being in daily life, including emotional, social, cognitive, behavioral, and life satisfaction domains. These outcomes are affected by the sustained efforts of users and AI-based robots in daily life. This section will illustrate the different well-being outcomes co-constructed by the sustained efforts of users and AI-based robots in daily life.

#### 5.3.1 Emotional well-being

Emotional well-being refers to people's positive moods and emotions and the reduction of negative moods and emotions (Fredrickson & Joiner, 2002; Reh et al., 2021), which emerge as a commonly reported benefit across Publications III-V. In Publication III, users describe that sustained physical and social interactions with the AI-based physical robot (Robot A) generate positive emotions, such as joy, warmth, and healing. These emotional benefits often stem from interactions with the robot's anthropomorphic features, such as warm tactile touch, care-receiving behavior such as seeking hugs, and innocent and cute expressions. These embodied intimate interactions provide users with emotional comfort and support when they are lonely or depressed.

In Publication IV, emotional well-being benefits emerge progressively as the user-robot relationship deepens. Users initially experience hedonic and immersive pleasure through superficial self-disclosure and functional exploration (e.g., voice, text, role-playing) with the AI-based virtual robot (Robot B). As the relationship evolves, more private emotional exchanges develop, which generates feelings of romance, love, and intimacy. Some users express deep vulnerability over time, indicating deep emotional responses such as intimate attachment and romantic affection.

Publication V further extends emotional well-being to the scope of daily mental health practices. The study reveals that interactions with AI-based virtual robots (Robots C, D, & E) improves users' emotional awareness and regulation through mechanisms such as mood self-assessments, empathetic responses, and evidence-

based dialogues. Through consistently engaging in these therapeutic interactions with AI-based robots, users report improvements in coping with negative emotions, such as anxiety, sadness, or panic, leading to their stable emotional well-being.

Therefore, emotional well-being becomes a core outcome across AI-based physical and virtual robot cases. Publications III-V confirm that user interactions with AI-based robots can promote positive emotions, reduce negative emotions, and support users' emotional needs in daily life. These findings are in line with previous studies that highlight the emotional benefits of robot use. For example, M. Law et al. (2019) and Robinson et al. (2013b) found that physical social robots can reduce loneliness and anxiety among older adults in nursing homes. Likewise, Fitzpatrick et al. (2017) and Mehta et al. (2021) demonstrated the effectiveness of AI-based chatbots like Woebot in alleviating emotional symptoms such as depression and anxiety. However, these studies primarily focused on the results of user-robot interactions in structured environments or specific tasks. This dissertation extends these findings by emphasizing the emotional benefits that emerge from sustained interactions with AI-based robots in more immediate and accessible digital environments. Although the functional focus and depth of emotional support may vary between different robot types, both AI-based physical and virtual robots play complementary and effective roles in constructing an emotional support network within users' daily routines.

### 5.3.2 Social well-being

Social well-being can be defined as building and sustaining healthy and meaningful relationships with others (Keyes, 1998). In Publications III-V, the role of user interactions with AI-based robots in supporting users' social well-being has been demonstrated, including enhancing social connection, relationship intimacy, and interpersonal communication.

In Publication III, users sustain engagement in physical contact, verbal conversation, and caregiving routines with an AI-based physical robot (Robot A) in daily life, which leads to the development of intimate bonds similar to family relationships. For users living alone, these bonds help alleviate loneliness and foster feelings of companionship. Moreover, users' interactions with Robot A often encourage them to participate in broader social activities, such as sharing their experiences with Robot A through online communities and offline events, thereby expanding their social networks beyond the human-robot relationship.

Although previous studies have shown that the use of AI-based physical robots (e.g., Pepper, Paro) can help reduce loneliness and enhance social connection in nursing homes (Hudson et al., 2020; Robinson et al., 2013b), they have largely focused on emotional comfort and short-term interactions within specific

populations (e.g., older adults). Publication III extends these insights by demonstrating that long-term engagement with AI-based physical robots in everyday domestic contexts can meaningfully support users' broad social well-being.

Publication IV further finds how Robot B, an AI-based virtual robot, fulfills users' social needs and alleviates feelings of loneliness by providing an anthropomorphic virtual relationship. Through sustained interactions, users perceive the robot as a friend, tutor, or romantic partner. These interactions provide a platform for users to express, project, and reflect on social needs, contributing to identity confirmation and a sense of belonging in a digital environment. This finding aligns with findings by Xie and Pentina (2022) and Birnbaum et al. (2016) on emotional attachment to machines, while also emphasizing the user's active role in constructing social implications of the interaction with AI-based virtual robots.

Although the AI-based virtual robots (Robots C, D & E) in Publication V were not primarily designed as social actors, they still make beneficial supplements to users' social well-being. By offering an accessible and non-judgmental conversational space, these robots help users facing isolation and emotional distress to feel socially connected. Moreover, through engaging in therapeutic conversations with robots, users report enhanced confidence and communication skills in real-world social interactions with other people, such as reducing social anxiety and improving social motivations. While previous research has recognized the role of AI-based virtual robots in reducing loneliness, it has largely focused on therapeutic effectiveness (Hudson et al., 2020; Robinson et al., 2013a). Our findings highlight the broader, often indirect ways in which AI-based virtual robots contribute to users' social well-being within the context of daily mental health practices.

### 5.3.3 Cognitive well-being

Cognitive well-being refers to people's evaluation and perception of themselves and their life circumstances (Kim et al., 2021; Veenhoven et al., 2011). In Publication V, cognitive well-being is supported through users' sustained interactions with AI-based virtual mental health robots (Robots C, D, and E). Users report improvements in self-perception and thought patterns after engaging in structured, evidence-based dialogues with the robots. These conversations help them challenge negative thoughts, develop self-compassion, and adopt positive thinking patterns about their experiences. While previous research has highlighted the use of AI-based virtual robots in enhancing the cognitive capabilities of children with autism in experiments (Louie et al., 2021; Manca et al., 2021), our study extends such effects to everyday mental health support contexts by demonstrating how general users interact with AI-based virtual robots to cope with persistent negative thoughts and cultivate more positive self-perceptions in daily life.

Likewise, Publication III identifies life satisfaction as an overall outcome that reflects users' broader cognitive evaluations of their life circumstances. Users describe how sustained interactions with the AI-based physical robot (Robot A) brings emotional warmth and companionship, and reduces loneliness in independent living environments. These benefits are reinforced by features such as real-time home monitoring, which contributes to a sense of safety and support in the living environment. Together, these factors lead to enhanced life satisfaction, which is in line with earlier research on the companionship effects of animal-like robots (Broadbent et al., 2014; Orejana et al., 2015). These results suggest that users' sustained, meaningful interactions with AI-based robots can support a positive evaluation of their overall well-being in daily life.

### 5.3.4 Behavioral well-being

Behavioral well-being refers to people's engagement in healthy and goal-directed actions and routines that support the overall functioning and regulation of daily life (Penedo & Dahn, 2005; Weisner, 2010). Publication V shows that stable and continuous interactions with AI-based virtual robots (Case C, D & E) promotes users' long-term behavioral improvements, including maintaining self-care routines, and emotional management habits, and alleviates behavioral disorders. Likewise, Publication III highlights the role of an AI-based physical robot (Case A) in facilitating user engagement in physical and social activities, helping to cultivate a sense of structure and purpose in daily life. These results align with prior research on socially assistive robots, such as Paro and Pepper, which have been found to increase engagement in physical activity and routine adherence among older adults and individuals facing loneliness (Sheba et al., 2018; Tanioka et al., 2019). Our findings build on these works by emphasizing the importance of interaction stability and user engagement over time in achieving sustained behavioral outcomes in real-life contexts.

Taken together, Publications III-V provide a multidimensional empirical perspective on how interactions between individuals and AI-based robots promote individual well-being in daily life across emotional, social, cognitive, and behavioral levels. These studies demonstrate not only the positive effects of AI-based physical and virtual robots, but also emphasize that these well-being outcomes rely on sustained and meaningful interactions between users and robots. This interactive process reflects a sociotechnical perspective (Pekkarinen et al., 2020) in which humans (end-users) and non-human actors (AI-based robots) collaboratively shape experiences, adjust interaction paths, and negotiate the meaning in specific practices.

## 5.4 Closing remarks on the discussion

Based on the findings from the five publications, this dissertation provides answers to the main RQ: how do individuals interact with AI-based robots to support their well-being in daily life? As illustrated in Figure 10, the results synthesize how users interact with AI-based robots across different contexts, thereby addressing all three sub-RQs, as well as the overarching RQ of this study.

First, Publications I and II offer a conceptual foundation by synthesizing the antecedents and outcomes of user–robot interactions in well-being contexts. These studies consolidate key insights and establish a theoretical basis for investigating AI-based robots in daily life. Moreover, they identify critical knowledge gaps, particularly the need to explore the dynamic mechanisms and processes of HRI, as well as the real-life well-being outcomes of these interactions across different settings. Thus, these findings answer RQ1 and motivate the subsequent empirical studies.

Second, Publications III-V, through multiple case studies, answer RQ2 and RQ3. Findings related to RQ2 show that the interaction between users and AI-based robots is a highly contextual, dynamic, and co-constructed process, shaped by robot embodiment, functionality, contexts, and user needs. These interactions often follow nonlinear trajectories, while users may delay or withdraw from interactions due to various negative experiences. Additionally, findings for RQ3 emphasize the multidimensional impacts of HRI on human well-being. These collective outcomes demonstrate how sustained and meaningful interactions with AI-based robots can enhance emotional, social, cognitive, and behavioral aspects of well-being.

In sum, this dissertation contributes both a synthesis of current knowledge and an empirical exploration of how HRI unfolds in diverse well-being contexts. Integrating conceptual and empirical insights advances our understanding of the dynamic evolution of user–robot interaction and its diverse well-being outcomes, thereby offering a holistic answer to the main RQ.

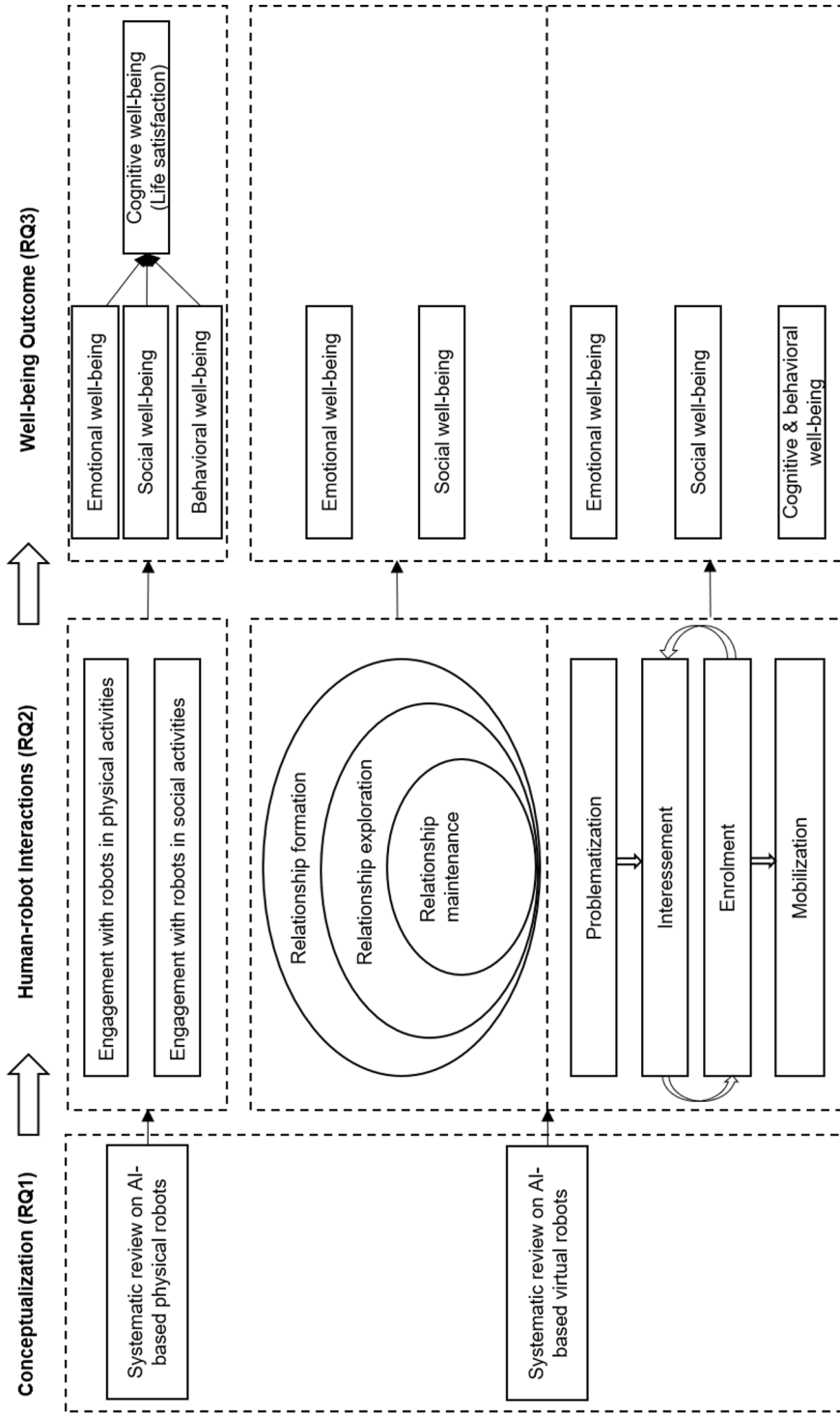


Figure 10. The integrative research framework of this dissertation.

# 6 Conclusion

This chapter presents the theoretical and practical contributions of this dissertation. Next, the research evaluation, limitations, and future research avenues are discussed.

## 6.1 Theoretical contribution

From a theoretical perspective, this dissertation makes several contributions to the IS and HRI academic fields.

First, this dissertation systematically synthesizes and conceptualizes the current state of research on AI-based physical and virtual robots in well-being contexts, offering a more structured theoretical foundation for understanding this emerging area. Although existing studies have explored the use of AI-based robots in both individual (e.g., end-users, healthcare professionals) and institutional (e.g., hospitals, nursing homes) care settings, they often focus on isolated factors influencing robot use, such as individual-related antecedents (e.g., attitudes, acceptance) or psychological outcomes (e.g., reduced loneliness, improved mood). Moreover, the current empirical studies are dispersed across multiple disciplines including IS, computer science, and the healthcare domain. Notably, there is a lack of an integrated analytical framework to consolidate these fragmented insights and variables.

To address this gap, this dissertation conducted two SLRs: one focused on AI-based physical robots in healthcare contexts, and the other on AI-based virtual robots in daily life contexts. Based on the findings, this dissertation developed a multidimensional conceptual framework that identifies key components of interactions between human and AI-based robots, including user characteristics (e.g., age, motivation, prior experience), robot attributes (e.g., anthropomorphism, communication skills, representation), and contextual/task features (e.g., usage scenarios, interaction tasks). The framework also categorizes outcomes of user interactions with AI-based robots, including users' emotional, cognitive, behavioral, and well-being promotion-related outcomes. This conceptualization offers both a solid theoretical foundation and a guide for selecting variables in future empirical studies. In comparison, previous literature review studies on AI-based robots in healthcare contexts have primarily examined the functional roles of AI-based robots in delivering psychological or assistive support tasks (Sujan Sarker et al., 2021;

Schachner et al., 2020). This dissertation further advances conceptual understanding by distinguishing between AI-based physical and virtual robots and highlighting their fundamental differences in technological design, interaction modes, applied contexts, user responses, and well-being-related outcomes.

Moreover, this dissertation identifies key underexplored research gaps in two SLRs from conceptual, thematical, methodological, and technological perspectives. In response, a clear research agenda for future investigation in the field was proposed, including diversifying robot types, application contexts, and stakeholders; advancing research methodologies; expanding thematic dimensions; and embracing multidisciplinary perspectives. Thus, the conceptual findings of this dissertation not only clarify the current state of knowledge, but also outline promising directions for future theoretical development and empirical investigation.

Second, this dissertation advances a contextualized understanding of HRI by demonstrating how robot representation (physical vs. virtual), functional design (companionship vs. therapy), and user needs (emotional, social, cognitive) collectively shape interaction patterns. For instance, Publication III shows how users interact with an AI-based physical robot through physical engagement in home environments, fostering continuous emotional and intimate bonding. Publication IV examines how users build social relationships with an AI-based virtual robot via reciprocal self-disclosure based on multimodal digital interfaces (text, voice, avatars, augmented reality) of the robot in a digital social environment. Publication V reveals a third pattern: users and AI-based virtual robots interact to cope with mental health issues on digital platforms. Together, these studies provide a nuanced view of HRI beyond traditional taxonomies or function-driven frameworks. Previous research often treats robot design and context factors as isolated or static design variables (Mehta et al., 2021; Benedict Tay et al., 2014). In contrast, this dissertation offers a nuanced perspective to understand the social, relational, and therapeutic roles that AI-based robots play in users' daily life and reveals how interaction trajectories differ across real-life contexts.

Third, this dissertation makes a theoretical contribution by conceptualizing HRI as a dynamic, nonlinear, and co-constructed process. Across Publications III-V, users and AI-based robots are both regarded as key actors who continuously engage in interactions for well-being support. Drawing on SPT and ANT, the studies trace the evolving trajectories of user interactions with AI-based robots. In Publication IV, the user-robot relationships unfold through a life cycle view, including relationship formation, exploration, maintenance, and termination. Publication V reveals four stages in the mental health co-construction process of user interactions with AI-based robots: problematization, interesement, enrolment, and mobilization. Publication III complements these findings by showing how sustained physical and social engagement with AI-based physical robots fosters stable emotional and relationship

bonding, ultimately leading to stable companionship in users' independent lives. These findings challenge the linear utilitarian assumptions of some dominant IS models (e.g., TAM, UTAUT) (Moussawi et al., 2022), which frame users as rational actors driven primarily by perceived usefulness and ease of use. In contrast, this dissertation promotes a sociotechnical perspective on HRI by highlighting users and AI-based robots as focal actors in a dynamic, evolving interaction process, which is unfolded by ongoing negotiation of roles, mutual behavioral adaptation, and co-construction of value in daily life.

Fourth, the dissertation provides a critical reflection on the structural asymmetry of HRI, particularly in virtual contexts. Compared to human-to-human relationships, users typically find it easier to initiate and maintain interaction, while AI-based robots are designed to remain responsive, compliant, and non-confrontational. This asymmetry may enhance user comfort and perceived safety in the relationship, but it also raises ethical concerns regarding emotional overdependence and reduced motivation to engage in authentic human relationships. These insights contribute to ongoing debates about emotional interactions, social relationships, and ethical concerns of user–AI interactions in our society.

Furthermore, the comparison between AI-based physical and virtual robot cases reveals how robot embodiment, financial investment, and spatial presence affect interaction stability. The existing comparative studies on physical and virtual robots primarily focus on the differences in robot designs and users' perceived social presence (K. M. Lee et al., 2006; Li, 2015). This dissertation extends the discussion by examining how these factors shape users' long-term engagement and the evolution of their relationships with robots in daily life.

Finally, this dissertation extends empirical evidence of the positive well-being outcomes of HRI across emotional, social, cognitive, and behavioral dimensions from controlled settings into real-world daily life contexts. This dissertation conducts multiple case studies to analyze how users interact with AI-based physical robots (Publication III) and virtual robots (Publications IV and V) in daily life contexts, such as private homes, digital platforms, and digital mental health routines. Through synthesizing findings, this dissertation reconceptualizes well-being not as a static outcome, but as a co-constructed, evolving experience. Importantly, these outcomes are not only driven by robot features or technical performance, but also emerge from the sustained and stable interactions between users and AI-based robots. This dissertation responds to growing calls for the healthcare digitalization field to move beyond functional or performance-based evaluations (Gaffney et al., 2019; Sujan Sarker et al., 2021), offering a more holistic view of how AI-based robots become integrated into users' emotional, social, cognitive, and behavioral lives.

## 6.2 Practical contribution

Drawing on the findings from five publications, this dissertation offers practical insights for key stakeholders involved in the design, deployment, and governance of AI-based robots in well-being contexts. By uncovering how human interactions with AI-based robots support emotional, social, cognitive, and behavioral dimensions of well-being in daily life, the study provides actionable guidance for individuals, robot developers, welfare systems, and policymakers.

First, this dissertation offers practical insights into how AI-based robots can be effectively integrated into daily life to support multiple dimensions of personal well-being, such as emotional expression, social connection, cognitive reflection, and behavioral adaptation. The findings help individuals better understand how different types of robots (e.g., physical robots and virtual agents) can meet specific well-being needs. The research also encourages users to cultivate sustainable interaction habits that can foster long-term benefits for emotional, social, and psychological health. Moreover, it raises awareness of potential ethical risks in AI-based robot use, such as emotional overdependence or data privacy issues, which can support users in making more informed and intentional decisions when engaging with AI-based robots. These insights empower individuals to co-create more meaningful and balanced well-being experiences in collaboration with AI-based technologies.

Second, this dissertation offers empirically grounded guidance for developers aiming to design user-centered AI-based robots that effectively support human well-being. By uncovering how users' cognitive, emotional, and behavioral experiences during their interactions with AI-based robots are linked to broader well-being outcomes, the study provides valuable insights into creating meaningful and supportive interactions with both physical and virtual robots. Additionally, the findings highlight key robot characteristics that contribute to positive user experiences, such as empathetic responses, and natural and dynamic conversational flow. Developers are encouraged to incorporate these features, which foster personalized and meaningful interaction experiences, thereby enabling stable and supportive robot service in users' daily lives.

Moreover, this dissertation also emphasizes the need to differentiate design strategies for AI-based physical and virtual robots. Elements such as embodiment, interaction modes, and perceived social presence are shown to significantly influence user experience and the stability of user-robot relationships. Understanding these differences helps robot developers enhance how AI-driven solutions can be effectively tailored to diverse user needs, tasks, and daily life contexts. These insights will provide integrative guidance for robot developers to enhance the responsible and meaningful integration of AI-based robots into daily life.

Third, this dissertation offers practical insights into how AI-based robots can help alleviate pressure on healthcare and welfare systems and support the

development of sustainable, scalable digital services. The findings show that AI-based robots represent promising emerging technologies that can enhance the sustainability and accessibility of care systems as complementary pathways, particularly in resource-constrained or overburdened environments. For example, AI-based virtual robots can offer continuous, cost-effective, and scalable mental health support, including mood monitoring, therapeutic conversations, and self-care exercises. These strategies are valuable for individuals who require ongoing low-intensity support, which human providers may not be able to deliver consistently on a daily basis. Therefore, this dissertation encourages healthcare and welfare systems to adopt AI-based robots and extend their reach beyond traditional institutional or clinical settings into private homes, community spaces, and digital environments.

Fourth, this dissertation advocates for the responsible deployment of AI technologies within public health and social welfare systems, contributing to ongoing ethical and policy-oriented discussions. The findings emphasize the importance of emotional safety, trust, relationship sustainability, and service accessibility in the design and implementation of robot services. These factors are significant especially when AI-based robots are used by vulnerable populations such as older adults, people with disabilities, and those experiencing mental health challenges. Through integrating empirical evidence with actionable recommendations, this dissertation supports policymakers, healthcare professionals, and welfare systems in understanding how AI-based robots can serve not as replacements, but as strategic complements to human-centered care services. In doing so, the dissertation helps bridge the gap between technological innovation and social responsibility, advancing the ethical, inclusive, and meaningful integration of AI-based robots into our society.

### 6.3 Research evaluation

The effective way to assess the quality and rigor of a study is to adopt a pluralistic approach by selecting evaluation criteria that align with the underlying research paradigm (Welch & Piekkari, 2017). Given that this study employs SLR and a multiple-case study design integrating quantitative text mining techniques and qualitative analysis, a pluralistic approach to quality measurement is adopted, aligning with best practices in both research paradigms (Creswell & Creswell, 2017). This study enhances methodological robustness through established criteria for validity and reliability in quantitative analysis, as well as trustworthiness in the qualitative research framework (Lincoln & Guba, 1986). The integration of quantitative text mining techniques with qualitative analysis requires a rigorous evaluation framework to enhance the credibility of findings across different methodological dimensions.

Quantitative research prioritizes objectivity, generalizability, and replicability, which are enhanced through validity and reliability (Heale & Twycross, 2015). Validity facilitates how research accurately captures the intended concepts, while reliability enhances how findings are consistent and reproducible (Creswell & Creswell, 2017).

In the quantitative components of this study, including topic modeling and emotion analysis, several methodological strategies were adopted to enhance validity and reliability (Mettler, 2025). In LDA topic modeling, the study adopted systematic data pre-processing techniques to refine the dataset and improve the quality of extracted themes, including noise reduction, relative pruning, and TF-IDF-based feature selection. These steps enhance how only the most relevant and representative text data are used for analysis, minimizing noise and improving the accuracy and consistency of the analysis. Additionally, the optimal number of topics was determined using coherence scores, which measure the semantic similarity of words within topics (Blei et al., 2003). To verify topic coherence and alignment with user discussions, the study also employed qualitative validation by manually reviewing the top 50 most representative tweets for each topic. For emotion analysis, the NRC lexicon was applied to classify words into predefined emotion categories. To enhance contextual accuracy, 30 keywords related to emotional issues per case were manually selected from the most frequently labeled words in each negative emotion category. This manual refinement process facilitated how the automated classifications were closely aligned with users' expressions about their emotional issues. Additionally, a cross-validation step was conducted by manually reviewing extracted user reviews to confirm consistency between emotion analysis results and the emotional experiences described by users. These validation techniques enhanced how the quantitative analyses were methodologically rigorous, reduced bias, and improved the reliability of insights drawn from large-scale user-generated text data.

For the qualitative components of this study, including qualitative interpretation and thematic analysis, the framework of Lincoln and Guba (1985) was applied to improve trustworthiness and rigor. This framework provides a robust set of criteria for evaluating qualitative research, including credibility, transferability, dependability, and confirmability, which serve as qualitative counterparts to traditional validity and reliability measures used in quantitative research (Eriksson & Kovalainen, 2015).

Credibility refers to the accuracy and believability of the findings, ensuring that they reflect the realities of the participants or data sources (Lincoln & Guba, 1985). Two SLRs in this dissertation were conducted following the transparent and replicable guidelines, including relevant search strategies, predefined inclusion and exclusion criteria, and structured screening and selection processes (Okoli, 2015). Moreover, data extraction and synthesis were grounded in detailed context analysis,

ensuring that the findings accurately reflected the trends and gaps in the reviewed literature. Regarding the empirical research, this dissertation improved the credibility of findings through data triangulation and methodological triangulation (Billups, 2019). Our data, including user-generated reviews and social media discussions, were collected from multiple resources, such as Google Play Store, Apple App Store, X, and RED, to enhance a diverse and representative dataset. Methodological triangulation was achieved by integrating quantitative text mining methods such as topic modeling and sentiment analysis with qualitative interpretation and thematic analysis, allowing for cross-validation of research findings. Additionally, our thematic analysis process followed a structured coding approach, including open coding, axial coding, and theme development, to facilitate systematic traceability from raw data to final themes. During the analysis, multiple researchers participated in the coding process, with discrepancies resolved through discussion and negotiation, to improve coding accuracy and consistency (Guba, 1994).

Transferability refers to the extent to which findings can be applied to other contexts (Lincoln & Guba, 1985). The SLRs provide sufficient contextual information on AI-based physical robots and virtual robots for readers and researchers to assess relevance and applicability across different robot types, contexts, and user groups. Moreover, this dissertation enhanced the transferability in the empirical studies by providing detailed descriptions of AI-based robot cases, including applied contexts, target users, primary functions, and physical embodiments, enabling future researchers and practitioners to assess relevance to other contexts. Meanwhile, by adopting a multiple-case study design, this dissertation examined and compared user experiences with four distinct AI-based robots, improving the applicability and generalizability of findings (Shenton, 2004).

Dependability emphasizes the consistency and reproducibility of research findings over time and across researchers (Lincoln & Guba, 1986). This dissertation adopted an audit trail that documented all data collection procedures, coding processes, and theme development steps to enhance transparency and replicability in both SLRs and multiple case studies (Given, 2008). To further enhance intercoder consistency, two researchers independently coded the qualitative data, and discrepancies were discussed and resolved through consensus. This dissertation also maintained an iterative approach throughout the qualitative analysis process by refining the coding framework to align with emerging insights and evolving data patterns.

Confirmability facilitates how findings are derived from the data rather than researcher bias (Lincoln & Guba, 1986). The inclusion of multiple coders, inductive content analysis, iterative discussion, and consensus-building reduced researcher bias in the SLRs. Likewise, the use of secondary data from real-world user-generated content in the empirical research minimized researcher interference, ensuring that

findings accurately reflected users' experiences. In the data analysis process, this dissertation used direct excerpts from user reviews, ensuring that findings are derived from data rather than researcher interpretations. Furthermore, reflexivity was incorporated through continuous discussions within the research team to document and critically evaluate potential biases. In Publications III, IV, and V, theoretical frameworks such as HRI, SPT, and ANT were applied at later stages of analysis to support how themes emerged organically from the data rather than being imposed prematurely.

By following these methodological strategies, this study enhances the validity and reliability of quantitative findings while maintaining the trustworthiness of qualitative insights.

## 6.4 Limitations and future research avenues

It is important to acknowledge the limitations of this dissertation, which should be considered when interpreting or applying the findings.

First, in the two SLRs, the literature search used a couple of keywords to search for relevant studies from a limited number of academic databases and publication outlets. While this approach enhanced the search focus and relevance to research objectives, it may have excluded relevant studies that did not contain the selected keywords in their titles or abstracts, or that were published in alternative databases or publications not included in the search. This constraint may have led to an incomplete representation of the current research landscape on AI-based physical and virtual robot use in well-being contexts. To address this limitation, future research should consider expanding the breadth and depth of literature searches, including incorporating a wider range of search terms and synonyms, exploring additional databases across disciplines, and considering grey literature or industry reports that may contain valuable insights. Through broadening the scope of search strategies and inclusion criteria, future SLRs can offer a more extensive and interdisciplinary overview of the state of research on AI-based robots and their role in supporting human well-being.

Second, several methodological limitations in the empirical studies must be acknowledged. The empirical component of this dissertation adopts a multiple-case study design based on a small number of selected AI-based robots: one physical robot case and several virtual robot cases. While this approach enables rich, in-depth exploration of user experiences, the findings may have limited generalizability across the broader spectrum of AI-based robots, user populations, and cultural contexts. To enhance external validity, future research could adopt large-scale quantitative methods, such as cross-sectional surveys or panel data analysis, to validate and extend the generalizability of key insights.

In addition, the case study of this dissertation relies heavily on user-generated secondary data, which often lack contextual depth, demographic detail, and longitudinal consistency. The anonymity of users further limits the ability to link interaction patterns to individual characteristics or trace interaction experiences over time. To address this, future studies should incorporate primary data sources through methods such as in-depth interviews, ethnographic fieldwork, or longitudinal diary studies. These methods would allow for a more nuanced understanding of users' evolving experiences, motivations, and unmet needs.

Moreover, the current dataset of this dissertation does not allow for longitudinal tracking of the same users, although it emphasizes the dynamic and evolving nature of HRI. This limits the ability to investigate how relationships with AI-based robots develop, stabilize, or dissolve over time, and how sustained interaction shapes long-term well-being outcomes. Therefore, future research should adopt longitudinal designs to examine how user–robot interactions and their impacts unfold over time. Such approaches would deepen our understanding of the temporal dynamics of HRI, including relationship progression, emotional dependency, and interactional decline.

Third, the current study is limited by its focus on a narrow set of human and technological actors. In conceptualizing users and AI-based robots as the primary focal participants in well-being support networks, this research has not fully accounted for the broader constellation of actors that may significantly influence well-being outcomes. Important stakeholders, such as healthcare professionals, application developers, platform providers, and regulatory institutions, are largely absent from the empirical scope. However, these actors play a critical role in shaping how AI-based robots are designed, deployed, governed, and integrated into users' daily lives. Thus, future research should adopt a more holistic sociotechnical perspective that includes these multiple stakeholder groups and the underlying power structures that mediate HRI in well-being contexts.

Finally, this dissertation primarily focuses on the positive impacts of human interactions with AI-based robots on individual well-being. While it acknowledges the asymmetrical nature of HRI and discusses how negative user experiences can disrupt or terminate interactions, it lacks a critical reflection on the broader societal implications of integrating AI-based robots into daily life. For instance, issues such as emotional overdependence, reduced human-to-human interaction, or reinforcement of social isolation remain underexplored. To address this gap, future research should adopt a more critical and balanced perspective that systematically considers the unintended consequences and ethical dilemmas associated with HRI in daily life. By integrating both the bright and dark sides of human–AI interaction, future studies can offer a more holistic understanding of the evolving role of AI in society and support the development of responsible AI-based robot systems.

# Abbreviations

AI	Artificial Intelligence
ANT	Actor-Network Theory
CBT	Cognitive Behavioral Therapy
DBT	Dialectical Behavioral Therapy
HCI	Human-Computer Interaction
HRI	Human-Robot Interaction
IFR	International Federation of Robotics
IPT	Interpersonal Psychotherapy
IS	Information Systems
LDA	Latent Dirichlet Allocation
MMAT	Mixed Methods Appraisal Tool
NRC	National Research Council
OECD	Organization for Economic Co-operation and Development
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RQ	Research Question
SLR	Systematic Literature Review
SPT	Social Penetration Theory
TAM	Technology Acceptance Model
TF-IDF	Term Frequency-Inverse Document Frequency
UTAUT	Unified Theory of Acceptance and Use of Technology
WHO	World Health Organization

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