

Understand the role of technology embodiment in facilitating social connectivity to address loneliness across the lifespan: A systematic review

George Mois PhD^{a,*}, Taylor A. Leathers^b, Alec Murphy^b, Kerstin G. Emerson PhD^b, Tiffany R. Washington PhD^c, Jenay M. Beer PhD^{b,c}

^aCollege of Applied Health Sciences, University of Illinois Urbana Champaign, Champaign Illinois, United States; ^bCollege of Public Health, University of Georgia, Athens Georgia, United States; ^cSchool of Social Work, University of Georgia, Athens, Georgia, United States; *Corresponding author: mois@illinois.edu

Abstract

Background: Loneliness is an emerging societal emerging societal public health challenge affecting adults' well-being and overall quality of life across the lifespan. Leveraging communication technology presents an opportunity to support social connectivity and meaningful relationships among adults. However, little is known about communication technologies' use, application, and functionalities to support connectivity for adults across the lifespan.

Objective: This review aimed to understand the role of communication technologies in facilitating social connectivity across the aging process.

Method: This review was conducted utilizing the PRISMA guidelines for systematic reviews. After systematically reviewing the current literature a total of 15 studies met the inclusion criteria.

Results: Communication technologies present opportunities to enhance and support social connectivity. The range in functionalities and applications of technologies represents a continuum of embodiment.

Conclusion: Technologies with higher levels of embodiment may hold enhanced opportunities to expand the sense of social connectivity through use.

Keywords: communication technology, telepresence, embodiment, social connectivity, loneliness

INTRODUCTION

Loneliness is an emerging societal public health challenge that has tremendous ramifications for adults of all ages. Loneliness is commonly defined as the difference in one's desired and actual quality and number of social relationships (De Jong Gierveld & Van Tilburg, 1999; Hawkey & Cacioppo, 2007; Peplau & Perlman, 1982). In the United States, two in five adults (aged 18+) report feeling isolated and a lack of meaningful relationships (Cigna U.S. Loneliness Index, 2018). In a study conducted by the American Association of Retired Persons (AARP) more than 35% of participants aged 45 and over reported feeling lonely (Anderson, Oscar, & Thayer, 2018). Across various stages of adulthood, as highlighted in Erikson's developmental framework, the experience of loneliness varies based on an individual's ability to achieve intimacy, generativity, and integrity (Malone et al., 2016; Ryff, 1982; Slater, 2003). Furthermore, the understanding of the factors that impact the experience of loneliness is expanded by the cognitive and attachment theories of loneliness. These theoretical frameworks

highlight factors such as attachment styles, anxiety, self-esteem, depression, and feeling of control over one's own life as key influences in the experience of loneliness (Besser & Priel, 2005; Hojat et al., 1990; Wiseman et al., 2007). The cognitive reaction to changing social relationships helps inform how individuals perceive, experience, and evaluate loneliness as a phenomenon (Gierveld, 1998; Peplau & Perlman, 1982).

The social network developed over the course of an adult individual's life presents unique insights into how individuals form and support meaningful and quality relationships. Careful attention must also be placed on how shifts and changes impact an individual's sense of social connectivity. For example, changes in the structure of networks and loss of support facilitated by meaningful relationships can negatively impact one's sense of social connectedness, contributing to a stronger sense of loneliness. Previous work has indicated that strategies aimed to enhance social engagement and promote social connectivity can have beneficial outcomes on participants'

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Table 1. Inclusion criteria

Condition	Criteria
Publication dates	1 January 2009 – 1 January 2020
Publication types	Primary research articles (Journal articles)
Study types	Cross-sectional, longitudinal, qualitative, quantitative, mixed methods
Age groups	Adults (18+)
Outcomes	Loneliness/Social isolation
Language	English
Geographic location	All countries
Settings	Residential, community, health facilities, and institutionalized care

well-being and have resulted in a reduction in loneliness (Antoci et al., 2014; Hua Wang & Wellman, 2010; Poscia et al., 2018). Yet, interventions aimed to promote social connectivity can often be limited by both organizational and individual resources, making their effectiveness limited. To address this limitation, communication technologies have been proposed as having the potential to help improve access to opportunities to increase connectivity (Berg et al., 2017; Campos Antunes et al., 2019; Fang et al., 2019).

Communication technologies and the role of embodiment

Communication technologies include a variety of online platforms, software, and hardware through which individuals can communicate electronically. The user base of these technologies is continually growing, as more adults are adopting them to engage with others and facilitate communication. However, the types of these technologies vary considerably, from social media platforms to telepresence robots, thus offering consumers a wide range of device types to choose from.

Social media platforms such as Facebook, Instagram, and Twitter can allow individuals to share short messages and photos with their followers. The user base of these platforms is rapidly increasing among middle to late-aged adults: the number of social media users aged 18-29 increased from 79% in 2011 to roughly 90% in 2018, and the number of older adults aged 65+ increased from 14% in 2011 to roughly 37% in 2018 (Pew Research Center, 2018b).

The use of mobile communication hardware, such as smartphones and tablet computers (e.g., iPad, Galaxy Tab) also continues to grow among adults in the US (Pew Research Center, 2018a). These devices not only allow users to engage via voice calls and text messages but also provide the opportunity to access telepresence software (e.g., Zoom, Skype), where users are equipped with the ability to engage with each other through face-to-face video interaction. The term telepresence is defined as the experience of presence in an environment facilitated through a communication medium (Dolezal, 2009; Kidd & Breazeal, 2004; Kose-Bagci et al., 2009; Steuer, 1995). More advanced communication technolo-

gies, such as smart displays (e.g., Google Home Hub, Echo Show, Facebook Portal) and telepresence robots (e.g., Toyota Telepresence Robot, AVA Telepresence Robot), are providing users with a more immersive synchronous communication experience through the ability to pan and tilt the remote display and/or navigate around the remote environment.

The sense of presence that an individual can achieve through technology-mediated communication can be best described as a form of embodiment. Embodiment as a phenomenon has been explained and discussed in a variety of fields. (Ciocan, 2015; Husserl & Schuhmann, 1977; Taipale, 2014). Recent breakthroughs in communication technologies, more specifically one's ability to interact with a remote environment and alter them through technology, resulted in the need to expand the current understanding of the phenomenon and its connection to what it means to be present. The varying embodied levels achieved through communication technologies affect the sender's and receiver's perceptions and sense of "being there." For example, the communication achieved through social media is generally limited to one-way communication. However, high-level embodied communication technologies, such as telepresence robots, can create a heightened sense of "being there" (e.g., through pan/tilt or locomotion), thus potentially supporting the individuals' sense of social connectedness (Sakamoto et al., 2007; Takayama, 2015).

Current systematic reviews have aimed to describe how technology may serve the role of facilitating communication (Barr et al., 2019; Ibarra et al., 2020; Shah et al., 2019). These reviews have supported that technology may hold opportunities for the expansion of resources and tools needed to help facilitate social connectivity. However, there are significant gaps in the understanding due to limited significant findings related to the application of digital technology interventions capable of addressing the experience of loneliness. Current systematic reviews focus on specific age groups (e.g., young adults, older adults) and subsets of communication technologies (e.g., social media, cellphones, and videoconferencing). Furthermore, there are limited reviews that identify the role of embodiment in the context of communication technology interventions to facilitate social connectivity as an intervention aimed to address loneliness across various stages of adulthood (Banbury et al., 2018; Bemelmans et al., 2012; Bessaha et al., 2020). Addressing these gaps can help clarify the types of technologies being used by adults across the lifespan and how technology functionalities may help serve a role if facilitating more meaningful relationships.

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Table 2. Online databases

No.	Database
1	Abstracts in Social Gerontology
2	American Psychological Association (APA) Psych Info
3	Cumulative Index of Nursing and Allied Health Literature (CINAHL)
4	Institute of Electrical and Electronics Engineers (IEEE)
5	Medline
6	ProQuest
7	Web of Science: Science Citation Index (SCI)
8	SocINDEX with Full Text

Aim and objectives

This systematic review helps address a gap in the current research, as we aimed to map the various technologies used and the role of embodiment in facilitating opportunities for social connectivity. Unlike previous work, this study aims to understand the role of communication technologies across various levels of embodiment in facilitating social connectivity and addressing the experience of loneliness across the aging process (Bessaha et al., 2020; Poscia et al., 2018). We aimed to synthesize the current literature and map the various technology embodiment levels and their implications for creating social connections. Below we identified three objectives that aim to address three key goals: guide the development of interventions, inform future research, and provide elements for the organization of current communications technologies.

Objectives:

- Understand how loneliness is described and conceptualized in technology-focused studies across the aging process.
- Understand the types of communication technologies adopted and implemented through interventions to assist adults to formulate social connectedness and address loneliness.
- Understand how one's sense of social connectedness may be impacted by the level of technology embodiment used.

METHODS

Study selection and eligibility criteria

The studies included in this review had to meet the initial set of predefined criteria for inclusion (Table 1). The studies included span a period of ten years, nested between 1 January 2009 and 1 January 2020. This time frame denotes a crucial shift in accessibility to mobile defines that support synchronous video communication. Studies were included if participants were aged 18+, reported experiencing a form of social isolation and/or loneliness, and were asked about technology use or part of technology intervention. All studies addressed or provided a clear explanation or conceptualized loneliness as a construct. All studies either implemented a technology intervention or aimed to understand how the use of communication technologies impacted the users' sense of social connectedness.

Data source

This review was conducted utilizing the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for systematic reviews (Liberati et al., 2009). Two researchers systematically searched for articles published in 8 large and widely used online databases (Table 2). These databases covered fields such as sociology, engineering, medicine, psychology, nursing, health technology, healthcare, social work, and public health. The literature search covered a publication period of 10 years and 2 months, ranging from 1 January 2009 to 1 January 2020.

Search strategy

Systematic literature searches were undertaken in each of the eight online databases (Table 2). Pre-identified search terms and subject headings were identified through careful consideration of the literature, theoretical frameworks (e.g., Cognitive Theory of Loneliness, Social Presence Theory, Erikson's stages of development), and with the help of a research librarian (Table 3). The technologies terms identified in this review were adapted from communication technology terms identified by previous systematic reviews (Best et al., 2014; Campos Antunes et al., 2019; Chen & Schulz, 2016; Liberati et al., 2009). The literature was investigated using both keywords and subject headings in the "title" and "abstract" search fields of the identified online databases. Searches will be filtered by applying the search criteria outlined in Table 3 and through the use of Boolean operators such as "AND" and "OR".

Study selection

The process of study selection was conducted by a group of two researchers. All records found in searches were downloaded and exported utilizing Zotero (Zotero, 2020). Zotero is a citation manager that allows users to organize bibliographic records and citations. The first screening phase, which screened article titles and details relevant items highlighted in Table 2 was conducted by one researcher. The second screening phase consisted of both researchers reviewing study abstracts. Following the completion of the second phase, both researchers reviewed the full papers of all relevant articles to assess eligibility. Following the completion of the review, discrepancies in the selection of studies were discussed among the two researchers until a consensus was reached.

Data extraction procedures

Two reviewers completed the synthesis and data extraction of the final articles. To eliminate bias and reduce errors, the reviewers compared their findings and discussed any differences or discrepancies in the data collected. Following the review agreement, a final data extraction form was created to reflect these changes. The data extraction

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Table 3. Key words and subject headings

Condition/Challenge	Strategy	Communication technology
Loneliness ²	Social connectedness ²	Tele technology ¹
Isolation ¹	Social communication	Robot*
Isolated ¹	*Communication ²	Technology ¹
Isolating ¹	Communi* ²	Telepresence ¹
Social deprivation ²	Social communities	Embodiment ²
	Social connect*	Social Media ¹
	Social support ²	Video communication ²
	Social prescribing ²	Information and communication ¹
	Social presence ²	Information technology ¹
	Interpersonal interaction ²	Videoconference ¹
		Twitter ¹
	Online social networks ¹	Facebook ¹
		Instagram ¹
		Snapchat ¹
		Telecommunication ¹
		Teleconferencing ¹
		Information seeking behavior ¹
		Communication
		Social networking ¹

Notes:

*Boolean phrase – allows for all varying forms of the word

¹Item identified based on previous literature

²Item identified based on theoretical frameworks

form focused on three primary areas of interest: loneliness, social connectedness, and communication technologies. These areas of interest were focused on the understanding of how communication technologies are being utilized across the lifespan to facilitate social connectedness to address loneliness. The data collected included: the study aim, research questions, demographics of the study sample, and findings related to technology, social connectivity, loneliness, and well-being.

Quality of studies

The studies were assessed using the Quality Assessment Tool for Quantitative Studies (EPHPP, 2009) and Qualitative assessments for interpretive validity and each reviewer attributed a rating for each criterion and then assigned a final score that attributed to each study. Following the completion of the quality of studies by the two reviewers, they compared their final scores and discussed any discrepancies. Following the agreement, the two assigned a final global score for each study. To help support and facilitate consistency for scoring across varying methodological approaches, scoring, and language were adapted based on the EPHPP instrument.

RESULTS

Study selection

The total number of articles downloaded before duplicate removal was 3654. Two investigators identified all duplicates through manual review and using the Zotero (Zotero | Your Personal Research Assistant, 2020) duplicate identifier tool. Upon removal of all duplicates, the search concluded with 2799 records. During the first screening phase, the articles' titles were reviewed. Articles were excluded if they were not primary research and/or did not discuss loneli-

ness, social connectedness, or technology. It's important to note that if the researcher was not able to make an informed decision based on the title of the article, the abstract was screened for clarification. Following the initial screening phase of the article titles, 332 articles remained.

During the second screening phase, articles were screened for the complete screening criteria outlined in Table 1. Two researchers reviewed the 332 articles abstract arriving at a total of 119 articles. During the third stage of review, the full text of the remaining 119 articles was reviewed by two researchers narrowing the total number of

articles eligible for this systematic review to a total of 15 articles (Figure 1). The included studies analyzed the role of technologies, across varying levels of embodiment, and their role in facilitating social connectivity and addressing loneliness.

Features of studies included

The 15 studies selected were published between January 2009 and January 2020. These studies were conducted across 8 different countries and include the United States (5 Studies), China (3 Studies), United Kingdom (2 Studies), Canada (1 Study), Netherlands (1 Study), New Zealand (1 Study), and Portugal (1 Study).

Study design

All the studies identified implemented a cross-sectional design thus providing a single snapshot of the technology's role in the facilitation of social connectivity and the experience of loneliness. The studies implemented quantitative (10), mixed (4), and qualitative (1) methodological approaches.

Quality of studies

Of the studies included 6 studies received a strong quality score (2,3,5,8,13,14) and 9 studies (1,3,5,6,9,10,11,12,15) received moderate scores. The range of quality of ratings for both qualitative and quantitative studies has been mapped and displayed in Figures 2 and 3 respectively. Studies that had moderate scores had at least one weak sub-quality rating, but the majority of sub-quality ratings were moderate. The studies that were identified as strong had no low-quality sub-ratings and a majority of high-quality sub-ratings.

Study participants

Participants across studies included a range of various adult age groups, including young adults

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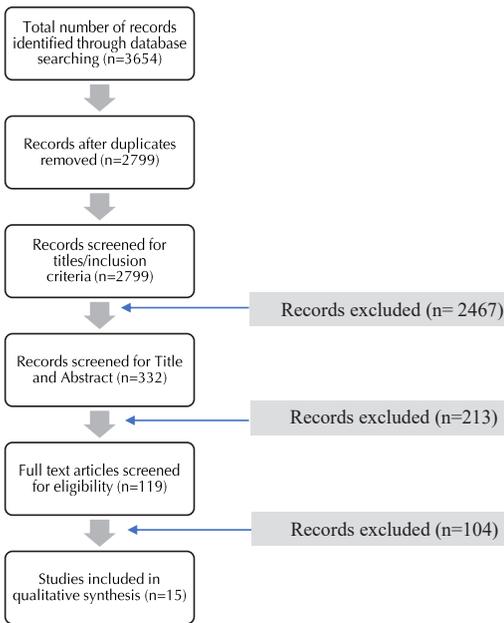


Figure 1. PRISMA flowchart of the literature review

(age 18-34) 6 studies, middle-aged adults (age 35-64) 2 studies, and older adults (age 65+) in 8 studies. The mean age across studies ranged from 19 to 82, with a mean age of 52, SD 24.74. The sample size ranged from 12 to 1787, the mean sample size across studies was 523 SD 554.36. The participants across all studies were predominantly female.

Loneliness measures

Across studies, a total of six loneliness scales were implemented. These scales are summarized in Table 4.

Technology types

The studies described the use of social networking sites, tablet-based applications, videoconferencing, Personal Reminder Information and Social Management System, and Internet-based Social Technologies. Table 5 shows a complete overview of various technology types. The technologies researched across the identified studies ranged in features representing varying levels of embodiment. For example, technologies with features such as video and mobility can enable users a stronger sense of presence. The types of technologies researched varied across age groups. Studies that included their sample of older adults had the widest range of technologies (Table 5).

Social networking sites

Across the studies included in this systematic review, 8 papers focused on the use of social networking sites, making it the most predominant researched type of communication technology. Furthermore, social networking sites were the

only types of technology that were investigated across phases of adulthood. However, the benefits of its application and use varied for individuals across the lifespan. Active use of social networking sites was associated with a decrease in feelings of loneliness, social connectivity, social support, maintenance of relationships, and self-efficacy (Lin et al., 2020; Primack et al., 2017; Thomas et al., 2020; Yu et al., 2016; Zhou, 2018). However, the overuse of social media was associated with the possibility of displacing the time one may have to interact in face-to-face communication (Lima et al., 2017; Primack et al., 2017). Furthermore, communication facilitated through social networking sites was associated with bridging capital and helped enable connections with non-family members (Lima et al., 2017; Yu et al., 2016). The embodiment features enabled through social networking platforms influenced the directionality of the users' sense of loneliness. For example, when comparing the experiences of users of text-based social networking sites to that of image-based platforms, the users of image-based social media platforms reported lower rates of loneliness (Pittman & Reich, 2016).

Tablet and app intervention

One study (Neves et al., 2017), focused on the implementation of a tablet-based communication application that aimed to enhance social connectedness among older adults living in a residential care setting. Users were able to send and receive audio, text, photo, and video messages. Study findings indicate high acceptance of technologies, however, providing training that meets the users' comfort level was important. The increase in technology embodiment features may require additional training, support, and engagement from those with whom individuals have meaningful relationships. Study findings indicate that participants whose relatives were actively engaged in communicating through technology were more likely to find it easier to use the application. Findings also reinforced the social capital theory of social connectivity which indicates that the quality of relationships one can achieve is more important than the quantity of relationships one has.

Video conferencing

Two studies (Banbury et al., 2017; Zamir et al., 2018) focused on the use of video conferencing. These studies indicate that video conferencing had a positive impact on reducing feelings of loneliness. Participants (Banbury et al., 2017; Zamir et al., 2018) reported the use of video conferencing as beneficial and made them feel more connected. Furthermore, some participants reported that video conferencing made them feel more emotional support and an enhanced sense of connectivity compared to a voice call (Ban-

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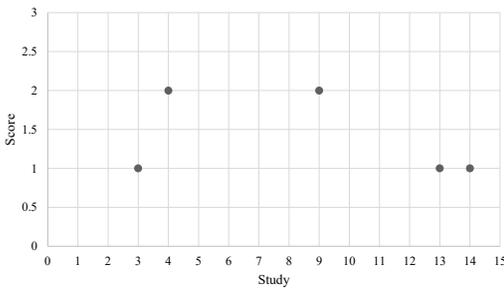


Figure 2. *Quality of qualitative studies*

bury et al., 2017). Video conferencing was identified as a useful tool to develop a social support network and facilitate opportunities for new social connections. Visual cues provided through video conferencing were identified as an important factor in helping enhance social contact (Banbury et al., 2017). Communication facilitated through video conferencing provides the users with additional features such as synchronous video and voice, enabling a stronger sense of embodiment. The main challenges influencing the use of video conferencing by participants included a family commitment to participate in video calls and a lack of customizability to meet the users' preferences (Zamir et al., 2018).

Personal reminder information and social management system

One study (Czaja et al., 2016) utilized a reminder and information and social management system to provide the user with the ability to engage and connect with family and friends easier. Personal Reminder Information and Social Management System is an easy-to-use computer-based system designed to facilitate social interaction and increase access to community resources (Czaja et al., 2018). The findings of this study indicate that the application of information communication technologies can have an important value in reducing the barriers that may create risks of social isolation and foster opportunities for social connectivity.

Internet-based communication

Three studies (M. Hu, 2009; Szabo et al., 2017; Ten Bruggencate et al., 2018) focus on trying to understand the role of internet-based communication to help facilitate social connectivity and its impact on feelings of loneliness. Findings indicate the use of the social internet predicted an increase in feelings of well-being and lower rates of loneliness. Social internet use predicted greater well-being and reduced loneliness over time (Szabo et al., 2017). One study (M. Hu, 2009) indicated that the use of online chatting is less effective at addressing feelings and coping with feelings of loneliness than face-to-face communication. Among individuals who experienced chronic loneliness, the mood loneliness in com-

puter-mediated communication, was significantly higher when compared with face-to-face communication. However, the interaction conducted in this study was conducted among strangers and not with individuals with whom the participants had previously developed meaningful social connections. Lack of resources, perceived usefulness, cost, and concerns regarding overuse, privacy, and misuse were identified as the key challenges in the adoption and application of internet-based communication technologies (Szabo et al., 2017; Ten Bruggencate et al., 2018).

Loneliness across adulthood and communication technology use

The experience of loneliness across adulthood has been discussed and explored in relation to technology use and adoption. This systematic review provides insights into the experience of loneliness across the various phases of adulthood in daily life shaped by digitalization. Of the studies included six explored the experience of loneliness across young adulthood. Two of the studies explored the experience of loneliness across middle adulthood. Eight studies explored the experience of loneliness across older adulthood.

Young adults

The experience of loneliness in early adulthood has been predominantly linked to factors such as social support, self-esteem (Lin et al., 2020), locus of control, personal relationships, individual's well-being (Ye & Lin, 2015), communication medium (M. Hu, 2009; Pittman & Reich, 2016), connectivity (Primack et al., 2017), sense of community, and social isolation (Thomas et al., 2020). The predominant technology type explored among young adults included social networking sites (e.g., Facebook, Instagram, Twitter) and internet-based communication platforms (e.g., online chatting, forums). The use of social networking sites has been identified as having the potential to maintain, facilitate, and bridge social connections (Primack et al., 2017; Thomas et al., 2020). The use of social media has been linked to serving an important role in facilitating and providing opportunities for offline relationships (Thomas et al., 2020) and facilitating social interaction for individuals with physical limitations (Primack et al., 2017). However, young adult users who report feeling lonely are more likely to report a preference for online interactions than those in-person (Ye & Lin, 2015). Furthermore, the type of social networking site and its capabilities can have various implications on the experience of loneliness and social connectivity among young adults. One article identified that the users of image-based social networking sites are more likely to report feeling happy and satisfied with their own life, and report feeling less lonely (Pittman & Reich, 2016).

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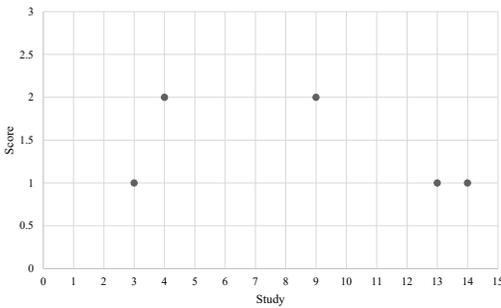


Figure 3. Quality of quantitative

Middle-age adults

Loneliness among middle-aged adults has been predominantly attributed to their perceived sense of support, friendships, quality of relationships, health, and bridging and bonding social capital (Lima et al., 2017; Yu et al., 2016). Across the studies that included a middle-aged adult sample, social networking sites were the only communication technologies explored. When comparing the impact on one's health of face-to-face friendships and online friendships, only face-to-face connections had a clear direct link to well-being. Face-to-face communication was identified as providing the individual to form a more intimate and supportive link through bonding and increasing social bridging through social integration (Lima et al., 2017). Online relationships, such as Facebook friends, have been linked to bridging social capital but not bonding social capital. Among middle-aged adults, perception and use behaviors of social media platforms can vary across various segments of this population. It is important to note that middle-aged adults were the least researched age group across the existing literature, only two studies included a middle-aged sample. However, unlike studies geared towards the young adult and older adult population, there were no studies aimed directly at understanding the experience of loneliness and the use of technology to facilitate social connectedness by middle-aged adults.

Older adults

The experience of loneliness among older adults has been predominately attributed to social capital, social connectedness, quality of relationships (Banbury et al., 2017; Barbosa Neves et al., 2019; Ten Bruggencate et al., 2018), self-efficacy, social support (Yu et al., 2016; Zamir et al., 2018; Zhou, 2018), relationship-type (Czaja et al., 2018), community engagement, activities (Szabo et al., 2017), and resources (Ten Bruggencate et al., 2018). Studies that included older adults had the most diverse set of communication platforms. These platforms included social networking sites, tablet and app interventions, video conferencing, personal reminder information and social management system, and internet-based com-

munication platforms (e.g., chat rooms). Among older adults, the use of social networking sites was associated with improvements in self-efficacy, reduced sense of loneliness and social isolation, and improved sense of social support (Ten Bruggencate et al., 2018; Yu et al., 2016; Zhou, 2018). Older adults are more likely to experience a stronger sense of connectedness through the use of social networking sites when compared to middle-aged adults (Yu et al., 2016). However, connections achieved through social networking sites were primarily perceived as beneficial with friends and least effective in connecting with immediate family members.

DISCUSSION

This is the first systematic review that aims to help identify the role of communication technologies across various levels of embodiment in facilitating social connectivity and addressing the experience of loneliness. The current literature base provides limited insight into the experience of loneliness across the lifespan and the use of diverse communication technologies to facilitate social connectivity. Loneliness has become a worldwide epidemic that has significant ramifications on the physiological, psychological, and social well-being across with significant implications across the lifespan. Understanding the experience of loneliness and how it may be best addressed across each phase of adulthood is an important component in helping promote well-being and healthy aging. This systematic review aims to provide an overview of the current knowledge base and gives future research a structured perspective on the application and implementation of communication technologies across various levels of embodiment to facilitate social connectivity.

Understand the experience of loneliness across various phases of adulthood

Across the articles included in this systematic review, the experience of loneliness across various phases of adulthood has been predominantly attributed to similar factors although some distinct factors were noted across each phase. The experience of loneliness in early adulthood was linked predominantly to social support, self-esteem, locus of control, formation of personal relationships, connectivity, sense of community, and the experience of social isolation (S. S. Hu et al., 2010; Lima et al., 2017; Lin et al., 2020; Pittman & Reich, 2016; Primack et al., 2017; Thomas et al., 2020; Ye & Lin, 2015). Loneliness among middle-aged adults was attributed to the perceived sense of support, friendships, perceived quality of relationships, health, and bridging and social capital (Lima et al., 2017; Yu et al., 2016). Among older adults, the experience of loneliness was mostly attributed to the sense of social capi-

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Table 4. Loneliness scales utilized across literature

Studies	Loneliness measures						
	The emotional and social loneliness scale	UCLA loneliness scale	Brief measure of social support	De Jong Gierveld loneliness scale for loneliness	Shortened 3 item UCLA loneliness scale	PROMIS social isolation	Qualitative interviews
1 (Lin et al., 2020)	x						
2 (Lima et al., 2017)		x*					
3 (Neves et al., 2017)					x		
4 (Banbury et al., 2016)							x
5 (Ye & Lin., 2015)		x					
6 (Zhou, 2018)		x					
7 (Czaja et al., 2016)		x					
8 (Szabo et al., 2018)				x			
9 (Pittman & Reich, 2015)					x		
10 (Primack et al., 2017)						x	
11 (Thomas et al., 2019)		x					
12 (Yu et al., 2016)		x					
13 (Zamir et al., 2018)							x
14 (Bruggencate et al., 2018)				x			
15 (Hu, 2009)		x					

*Sections of the scale were included in a battery of questions

tal, social connectivity, quality of relationships, self-efficacy, sense of social support, relationship types, and resource accessibility (Banbury et al., 2017; Barbosa Neves et al., 2019; Czaja et al., 2018; Szabo et al., 2017; Ten Bruggencate et al., 2018). Across adulthood, the ability to support social connectivity and quality relationships was associated with lower rates of loneliness.

Understand the types of communication technologies adopted and implemented through interventions to assist adults to formulate social connectedness and address loneliness

The literature included in this systematic review presents a moderate range of existing technologies. The technologies identified in this review included social media (Lima et al., 2017; Lin et al., 2020; Pittman & Reich, 2016; Primack et al., 2017; Thomas et al., 2020, 2020; Ye & Lin, 2015; Yu et al., 2016), video conferencing (Banbury et al., 2017; Das Neves Cavaco et al., 2017; Zamir et al., 2018), and internet-based communication technologies (e.g., chatrooms, online forums) (M. Hu, 2009; Szabo et al., 2017; Ten Bruggencate et al., 2018), and a personal reminder and social management system (Czaja, 2016).

The most prevalent technology identified in this review was social media, which was the only technology studied across adulthood. Findings indicate that social media use was associated with a decrease in feelings of loneliness, social connectivity, social support, maintenance of relationships, and self-efficacy (Lin et al., 2020; Primack et al., 2017; Thomas et al., 2020; Yu et al., 2016; Zhou, 2018). However, overuse of social

media was associated with decreases in face-to-face interactions (Lima et al., 2017; Primack et al., 2017). An explanation for these findings could be related to the use behaviors of those engaging on social media (Boulianne, 2015). For example, users who utilize social media to facilitate opportunities for face-to-face interactions may report feeling less lonely (Pittman & Reich, 2016). However, some research has indicated that those who report feeling more lonely are often more likely to resort to online social interactions, through social media or internet-based communication technologies (M. Hu, 2009; Ye & Lin, 2015). These findings indicate that the use of communication technologies such as social media and internet-based communication may present some challenges for those who may report loneliness and may decrease opportunities for meaningful social connections.

In this review, studies that leveraged technologies with the increased number of technology embodiment features such as tablet-based communication applications (Neves et al., 2017) and video conferencing (Banbury et al., 2017; Zamir et al., 2018) presented promising opportunities for facilitating social connections. Findings indicated high acceptance and a positive impact on helping promote meaningful social connections and reducing feelings of loneliness. Furthermore, video conferencing was identified as a useful tool for developing social support and strengthening social ties (Banbury et al., 2017). Findings indicate that leveraging technologies with more embodiment features can present opportunities for engagement and social connections.

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Table 5. Overview of technology types and technology embodiment features

Technology type	Study	Technology embodiment features				
		Text	Image	Voice	Video	Mobility
SNS	(Lin et al., 2020)	x				
	(Lima et al., 2017)	x				
	(Ye & Lin., 2015)	x				
	(Zhou, 2018)	x				
	(Pittman & Reich, 2015)	x	x			
	(Primack et al., 2017)	x				
	(Thomas et al., 2019)	x				
	(Yu et al., 2016)	x				
Tablet and app intervention	(Neves et al., 2017)	x	x	x	x	
Videoconferencing	(Banbury et al., 2016)			x	x	
	(Zamir et al., 2018)			x	x	x
Personal reminder information and social management system	(Czaja et al., 2016)	x	x	x	x	
Internet-based social technologies	(Szabo et al., 2018)	x				
	(Bruggencate et al., 2018)	x				
	(Hu, 2009)	x				

Understand how one's sense of social connectedness may be impacted by the level of technology embodiment used

This review indicates that communication technologies do not always provide users with similar functions and capabilities. For example, among social networking sites, their use and application impacted users' perception of social connection and experience of loneliness. Although there is very little support, findings indicate that there is a noted difference between social networking sites that enable users to share images (Pittman & Reich, 2016). Findings indicate that social networking sites have a diverse set of functions that serve various roles, including but not limited to communication, opportunities for social interactions, sharing information, and supporting relationships (Aarts, 2018; Antoci et al., 2014; Appel et al., 2020; Batinic & Göritz, 2009). However, it is often unclear as to what is the most common use, how individuals across the lifespan are using these platforms, and what functions users perceive as most beneficial in forming meaningful social interactions. This suggests that the inconsistency across literature pertaining to the usefulness of social media in facilitating meaningful relationships may be closely tied to a lack of insights into how participants use and leverage social media to form meaningful social connections.

In studies conducted with older adults, particularly those focused on video conferencing and interventions aimed to support social connectivity, the experiences reported by participants indicate an improved sense of connectivity. These types of technologies have a more diverse set of functions and capabilities when compared to

social networking sites, expanding the ability to communicate through image sharing, video, and synchronous communication (Balsamo, 1995; Luna Dolezal, 2009). Human communication is made up of three core components: verbal communication, non-verbal communication, and para-verbal communication. The ability to engage through communication technologies that allow individuals to share and receive messages that most closely resemble that of in-person communication may be beneficial in helping support a stronger sense of connectivity and allow them to feel embodied through the communication medium. Research indicates that social connectivity is a core component that has been linked to lower rates of loneliness. Across the research, opportunities for meaningful social connections are often reported to be more important than the number of social interactions an individual may experience (Fairchild et al., 2017; Ortiz-Ospina & Roser, 2020; Thayer & Anderson, 2018). Therefore, creating an experience for the user of the technology that enhances immersion may help strengthen the quality of connections achieved through technology mediated communication.

Limitations

The current systematic review provides an overview of the current state of the literature on the use and application of communication technologies and their use in facilitating social connectivity across various phases of adulthood. An underlying limitation of this review is the moderate quality of the studies included and the limited research exploring the role of communication technology in addressing loneliness. Furthermore, the studies included in this review

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implemented a cross-sectional design that limits the determination of causality. It is important to note that previous studies have indicated that technology-focused research may have biased samples, that can result in an overestimation of results (Toscos et al., 2019). Considering the technology focus of this review, biased sampling in the studies included may have implications on the overall generalizability of the results presented. Additionally, the inclusion of English-only articles in our review may have increased the chance of language bias and limited the diversity of the articles included. Overall, the current literature provides very minimal insights into the use and application of communication technologies across each phase of adulthood and over time.

Implications for future research and practice

The technologies identified in this review represent a small portion of the types of communication technologies individuals use to engage in communication and adapt to changing societal norms. Furthermore, the types of technologies that are often used by adults change as new technologies emerge on the market older ones often become obsolete (Nowland et al., 2018). With the emergence and access to the internet adults across all age groups are using communication technologies at a higher rate than ever before (Anderson et al., 2019). The role and purpose of communication technologies can vary for individuals along with how they are being used and implemented to support the needs of their users (Freeman et al., 2020; Rama et al., 2001). Research in these areas is needed to help understand the types of communication technologies adults are using and implementing to support meaningful connections across the lifespan. Furthermore, an understanding of the social technologies used by older adults serves an important role in the development of interven-

tions and development of community programs aimed at addressing the experience of loneliness.

Translation of research focused on the application of communication technology is an important step toward real-world resource development to support healthy aging (Mois & Fortuna, 2020). Partnerships facilitated between researchers and practitioners can promote discussions surrounding the opportunities and challenges of technology to facilitate communications (Sebastian et al., 2018). Furthermore, understanding the needs, challenges, and concerns of community members surrounding accessibility and application of technology can inform the development of technology platforms that are more attentive to user needs.

CONCLUSION

This systematic review presents the current state of the literature related to the range of communication technologies being used and implemented through interventions to support social connectivity and address the experience of loneliness. Findings indicate that communication technologies hold the potential in helping facilitate social connections. Technology embodiment functions present an important role in how social connections are mediated through communication technology. However, there is limited understanding surrounding the application of higher-level embodiment technologies in the lives of young and middle-aged adults (Bevilacqua et al., 2014; Casiddu et al., 2015). Future research should aim to capture the use and application of communication technologies to facilitate social connections in the lives of individuals across the lifespan. Furthermore, research needs to consider how short- and long-term use of communication technologies impact humans' sense of social connectivity as they transition across various phases of adulthood.

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