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Rethinking Social Relationships in Old Age:

Digitalization and the Social Lives of Older Adults

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Abstract

Interactions with technology have been shaping human society since its beginning. Recently, digitalization has pervaded all aspects of our lives and provided us with new ways to communicate with our social contacts and develop new social ties. We address how these changes shape the social lives of older adults today. Several factors may give rise to concerns that older adults today are at risk for social isolation, including demographic trends toward smaller families, or reduction of previous activities due to health limitations. At the same time, older adults today have access to new technologies that may enable them to overcome geographical distance and mobility barriers. First, based on models of technology adoption, we review research on digital technology use by older adults. Although older adults use technology at lower rates than other age groups, rates of (social) internet use are increasing. However, socio-demographic disparities exist in access to technology. Second, we focus on three key questions and methodological directions for future research: (a) Does (social) internet use contribute to more positive social experiences and well-being in old age? (b) What are future methodological directions in the study of social technology use in older adults? (c) Do digital technologies reshape the social experience in old age or do they reinforce existing preferences and behaviors? Addressing these questions will allow us to understand the effects of technology on older adults' daily lives and how this in turn affects multiple domains of functioning (e.g., well-being, cognitive function, physical health) in future generations.

Words: 249

Keywords: social relationships; technology use; digitalization; well-being; loneliness

Public significance

Digitalization has pervaded all aspects of our lives including our social relationships. Although older adults under-utilize digital communication technologies relative to other age groups, rates of social internet use are increasing. This article reviews research on (social) technology use in older adults and associations with social integration and well-being. Furthermore, it highlights open questions for future research in order to better understand the role of technology use for social integration in older adults, the fastest growing population segment in many industrialized countries.

Rethinking Social Relationships in Old Age:

Digitalization and the Social Lives of Older Adults

Social relationships are fundamental to social integration (Cutrona & Russell, 1987), quality of life (Myers, 1999), and well-being (Diener & Seligman, 2002) throughout the lifespan (Antonucci, 2001). Social relationships are central for fulfilling fundamental human needs such as need for relatedness (Deci & Ryan, 2000), intimacy (McAdams & Constantian, 1983), or need to belong (Baumeister & Leary, 1995), and also provide an important context in which to give and receive social support (Fiori, Smith, & Antonucci, 2007). Furthermore, social integration and social participation predict more positive health (Cacioppo & Cacioppo, 2014; Holt-Lunstad, Smith, & Layton, 2010; House, Landis, & Umberson, 1988; Steptoe, Shankar, Demakakos, & Wardle, 2013) and cognitive (Fratiglioni, Wang, Ericsson, Maytan, & Winblad, 2000; Hertzog, Kramer, Wilson, & Lindenberger, 2008; Lövdén, Ghisletta, & Lindenberger, 2005; Seeman, Lusignolo, Albert, & Berkman, 2001; Wilson et al., 2007) outcomes: For example, higher levels of social participation predicted less subsequent longitudinal decline in perceptual speed in old and very old participants of the Berlin Aging Study (Lövdén et al., 2005).

Although social relationships are important for an individual's well-being throughout the lifespan, they may be even more important for older adults. According to the socio-emotional selectivity theory, with declining future time perspective, that is, when future time is perceived as limited, older adults prioritize close social relationships over more distant ones in order to enhance well-being (Carstensen, Isaacowitz, & Charles, 1999). Older adults have smaller social networks than younger and middle-aged older adults and view close social relationships as more important (Lang & Carstensen, 1994).

Several changes in the recent decades may have led to changes in older adults' social lives over historical time: Socio-demographic trends such as increasing proportions of unmarried and

childless individuals in the Baby Boomer cohort (Lin & Brown, 2012; Rowland, 2007) may lead to concerns that older adults today may become socially isolated. However, older adults today report even lower levels of social and emotional loneliness than older adults in previous generations (Eloranta, Arve, Isoaho, Lehtonen, & Viitanen, 2015; Hülür et al., 2016). Also, older people's social networks are geographically less proximal and they may have less access to social resources than younger adults (Ajrouch, Antonucci, & Janevic, 2001).

Thus, one important question is: How do older adults today compensate for smaller family networks and geographical distances? Research has shown that older adults today have more friend-oriented social networks than older adults in previous generations (Ajrouch, Akiyama, & Antonucci, 2017; Schnettler & Wöhler, 2016; Suanet, van Tilburg, & Broese van Groenou, 2013). That is, older adults today place more importance on voluntary non-family relationships. In older adults of more recent generations, the proportion of non-family among one's social network is largely maintained with age compared to previous generations (Suanet et al., 2013). Also, the psychosocial disadvantage associated with being unmarried has declined across cohorts (van Tilburg, Aartsen, & van der Pas, 2015; van Tilburg & Suanet, in press): For example, being divorced had a weaker effect on social loneliness in older adults in 2012 than it had in 1992 (van Tilburg et al., 2015).

Not only the structure of social networks (e.g., family vs. non-family) is changing across historical time, but also the way these relationships are maintained, for example, via technology. Interactions with technology have been shaping human society since its beginning. Over the recent decades, the digital revolution has rapidly been changing our lives, for example, how we search for and access information or how we engage in service and business transactions. Furthermore, digital technologies are considerably shaping the social landscape, with more and more people using digital communication technologies to stay in contact with close others and to

develop new social ties. It is possible that older adults today rely on information technologies to keep in touch with existing family and friends living further away and to develop new social contacts, an opportunity that was not available to previous generations. Less is known about which specific online social activities older adults pursue, how these activities complement their offline social life, and how this relates to social integration and well-being.

In this article, we review research on social internet use by older adults building upon theoretical models of technology acceptance. Furthermore, we discuss three key questions in technology use and social relationships in old age: (1) How does the increasing use of digital communication technologies shape social resources and well-being in old age? (2) What are methodological issues in the study of social relationships and technology use in older adults? (3) Is digital transformation reshaping the nature of social relationships in old age, or does it reinforce existing behavior patterns?

Technology Adoption in Older Adults

Information technologies increasingly pervade our daily lives, however, there are striking differences in how people view and engage with these technologies. In the recent decade, the number of internet users increased rapidly in all age groups, including older adults, who nevertheless still utilize digital technologies at lower rates than younger people. The Pew Research Center reported in April 2019 (Anderson, Perrin, Jiang, & Kumar, 2019) that while 90% of adults under 65 years of age in the US use the internet, only 73% of adults 65 or older do the same. The European Union reports even lower numbers of elderly internet users: On the whole only 45% of 65-74 year olds used the internet “at least once a week” in 2016 with large variety between member states (e.g., 81% in Denmark vs 12% in Bulgaria) (Eurostat, 2019). Given the increasing reliance on online services (e.g. for online banking or travel arrangements), this could mean that older people are excluded from important aspects of society. In addition,

using the internet for communication has important advantages for older people in particular: Being able to keep in touch with distant family members and friends may help to overcome geographical distances (Oishi, 2010) and physical mobility barriers (Diehr, Williamson, Burke, & Psaty, 2002) in order to prevent feelings of loneliness and isolation (Antonucci, Ajrouch, & Manalel, 2017).

Research on the digital divide has widely documented that access to the internet depends on socio-demographic factors. In the Pew American Life Project, internet use was lower among those who were older, less affluent, part of a minority group, less educated, and living in rural areas (Anderson et al., 2019). While the so-called "young old" (third age, Baltes & Smith, 2003) are gaining access to the internet in increasing numbers, rates of internet use are much lower for the so-called "old-old" (fourth age, Gell, Rosenberg, Demiris, LaCroix, & Patel, 2015). Most studies that examined the role of gender find that older men are more likely to be internet users than older women (Gell et al., 2015; Nayak, Priest, & White, 2010; Selwyn, Gorard, Furlong, & Madden, 2003; van Deursen & Helsper, 2015; but see Yu, McCammont, Ellison, & Langa, 2016); however, no gender difference is found in younger and middle aged adults (Wasserman & Richmond-Abbott, 2005). It is possible that the early studies finding gender differences reflect cohort effects, i.e. a larger proportion of men than women may have been familiar with digital technology in the early internet age who have now aged and contribute to the gender differences found in older adults. This finding also indicates that gaps between older women's and men's internet use may be closing in the decades to come.

Models of Technology Acceptance

Several models of technology acceptance have been proposed to explain individual differences in technology use, and three have been influential in understanding technology use in older adults: The Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh,

Morris, Davis, & Davis, 2003) the Senior Technology Acceptance Model (STAM) (Chen & Chan, 2014), and the CREATE model (Czaja et al., 2006). Although UTAUT has initially been developed in the work setting, it has since been applied to understand individual differences in technology use among older adults (Bixter, Blocker, Mitzner, Prakash, & Rogers, 2019; Macedo, 2017). STAM is an extension of the general technology acceptance model (Davis, Bagozzi, & Warshaw, 1989) that specifically focuses on technology use in older adults. Table 1 shows similarities and differences regarding the concepts and predictor included in each of these models. According to both STAM and UTAUT, *perceived usefulness* of a technology (called "performance expectancy" in UTAUT) and *perceived ease of use* (called "effort expectancy" in UTAUT) are central predictors of technology use. Both models incorporate the role of facilitating conditions, such as perceived availability of support in case of difficulties with technology. Furthermore, *social influence* is one of the central predictors in UTAUT, and *attitude toward technology* is one of the central predictors in STAM. Recently, Bixter and colleagues (2019) proposed to extend UTAUT to include *privacy and security concerns*, which were often a reason for older adults not to use digital communication technologies.

CREATE is centered on the role of *computer efficacy*, *computer anxiety*, and *cognitive resources* in predicting technology adoption (Czaja et al., 2006). Older age is hypothesized to be associated with lower levels of computer efficacy and higher levels of computer anxiety, as well as declining levels of cognitive resources. Based on two-factor theories of intelligence (Cattell, 1963), age is expected to be associated with lower levels of fluid intelligence (i.e. cognitive resources, relatively content-free abilities related to basic information processing) and higher levels of crystallized intelligence (acquired knowledge such as vocabulary or general knowledge). Czaja and colleagues found support for this model in a lifespan sample of adults in the US (Czaja et al., 2006).

Research based on these theoretical models has examined the role of factors related to interactions with technology, such as previous experience with, interest in, and attitudes toward technology. Perceived usefulness and ease of use, two of the central predictors in UTAUT and STAM emerged as playing a central role in technology adoption in community samples of older adults (Choi & DiNitto, 2013; Nayak et al., 2010; Pan & Jordan-Marsh, 2010). Furthermore, it has repeatedly been shown that one of the main factors predicting computer use was previous use, for work or private purposes (Braun, 2013; Choi & DiNitto, 2013; Czaja et al., 2006; König, Seifert, & Doh, 2018; Mitzner et al., 2019; Tacken, Marcellini, Mollenkopf, Ruoppila, & Széman, 2005). Previous experience with technology likely increases perceived usefulness, reduces the expected amount of effort, and increases efficacy and lowers anxiety. In addition, a general interest in using computers and lower levels of computer anxiety were also predictive of technology use in samples of community-dwelling older adults (Czaja et al., 2006; Czaja & Sharit, 1998; Ellis & Allaire, 1999; Vroman, Arthanat, & Lysack, 2015). Highlighting the role of social influence, a central predictor in UTAUT, older adults were more likely to use digital devices if a friend or an adult child used one (Gatto & Tak, 2008).

Based on these theoretical models, researchers aimed to increase technology use in older adults by creating familiarity with as well as boosting their efficacy in computer and internet use. Criticisms of some of the earlier intervention studies (late 1990s and early 2000s) include small sample sizes, lack of active control groups (it is unclear whether effects are attributable to the contents of the training or face-to-face social interaction with trainers and other participants), and cross-group contamination, that is, the control group learning about the intervention if they are part of the same community (Dickinson & Gregor, 2006). An earlier randomized controlled intervention study with 191 healthy participants aged 64-75 years found no effects on everyday functioning, well-being, mood, and social networks (Slegers, Boxtel, & Jolles, 2007). A more

recent randomized control study by Czaja and colleagues targeted older adults at risk of social isolation, defined as individuals aged 65 or older who live alone, show minimal computer or internet use, are not employed or volunteering for a substantial amount of time, and spend little time at senior centers or formal organizations (Czaja, Boot, Charness, Rogers, & Sharit, 2018). The intervention involved a computer system designed specifically for older adults as well as an active control group. In the intervention group, loneliness was reduced and social support was increased at 6 month follow-up in comparison to the active control group. Although the intervention group showed some improvement compared with baseline, differences between the intervention group and active control group were not maintained at 12 months. Booster sessions after the initial intervention may have been beneficial in sustaining the effects obtained at 6 months over the long term. Another important finding of randomized controlled intervention studies is that participants in the training group continue to use technology after the end of the intervention (e.g., White et al., 2002).

In sum, these findings suggest that internet use in older adults will become more common in future generations with more positive attitudes toward computers (Lee et al., 2019) and more extensive previous experience. Furthermore, interventions have delivered promising results to increase internet use and improve social outcomes and guidelines are being developed to make technology more accessible to older adults (Cotten et al., 2016).

Social Internet Use in Older Adults

The internet is being used for increasingly diverse purposes, such as social internet use to reach out to others, instrumental use, such as online banking or online shopping, informational use, such as searching for information, or for entertainment. According to the socio-emotional selectivity theory, older adults prioritize social goals over informational goals (Charles & Carstensen, 2010). Thus, it may be expected that their technology use is in line with these

priorities (Chang, Choi, Bazarova, & Löckenhoff, 2015; Sims, Reed, & Carr, 2017). Available evidence supports this reasoning: Older adults use the internet primarily for social purposes. For example, a survey of a nationally representative sample of US adults shows that e-mail is the most used online tool, with 86% of online older adults (65+) using it, 48% on a daily basis (Zickuhr & Madden, 2012). Furthermore, similar developments are observed globally: A recent report by the Pew Research Center (Silver et al., 2019) documented rates of social media use (WhatsApp and Facebook) in older adults (50+) from emerging economies. Although older adults used social media less than other age groups, rates were still substantial: For example, 60% of older adults in Lebanon used WhatsApp and 37% used Facebook. However, there were also between-country differences with regard to social media use of older adults. For example, only 11% and 9% of older adults in India used WhatsApp and Facebook, respectively. In all countries included in this survey, older adults were less likely to use social media than younger and middle-aged adults.

Although older adults currently use social networking sites to a lesser extent than other age groups; the numbers are expected to grow rapidly, as identified in a systematic review (Nef, Ganea, Müri, & Mosimann, 2013). A common concern of older adults who did not use social networking sites was privacy, as well as a fear of inappropriate content (see also Bixter et al., 2019). In contrast, older adults who used social networking sites, or began using them through the course of an intervention study, saw the benefit of staying in touch with younger family members (Nef et al., 2013). Indeed, the strongest predictors of social networking site use in older adults were trust and perceived usefulness in addition to the frequency of internet use (Braun, 2013). This suggests that once older adults have a reason to use social networking sites and are familiar with the technology, they begin to see the benefits. Older adults do not yet use online dating websites at the same rate as other age groups, but the numbers are expected to grow in the

future: The Pew research center reports that the use of online dating sites in those aged 65+ remained stable at 3% between 2013 and 2015, while the numbers doubled from 6% – 12% in 55 to 65 year olds (Smith, 2016). Older adults who use the internet relatively more frequently perceive it as having increased the quantity of communication and made it easier to stay in touch with existing contacts and to meet new people (Cotten, Anderson, & McCullough, 2013).

Current Knowledge and Directions for Future Research

Does (social) internet use contribute to more positive social experiences and well-being in old age?

Earlier studies on internet use, social relationships and well-being primarily focused on adolescents and younger adults. The earlier years of this research were characterized by worries that communication over the internet may replace face-to-face interactions and increase social alienation (Nowland, Necka, & Cacioppo, 2018). However, research has shown that internet users did not have fewer offline friends than non-users (Wang & Wellman, 2010). Despite widespread concerns related to digital technology use by adolescents, a study based on three large scale data sets from the US and the UK has found that technology use had only minimal effects on well-being, explaining at most 0.04% of individual differences (Orben & Przybylski, 2019).

It is unclear whether findings obtained in younger populations can be generalized to older adults (Nowland et al., 2018). Older adults today adopted internet use at a comparably later age and might perceive digital communication differently than younger adults. A growing number of studies examine whether the use of internet and communication technologies is related to better social integration and higher well-being in older adults. So far, these studies have reached mixed conclusions.

An analysis of cross-sectional data obtained in 2008 in the Health and Retirement Study indicated that internet use was associated with a variety of positive psychosocial outcomes, such

as social support, lower levels of loneliness, higher life satisfaction and higher levels of psychological well-being (Heo, Chun, Lee, Lee, & Kim, 2015). However, as noted in the previous sections, older internet users and non-users differ in a number of socio-demographic and psychological variables, which may be at least partially responsible for the observed associations. Based on data from the National Health and Aging Trends Study in the US, Elliot and colleagues (Elliot, Mooney, Douthit, & Lynch, 2014) found no association between information and communication technology use and depressive symptoms after controlling for age, socio-economic status, cognitive function, health, and social integration. Likewise, Quintana and colleagues analyzed data from the English Longitudinal Study of Aging and found that internet use was unrelated to life satisfaction and enjoyment of life (Quintana, Cervantes, Sáez, & Isasi, 2018) after controlling for gender, education, marital status, physical activity, and voluntary work. Internet use was only related to eudaimonic well-being (encompassing control, personal growth, and self-acceptance), with the difference between users and non-users amounting to an effect size of 9% of a standard deviation unit (Quintana et al., 2018).

Some studies find unique associations of internet use with well-being independent of socio-economic status in some older adult populations: Based on data from the Health and Retirement Study, Cotten and colleagues found that internet use was associated with a lower probability of depression in retired older adults, especially in those living in smaller households (Cotten, Ford, Ford, & Hale, 2012, 2014). These findings suggest that social contacts through the internet may serve a compensatory function in older adults with smaller family networks. There are several other findings suggesting that internet use may serve a compensatory function: For example, in a convenience sample of 222 older Australians, participants who expressed more feelings of loneliness related to family also used the internet more frequently with the goal of meeting new people (Sum, Mathews, Hughes, & Campbell, 2008). Also, in an analysis of the 2004 wave of the

Health and Retirement Study, internet users tended to have less personal contact with close family members, but participated more in organizations and clubs (Hogeboom, McDermott, Perrin, Osman, & Bell-Ellison, 2010). Thus, internet use may have positive effect on social activities in older adults lacking large family networks.

A study focusing on the role of disability also suggests that internet use may play a compensatory function: In an analysis based on the National Health and Aging Trends Study in the US, disability was associated with lower likelihood of internet use (Gell et al., 2015). However, this relationship was not straightforward: While higher levels of disability and difficulty with everyday tasks were associated with lower likelihood of internet use, higher levels of pain and breathing difficulties were associated with higher likelihood of internet use. This might reflect the effect of two distinct forces: On the one hand, existing technologies may be challenging to use for individuals with disabilities. On the other hand, internet use may be particularly beneficial for those persons who otherwise find it hard to communicate or engage in other activities due to pain or respiratory issues. It is a possibility that these individuals recognize the benefits and engage in technology use despite the barriers (Gell et al., 2015).

The purpose of internet use has been found to play an important role in its associations with well-being: In a longitudinal analysis based on a national sample from New Zealand, Szabo and colleagues (Szabo, Allen, Stephens, & Alpass, 2019) found that social internet use was associated with lower levels of loneliness and higher levels of social participation, which in turn predicted higher levels of well-being. Informational and instrumental use of the internet were associated with more social participation, but were unrelated to feelings of loneliness.

In sum, research to date is not yet clear whether there are any benefits of social internet use for social integration and well-being. One of the critical issues is that the same factors that predict internet use are also related to the outcomes in the domain of well-being and social relationships.

For example, is social integration an outcome of internet use or do older adults who are less (or more) more socially integrated use the internet more often? Analyses using case-matching to reduce the impact of confounding variables (e.g., Cotten et al., 2012, 2014) as well as analyses of time-ordered associations (e.g., Kamin & Lang, 2019) are promising strategies to address this question. Questions related to internet use are incorporated in major longitudinal studies on aging such as the Health and Retirement Study and the Survey of Health, Ageing and Retirement in Europe, allowing analysis of this question in population-based samples. In addition, research needs to increasingly focus on specific activities performed online as well as older adults' motivations for pursuing these activities. Also, effects may differ across individuals: Older adults without larger family networks as well as those with health limitations may benefit more from using the internet. Thus, internet use may serve a compensatory function (Baltes, 1997) in these individuals.

Another set of open questions revolves around potential protective effects of social internet use outside the domain of social relationships, for example, on cognitive functioning and health. Although a number of studies identified associations between internet use and cognitive functioning (Carpenter & Buday, 2007; Czaja et al., 2013; Freese, Rivas, & Hargittai, 2006; Tun & Lachman, 2010; Umemuro, 2004) , there is very little research on whether higher levels of cognitive function lead to more frequent internet use or vice versa (Kamin & Lang, 2019). If using the internet can increase social connectedness and reduce loneliness, this might, in turn, also be expected to affect cognitive function positively, given previous research linking social integration and social participation with cognitive aging (Hertzog et al., 2008). Furthermore, according to "use it or lose it" theories of cognitive aging, engaging in cognitively enriching activities is beneficial for maintaining cognitive function in old age (Hertzog et al., 2008). Internet use can serve as another cognitively enriching activity. Internet use has also been linked

to the health domain: For example, in the Health and Retirement Study, the participants' own, as well as their partners' internet use was associated with health behaviors such as getting health exams or influenza vaccination (Nam, Han, & Gilligan, 2019). Thus, internet use may have a positive effect on health behaviors. Available evidence also indicates that social internet use may help people to cope with chronic illness. Participation in online support groups was associated with better psychosocial outcomes in chronically ill rural women, such as social support and self-efficacy (Weinert, Cudney, & Hill, 2008). It is an important question for future research whether these psychosocial benefits can in turn change the disease trajectory.

New Methodological Approaches to Study the Use of Digital Communication Technologies

Although previous research has shown that associations of internet use with social integration and well-being depend on the type of activity, less is known about the specific social activities taking place online and how they are perceived by older adults. Furthermore, little is known about how online social activities are embedded in older adults (online and offline) daily lives. As a result, it is less well understood how digital communication technologies shape older adults' social lives.

One promising avenue to better understand the effects of digitalization on older adults' social lives is to study social experiences as they unfold in daily life. Studying social interactions and social relationships in daily life has several advantages over more global self-reports. These types of reports are less prone to retrospective biases. In contrast, when participants report more globally about their social behaviors and how they experience them, their responses may be biased by the salience of recent events (Moskowitz & Sadikaj, 2012). Micro-longitudinal assessments in daily life can take various formats. The event-contingent micro-longitudinal design has been utilized in previous studies of social interactions in daily life (Nezlek, Wesselmann, Wheeler, & Williams, 2015; Yao & Moskowitz, 2015). In an event-contingent

design, participants fill out a questionnaire after experiencing a pre-specified event (Bolger & Laurenceau, 2013), for example a social interaction of pre-specified type or duration. One of the advantages of this design is that participants report about the event immediately or soon after it happened, making it possible to capture their immediate experiences and reactions.

Studies focusing on social interactions in daily life typically used (adaptations of) the Rochester Interaction Record (Reis & Wheeler, 1991) to study patterns of social life. A study with younger, middle-aged, and older adults has shown that participants on average reported seven face-to-face interactions per day that last five minutes or longer (Ram et al., 2014; Wood et al., 2018). To be able to study the variety of social interactions taking place in people's daily lives, available measures need to be extended to online social interactions taking place on different devices (laptops, smartphones, tablets…) and via different applications (text, video chat, social media…).

It is also important to consider online and offline social activities conjointly. A qualitative study based on semi-structured interviews with older adults found that they preferred face-to-face interactions over other types, and communicated by phone in case face-to-face interactions were not possible (Yuan, Hussain, Hales, & Cotten, 2016). Video-calls (e.g., via Skype) were perceived as most similar to face-to-face interaction by those who used them; however, rates of use were rather low. Thus, it is an open question whether social interactions taking place over other channels can ever compensate for lack of face-to-face interaction. This may also depend on the purpose of the interaction: For example, communication via digital channels may be similarly effective as face-to-face communication in giving and receiving emotional support. However, for giving and receiving instrumental support, geographical proximity may be more important.

Focusing only on the quantity of (online and offline) social interaction may conceal important individual differences in people's interaction patterns. We use data from three

individuals collected as part of a larger study to illustrate this point (see Figure 1). Participants were asked to report their social interactions in an event-contingent design using a short questionnaire on a smartphone over the course of three weeks (21 days). Participants rated their closeness to each interaction partner using the Hierarchical Mapping Technique (Antonucci, 1986): Interaction partners in the inner circle were those to whom participants felt "so close that it is hard to imagine life without them" (p. 10), interaction partners who were important in participants' lives were categorized in the middle circle, and other more peripheral social contacts were in the outer circle. Also, participants indicated whether they interacted with a stranger or service provider. We chose three individuals (aged 67 to 76 years old) who reported a similar number of social interactions in total: 143 (Participant A) 164 (Participant B), and 169 (Participant C) interactions. Figure 1 shows several similarities and differences. For example, most interactions took place face-to-face for all three participants. However, there were also some differences, for example, the proportion of very close others among one's interaction partners was higher for participant B than participants A and C. In contrast to participants A and B, participant C did not use social media. Furthermore, participant B used social media primarily to connect with very close others, whereas participant A interacted with strangers/service providers via social media. In sum, these data illustrate that social interaction patterns in daily life vary widely among participants who engage in a similar number of interactions in total. Communication via digital technologies (text, e-mail, social media) probably serves different purposes in these individuals. Thus, it is vital that studies investigating older adults' internet use utilize micro-longitudinal studies to further explore these processes.

Another promising avenue to study social interactions in daily life is mobile sensing, i.e., by using smartphones to gather sensor data from participants, such as location, activity, and application use (Miller, 2012). Available evidence indicates that older adults' loneliness levels

can be inferred by smartphone data, such as information about calls and messages or visited locations (Sanchez, Martinez, Campos, Estrada, & Pelechano, 2015). Combined with self-report data about participants' perceptions of social interactions, data collected via smartphones may offer valuable insights into older adults' social lives. Furthermore, this information can also be utilized to deliver just-in-time adaptive interventions (Nahum-Shani, Hekler, & Spruijt-Metz, 2015) to enhance social integration (Schulz et al., 2015).

In summary, due to the many possibilities for how older adults can use the internet, one focus of future research should be on the detailed analysis of habitual day to day use as it is embedded in other activities in daily life rather than relying on broader retrospective reports. In addition, social activities taking place online and offline need to be considered conjointly to understand the function of social internet use and how this function differs between individuals.

Does (Social) Internet Use Reshape Social Relationships in Old Age or Does It Reinforce Existing Preferences?

Even though older adults primarily use the internet for social purposes, it is less clear whether internet use is reshaping social relationships or reinforcing existing preferences. Findings from studies with adolescents and younger adults suggest that the latter may be the case: Adolescents and younger adults primarily use the internet to stay in touch with existing friends and making new friends is a less common motivation (Gross, Juvonen, & Gable, 2002; Subrahmanyam, Reich, Waechter, & Espinoza, 2008). For example, in a study with college students, Subrahmanyam and colleagues (2008) found that 81% reported using the internet to stay in touch with friends and family, while 29% reported using the internet to meet new people. This may even be more evident for older people: The socio-emotional selectivity theory suggests that older people place more importance on close social relationships and that social networks become smaller with age (Lang & Carstensen, 1994). A study by Thayer and Ray (2006)

indicates that the preference for staying in touch with existing social contacts vs. developing new ones may indeed be stronger in older adults compared with other age groups (see also Beneito-Montagut, Cassián-Yde, & Begueria, 2018; Chang et al., 2015). Also, research has shown that even when older adults adopt new media, such as dating websites, they act within well-documented motivational preferences by placing more importance on social and emotional goals than their younger counterparts: An analysis of age differences in 4,000 dating profiles on popular websites has shown that older adults' profiles more frequently included first-person plural pronouns ("we", "our") and positive emotions, whereas younger adults' profiles more frequently included first-person singular pronouns ("I", "me") and words related to achievement (Davis & Fingerman, 2016).

On the other hand, there is evidence from other age groups suggesting that technology is indeed reshaping social relationships. For example, online dating has transformed dating for younger cohorts. Based on a national sample of US adults in the How Couples Meet and Stay Together survey, Rosenfeld and Thomas (2012) show that couples who met online were less traditional than others, with interreligious and same-sex couples being more likely to have met online. Also, the data showed that internet use may have increased partnership rates for middle-aged individuals (Rosenfeld & Thomas, 2012). Even though older adults were less likely to have met their partners online, this may increase in coming years (Smith, 2016). It is also an open question how digital technologies are affecting friendships in old age. It is a well-documented finding that the number of less close social contacts declines in old age (Fung, Carstensen, & Lang, 2001). Increased use of social media by older adults could mean that they can maintain these more distant social contacts with little effort. Also, because older people's social networks are geographically less proximal (Ajrouch et al., 2001), communicating via technology may provide new opportunities to stay in touch. Data on social network composition from newer

cohorts of older adults will allow researchers to examine whether these patterns continue to hold or are transformed through digital technologies.

Another important question is whether differences in older adults' preferences with regard to technology reflect cohort differences, that is, the effects of being socialized in an era where these technologies did not exist, or age differences, that is the effects of ontogenetic changes in health, cognition and motivations across the lifespan of an individual. If age differences observed in current research are solely based on cohort membership, they may be expected to diminish in the coming decades, because new generations of older adults will be more familiar with technology use. However, there will always be new technologies that current generations will not be familiar with when they enter old age. In addition, some of the barriers to technology use for older adults probably reflect the influences of age-related changes over the lifespan in addition to generational differences, for example, declining cognitive, fine motor, and sensory abilities (Charness & Boot, 2009; Gitlow, 2014). Thus, it will be an intriguing question for future research whether earlier experiences with technology will make future generations of older adults more likely to engage with these new technologies, or whether age gaps in technology use will continue to persist.

Conclusions

Interactions with technology have been shaping human society since its beginning. Recently, the digital revolution has been one of the central driving forces behind societal change and pervaded all aspects of our lives, including our social relationships. Although older adults lag behind other age groups in the use of internet and digital communication technologies, they are increasingly using the internet for social purposes. An open question is whether older adults' social internet use is in line with their well-documented social needs and preferences, or whether the availability of these technologies is reshaping social relationships in old age. For example, are

older adults today more likely to maintain non-family relationships because they have more opportunities to do so? Or do they primarily use the internet to stay in touch with others in a similar way as previous generations, only with different means? To answer these questions, fine-graded assessments of older adults' online social activities are necessary in addition to offline social activities. This will allow us to understand how digital communication technologies are shaping older adults' social lives and how this in turn affects multiple domains of functioning (e.g., well-being, cognitive function, physical health) in future generations of older adults, the fastest growing population segment in many industrialized countries.

Words: 6,080 (Text + Figure Caption)

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Table 1. Predictors of technology adoption in models influential in research on aging and technology

UTAUT	STAM	CREATE
Performance Expectancy	Perceived Usefulness	
Effort Expectancy	Perceived Ease of Use	
Social Influence		
Facilitating and Impeding Conditions	Facilitating Conditions	
	Attitudes Towards Use	
Trust (Privacy and Security)		
Perception of Content		
Current Knowledge/Skills		
Self-Efficacy	Gerontechnology Self-Efficacy	Computer Efficacy
Anxiety	Gerontechnology Anxiety	Computer Anxiety
Positive and Negative Affect		
	Health and Physical Functioning	
	Cognitive Ability	Fluid and Crystallized Intelligence
	Social Relationships	
	Attitude to Life and Life Satisfaction	
		Age
		Education

Notes. UTAUT: Unified Theory of Acceptance and Use of Technology (Bixter et al., 2019; Venkatesh et al., 2003); STAM: Senior Technology Acceptance Model (Chen & Chan, 2014); CREATE: Center for Research and Education on Aging and Technology Enhancement Model (Czaja et al., 2006).

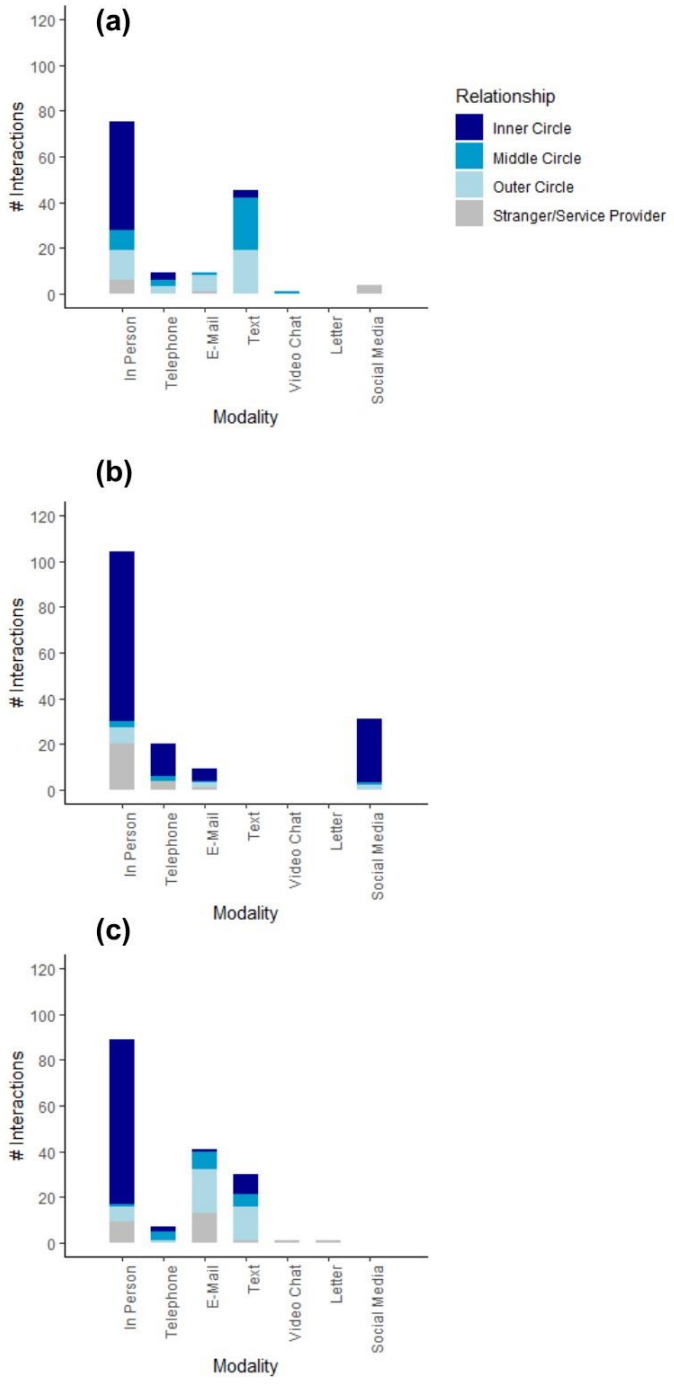

Figure 1. Illustrating individual differences in social interactions over 21 days in three participants (67 to 76 years old) who reported a similar number of interactions in total: Participant A (143 interactions), Participant B (164 interactions), Participant C (169 interactions). Most interactions took place face-to-face. Important interindividual differences include the proportion interaction partners in the inner circle (participant C interacted more with very close others as compared with participants A and B), as well as in social media use: Participant C did not use social media. While participant B used social media primarily to connect with very close others, participant C used it to communicate with strangers/service providers.