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ARTICLE

The role of social communication technologies in cognition and affect in older adults

Jessica Resor*, Steph Cooke and Benjamin Katz

Department of Human Development and Family Science, Virginia Tech, Blacksburg, Virginia, USA
*Corresponding author. Email: jmresor@vt.edu

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Abstract

Affect and cognition have both been associated with communication across one's social network during ageing. Thus, it is important to consider how communication varies by different aspects of one's social network, and by communication mode, including phone, email and social media. This study aimed to investigate the relationship between technology-mediated communication, depression and an executive function-related fluid-reasoning measure among older adults. Data were drawn from the Health and Retirement dataset's 2016 wave. Hierarchical regression analyses were conducted to examine the link between communication modes (phone, email and social media) with children, family and friends with a fluid-reasoning cognition measure and Center for Epidemiologic Studies Depression Scale, controlling for demographic covariates, among 3,798 older American adults. Phone and email communication, but not social media, were significantly related to depression and cognition. The model fit was considerably stronger for the analyses with cognition than depression. Curvilinear associations were found for communication via phone and email with cognition, suggesting moderate amounts of communication by phone and email across social groups were most closely linked with higher scores on fluid reasoning. For depression, curvilinear relationships were found for talking on the phone with family and friends, and emailing for children and family, indicating that moderate communication levels revealed the lowest depression levels. Implications for how older adults' social support may contribute to depression and cognition status are discussed.

Keywords: depression; cognition; communication technologies; ageing

Introduction

Both affect and cognition have been linked to communication within one's social network during ageing. These links are likely complex, and potentially bidirectional; for example, one's cognitive capacity may limit or enable one's ability to utilise novel communication technologies (Hill *et al.*, 2015), and the use of these technologies over time may also have a positive effect on certain aspects of cognitive function, such as episodic memory (Sharifian *et al.*, 2019). Similarly, one's affective

experience during ageing, such as depression status, may both influence, and be influenced by, the use of social communication technologies (Cotten *et al.*, 2013; Khosravi *et al.*, 2016; Teo *et al.*, 2019). However, while a growing body of research has focused on these links broadly across communication with one's social network, no study has yet investigated them simultaneously across individual communication technologies, such as phone, email and social media, and across different elements of one's social network, such as friends, family and children.

This is surprising given the considerable changes that occur in one's affective and cognitive status during ageing and the growing body of research into how these factors may be linked with communication technologies such as social media. For example, while depression might have serious consequences at any point in life, it may impact older adults differently. Over half of older adults with depression are experiencing it for the first time, known as late-onset depression (Fiske *et al.*, 2009). Depression in older adulthood also differs from depression in earlier stages of life; for example, it may be connected to higher suicide rates, more cognitive change and more loss of interest in everyday activities (Fiske *et al.*, 2009). Social ties, particularly negative relationships, may further prevent normative affective and cognitive functioning (Antonucci *et al.*, 1998).

Additionally, one's cognitive status changes across a variety of dimensions throughout ageing. Many individuals experience declines in executive function capacities, such as working memory, attention and inhibitory control (Buckner, 2004; Baudic *et al.*, 2006). While declines may be linked to individual conditions such as Alzheimer's disease and vascular dementia, they also occur during typical ageing. However, while these changes are widespread, there are important individual differences in how they occur; differences that may be linked to one's 'cognitive reserve', or the aggregated set of beneficial cognitive experiences one has had during the life-course (Stern, 2012). Social relationships and technology usage are both potential contributors to one's cognitive reserve – and thus social communication technologies may provide an important contribution to one's cognitive status during ageing that is more than the sum of its parts (Vance *et al.*, 2010; Clarke *et al.*, 2012; Astell, 2013).

Thus, communication with family and friends may be one crucial mechanism to curbing the effects of age-related depression and cognitive decline, and the Health and Retirement Study (HRS) dataset provides one promising avenue to investigate these topics. The HRS is a longitudinal dataset with a representative sample of approximately 20,000 older Americans that has been conducted at approximately two-year intervals since 1992. The HRS dataset has been used for a wide variety of applications during its extensive history, including in the examination of cognition and affect during ageing. Critically, later versions of the HRS have included a more expansive set of social network and communication technology variables, including phone, email and social media communication across individual social network components such as children, family and friends. Despite this level of granularity, however, extant studies have examined these links using summary scores, both across technologies in some instances, and generally by combining disparate social network elements (Chen and Feeley, 2014; Saczynski *et al.*, 2015). This may not fully capture the full nuance and complexity of one's social interactions,

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however, and there may be considerable value in exploring these links at a more granular level. Furthermore, how American older adults and families communicate may differ from the modes and frequency of communication by older adults of other countries.

Theoretical framework

Social relationships represent a vital component in maintaining affective and cognitive wellbeing over the course of one's life (Khosravi *et al.*, 2016; Sharifian *et al.*, 2019; Teo *et al.*, 2019; Vahia, 2019). The development of one's social resources throughout the lifecourse may be an evolving process, as individuals' proximity to different social network elements (*i.e.* spouses, children, friends, *etc.*) may shift over time. One prominent theoretical perspective, the convoy model, proposes that individuals move through life with the support of their social resources (Antonucci *et al.*, 2011). Each convoy member plays a critical, but somewhat different, role in one's life, *e.g.* connecting with other families that have children of similar ages and communities of faith (Denworth, 2018). There is variation, however, in the degree of closeness in each relationship, and in addition to the amount of time spent with social network contacts, relationship quality is also an important factor that may be linked to affect and cognition. In fact, quality is more predictive of health outcomes, both physical and mental health, than is relationship quantity (Hawkley *et al.*, 2008; Antonucci *et al.*, 2014). Furthermore, the convoy model facilitates a multi-dimensional view of an individual in the context of a variety of different relationships. Convoys are considered to be dynamic structures, with a mutual influence on cognition and affect between the individual and the convoy member (Antonucci *et al.*, 2011). Critically, the difference in relationship type and proximity may then influence how individuals maintain relationships. Technology-mediated platforms such as phone, email or social media may then increase proximity between older adults and their closest family and friends as they age but may operate differently across different elements of one's convoy. Given that prior research into social communication has combined spouses, children, extended family members and friends into one group (Cotten *et al.*, 2013; Hill *et al.*, 2015; Park *et al.*, 2016), there is potential value in re-examining these links across individual network components.

The convoy model promotes the application of this framework when answering the complex questions associated with ageing and changes throughout the lifecourse (Antonucci *et al.*, 2014). Hypothetically, technology-mediated communication may decrease depression symptoms because one would be able to maintain a positive relationship with their social resources. Similarly, one might expect that social communication technology usage might contribute to positive cognitive outcomes, but that the strength and nature of these links may vary across different elements of one's social network (*e.g.* one may use social media to continue communication with someone they consider close in real life, therefore, increasing these already salient connections; Adamic and Adar, 2003). Below we review the existing literature on the influence of social resources on depression, cognition and technology-mediated communication.

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Social resources and depression

Considerable interest has focused on the association between social connectedness and affective health during ageing (Teo *et al.*, 2019). Research indicates that older adults' social networks may have a significant positive impact on mental health (Fiori *et al.*, 2006). Fiori *et al.* (2006) found that having a diverse social network consisting of family, friends, and attendance at meetings and religious services had the best outcomes for depressive symptoms in contrast to restricted networks where individuals had very limited social ties, were typically unmarried or without children. Several studies demonstrate the important role family members play in supporting their older adult relatives (Hung *et al.*, 2017); particularly, research has shown that marriage is associated with a lower risk of depression (Robins and Regier, 1991). For instance, more positive experiences with one's spouse may potentially decrease depression symptoms, whereas other less-significant relationships, such as an acquaintance, may have less of an impact on mental health outcomes.

Several studies have directly examined the relation between different family members and depression outcomes in older adults. There is evidence to support that certain close relationships may have unintended negative outcomes (Fiori *et al.*, 2006). For instance, in grandparent-headed families, care-giving may interfere with one's mental health and wellbeing (Adams and Blieszner, 1995). Hung *et al.* (2017) examined specific types of family support and found that one's level of depression negatively correlates with one's perceived positive support from their spouse as opposed to perceived positive support from children and other immediate family members. Importantly, these associations may be bidirectional in nature: depressive symptoms may influence one's likelihood of engaging with social supports in addition to being impacted by them, although the evidence for bidirectional links is mixed (Monroe *et al.*, 1986; Gale *et al.*, 2012). Despite this promising work, extant research has not examined the ways in which types of technology-mediated *communication* with children, family members and friends may contribute to higher or lower rates of depression.

Social resources and cognition

Research has found that typical ageing is associated with declines in episodic memory, processing speed and executive functioning (Craik and Salthouse, 1999). For example, there is a wealth of evidence supporting links between age and verbal fluency performance among older adults. Bryan and Luszcz (2000) found significant inverse relations between age and performance on verbal fluency tasks in older adults. Specifically, age-related declines were noted for information-processing speed and incidental recall, and were greater for excluded letter fluency and Uses for Objects tasks (Bryan and Luszcz, 2000). Furthermore, a number of social network-linked individual difference factors may influence which cognitive domains are most impacted by the ageing process (van Hooren *et al.*, 2007). For example, several studies have found an association between an older adult's social network composition and episodic memory (*e.g.* Hughes *et al.*, 2008; Sharifian *et al.*, 2019). As with depression, it is possible that bidirectional links exist between cognitive functioning and social supports, although much of the extant work

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specifically examines long-term effects of earlier social support on later-life cognition (*e.g.* Sharifian *et al.*, 2019). In one study that examined the relationship between social relationship types (children, other family, friends, spouse) and health outcomes longitudinally, researchers found that more frequent contact with friends contributed to greater cognitive functioning in later life (Sharifian *et al.*, 2019).

One hypothesis that may explain this relationship is that friendships might require more cognitive effort and motivation to maintain, whereas relationships with family members are less voluntary. Additionally, unbalanced relationships (*i.e.* providing more support than one receives in return) are associated with an increased risk in Alzheimer's (Amieva *et al.*, 2010). Furthermore, technology-mediated communication, such as social media, has been linked to better memory outcomes over time, as it increases proximity to family and friends to maintain emotional ties (Barnes *et al.*, 2004; Sharifian and Zahodne, 2020). While much of the work in this space has thus far focused on episodic memory or global cognition, some studies have examined executive function-linked processes and capacities related to higher-level fluid reasoning, such as attention, working memory, inhibitory control or cognitive flexibility (Gow *et al.*, 2013; Katz *et al.*, 2020). We note that some studies suggest that social media may actually serve as a *mediator* between mental health indicators such as depression and cognitive functioning, through stress-buffering mechanisms (Hertzog *et al.*, 2009), and furthermore, that in certain situations, links between social resources may in fact be a double-edged sword: some research has also identified a potential role for social strain in deleterious effects on executive function (Tun *et al.*, 2013). Given established links between executive function and social resources, but a relative dearth of research focused specifically on social communications and executive function-related skills, we chose to focus on fluid reasoning in the present analysis – a particularly relevant skill given long-standing evidence for its plasticity during ageing (Blieszner *et al.*, 1981).

Social resources and communication technology

Feelings of isolation and loneliness can increase as adults retire, move or experience loss during ageing (Cotten *et al.*, 2014). Previous research has examined technology-mediated communication in helping older adults to maintain their social connectedness with family and friends (Cotten *et al.*, 2013). The study of 205 older adults in assisted and independent living communities by Cotten *et al.* (2013) found that the frequency of internet use was associated with less loneliness. Given that loneliness is associated with many negative outcomes in older adulthood, including risk of death, maintaining relationships via the internet has implications for the wellbeing of older adults (Cotten *et al.*, 2013). Furthermore, given the rapid advent of new communication technologies, different forms of communication (*e.g.* phone *versus* email *versus* social media) may operate differently. For example, lacking the appropriate skills to navigate the digitalisation of communication may lead to an increase in feelings of social isolation (Hill *et al.*, 2015). Nevertheless, technology-mediated communication (*i.e.* Facebook, Twitter, email, *etc.*) impacts older adults in different ways (Khosravi *et al.*, 2016). For example,

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social media sites like Facebook and Twitter have been found to reduce loneliness in older adults while they may cause loneliness for younger generations (Khosravi *et al.*, 2016).

Several studies have investigated different types of technology-mediated communication and affect in older adults. In a secondary analysis of the findings from the HRS, Vahia (2019) compared the 2012 data of self-reported video chat, instant messaging/online chatting, social media and email use to the 2014 data using the scores from the Center for Epidemiologic Studies Depression Scale (CES-D). Of these four variables, Vahia (2019) reported a significant correlation between video chat use and depressive symptoms, meaning that consistent video chatting was uniquely associated with lower depression scores among older adults. Teo *et al.* (2019) reported findings from the 2012 and 2014 waves of the HRS and found email was the most commonly used (58.3%) communication technology amongst older adults followed by social networks (28%), video chat (17.9%) and online chat/instant messaging (17.2%). Out of these four modalities, video chatting, such as Skype or Facetime, was the only one to be uniquely associated with a lower risk of depression (Teo *et al.*, 2019). In contrast, social media use and instant messaging/online chatting were less likely to correlate with negative depressive symptoms. These findings highlight the differential effects of various forms of technology-mediated communication, such as the unique potential of video chat, on affect in older adults.

Similarly, the increasing use of social media among older adults has led researchers to investigate the effects of communication technologies on cognition. Measures of cognitive function, such as everyday memory failures and global cognition, may be both positively and negatively linked to social media use during ageing (Kim and Kim, 2014; Sharifian and Zahodne, 2020). It is possible that social media may buffer the age-related impact on memory decline by acting as an 'external memory resource' (Sharifian and Zahodne, 2020: 542); however, consistent reliance on social media for memory storage may also pose challenges for cognitive functioning. Specifically, in their study on older adults, Sharifian and Zahodne (2020) reported consistent same-day and next-day memory failures, with more memory failures occurring on days with heavier social media use. There are two compelling possible reasons for this outcome: (a) offloading information limits our cognitive functioning and (b) social media is most commonly used on smartphones, therefore, phones may contribute to 'attentional disengagement' (Sharifian and Zahodne, 2020: 545). Significantly, much of this work with older adults has focused on links between social media usage and affect, or, when it does examine cognition, long-term memory. Relatively less work has specifically examined social media usage in the context of executive functioning or fluid reasoning-linked processes, and much of that is focused on children (*e.g.* media multi-tasking; Baumgartner *et al.*, 2014).

Finally, substantial evidence suggests that older adults are utilising social media sites such as Facebook to maintain social ties in substantial numbers (Park *et al.*, 2016). Usage of these platforms themselves may be linked, bidirectionally, to both affect and cognition, although extant work has generally focused on mental health rather than cognitive functioning. Specifically, social support via Facebook can help meditate feelings of isolation and loneliness. In their study on Facebook

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use in older adults, Park *et al.* (2016) found that more depressed individuals found greater social support from their negative Facebook posts compared to less-depressed individuals. This is not to say that depressed individuals post more negative disclosures; rather, it leads researchers to question which social relationships are salient on Facebook *versus* in real life. Additionally, Jung *et al.* (2017) found that one of the motivations for older adults using Facebook was to keep in touch with distant family members. Therefore, there is a need for research that looks more closely at social network composition and technology communication to determine the nuances of social relationships that rely on technology.

The present study

The purpose of this study is to investigate the association between technology-mediated communication, depression and fluid cognitive functioning in older adulthood. The present study aims to answer two primary research questions:

(1) How is technology-mediated communication with children, family members and friends associated with depression and cognition in older adulthood?
(2) Are depression and cognition influenced more or less by *specific forms of technology-mediated communication* (phone, email, social media)?

Given differences in how social resources might be related to these constructs, we expected to see differential effects on depression and cognition. Below we present five hypotheses by research question with our justification for each hypothesis.

For the first research question, we sought to examine associations between technology-mediated communication amongst one's social network, depression and cognition in older adulthood. We had three hypotheses related to children, family and friends. Specifically, we hypothesised (H1) that more communication with children and with family members would both be associated with lower depression scores and higher cognitive scores, while communication with friends, which may have more distant relationships with participants, would not be as closely associated with depression or cognition. We also hypothesised (H2) that communication with friends may be more strongly associated with affective, depression-related outcomes *versus* cognitive outcomes. While interacting with friends has been found in at least one study to improve executive function, potentially because of the relation between social intelligence and general intelligence (Ybarra *et al.*, 2011), we suspected that support from friends may be more closely linked to wellbeing and affect relative to cognition, given the intimate nature of friendships in supporting life satisfaction (*e.g.* Pagel *et al.*, 1987; Siebert *et al.*, 1999; Griffiths *et al.*, 2011). Third, we also expected (H3) to see a stronger association between frequency of communication across different technology types between children/family compared to friends, provided that children and family are more likely to provide instrumental support than friends (Adams and Blieszner, 1995).

For the second research question, we sought to investigate whether depression and cognition are influenced more or less by *specific forms of technology-mediated*

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communication, including phone, email and social media, across the different elements of one's social network mentioned above (children, family and friends). We had two hypotheses about communicating through technology. We hypothesised (H4) that phone and email will be more strongly associated with positive cognitive functioning than social media, as prior research has identified negative effects of social media on sleep, cognitive failures and problems with media multi-tasking (Hong *et al.*, 2016; Jeong and Hwang, 2016; Scott and Woods, 2018). Lastly, we expected (H5) to see quadratic effects for these outcomes, particularly within the cognitive measure, such that both too little, as well as too much, communication technology usage might be related to reduced cognitive performance. Specifically, it is possible that too little usage might not provide sufficient enrichment, but too much may also lead to 'technology overload' (Sharifian and Zahodne, 2020). Technology overload refers to excessive or above optimal use of technology which can cause negative consequences (Lee *et al.*, 2016).

Methods

Data source

We utilised the 2016 wave of the HRS for our dataset. The HRS is a nationally representative longitudinal dataset of approximately 20,000 ageing Americans conducted by the University of Michigan and funded by the National Institute on Aging (grant number U01 AG009740). The HRS has been collecting data every two years since 1992 via paper and online questionnaires. More recent waves of the HRS have included cognitive function variables, depression surveys, and a detailed set of social resource variables including social communication technology usage. For the 2016 wave, participants were compensated for each portion of the study as follows: baseline interview (US $100, average duration of three hours), panel interview (US $80, average duration of two hours), leave-behind survey (US $20, average duration of one hour) and mail surveys (US $25, average duration of one hour).

Sample

Our analytic sample of participants who had valid data for all variables of interest was 3,798. The sample was predominantly non-Hispanic White (67.7%), followed by 17.3 per cent non-Hispanic Black, 6.7 per cent Hispanic White, 4.4 per cent Hispanic other, 3.7 per cent non-Hispanic other and 0.2 per cent Hispanic Black. The mean age was 67.05 years (standard deviation (SD) = 10.33, range 50–96). The sample was 59.6 per cent female. Almost two-thirds (61.8%) of the sample were married in 2016. The mean number of years of education was 13.35 (SD = 2.68). The mean level of self-rated health was 3.22 (SD = 0.99).

Missing data are common in large publicly available datasets such as the HRS. While the HRS is a nationally representative dataset, various subsets of the dataset may not be. For instance, in our study, the social communication variables were asked to a subset of 2016 participants via the mailed questionnaire on Everyday Life and Well-being. The number of participants who answered all nine questions

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of the social communication variables was 4,084. From here, we note missing data were most common from the number series variable (n = 274), followed by CES-D score (n = 35), education (n = 16), race/ethnicity (n = 17), marital status (n = 7) and self-rated health (n = 3). We discuss the tradeoffs of listwise deletion in the Discussion section.

Measures

Demographic covariates

Race/ethnicity was recoded and created from two separate variables of race and hispanicity (race masked variables: White/Caucasian = 1, Black/African American = 2, other = 3; 'Do you consider yourself Hispanic or Latino?': not Hispanic = 0, Hispanic = 1) to create six groups: non-Hispanic White (0), non-Hispanic Black (1), non-Hispanic other (2), Hispanic White (3), Hispanic Black (4) and Hispanic other (5). Age was measured in years in 2016; participants under the age of 50 were excluded. Sex was measured by a binary variable for male (0) and female (1). A dummy coded variable for marital status (married =1, not married = 0) was created from one question: 'Just to clarify, are you currently separated, divorced, widowed or married?' Education was measured in years: 0 = no formal education, 1–11 = grades, 12 = high school, 13–15 = some college, 16 = college graduate, 17 = post college (17+ years).

Self-rated health was measured by one-item in 2016: 'Would you say your health is excellent, very good, good, fair or poor?' The five response items were reverse coded so that higher levels indicated better health: excellent = 5, very good = 4, good = 3, fair = 2, poor = 1.

Affective and cognitive variables

Depression was measured by scores on the eight-item CES-D (Turvey *et al.*, 1999) in the 2016 wave. The score is a summation of six negative minus two positive indicators for depression. The negative indicators with 'yes/no' responses refer to feeling depressed, everything is an effort, alone, sad, like you could not get going and having restless sleep. The positive indicators with 'yes/no' responses refer to participants feeling happy and enjoying life. Scores range from 0 to 8 with higher scores indicating higher levels of depressive symptoms. The eight-item scale has been found to produce similar results to the full CES-D scale consisting of 20 items and has been validated with a sample of older adults (Karim *et al.*, 2015).

Number series was used as our cognition measure because it is a quantitative non-verbal reasoning task that has been linked to executive functioning and also allowed us to maximise the size of the sample analysed here. In the number series tasks, participants are presented with a series of numbers with one number missing. The participant needs to identify the pattern in order to get the missing number (Unsworth *et al.*, 2009). Higher scores indicate higher levels of cognitive ability. The task was adaptive based on the participants' performance during the task. All participants were asked the same three items at the beginning and based on their performance, an easier or more difficult set of the task was then presented. The HRS provided the calculated score variable which was made by calculating the number of correct items the participants identified and assigning it a score

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from the scoring algorithm (Fisher *et al.*, 2014). Furthermore, this test is scored as a *W*-score with a possible range between 409 and 584 (Fisher *et al.*, 2014). The *W*-score is the recommended way for analysing and interpreting this task because it accounts for which blocks of items were asked, the number of items answered correctly and the item difficulty in terms of the probability that the participant will respond correctly (Fisher *et al.*, 2014). The *W*-score is based on a logit scale that accounts for the probability of the participant responding correctly to the items. The *W*-score is an interval scale, and a ten-point decrease equates to halving the probability of a correct response to an equally difficult item (Jaffe, 2009; Fisher *et al.*, 2014). We chose this single cognitive variable in order to draw from the largest sample possible for analyses. We discuss the trade-offs of this decision, as opposed to using a latent variable with multiple cognitive measures, in the Discussion section.

Social communication variables

Social communication by group was measured by the frequency of communication of each method by group (child, other family members and friends). For children, the following three questions were asked: 'On average, how often do you do each of the following with any of your children, not counting any who live with you?' 'Speak on the phone', 'Write or email', 'Communicate by Skype, Facebook or other social media'. For family, the three following questions were asked: 'On average, how often do you do each of the following with any of these family members, not counting any who live with you?' 'Speak on the phone', 'Write or email', 'Communicate by Skype, Facebook or other social media'. For friends, the three following questions were asked: 'On average, how often do you do each of the following with any of your friends, not counting any who live with you?' 'Speak on the phone', 'Write or email', 'Communicate by Skype, Facebook or other social media'. Items were reverse coded so that higher scores indicated higher frequency of communication: 1 = less than once a year or never, 2 = once or twice a year, 3 = every few months, 4 = once or twice a month, 5 = once or twice a week, 6 = three or more times a week. These variables were used in analyses individually and as a sum variable for each group: children, family members and friends.

Table 1 presents the descriptive statistics for study variables and Table 2 presents the correlation table.

Data analysis

IBM SPSS Statistics software version 26 was used to conduct all analyses. We performed six regression analyses to test the relationship between social communication (phone, email and social media) amongst the varying groups (children, family and friends), demographic variables, and either outcome variables, affect (depression) and cognition (number series). We used hierarchical multiple regression to assess the ability of social communication measures to predict levels of affect and cognition, after controlling for the influence of demographic covariates. For modes of communication (phone, email and social media), we investigated linear and quadratic variables to identify possible curvilinear relationships. Demographic

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Table 1. Descriptive statistics for study variables

Variable	%	Mean (SD)	Range
Age	–	67.05 (10.33)	50–96
Sex:			
Male	40.4		
Female	59.6		
Education (years)	–	13.35 (2.68)	0–17
Race/ethnicity:			
Non-Hispanic White	67.7		
Non-Hispanic Black	17.3		
Non-Hispanic other	3.7		
Hispanic White	6.7		
Hispanic Black	0.2		
Hispanic other	4.4		
Marital status:			
Married	61.8		
Not married	38.3		
Self-rated health	–	3.22 (0.99)	1–5
Number series score	–	534.64 (29.47)	409–584
CES-D score	–	1.17 (1.75)	0–8
Phone – children	–	4.98 (1.19)	1–6
Email – children	–	3.21 (1.89)	1–6
Social media – children	–	2.96 (2.02)	1–6
Phone – family	–	4.32 (1.37)	1–6
Email – family	–	2.63 (1.69)	1–6
Social media – family	–	2.46 (1.84)	1–6
Phone – friends	–	4.41 (1.23)	1–6
Email – friends	–	2.83 (1.82)	1–6
Social media – friends	–	2.61 (1.94)	1–6

Notes: SD: standard deviation. CES-D: Center for Epidemiologic Studies Depression Scale.

variables (race/ethnicity, age, sex, education, marital status and self-rated health) were entered at Step 1. Linear variables of communication mode for the specific social group (children, family or friend) were entered at Step 2 and quadratic variables of communication mode for the specific social group (children, family or friend) were entered at Step 3. For significant curvilinear relationships, we plotted them using the estimated marginal means.

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Table 2. Correlations for study variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Age	–															
2. Sex	−0.03	–														
3. Education (years)	−0.03	−0.03	–													
4. Marital status	−0.08***	−0.21***	0.12***	–												
5. Self-rated health	−0.03	−0.03	0.24***	0.14***	–											
6. Number series	−0.19***	−0.09***	0.43***	0.16***	0.23***	–										
7. CES-D	−0.10***	0.10***	−0.14***	−0.21***	−0.40***	−0.14***	–									
8. Phone – child	0.03	0.21***	−0.04**	−0.04*	0.00	−0.06***	−0.05**	–								
9. Email – child	−0.10***	0.07***	0.28***	0.11***	0.19***	0.23***	−0.13***	0.23***	–							
10. Social media – child	−0.28***	0.14***	0.12***	0.09***	0.11***	0.14***	−0.05*	0.23***	0.49***	–						
11. Phone – family	−0.05**	0.17***	−0.12***	−0.08***	−0.03*	−0.16***	0.01	0.32***	0.01	0.07***	–					
12. Email – family	−0.12***	0.10***	0.22***	0.07***	0.16***	0.17***	−0.10***	0.09***	0.62***	0.38***	0.23***	–				
13. Social media – family	−0.27***	0.16***	0.08***	0.04*	0.08***	0.09***	−0.02	0.14***	0.37***	0.70***	0.24***	0.52***	–			
14. Phone – friend	−0.02	0.15***	−0.03*	−0.16***	−0.00	−0.10***	0.01	0.19***	0.07***	0.08***	0.26***	0.11***	0.10***	–		
15. Email – friend	−0.18***	0.09***	0.31***	0.07***	0.20***	0.26***	−0.11***	0.02	0.60***	0.36***	−0.00	0.60***	0.35***	0.22***	–	
16. Social media – friend	−0.35***	0.16***	0.12***	0.03*	0.10***	0.16***	−0.02	0.09***	0.36***	0.67***	0.08***	0.37***	0.69***	0.17***	0.50***	–

Note: CES-D: Center for Epidemiologic Studies Depression Scale.
Significance levels: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Results

Results of the hierarchical multiple regressions analyses are reported in Tables 3 and 4. Our first hypothesis was that children and family would be more predictive of depression and cognition than friends. Hypothesis 1 was partially supported. Communication with children and family were more predictive of depression ratings than friends. For cognition, linear variables of communication with children and friends were more predictive than family. Our second hypothesis was that friends would have stronger associations with depression outcomes than cognitive outcomes. This hypothesis was not supported because communication with friends was significantly linked to cognitive outcomes, but not to depression outcomes.

Our third hypothesis was that we expected to see higher frequency of communication across different technology types between children/family compared to friends. Hypothesis 3 was partially supported. We summed the mean frequency of each mode of communication by social group to create total scores; participants' communication with children was 11.15, with friends it was 9.85 and with children it was 9.41. For each mode of communication (phone, email and social media), frequency of communications values ranged from 1 to 6. A score of 1 indicated communicating less than once a year or never, 2 = once or twice a year, 3 = every few months, 4 = once or twice a month, 5 = once or twice a week and 6 = three or more times a week. Participants' average communication by phone with children was 4.98, with friends it was 4.41 and with family it was 4.32. Average communication by email with children was 3.21, with friends it was 2.83 and with family it was 2.63. We found that participants communicated more with children in aggregate and across each individual mode of communication (phone, email and social media) than with family or friends. Unexpectedly, participants communicated with friends more than they did with other family members in total and within each mode of communication. Communication by social media was lowest across all modes of communication for all social groups; average communication by social media with children was 2.96, with friends it was 2.61 and with family it was 2.41. Given the amounts of communication, we saw the strongest links for both outcome variables with communication with children. Links were stronger with cognition for friends than family, and the reverse is true with depression.

Our fourth hypothesis was that communication through phone and email will be more associated with positive cognitive functioning rather than social media. Hypothesis 4 was partially supported. For children and friends, phone and email, but not social media, were positively and significantly associated with the cognitive outcome. For friends, email was positively and significantly associated with the cognitive outcome, but phone and social media were non-significant.

Our fifth hypothesis was that we expected to see quadratic effects for both outcomes. Hypothesis 5 was partially supported. For depression, looking at communication with children, communication by phone ($p = 0.001$) and email ($p < 0.05$) were significant, but not social media. The quadratic variables of communication by phone with family and friends were significant at $p < 0.05$ and $p < 0.001$, respectively. The quadratic variables of communication by email with children and by family were significant at the $p < 0.05$ level. *See* Figures 1 and 2 for the plot of estimated marginal means. Figure 1 shows very similar patterns for communication by

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Table 3. Regression analysis results for depression outcome by mode of communication

		Communication with children					Communication with family					Communication with friends				
Step	Predictor	*B*	SE	β	*t*	*p*	*B*	SE	β	*t*	*p*	*B*	SE	β	*t*	*p*
1	Constant	5.22	0.25	–	21.21	0.000	5.22	0.25	–	21.21	0.000	5.22	0.25	–	21.21	0.000
	Race/ethnicity	0.01	0.02	0.01	0.37	0.709	0.01	0.02	0.01	0.37	0.709	0.01	0.02	0.01	0.37	0.709
	Age	-0.02	0.00	−0.13	−8.35	0.000	−0.02	0.00	−0.13	−8.35	0.000	−0.02	0.00	−0.13	−8.35	0.000
	Sex	0.17	0.05	0.05	3.22	0.001	0.17	0.05	0.05	3.22	0.001	0.17	0.05	0.05	3.22	0.001
	Education	−0.02	0.01	−0.04	−2.28	0.023	−0.02	0.01	−0.04	−2.28	0.023	−0.02	0.01	−0.04	−2.28	0.023
	Marital status	−0.56	0.05	−0.16	−10.23	0.000	−0.56	0.05	−0.16	−10.23	0.000	−0.56	0.05	−0.16	−10.23	0.000
	Self-rated health	−0.65	0.03	−0.37	−24.42	0.000	−0.65	0.03	−0.37	−24.42	0.000	−0.65	0.03	−0.37	−24.42	0.000
2	Constant	5.59	0.27	–	20.91	0.000	5.45	0.27	–	20.40	0.000	5.38	0.27	–	19.74	0.000
	Race/ethnicity	0.01	0.02	0.01	0.60	0.549	0.01	0.02	0.01	0.63	0.529	0.01	0.02	0.01	0.33	0.740
	Age	−0.02	0.00	−0.13	−8.12	0.000	−0.02	0.00	−0.13	−8.36	0.000	−0.02	0.00	−0.13	−8.36	0.000
	Sex	0.23	0.05	0.06	4.15	0.000	0.20	0.05	0.06	3.74	0.000	0.19	0.05	0.05	3.57	0.000
	Education	−0.02	0.01	−0.03	−1.64	0.101	−0.02	0.01	−0.03	−1.96	0.050	−0.02	0.01	−0.02	−1.44	0.150
	Marital status	−0.54	0.05	−0.15	−9.98	0.000	−0.56	0.05	−0.15	−10.18	0.000	−0.56	0.06	−0.16	−10.18	0.000
	Self-rated health	−0.64	0.03	−0.36	−23.85	0.000	−0.64	0.03	−0.36	−24.03	0.000	−0.64	0.03	−0.36	−23.87	0.000
	Communication by phone	−0.08	0.02	−0.05	−3.30	0.001	−0.04	0.02	−0.03	−1.92	0.055	−0.02	0.02	−0.01	−0.93	0.354
	Communication by email	−0.04	0.02	−0.04	−2.41	0.016	−0.04	0.02	−0.04	−1.99	0.047	−0.04	0.02	−0.05	−2.55	0.011
	Communication by social media	−0.00	0.02	0.00	−0.19	0.849	−0.00	0.02	−0.00	−0.04	0.970	−0.00	0.02	−0.00	−0.05	0.959
3	Constant	5.79	0.32	–	18.31	0.000	5.91	0.31	–	19.30	0.000	6.01	0.33	–	18.49	0.000
	Race/ethnicity	0.01	0.02	0.01	0.56	0.573	0.01	0.02	0.01	0.44	0.658	0.00	0.02	0.00	0.13	0.900
	Age	−0.02	0.00	−0.13	−7.92	0.000	−0.02	0.00	−0.13	−8.30	0.000	−0.02	0.00	−0.14	−8.41	0.000
	Sex	0.22	0.06	0.06	3.99	0.000	0.19	0.05	0.05	3.57	0.000	0.19	0.05	0.05	3.54	0.000

(*Continued*)

Table 3. (*Continued.*)

Step	Predictor	Communication with children					Communication with family					Communication with friends				
		B	SE	β	*t*	*p*	*B*	SE	β	*t*	*p*	*B*	SE	β	*t*	*p*
	Education	−0.02	0.01	−0.02	−1.41	0.160	−0.02	0.01	−0.03	−1.63	0.104	−0.01	0.01	−0.02	−1.30	0.194
	Marital status	−0.54	0.06	−0.15	−9.86	0.000	−0.54	0.06	−0.15	−9.98	0.000	−0.54	0.06	−0.15	−9.81	0.000
	Self-rated health	−0.63	0.03	−0.36	−23.74	0.000	−0.63	0.03	−0.36	−23.73	0.000	−0.63	0.03	−0.36	−23.55	0.000
	Communication by phone	−0.15	0.11	−0.10	−1.36	0.173	−0.28	0.10	−0.22	−2.89	0.004	−0.45	0.10	−0.31	−4.28	0.000
	Communication by email	0.20	0.08	0.21	−2.56	0.010	−0.21	0.08	−0.21	−2.60	0.009	−0.09	0.08	−0.10	−1.13	0.260
	Communication by social media	0.05	0.08	0.06	0.60	0.547	0.06	0.09	0.06	0.67	0.505	0.12	0.08	0.13	1.37	0.170
	Communication by phone^2	0.01	0.01	0.05	0.63	0.527	0.03	0.01	0.19	2.45	0.014	0.05	0.01	0.31	4.16	0.000
	Communication by email^2	0.02	0.01	0.17	2.11	0.035	0.03	0.01	0.18	2.25	0.025	0.01	0.01	0.05	0.58	0.563
	Communication by social media^2	−0.01	0.01	−0.06	−0.66	0.507	−0.01	0.01	−0.07	−0.73	0.464	−0.02	0.01	−0.13	−1.41	0.160
Model 1		Adjusted $R^2 = 0.201$, R^2 change = 0.202, $p = 0.001$					Adjusted $R^2 = 0.201$, R^2 change = 0.202, $p < 0.001$					Adjusted $R^2 = 0.201$, R^2 change = 0.202, $p < 0.001$				
Model 2		Adjusted $R^2 = 0.206$, R^2 change = 0.005, $p < 0.001$					Adjusted $R^2 = 0.203$, R^2 change = 0.002, $p < 0.05$					Adjusted $R^2 = 0.203$, R^2 change = 0.002, $p < 0.05$				
Model 3		Adjusted $R^2 = 0.206$, R^2 change = 0.001, $p = 0.126$					Adjusted $R^2 = 0.205$, R^2 change = 0.003, $p < 0.05$					Adjusted $R^2 = 0.206$, R^2 change = 0.004, $p = 0.126$				

Notes: *B*: unstandardised coefficient. SE: standard error. β: standardised coefficient.

Table 4. Regression analysis results for cognition outcome by mode of communication

		Communication with children					Communication with family					Communication with friends				
Step	Predictor	*B*	SE	β	*t*	*p*	*B*	SE	β	*t*	*p*	*B*	SE	β	*t*	*p*
1	Constant	511.79	3.94	–	129.99	0.000	511.79	3.94	–	129.99	0.000	511.79	3.94	–	129.99	0.000
	Race/ethnicity	−4.90	0.34	−0.21	−14.30	0.000	−4.90	0.34	−0.21	−14.30	0.000	−4.90	0.34	−0.21	−14.30	0.000
	Age	−0.64	0.04	−0.23	−15.78	0.000	−0.64	0.04	−0.23	−15.78	0.000	−0.64	0.04	−0.23	−15.78	0.000
	Sex	−3.99	0.85	−0.07	−4.71	0.000	−3.99	0.85	−0.07	−4.71	0.000	−3.99	0.85	−0.07	−4.71	0.000
	Education	3.68	0.16	0.34	22.81	0.000	3.68	0.16	0.34	22.81	0.000	3.68	0.16	0.34	22.81	0.000
	Marital status	3.85	0.87	0.06	4.43	0.000	3.85	0.87	0.06	4.43	0.000	3.85	0.87	0.06	4.43	0.000
	Self-rated health	3.18	0.42	0.11	7.50	0.000	3.18	0.42	0.11	7.50	0.000	3.18	0.42	0.11	7.50	0.000
2	Constant	514.24	4.26	–	120.60	0.000	521.51	4.24	–	123.14	0.000	518.47	4.32	–	120.15	0.000
	Race/ethnicity	−4.81	0.34	−0.21	−14.07	0.000	−4.73	0.34	−0.20	−13.87	0.000	−4.78	0.34	−0.21	−14.09	0.000
	Age	−0.61	0.04	−0.22	−14.45	0.000	−0.62	0.04	−0.22	−14.93	0.000	−0.58	0.04	−0.20	−13.58	0.000
	Sex	−4.07	0.87	−0.07	−4.70	0.000	−3.64	0.86	−0.06	−4.25	0.000	−4.11	0.85	−0.07	−4.81	0.000
	Education	3.42	0.17	0.31	20.66	0.000	3.37	0.16	0.31	20.53	0.000	3.31	0.17	0.30	19.96	0.000
	Marital status	3.46	0.87	0.06	3.98	0.000	3.33	0.86	0.06	3.86	0.000	2.86	0.87	0.05	3.28	0.001
	Self-rated health	2.86	0.43	0.10	6.72	0.000	2.93	0.42	0.10	6.92	0.000	2.82	0.42	0.10	6.66	0.000
	Communication by phone	−0.94	0.36	−0.04	−2.59	0.010	−2.43	0.31	−0.11	−7.75	0.000	−2.24	0.35	−0.09	−6.49	0.000
	Communication by email	1.46	0.26	0.09	5.63	0.000	1.49	0.29	0.09	5.14	0.000	1.85	0.27	0.11	6.81	0.000
	Communication by social media	0.07	0.24	0.01	0.29	0.772	0.15	0.27	0.01	0.58	0.565	0.21	0.25	0.01	0.82	0.415
3	Constant	495.44	5.01	–	98.95	0.000	507.23	4.83	–	105.06	0.000	500.92	5.13	–	97.65	0.000
	Race/ethnicity	−4.72	0.34	−0.20	−13.90	0.000	−4.63	0.34	−0.20	−13.66	0.000	−4.74	0.34	−0.20	−14.02	0.000
	Age	−0.64	0.04	−0.22	−15.05	0.000	−0.622	0.04	−0.22	−14.98	0.000	−0.57	0.04	−0.20	−13.38	0.000

(*Continued*)

Table 4. (*Continued.*)

Step	Predictor	Communication with children					Communication with family					Communication with friends				
		B	SE	β	*t*	*p*	*B*	SE	β	*t*	*p*	*B*	SE	β	*t*	*p*
	Sex	−3.42	0.86	−0.06	−3.95	0.000	−3.36	0.85	−0.06	−3.94	0.000	−4.06	0.85	−0.07	−4.78	0.000
	Education	3.29	0.17	0.30	19.89	0.000	3.24	0.16	0.30	19.69	0.000	3.20	0.17	0.29	19.22	0.000
	Marital status	2.99	0.86	0.05	3.46	0.001	3.00	0.86	0.05	3.49	0.000	2.46	0.87	0.04	2.83	0.005
	Self-rated health	2.73	0.42	0.09	6.45	0.000	2.77	0.42	0.09	6.57	0.000	2.60	0.42	0.09	6.16	0.000
	Communication by phone	7.69	1.73	0.31	4.45	0.000	2.37	1.50	0.11	1.58	0.115	5.22	1.64	0.22	3.19	0.001
	Communication by email	5.90	1.21	0.38	4.88	0.000	7.92	1.29	0.45	6.17	0.000	6.73	1.28	0.42	5.27	0.000
	Communication by social media	1.60	1.25	0.11	1.28	0.200	1.19	1.34	0.07	0.89	0.375	0.51	1.33	0.03	0.38	0.702
	Communication by phone^2	−1.03	0.21	−0.35	−4.92	0.000	−0.58	0.19	−0.21	−3.00	0.003	−0.91	0.21	−0.31	−4.44	0.000
	Communication by email^2	−0.70	0.18	−0.30	−3.86	0.000	−1.07	0.21	−0.39	−5.21	0.000	−0.78	0.20	−0.31	−3.91	0.000
	Communication by social media ^{2}	−0.23	0.19	−0.10	−1.22	0.224	−0.14	0.21	−0.06	−0.69	0.491	−0.04	0.20	−0.02	−0.21	0.833
Model 1		Adjusted $R^2 = 0.280$, R^2 change = 0.281, $p < 0.001$					Adjusted $R^2 = 0.280$, R^2 change = 0.281, $p < 0.001$					Adjusted $R^2 = 0.280$, R^2 change = 0.281, $p < 0.001$				
Model 2		Adjusted $R^2 = 0.288$, R^2 change = 0.008, $p < 0.001$					Adjusted $R^2 = 0.294$, R^2 change = 0.015, $p < 0.001$					Adjusted $R^2 = 0.296$, R^2 change = 0.016, $p < 0.001$				
Model 3		Adjusted $R^2 = 0.298$, R^2 change = 0.011, $p < 0.001$					Adjusted $R^2 = 0.304$, R^2 change = 0.010, $p < 0.001$					Adjusted $R^2 = 0.304$, R^2 change = 0.009, $p < 0.001$				

Notes: *B*: unstandardised coefficient. SE: standard error. β: standardised coefficient.

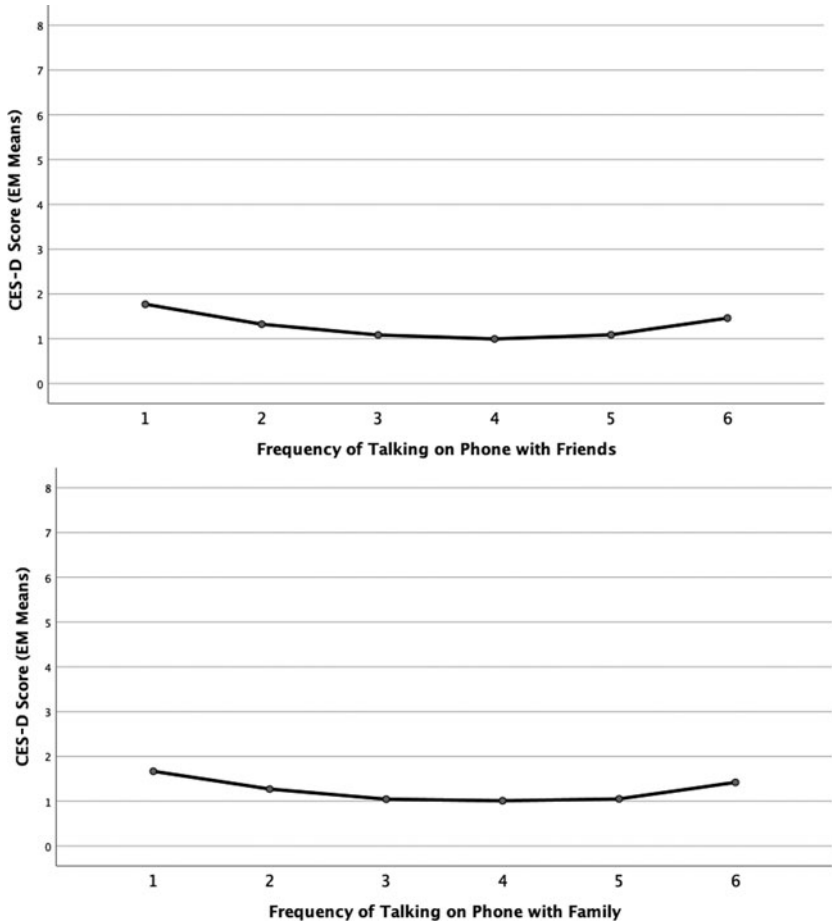

Figure 1. Estimated marginal (EM) means of Center for Epidemiologic Studies Depression Scale (CES-D) scores (depression) by frequency of talking on the phone.
Notes: The model controls for race/ethnicity, age, sex, education, marital status and self-rated health. The *y*-axis represents depression scores with a range of 0–8. A score of equal to or greater than 3 is used for the criteria of having depression. The *x*-axis represents frequency of talking on the phone: 1 = less than once a year or never, 2 = once or twice a year, 3 = every few months, 4 = once or twice a month, 5 = once or twice a week, 6 = three or more times a week.

phone with family and friends. Lower levels of communication by phone with these groups revealed higher levels of depression. The highest level of communication also revealed higher level of depression than moderate amounts of communication via phone. Figure 2 shows that low levels (never or once or twice a year) of communication with children via email is worse for depression than the highest level (three or more times a week) of communication with children via email. Mid-levels of communication with children via email revealed the lowest levels of depression. A similar pattern exists for communication with family via email; the lowest (never or once or twice a year) and highest (three or more times a week) level of communication had elevated levels of depression.

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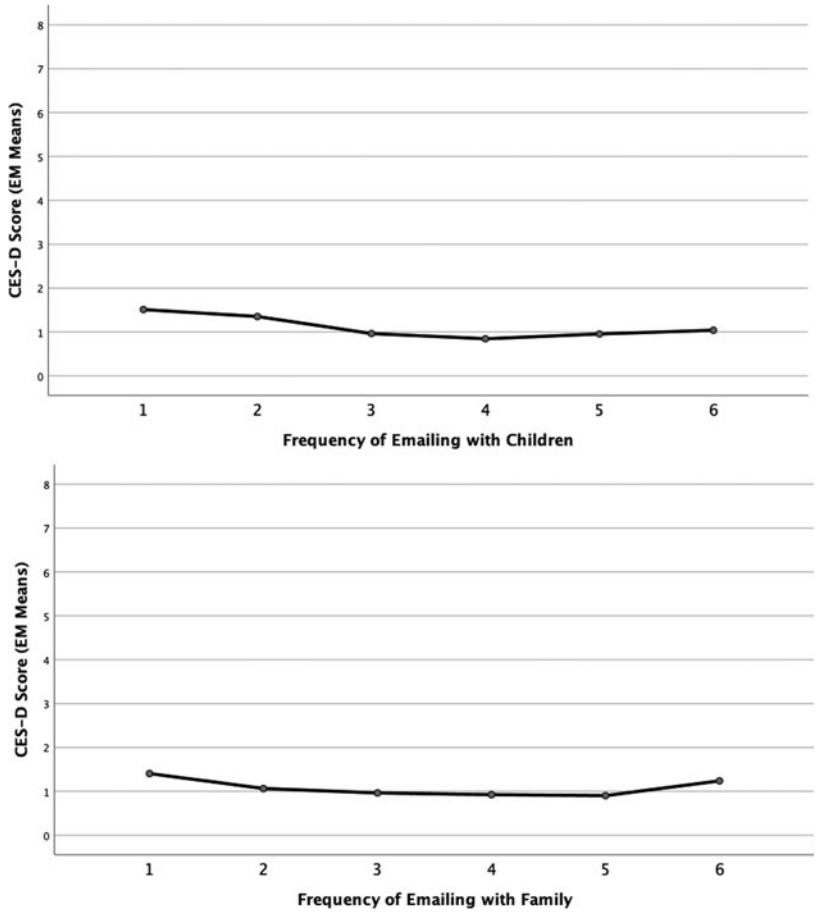

Figure 2. Estimated marginal (EM) means of Center for Epidemiologic Studies Depression Scale (CES-D) scores (depression) by frequency of emailing.
Notes: The model controls for race/ethnicity, age, sex, education, marital status and self-rated health. The *y*-axis represents depression scores with a range of 0–8. A score of equal to or greater than 3 is used for the criteria of having depression. The *x*-axis represents frequency of emailing: 1 = less than once a year or never, 2 = once or twice a year, 3 = every few months, 4 = once or twice a month, 5 = once or twice a week, 6 = three or more times a week.

We interpreted these findings with caution as it is important to note that the levels of depression found here were fairly low on average, and that almost no participants met the criteria for having clinical depression. A score of 3 or more on the eight-item CES-D scale is typically used as the criteria for having depression (Schane *et al.*, 2008). The mean score for CES-D in our sample was 1.17 (SD = 1.75). The results signify that while there are differences in depression by communication level, the changes are not drastic across the sample as a whole. Therefore, these changes represent a small change in depressive symptoms that, while potentially meaningful for one's overall affective wellbeing, does not generally rise to the level of a clinical diagnosis. Our findings are consistent with previous research using

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the CES-D. In an intervention study for mothers of adolescents who had elevated depressive symptoms at the time of screening, the average decrease in CES-D scores over time were statistically significant even though most mothers did not meet the cut-off for a clinical diagnosis (Spiro-Levitt *et al.*, 2019). These decreases in depressive symptoms are important for wellbeing and prevention of clinical depression (Siddaway *et al.*, 2017; Spiro-Levitt *et al.*, 2019). In a population-based study that assessed depression symptomology in older adults, the majority (79%) of older American adults had no depressive symptoms or acute depressive symptoms (Zivin *et al.*, 2013). While depressive symptoms may be low, the prevalence of acute, elevated and severe symptomology in the older adult population is high (Zivin *et al.*, 2013).

For cognition, both the linear and quadratic variables for phone and email were significant for each social group. *See* Figures 3 and 4 for plots of the estimated marginal means of phone and email. Figure 3 shows the various patterns of talking on the phone with children, family and friends for cognition. The mean cognitive score in our sample was 534.64 (SD = 29.47). For children, family and friends, moderate levels of communication by phone revealed the highest scores of number series. Talking on the phone with friends was the flattest of the three curvilinear relationships for cognition. Finally, talking on the phone with family at the highest level was worse for cognition than the lowest level of communication. As mentioned in the Methods section, performance on the number series cognitive task is calculated as a *W*-score. A ten-point increase in the *W*-score reflects doubling the probability of answering an equally difficult item correctly (Jaffe, 2009; Fisher *et al.*, 2014). That is, participants with a *W*-score of 530 have a probability of 0.50 of answering equally difficult items contrasted with a probability of 0.25 for participants with a *W*-score of 520.

Discussion

While technology-mediated communication was associated with both cognition and depression, the improvement in model fit was greater for the cognition and technology-mediated communication model than for the model including depression and technology-mediated communication. The weaker link with depression may suggest that the effect may be less closely linked to dosage of technology-mediated communication, at least, than fluid cognition functioning as measured by the number series test. We examined communication across different aspects of one's social network, including children, family members and friends, in order to get a more nuanced view of how different elements of one's network might be linked to cognition and affect. Our results suggest that it is important to differentiate between various social groups. This finding suggests that communicating with children, family and friends impacts affect and cognition in different ways. Specifically, communicating with children by phone and email was most closely linked with the outcome measures included here. For cognition, communication with children, family and friends by email and phone were significant. Understanding the differential impact on these two outcomes and considering why social media may not have been linked to the measures included here may have important implications for supporting older adults and their families during ageing.

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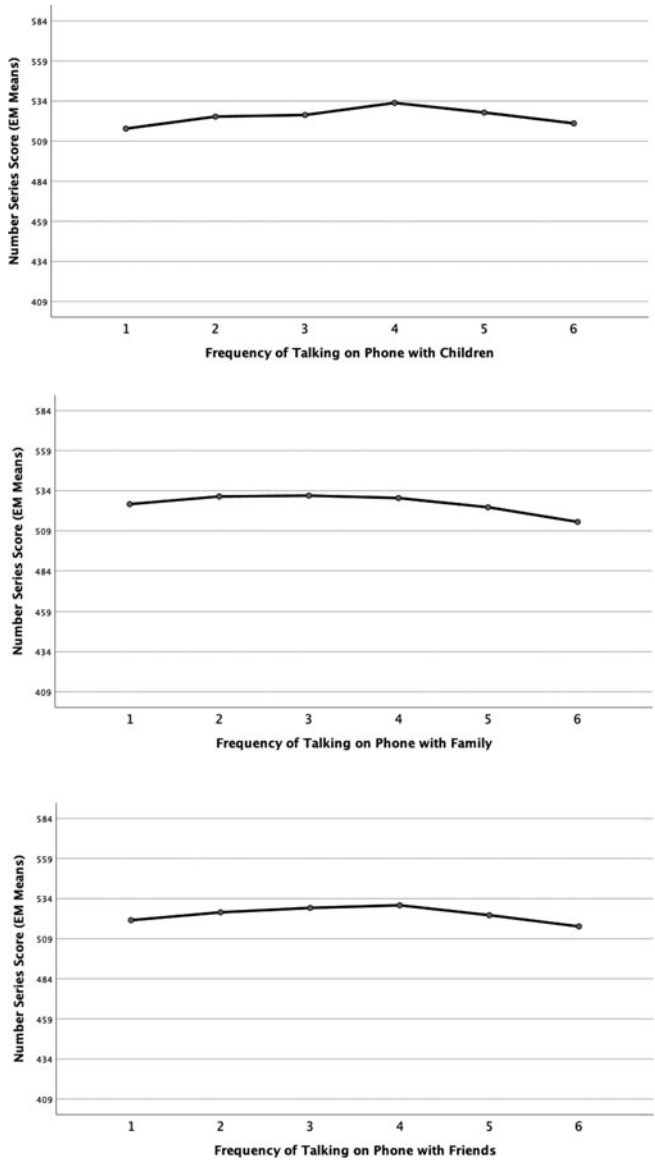

Figure 3. Estimated marginal (EM) means of number series score (cognition) by frequency of talking on the phone.

Notes: The model controls for race/ethnicity, age, sex, education, marital status and self-rated health. The *y*-axis represents the possible range of the cognitive test, 409–584. The *x*-axis represents frequency of talking on the phone: 1 = less than once a year or never, 2 = once or twice a year, 3 = every few months, 4 = once or twice a month, 5 = once or twice a week, 6 = three or more times a week.

Surprisingly, and contrary to our initial beliefs, across all social network categories examined here, social media was not significantly associated with depression or cognition for older adults. In other words, social media was less closely linked to

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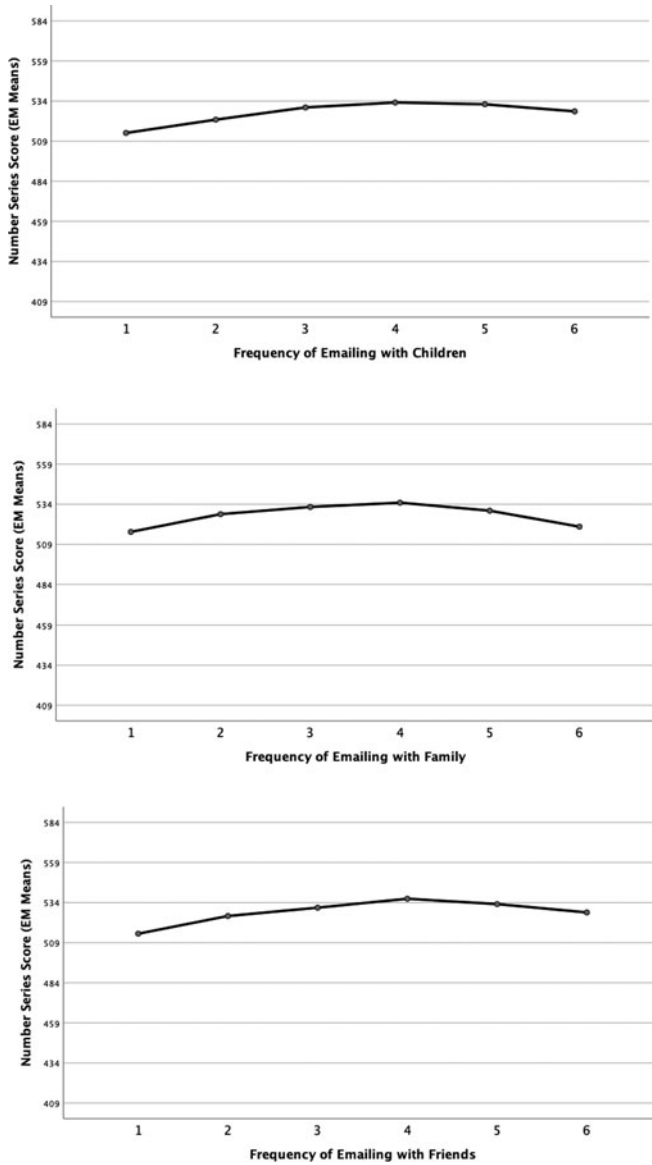

Figure 4. Estimated marginal (EM) means of number series score (cognition) by frequency of emailing. *Notes*: The model controls for race/ethnicity, age, sex, education, marital status, and self-rated health. The *y*-axis represents the possible range of the cognitive test, 409–584. The *x*-axis represents frequency of emailing: 1 = less than once a year or never, 2 = once or twice a year, 3 = every few months, 4 = once or twice a month, 5 = once or twice a week, 6 = three or more times a week.

depression and cognition than email and phone. This finding diverges from previous findings that link social media use with depression generally, such as Aalbers *et al.* (2019), and by amount of use, such as Hunt *et al.* (2018). There has been

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research on the effects of social media on familial relationships, such as 'technoference', which highlights how technology can intrude or interrupt everyday interactions and family communication (McDaniel, 2015). Perhaps one reason why social media was not associated with depression or cognition in our study has to do with dosage. In our sample, frequency of communication by social media was the lowest out of the modes of communication. Our participants did not communicate as frequently with children, family members and friends by social media as with phone and email, which would impact the associations. Why dosage is lower for social media is also important to consider. It is possible that older adults in the HRS sample have real or perceived barriers about using social media, such as feeling less comfortable, vision impairments and computer anxiety (Leist, 2013), so they may gravitate towards the familiar use of phone primarily and then email. Similarly, there may be differences between older adult non-social media users and social media users, as noted in Bell *et al.* (2013) for social satisfaction and confidence with technology. Therefore, future research could stratify participants as non-social media users and social media users to get a more nuanced perspective of the associations of social media use and depression and cognition. Perhaps another reason that emailing and talking on the phone may be more closely linked to our outcomes is that they are typically more personal forms of connections than social media. Email and phone were significant for children, family and friends for cognition. For emailing, it makes sense that reading and typing email messages requires more cognitive resources. Given that the variables for technology-mediated communication only accounted for frequency, we are not able to comment on the quality of communication between these groups. While social media will undoubtedly continue to be a major focus in research, our findings suggests that it is imperative that more traditional forms of communication are not neglected.

Importantly, this study has established some support for curvilinear associations between cognition and social communication – emphasising the value of breaking communication down by technology type. We saw curvilinear relationships for depression in talking on the phone with family and friends (*see* Figure 1) and in emailing with children and family (*see* Figure 2) and for cognition with phone and email for all social groups (*see* Figures 3 and 4). There may be several explanations for these curvilinear patterns. For example, the goldilocks hypothesis, that too little or too much of a certain experience may have negative effects, is sometimes found in the literature focused on adolescent screen time and wellbeing (Przybylski and Weinstein, 2017). Another explanation is the time displacement hypothesis: if individuals are spending great amounts of time communicating via technology, it may be displacing time that they could be spending with their families and friends in person (Abdelfattah, 2012; Chesley and Johnson, 2014); or, in a situation where 'technology overload' exists, perhaps too much communication through these technologies might cause cognitive fatigue, while too little might not provide sufficient enrichment (Lee *et al.*, 2016). Of course, technology overload may also operate differently across modalities; communication technology overload may be applicable to our sample if the demands of the communication technology exceed the participants' capacities or system overload if the features are too complex (Karr-Wisniewski and Lu, 2010; Cho *et al.*, 2011). Further investigations into why too little or too much communication with certain social groups or by certain

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modes is worse for affect and cognition are needed. For example, these relationships may vary differently by demographics. In one study using a subset of the HRS, Katz *et al.* (2020) found curvilinear relationships for close social network connections and executive functioning for family and children varied by race and ethnicity.

The convoy model was recently highlighted as being useful for addressing the emerging area of technology and communication in families by Fuller *et al.* (2020). As these media have provided new ways for older adults to stay connected to family and friends, the convoy model may help to identify social networks derived from technology-mediated communication and potential inequalities across intimate relationships (Fuller *et al.*, 2020). Fuller *et al.* (2020) affirmed that the convoy model may be used to examine whether technology use in older adulthood improves or reduces social connections. This point has implications for the wellbeing and health of older adults, particularly for prevention and intervention. As prior research has demonstrated, smaller network sizes are associated with higher depressive symptoms (Shouse *et al.*, 2013). Promoting healthy and supportive communication with one's convoy in older adulthood may be important for lowering depression and improving or maintaining cognitive abilities over the life-course. Different members of one's convoy, whether they are relatives or friends, may support older adults in different, nuanced ways, particularly regarding how they communicate and the frequency of communication. Furthermore, these nuances may be culturally specific. How American older adults and their families communicate may not be the same for people in other countries. More research is needed on cross-cultural comparisons of the associations between mode of communication and social networks in ageing adults.

Several studies have looked at smartphone use and cognitive function among older adults, but fewer have looked specifically at smartphone use in the context of maintaining social capital. For example, Hardill and Olphert (2012) found that smartphones are an integral part of everyday activities because of their many functions, but they did not replace landline phone use when it came to communication with friends and family. Lin *et al.* (2020) looked at smartphone use in the context of residential care homes. They found that older adults in residential care homes used smartphones as a way to communicate, entertain oneself and search for information on the Web. Compared to non-users, smartphone users had higher scores on the Montreal Cognitive Assessment and lower scores on the Geriatric Depression Scale-15. These findings could be explained by the powerful role social interaction plays in maintaining or improving cognitive function and affect; however, it is difficult to separate the social communication aspects of these technologies from the other activities facilitated through such technologies without a detailed analysis of time spent on individual applications and device features. In our study, it was not specified if participants communicated by landline, regular mobile phone or smartphone. Future research should examine how cognition varies by use of landlines compared with smartphones.

Strengths and limitations

One strength of this study is that we examined communication with social networks across specific social groups (children, family and friends) and, furthermore,

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we looked at the mode of communication individually (phone, email and social media). As previously stated, previous research commonly looks at these variables aggregated together. Our results demonstrated that these relationships do vary by both social group and communication type. However, this study is not without limitations.

We used one cross-sectional wave of the HRS dataset with American older adults. Therefore, we cannot establish causality in these relationships; furthermore, these relationships may be bidirectional in nature. We chose to focus on 2016 as it is the most recent full wave available. In the 2016 wave, social media technologies were combined by asking how often participants communicate via 'by Skype, Facebook or other social media'. We were not able to parse out different types of social media or video chat. There may be differential links between different technologies defined as social media in the HRS. For example, video chatting with family may be more engaging than scrolling through Facebook or Instagram, and given the current proliferation of video calling, including not only Skype but also Zoom and other related technologies, this remains a worthy topic of continued investigation.

We suggest that future research in this area should use latent variables to get a better sense of the relationships. In this study, we used a single composite score for depression (CES-D) and very few participants met the criteria for having depression. For cognition, we used a single calculated item for number series to maximise the sample size available here; using multiple variables would have significantly reduced the number of participants available for examination here. Although we propose that future research should investigate additional cognitive variables, as well as latent variables created across multiple outcomes, we also informally looked at these analyses with a measure of retrieval fluency in a smaller sample of participants that had completed that measure, and similar patterns of results were found. That we saw these patterns across both a verbal fluency measure and number series suggests that the relationships are not merely an effect of verbal ability, but rather fluid cognitive ability more generally. Additionally, future qualitative or mixed-methods work may be valuable to explore the everyday experiences of older adults using these technologies. Finally, listwise deletion resulted in the removal of 286 participants, or 7 per cent of the sample of participants who answered all social communication technology questions; the majority of the presence of missing data came from the number series variable. As common with large publicly available datasets, missing data is a known and continuing issue with the HRS. Future work may explore mean imputation or use latent variables to navigate this issue. Overall, there will likely be continuing opportunities with future waves of the HRS, as well as other datasets, to investigate these links with larger sample sizes over time.

Conclusion

In this paper, we examined the link between different forms of communication (phone, email and social media) with children, family and friends and cognition and depression in a sample of American older adults drawn from the 2016 wave of the HRS. Overall, we found significant links between the amount of phone

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and email communication, but not social media, with both depression and cognitive function, however, the model fit was much stronger for the regression including number series cognition variable. Furthermore, we found that for some types of communication with some elements of one's social network (*e.g.* family communication by phone with cognition) that quadratic variables were more closely associated with the outcomes than the linear ones. This suggests considerable nuance in the links between communication with one's social network and cognition and affect that as yet has not been closely examined in quantitative research. Not only is it important to examine elements of one's social network, and the communication technologies they use, individually, but the nature of these relationships merits further investigation into the qualitative nature of these communications, rather than dosage alone. Future research should seek not only to investigate longitudinal analyses of these communication technologies, but also potentially explore interventions to foster positive use of communication of them which may have the potential to improve affect and cognition in older adults.

Conflict of interest. The authors declare no conflicts of interest.

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