

Internet use, social isolation and loneliness in older adults.

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Abstract

The aim of this study was to explore associations between internet/email use in a large sample of older English adults with their social isolation and loneliness. Data from the English Longitudinal Study of Ageing wave 8 were used, with complete data available for 4492 men and women aged ≥ 50 years (mean age 64.3 ± 13.3 years; 51.7% males). Binomial logistic regression was used to analyse cross-sectional associations between internet/email use and social isolation and loneliness. The majority of older adults reported using the internet/email every day (69.3%), fewer participants reported once a week (8.5%), once a month (2.6%), once every three months (0.7%), less than every three months (1.5%) and never (17.4%). No significant associations were found between internet/email use and loneliness, however non-linear associations were found for social isolation. Older adults using the internet/email either once a week (OR=0.60, 95% CI 0.49-0.72) or once a month (OR=0.60, 95% CI 0.45-0.80) were significantly less likely to be socially isolated than every day users; those using internet/email less than once every three months were significantly more likely to be socially isolated than every day users (OR=2.87, 95% CI 1.28-6.40). Once every three months and never users showed no difference in social isolation compared with every day users. Weak associations were found between different online activities and loneliness, and strong associations found with social isolation. The study updated knowledge of older adults' internet/email habits, devices used and activities engaged in online. Findings may be important for the design of digital behaviour change interventions in older adults, particularly in groups at risk of or interventions targeting loneliness and/or social isolation.

Key words: internet, email, older adult, loneliness, social isolation

Introduction

Population ageing is a global phenomenon, and older adults (≥ 50 years) make up a substantial and growing proportion of the population. In Europe, 40 per cent of the population are aged 50 and older (Eurostat 2018), and in the UK it is 35.4 per cent (self-calculated using data from (Office for National Statistics 2017)), and these figures are projected to increase over the coming years (Office for National Statistics 2018b). Although people are living longer, the number of disability-adjusted life years is increasing (Murray *et al.* 2012) and quality of life is not guaranteed (Beard *et al.* 2016). In addition, older adults are at greater risk of social isolation (Iliffe *et al.* 2007) and feelings of loneliness (Shankar *et al.* 2011). The reasons for this are complex and multifactorial but include widowhood, having no (surviving) children, living alone, deteriorating mental or physical health, retirement, relocation and bereavement – which are commonly experienced in later life (Age UK 2018a, Cotten, Anderson and McCullough 2013, Courtin and Knapp 2017, Grenade and Boldy 2008, Peplau 1985). Understanding the factors associated with social isolation and loneliness in later life is important for identifying those at greatest risk and informing targeted interventions.

Social isolation refers to the objective status of a person's social relationships including network size, diversity and frequency of contact, whereas loneliness refers to the subjective psychological experience of the gap between a person's desired and actual levels of social contact (Age UK 2018b, Cacioppo *et al.* 2011, Hawkley and Cacioppo 2007, Kobayashi and Steptoe 2018, Peplau 1985, Peplau and Perlman 1982, Perlman and Peplau 1984, Shankar *et al.* 2011, Steptoe *et al.* 2013b). Although the two constructs have been shown to be positively correlated (Cornwell and Waite 2009a, Petersen *et al.* 2016a, Shankar *et al.* 2011, Steptoe *et al.* 2013b), persons who are socially isolated may not experience loneliness whilst loneliness

may occur without social isolation (Beneito-Montagut, Cassián-Yde and Begueria 2018, Cornwell and Waite 2009b, Coyle and Dugan 2012, de Jong Gierveld and Havens 2004, Hawkley and Cacioppo 2007, Hawkley and Cacioppo 2010, Kobayashi and Steptoe 2018, Peplau 1985, Perlman and Peplau 1984). Prevalence estimates of loneliness among older adults (60-80 years) in Europe range from 8.1 per cent to 46.8 per cent (Hansen and Slagsvold 2016). It is estimated that up to 30.0 per cent of older adults (≥ 50 years) in Europe are socially isolated (Cantarero-Prieto, Pascual-Sáez and Blázquez-Fernández 2018).

Social isolation and loneliness are important issues because they are reciprocally related to health and wellbeing; that is, they are both a risk factor for and a consequence of poor health (Hawkley 2017). For instance, a scoping review found both social isolation and loneliness can detrimentally affect the physical and mental health of older adults (Courtin and Knapp 2017). However, physical and mental health problems can lead also to increased risk of social isolation and/or loneliness (Fokkema and Knipscheer 2007).

The health risks associated with social isolation and loneliness are many and varied, and may also be due to having a negative effect on health behaviours (Lauder *et al.* 2006). Loneliness is associated with increased risk of premature all-cause mortality in older adults (Luo *et al.* 2012, Perissinotto, Stijacic Cenzer and Covinsky 2012, Rico-Uribe *et al.* 2018). Compared with never lonely older adults, those reporting often feeling lonely had a 130 per cent increased risk of cardiovascular disease risk and 22 per cent increased risk of ischemic heart disease, even when controlling for age and sex (Patterson and Veenstra 2010). Loneliness is also an independent risk factor for cognitive decline in older adults – for instance poorer cognitive performance, hastened cognitive decline, poorer executive functioning, slower processing speed and poorer memory (Boss, Kang and Branson 2015, Cacioppo and Hawkley 2009, Wilson *et al.* 2007) – and

is associated with 17 per cent higher odds of having a mental health condition in older adults (≥ 50 years) (Coyle and Dugan 2012). Loneliness has been shown to be a risk factor for sedentariness and lower likelihood of engaging in physical activity, and increased likelihood of discontinuing physical activity (Hawkey and Kocherginsky 2017, Hawkey, Thisted and Cacioppo 2009, Netz *et al.* 2013), and is also a risk factor for obesity, smoking and alcohol abuse (Hawkey and Kocherginsky 2017).

Social isolation is a predictor of mortality, independent of experiencing loneliness (Steptoe *et al.* 2013b). Social isolation has been independently associated with cardiovascular disease risk in older adults (Grant, Hamer and Steptoe 2009, Leigh-Hunt *et al.* 2017) and is associated with increases in systolic and diastolic blood pressure (Shankar *et al.* 2011). People who are socially isolated are also less likely to consistently engage in moderate-to-vigorous physical activity (MVPA) at least once a week, and are more likely to be overweight or obese and smoke (Kobayashi and Steptoe 2018).

One possible means of reducing social isolation and loneliness in old age is the use of modern technology, in particular the internet. Geographical distance to friends or family, mobility issues and time-consuming roles (e.g. care giver) may impair older adults' ability to engage socially, leaving them vulnerable to social isolation and feelings of loneliness (Leist 2013). However, using the internet may help foster social support, keeping in contact, development of social networks and improve self-confidence among older adults (Chen and Schulz 2016). Using technology provides a low-cost and accessible means for communication that has the potential to reduce loneliness and social isolation in older adults (Chippis and Jarvis 2016).

A systematic review showed technologies – such as social networking sites, general information communication technology (ICT), video games, chat rooms, 3D virtual

environments – can be useful for reducing social isolation in older adults (≥ 50 years) (Khosravi, Rezvani and Wiewiora 2016). Another systematic review of 25 studies showed that the use of ICT– such as Skype, Windows live messenger and telephone – increased social support, social connectedness and reduced social isolation among the elderly (age range 66-83 years), although the effects rarely lasted more than six months post-intervention, and even with adequate training some ICT interventions were not suitable for every older adult (Chen and Schulz 2016). Many of the included interventions were only tested at one time point, usually short-term, and used a relatively small number of participants, thus the authors suggest a need for more well-designed studies (Chen and Schulz 2016).

In a cross-sectional study of 11,000 older adults (≥ 65 years) living in Europe, loneliness was reported less frequently by those who used the internet daily or sometimes compared with never users, and social isolation was less common among those who used the internet every day and sometimes compared with never users (Lelkes 2013). Despite indications that interventions using technology, particularly the internet, can reduce social isolation and loneliness, there is limited up to date information investigating associations between older adults' current internet/email use in relation to their social isolation and loneliness.

Therefore, the present study used data from ELSA to explore (i) the prevalence of internet/email use in older adults, particularly devices used and online activities engaged in, and (ii) the associations between frequency of internet/email use with social isolation and loneliness. It was hypothesised that older adults who more frequently engage with the internet/email would be less likely to be socially isolated or to report feeling lonely, and that associations would be stronger for those who used technology most frequently.

Methods

Population

The English Longitudinal Study of Ageing (ELSA) is a longitudinal survey of a representative cohort of adults aged ≥ 50 years old living in England. The study began in 2002, with data collected via computer-assisted personal interviews and self-completion questionnaires in biennial waves (Step toe *et al.* 2013a). To ensure the most current technology usage possible in a rapidly changing industry, cross-sectional data from the most recent wave, wave 8 (collected 2016/2017), were used. Moreover, longitudinal analysis was considered not feasible due to attrition reducing the sample size within individual categories of internet/email use even further, leading to problems with statistical power. Complete data on all variables of interest were available for 4492 of the total sample of 8445 participants. Ethical approval was obtained from the London Multi-centre Research Ethics Committee and all participants provided full informed consent.

Measures

Outcome variables: social isolation and loneliness

Social isolation was computed using a five-item index as used in previous literature (Jackson *et al.* 2019b, Kobayashi and Steptoe 2018, Shankar *et al.* 2011, Steptoe *et al.* 2013b). One point was assigned to each of the following: if they reported having less than monthly contact (including face-to-face contact, telephone, and written/email/text messaging contact) with children, other family members and friends, if they did not belong to a social organisation or club, and if they lived alone. Scores ranged from 0 – 5, with higher scores indicating a greater degree of social isolation. As in previous studies, scores were dichotomised at ≥ 2 versus < 2

points to indicate high versus low levels of social isolation (Jackson *et al.* 2019b, Steptoe *et al.* 2013b).

Loneliness was self-reported using a three-item short form of the Revised University of California Los Angeles (UCLA) Loneliness Scale (Russell 1996). Questions included: “how often to you feel you lack companionship?”, “how often do you feel left out?”, and “how often do you feel isolated from others?”. Response options were ‘hardly ever or never’ = 1, ‘some of the time’ = 2 or ‘often’ = 3. Total scores ranged from 3 to 9, with higher scores indicating greater loneliness. As in previous papers, these were dichotomised at ≥ 6 versus < 6 to indicate high versus low loneliness (Jackson *et al.* 2019a, Steptoe *et al.* 2013b).

Exposure variable: internet/email use

Frequency of internet/email use was assessed in the self-completion questionnaire, with the question “on average, how often do you use the internet or email?”. Response options were “every day, or almost every day”, “at least once a week (but not every day)”, “at least once a month (but not every week)”, “at least once every 3 months” or “never”.

Those who responded that they accessed the internet/email more than every 3 months, were asked about the devices they used to access the internet: “On which of the following devices do you access the internet?”. Response options included desktop computer, laptop computer, tablet (e.g. iPad, Samsung Galaxy Tab), smartphone (e.g. iPhone, Android phone), other device, or do not access internet. In addition, participants were asked “for which of the following activities did you use the internet in the last 3 months? Tick all that apply”. Response options included “sending/receiving emails”, “telephoning over the internet/video calls (via webcam) over the internet”, “searching for information for learning, research, fact finding”, “finances (banking, paying bills)”, “shopping/buying goods or services”, “selling goods or services over

the internet e.g. via auctions”, “use social networking sites (Facebook, Twitter, Myspace)”, “creating, uploading or sharing content (YouTube, blogging or Flickr)”, “news/newspaper/blog websites”, “streaming/downloading live or on demand TV/radio (BBC iPlayer, 4OD, ITV Player, Demand 5)”, “music (iTunes, Spotify), or eBooks”, “games”, “looking for jobs or sending a job application”, “using public services (e.g. obtaining benefits, paying taxes)”, “other” or “none of the above”.

Covariates

Covariates were selected a priori on the basis of previous studies showing associations between these variables and the exposure and outcomes of interest. Covariates assessed in this study were age and sex, as they are both independently associated with differences in internet use (Berner, Aartsen and Deeg 2017, Bol, Helberger and Weert 2018, Choi and Dinitto 2013, Hogeboom *et al.* 2010, Office for National Statistics 2018a, Quintana *et al.* 2018), loneliness and social isolation (Kobayashi and Steptoe 2018). Sex was reported as male or female. Age was input in categories of ‘50-59y’, ‘60-69y’, ‘70-79y’, ‘80-89y’ and ‘90+ y’. Marital status (married/living as married versus single) has also been associated with internet use (Berner, Aartsen and Deeg 2017, Hogeboom *et al.* 2010), social isolation and loneliness (Grenade and Boldy 2008, Hawkley and Kocherginsky 2017, Kobayashi and Steptoe 2018, Peplau 1985, Steptoe *et al.* 2013b). Socioeconomic status (SES) was assessed using household non-pension wealth as this has been identified as an appropriate indicator of SES in older adults (Banks, Karlsen and Oldfield 2004) and used in previous studies utilising the ELSA dataset (Hamer, Lavoie and Bacon 2014, Jackson, Hackett and Steptoe 2019, Jackson *et al.* 2019b, Quintana *et al.* 2018, Smith *et al.* 2015). This was entered as a covariate as it has previously

been associated with internet use (Berry 2011, Hogeboom *et al.* 2010), social isolation and loneliness (Choi and Dinitto 2013, Kobayashi and Steptoe 2018, Steptoe *et al.* 2013b).

Limiting long-standing illness has previously been associated with internet use (Choi and Dinitto 2013, Hogeboom *et al.* 2010), social isolation and loneliness (Grenade and Boldy 2008). Participants were asked if they had any long-standing (meaning anything that has troubled them over a period of time, or that is likely to affect them over a period of time) illness, disability or infirmity. Response options were yes or no. Those answering yes were then asked if these illness(es) or disability(ies) limit their activities in any way. Response options were yes or no. Participants responding yes to the second question were categorised as having a limiting long-standing illness, otherwise were categorised as not having a limiting long-standing illness.

Depression has been associated with internet use (Cotten *et al.* 2012, Cotten *et al.* 2014), social isolation and loneliness (Cacioppo, Hawkley and Thisted 2010, Cacioppo *et al.* 2006, Cornwell and Waite 2009b, Cotten, Anderson and McCullough 2013, Coyle and Dugan 2012, Domenech-Abella *et al.* 2017, Peplau 1985, Perlman and Peplau 1984, Victor and Yang 2012) in older adults so was included as a covariate. The eight-item Centre for Epidemiologic Studies Depression Scale (CES-D) was used to identify people at risk of depression, although one question was excluded to avoid overlap with loneliness scores meaning a total of seven questions were used; scores were dichotomised as high risk ≥ 3 , and low risk < 3 in line with previous literature (Kobayashi and Steptoe 2018, Steptoe *et al.* 2013b, Turvey, Wallace and Herzog 1999, White *et al.* 2018). Questions included; '(much of the time during the past week) you felt depressed, you felt that everything you did was an effort, your sleep was restless, you were happy, you enjoyed life, you felt sad, you could not get going?' to which participants could respond yes or no. The CES-D has acceptable psychometric properties in older adults (Cosco *et al.* 2019).

Physical activity was entered as a covariate as individuals who are socially isolated and/or lonely tend to be less physically active (Hawkley and Kocherginsky 2017, Hawkley, Thisted and Cacioppo 2009, Kobayashi and Steptoe 2018, Lauder *et al.* 2006). Currently there is no literature on associations of physical activity and internet use in older adults. Level of physical activity was assessed at interview with questions on the frequency of mild, moderate and vigorous physical activity participants engaged in. Responses included 'more than once a week', 'once a week', 'one to three times a month', and 'hardly ever or never'. It was not possible to calculate and then dichotomise physical activity based on the recommended guidelines of 150 min/week MVPA, due to the information available from the ELSA wave 8 dataset. Responses were dichotomised as physically active if moderate and/or vigorous intensity physical activity \geq once a week and inactive as $<$ once a week, in line with previous literature in this cohort regarding physical activity and health outcomes (Demakakos *et al.* 2010, Hamer, de Oliveira and Demakakos 2014, Hamer, Lavoie and Bacon 2014, Hamer *et al.* 2009, Kobayashi and Steptoe 2018, Smith *et al.* 2015).

Statistical analysis

Data were weighted to correct for sampling probabilities and non-response to the self-completion questionnaire. Characteristics of the study population, devices used to access the internet and online activities were summarised using descriptive statistics. Differences in covariates, devices and internet activities according to internet/email use were analysed using Pearson's chi-square analysis. Differences in devices and internet activities according to loneliness and social isolation were also analysed using Pearson's chi-square analysis. Results were presented as p values with Cramer's V effect sizes. Binomial logistic regressions were

used to analyse associations between internet/email use and social isolation and loneliness, and were adjusted for covariates listed above. Daily use was chosen as the reference group as it was hypothesised that this group would be lowest risk. Results were reported as odds ratios (OR) with 95 per cent confidence intervals (CI). All data were analysed in IBM SPSS Statistics v24. Statistical significance was accepted at $p \leq 0.05$.

Results

The initial sample comprised 8445 older adults, however the exclusion of older adults with missing data resulted in a final analytical sample of 4492 men and women (mean age 64.3 ± 13.3 years; 51.7% males). The majority of older adults reported using the internet/email every day (69.3%), fewer participants reported once a week (8.5%), once a month (2.6%), once every three months (0.7%), less than every three months (1.5%) and never (17.4%). Overall, 19.4 per cent of the sample reported high levels of loneliness and 32.9 per cent were classified as social isolated.

Table 1 summarises sample characteristics in relation to frequency of internet/email use. Significant differences were found in all characteristics when comparing internet/email use groups. Compared with less frequent users, older adults who used the internet/email every day were more likely to be younger, male, married/living as married, in richer SES quintiles, have no limiting long-standing illness, exhibit high levels of depressive symptoms, be physically active, not lonely and not socially isolated. Those never using the internet/email were more likely to be older, female, married/living as married, in the poorest SES quintile, have a limiting long-standing illness, exhibit high levels of depressive symptoms, be physically active, not lonely but socially isolated. Although both every day and never users were more likely to be married/living as married, have high depression and be physically active, never users had a higher proportion of people who were single, had high levels depression and physical inactivity compared with every day users. Compared with other frequencies of internet/email use, those who reported using the internet/email once every three months had the highest prevalence of loneliness and social isolation.

<Insert Table 1 about here>

Unadjusted logistic regressions found once a week users were significantly less likely to experience loneliness than every day users (OR = 0.63, 95% CI = 0.52 - 0.76) and the same was found when only adjusting for social isolation (OR = 0.76, 95% CI = 0.63 - 0.92); however this became non-significant when adjusted for covariates (OR = 1.11, 95% CI = 0.89 - 1.37) (table 2). Less than once every three month users were significantly more likely to be lonely when adjusting for covariates (OR = 2.49, 95% CI = 1.05 - 5.90), but became non-significant when additionally adjusting for social isolation. No significant associations were found between other frequencies of internet/email use and loneliness in either the unadjusted or any adjusted regression model.

<Insert table 2 about here>

In the unadjusted and all adjusted models, once a week (adjusted for loneliness and covariates OR = 0.60, 95% CI = 0.49 - 0.72) and once a month users (adjusted for loneliness and covariates OR = 0.60, 95% CI = 0.45 - 0.80) were significantly less likely to be socially isolated than every day users (table 3). In contrast those using the internet less than once every three months were more likely than every day users to experience high levels of social isolation, but only in the covariate adjusted and loneliness plus covariate adjusted model (adjusted for loneliness and covariates OR = 2.87, 95% CI = 1.28 – 6.40). Never users in the unadjusted and loneliness adjusted models were less likely to be socially isolated than everyday users (unadjusted OR = 0.51, 95% CI = 0.30 - 0.87; loneliness adjusted OR = 0.50, 95% CI = 0.29 - 0.85), however, this became non-significant when covariates were adjusted for. Once every three month were no more likely than every day users to experience high levels of social isolation in any of the adjusted or unadjusted models (adjusted for loneliness and covariates OR = 0.95, 95% CI 0.61 - 1.45).

<Insert table 3 about here>

Among all older adults, the tablet (47.5%), smartphone (47.4%) and laptop (47.0%) were the most commonly mentioned devices used to access the internet/email (table 4). Everyday users most likely to use a smartphone compared to less frequent users, whereas a laptop was most commonly used among less frequent users. Significant differences between internet/email use frequency and the devices used to access the internet were found among all devices were found.

<Insert table 4 about here>Smartphones were most commonly reported device used among those with high loneliness (41.6%) and low social isolation (54.1%); whereas a tablet was most common in those with low loneliness (49.7%) and a laptop amongst those who were socially isolated (41.0%) (table 5). Weak associations were found between all devices and loneliness, however strong associations were found for social isolation.

<Insert table 5 about here>

Searching for information, sending/receiving emails and shopping/buying were the three most common internet activities in the last three months among all participants, and even when split by internet/email frequency use (table 6). However, every day users more frequently reported sending/received emails than searching for information. Significant differences between the frequency of internet/email use groups were seen among all internet activities.

<Insert table 6 about here>

Weak associations were found between loneliness all types of activities engaged with online excluding job searching/application which showed moderate association with loneliness (table 7). All online activities were strongly associated with social isolation status. A larger proportion

of those with low loneliness engaged with most of the online activities compared with the proportion of those with high loneliness, excluding creating, uploading and sharing content (high = 11.0%; low = 8.8%), job searching/application (high = 13.6%; low = 7.8%) and other online activities (high = 7.0%; low = 5.7%). The same was true in job searching/application for social isolation status (high = 9.4%; low = 8.7%).

Discussion

The aim of this study was to explore associations between internet/email use in a large sample of older English adults with their social isolation and loneliness. The use of internet/email was highly prevalent in the study population; 69.3 per cent of older adults (≥ 50 years) use the internet/email every day and 77.8 per cent at least once a week. This means that using the internet/email as a method to deliver behaviour change interventions (e.g. physical activity, dietary, smoking cessation) has potential in this population, particularly those who may be harder to reach such as those who are socially isolated, without much additional cost.

No associations between frequency of internet/email use and loneliness were found in the present study when adjusted for covariates and social isolation; however, previous studies found greater use of the internet was associated with lower loneliness in older adults (Chopik 2016, Cotten, Anderson and McCullough 2013, Erickson and Johnson 2011, Heo *et al.* 2015), as measured by the 20-item UCLA loneliness scale (Russell, Peplau and Cutrona 1980), 3-item UCLA loneliness scale (Russell 1996) or the 11-item short scale for measuring loneliness in large surveys (Hughes *et al.* 2004). One explanation for the null findings in the present study may be that loneliness is perceived by some older adults as a complex and private matter (Kharicha *et al.* 2017) so self-completion questionnaire answers may not reflect true feelings of loneliness. The 3-item UCLA questionnaire to measure loneliness was selected to minimise this in the present study, rather than using the direct questions available in the ELSA data set that explicitly mention loneliness (Campaign to end loneliness 2015). In addition, the UCLA 3-item questionnaire only uses negative wording in the questions which may lead to participants providing the same answer for each question without properly considering what they are being asked (Campaign to end loneliness 2015). Equally, the use of different measures of loneliness

may also provide reasoning for the different findings between previous studies and the present study.

A previous study found older adults' online communities were most heavily used on afternoon weekdays, and fewer interactions occurred at weekends or during the Christmas holidays (Nimrod 2010). This suggests that when face-to-face interactions are available (e.g. with family members who work full-time), older adults choose these over online communities. Therefore, loneliness may only be associated with time spent with real-world connections, rather than online connections in older adults, hence the null findings in the present study. Loneliness in older adults is related to the quality rather than quantity of relationships (Beneito-Montagut, Cassián-Yde and Begueria 2018, Holt-Lunstad, Smith and Layton 2010, Russell *et al.* 2012), and relationships among older adults in online communities seem mostly superficial and rarely extend to offline domains (Nimrod 2010), so there is also potential that the objective measure of frequency of internet/email use in the present study has no bearing on the quality of a relationship for older adults.

The types of activities engaged in whilst online may, however, impact loneliness. In the present study, weak associations were found between most online activities and loneliness status. Loneliness was previously significantly negatively correlated with internet use for communication among older adults, whereas internet use for information, entertainment or total internet use were not correlated with loneliness, measured with the 20-item UCLA loneliness scale (Erickson and Johnson 2011). In older adults (≥ 52 years) Facebook use was not associated with loneliness, measured with the 20-item UCLA loneliness scale (Bell *et al.* 2013), which although could be seen as a communication tool, may suggest older adults use Facebook for other reasons such as entertainment or information. Video calls are a useful tool for

overcoming barriers to connect people who cannot meet face-to-face (e.g. geographic distance, time constraints) (Khalaila and Vitman-Schorr 2018), however they mostly foster established relationships, rather than creating new ones. Elderly residents of a nursing home showed significantly lower loneliness scores, measured using the 20-item UCLA loneliness scale, after three months of video-conferencing with relatives for 5-minutes per week (Tsai *et al.* 2010). Previous research showed the number of outgoing telephone calls was not associated with loneliness in older adults, however the number of incoming calls was negatively associated with loneliness (Petersen *et al.* 2016b), measured using the 20-item UCLA loneliness scale (Russell, Peplau and Cutrona 1980). Communicating via the internet with family and friends has been shown to reduce older adults' (≥ 55 years) feelings of loneliness (Sum *et al.* 2008), measured using the Social and Emotional Loneliness Scale (SELSA) (DiTommaso, Brannen and Best 2004), which may suggest the type of online activity and the relationship with whom they are communicating may be an important factor. Future studies should therefore consider investigating the quality of these online and offline relationships when researching loneliness.

Older adults using the internet/email once a week or once a month were less likely to be socially isolated than every day users. Conversely, a previous study found that social isolation was reported less frequently in older adults using the internet every day compared with never and sometimes users (Lelkes 2013). A previous study that gave older adults computers with internet access for three years found that participants were able to stay in touch with their real-world contacts whilst suffering illness (Fokkema and Knipscheer 2007). Thus, it may be that participants in the present study are unable to reduce their social isolation, however, remain in contact with the outside world through these means (Chen and Schulz 2016). There is also the possibility that it may encourage isolation due to convenience.

In a similar way to loneliness, explanations for the associations between social isolation and frequency of internet/email use may come from specific online activities. Strong associations were found between social isolation and all online activities in the present study. Communicating with family and friends via the internet reduced older adults' (≥ 55 years) social isolation, but when used often, for long durations and to communicate with strangers was associated with greater social isolation (Sum *et al.* 2008). Therefore, using internet/email as complementary, rather than replacement, of face-to-face social meetings may protect against social isolation and potentially loneliness (Cornejo, Tentori and Favela 2013, Fokkema and Knipscheer 2007, Lelkes 2013). Another explanation for the findings in the present study could be that every day users may either be online too frequently and/or for long durations, which may lead to greater social isolation. Once a week and once a month users in the present study may have a better balance, for example are too busy with real-world contacts and activities to spend as much time online, leading to reduced social isolation. Future interventions targeting social isolation in older adults may utilise the internet for cost-effectiveness, however in addition to real-world interactions to reduce the increased risk of loneliness. Previous research suggests that sharing content online can enhance conversations and promote real-world interactions that strengthen older adults networks, particularly intergenerationally (Cornejo, Tentori and Favela 2013). Future research should consider exploring the frequency and duration of internet use, in addition to online activities, when exploring associations with social isolation and loneliness.

Those using internet/email less than once every three months were more likely to be socially isolated than every day. Explanations for this could be poor access to internet/email services, lack of internet/email education, or even a purposeful decision to live 'offline'. Future digital interventions should thus consider the frequency and duration of use and time spent in face-

to-face interactions to ensure quality relationships are fostered/maintained in order to reduce social isolation and feelings of loneliness in older adults.

One limitation of the present study is the data are self-reported, which although is useful for gathering sensitive information such as loneliness and social isolation, may include bias and potential under or overestimations of reported behaviours (Araujo *et al.* 2017, Lee *et al.* 2011, Prince *et al.* 2008, Scharkow 2016). When split by frequency of internet/email use, some groups include low numbers of participants, which may potentially lead to type 1 statistical error. One purpose of internet use involves communication with others, which was also captured in the social isolation measures including written/email/text messaging contact, therefore there may be some overlap between these variables. In addition, the single item question relating to internet/email use may not provide enough information to gain true insight into the duration of time spent online, via which device and for which activities. Therefore, future studies should aim to elicit more detailed information, including duration of use per day as total time and in bouts of use, in self-report questionnaires on technology use. The present study explores associations, and whilst speculations can be made, causation regarding internet use, social isolation and loneliness in older adults requires further research.

Conclusion

The present study found older adults' perceived loneliness is not associated with their frequency of internet/email use; however social isolation is associated with frequency of internet/email use, but not linearly. This suggests that internet use bears no impact on the perceived quality of relationships for older adults and is often used to keep contact with established real-world connections. The study also highlights that 66 per cent of older adults

use the internet/email every day and 75 per cent at least once a week, and that smartphones and tablets are more popular with every day users whereas less frequent users tend to use laptops or tablets. This may have important implications for future digital behaviour change interventions for health specifically in older adults.

References

Age UK (2018a) *All the lonely people: Loneliness in later life*. Available online at https://www.ageuk.org.uk/globalassets/age-uk/documents/reports-and-publications/reports-and-briefings/loneliness/loneliness-report_final_2409.pdf [Accessed 16 January 2019].

Age UK (2018b) *Loneliness and isolation – understanding the difference and why it matters*. Available online at https://www.ageuk.org.uk/globalassets/age-uk/documents/reports-and-publications/reports-and-briefings/loneliness/rb_feb2018_180208_careconnect_ageuk_loneliness_research_article_isolation.pdf [Accessed 28 April 2019].

Araujo, T., Wonneberger, A., Neijens, P. and de Vreese, C. (2017) How Much Time Do You Spend Online? Understanding and Improving the Accuracy of Self-Reported Measures of Internet Use. *Communication Methods and Measures* **11**, 173-190.

Banks, J., Karlsen, S. and Oldfield, Z. (2004) *Socio-economic position*. Available online at <http://www.elsa-project.ac.uk/uploads/elsa/report03/ch3.pdf> [Accessed 14 December 2018].

Beard, J.R., Officer, A., de Carvalho, I.A., Sadana, R., Pot, A.M., Michel, J.-P., Lloyd-Sherlock, P., Epping-Jordan, J.E., Peeters, G.M.E.E., Mahanani, W.R., Thiyagarajan, J.A. and Chatterji, S. (2016) The World report on ageing and health: a policy framework for healthy ageing. *The Lancet* **387**, 2145-2154.

Bell, C., Fausset, C., Farmer, S., Nguyen, J., Harley, L. and Fain, W.B. 2013. Examining social media use among older adults. In *Proceedings of the 24th ACM Conference on Hypertext and Social Media*. ACM, Paris, France, 158-163.

Beneito-Montagut, R., Cassián-Yde, N. and Begueria, A. (2018) What do we know about the relationship between internet-mediated interaction and social isolation and loneliness in later life? *Quality in Ageing and Older Adults* **19**, 14-30.

Berner, J., Aartsen, M. and Deeg, D. (2017) Predictors in starting and stopping Internet use between 2002 and 2012 by Dutch adults 65 years and older. *Health Informatics Journal*, 1460458217720398.

Berry, R. (2011) *Older people and the internet: Towards a 'system map' of digital exclusion*. Available online at https://ilcuk.org.uk/wp-content/uploads/2018/10/pdf_pdf_181.pdf [Accessed 8 February 2019].

Bol, N., Helberger, N. and Weert, J.C.M. (2018) Differences in mobile health app use: A source of new digital inequalities? *The Information Society* **34**, 183-193.

Boss, L., Kang, D.H. and Branson, S. (2015) Loneliness and cognitive function in the older adult: a systematic review. *Int Psychogeriatr* **27**, 541-53.

Cacioppo, J.T. and Hawkley, L.C. (2009) Perceived social isolation and cognition. *Trends Cogn Sci* **13**, 447-54.

Cacioppo, J.T., Hawkley, L.C., Norman, G.J. and Berntson, G.G. (2011) Social isolation. *Annals of the New York Academy of Sciences* **1231**, 17-22.

Cacioppo, J.T., Hawkley, L.C. and Thisted, R.A. (2010) Perceived social isolation makes me sad: 5-year cross-lagged analyses of loneliness and depressive symptomatology in the Chicago Health, Aging, and Social Relations Study. *Psychol Aging* **25**, 453-63.

Cacioppo, J.T., Hughes, M.E., Waite, L.J., Hawkley, L.C. and Thisted, R.A. (2006) Loneliness as a specific risk factor for depressive symptoms: cross-sectional and longitudinal analyses. *Psychol Aging* **21**, 140-51.

Campaign to end loneliness (2015) *Measuring your impact on loneliness in later life*. Available online at <https://www.campaigntoendloneliness.org/wp-content/uploads/Loneliness-Measurement-Guidance1.pdf> [Accessed 19 August 2019].

Cantarero-Prieto, D., Pascual-Sáez, M. and Blázquez-Fernández, C. (2018) Social isolation and multiple chronic diseases after age 50: A European macro-regional analysis. *PloS one* **13**, e0205062-e0205062.

Chen, Y.R. and Schulz, P.J. (2016) The Effect of Information Communication Technology Interventions on Reducing Social Isolation in the Elderly: A Systematic Review. *J Med Internet Res* **18**, e18.

Chipps, J. and Jarvis, M.A. (2016) Technology-assisted communication in older persons in a residential care facility in South Africa. *Information Development* **33**, 393-405.

Choi, N.G. and Dinitto, D.M. (2013) The digital divide among low-income homebound older adults: Internet use patterns, eHealth literacy, and attitudes toward computer/Internet use. *Journal of medical Internet research* **15**, e93-e93.

Chopik, W.J. (2016) The Benefits of Social Technology Use Among Older Adults Are Mediated by Reduced Loneliness. *Cyberpsychology, Behavior, and Social Networking* **19**, 551-556.

Cornejo, R., Tentori, M. and Favela, J. (2013) Enriching in-person encounters through social media: A study on family connectedness for the elderly. *International Journal of Human - Computer Studies* **71**, 889-899.

Cornwell, E.Y. and Waite, L.J. (2009a) Measuring social isolation among older adults using multiple indicators from the NSHAP study. *J Gerontol B Psychol Sci Soc Sci* **64 Suppl 1**, i38-46.

Cornwell, E.Y. and Waite, L.J. (2009b) Social disconnectedness, perceived isolation, and health among older adults. *Journal of health and social behavior* **50**, 31-48.

Cosco, T.D., Lachance, C.C., Blodgett, J.M., Stubbs, B., Co, M., Veronese, N., Wu, Y.T. and Prina, A.M. (2019) Latent structure of the Centre for Epidemiologic Studies Depression Scale (CES-D) in older adult populations: a systematic review. *Aging Ment Health*, 1-5.

Cotten, S.R., Anderson, W.A. and McCullough, B.M. (2013) Impact of Internet Use on Loneliness and Contact with Others Among Older Adults: Cross-Sectional Analysis. *Journal of Medical Internet Research* **15**, e39.

Cotten, S.R., Ford, G., Ford, S. and Hale, T.M. (2012) Internet use and depression among older adults. *Computers in Human Behavior* **28**, 496-499.

Cotten, S.R., Ford, G., Ford, S. and Hale, T.M. (2014) Internet Use and Depression Among Retired Older Adults in the United States: A Longitudinal Analysis. *The Journals of Gerontology: Series B* **69**, 763-771.

Courtin, E. and Knapp, M. (2017) Social isolation, loneliness and health in old age: a scoping review. *Health Soc Care Community* **25**, 799-812.

Coyle, C.E. and Dugan, E. (2012) Social isolation, loneliness and health among older adults. *J Aging Health* **24**, 1346-63.

de Jong Gierveld, J. and Havens, B. (2004) Cross-national comparisons of social isolation and loneliness: introduction and overview. *Can J Aging* **23**, 109-13.

Demakakos, P., Hamer, M., Stamatakis, E. and Steptoe, A. (2010) Low-intensity physical activity is associated with reduced risk of incident type 2 diabetes in older adults: evidence from the English Longitudinal Study of Ageing. *Diabetologia* **53**, 1877-1885.

DiTommaso, E., Brannen, C. and Best, L.A. (2004) Measurement and Validity Characteristics of the Short Version of the Social and Emotional Loneliness Scale for Adults. *Educational and Psychological Measurement* **64**, 99-119.

Domenech-Abella, J., Lara, E., Rubio-Valera, M., Olaya, B., Moneta, M.V., Rico-Urbe, L.A., Ayuso-Mateos, J.L., Mundo, J. and Haro, J.M. (2017) Loneliness and depression in the elderly: the role of social network. *Soc Psychiatry Psychiatr Epidemiol* **52**, 381-390.

Erickson, J. and Johnson, G.M. (2011) Internet Use and Psychological Wellness during Late Adulthood. *Canadian Journal on Aging / La Revue canadienne du vieillissement* **30**, 197-209.

Eurostat (2018) *Population by age group*. Available online at <https://ec.europa.eu/eurostat/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=tps00010&language=en> [Accessed December 10, 2018].

Fokkema, T. and Knipscheer, K. (2007) Escape loneliness by going digital: a quantitative and qualitative evaluation of a Dutch experiment in using ECT to overcome loneliness among older adults. *Aging Ment Health* **11**, 496-504.

Grant, N., Hamer, M. and Steptoe, A. (2009) Social isolation and stress-related cardiovascular, lipid, and cortisol responses. *Ann Behav Med* **37**, 29-37.

Grenade, L. and Boldy, D. (2008) Social isolation and loneliness among older people: issues and future challenges in community and residential settings. *Aust Health Rev* **32**, 468-78.

Hamer, M., de Oliveira, C. and Demakakos, P. (2014) Non-exercise physical activity and survival: English longitudinal study of ageing. *Am J Prev Med* **47**, 452-60.

Hamer, M., Lavoie, K.L. and Bacon, S.L. (2014) Taking up physical activity in later life and healthy ageing: the English longitudinal study of ageing. *British Journal of Sports Medicine* **48**, 239-243.

Hamer, M., Molloy, G.J., de Oliveira, C. and Demakakos, P. (2009) Leisure time physical activity, risk of depressive symptoms, and inflammatory mediators: The English Longitudinal Study of Ageing. *Psychoneuroendocrinology* **34**, 1050-1055.

Hansen, T. and Slagsvold, B. (2016) Late-Life Loneliness in 11 European Countries: Results from the Generations and Gender Survey. *Social Indicators Research* **129**, 445-464.

Hawkley, L.C. 2017. Loneliness and Health. In Gellman, M. and Turner, J.R. (eds), *Encyclopedia of Behavioral Medicine*. Springer New York, New York, NY, 1-5.

Hawkley, L.C. and Cacioppo, J.T. (2007) Aging and Loneliness: Downhill Quickly? Current Directions in Psychological Science **16**, 187-191.

Hawkley, L.C. and Cacioppo, J.T. (2010) Loneliness matters: a theoretical and empirical review of consequences and mechanisms. *Annals of behavioral medicine : a publication of the Society of Behavioral Medicine* **40**, 218-227.

Hawkley, L.C. and Kocherginsky, M. (2017) Transitions in Loneliness Among Older Adults: A 5-Year Follow-Up in the National Social Life, Health, and Aging Project. *Research on Aging* **40**, 365-387.

Hawkley, L.C., Thisted, R.A. and Cacioppo, J.T. (2009) Loneliness predicts reduced physical activity: cross-sectional & longitudinal analyses. *Health psychology : official journal of the Division of Health Psychology, American Psychological Association* **28**, 354-363.

Heo, J., Chun, S., Lee, S., Lee, K.H. and Kim, J. (2015) Internet use and well-being in older adults. *Cyberpsychol Behav Soc Netw* **18**, 268-72.

Hogeboom, D.L., McDermott, R.J., Perrin, K.M., Osman, H. and Bell-Ellison, B.A. (2010) Internet Use and Social Networking Among Middle Aged and Older Adults. *Educational Gerontology* **36**, 93-111.

Holt-Lunstad, J., Smith, T.B. and Layton, J.B. (2010) Social relationships and mortality risk: a meta-analytic review. *PLoS Med* **7**, e1000316.

Hughes, M.E., Waite, L.J., Hawkley, L.C. and Cacioppo, J.T. (2004) A Short Scale for Measuring Loneliness in Large Surveys: Results From Two Population-Based Studies. *Research on aging* **26**, 655-672.

Iliffe, S., Kharicha, K., Harari, D., Swift, C., Gillmann, G. and Stuck, A.E. (2007) Health risk appraisal in older people 2: the implications for clinicians and commissioners of social isolation risk in older people. *Br J Gen Pract* **57**, 277-82.

Jackson, S., Hackett, R. and Steptoe, A. 2019. *Associations between age discrimination and health and wellbeing: cross-sectional and prospective analysis of the English Longitudinal Study of Ageing*.

Jackson, S., Yang, L., Veronese, N., Gorely, T., Grabovac, I., Johnstone, J., Firth, J. and Smith, L. (2019a) Reducing loneliness among older adults through providing free travel access: A population-based assessment of social isolation and free bus travel in older adults in England. Preprint.

Jackson, S.E., Firth, J.A., Firth, J., Veronese, N., Gorely, T., Grabovac, I., Yang, L. and Smith, L. (2019b) Social isolation and physical activity mediate associations between free bus travel and wellbeing among older adults in England. *Journal of Transport & Health* **13**, 274-284.

Khalaila, R. and Vitman-Schorr, A. (2018) Internet use, social networks, loneliness, and quality of life among adults aged 50 and older: mediating and moderating effects. *Quality of Life Research* **27**, 479-489.

Kharicha, K., Iliffe, S., Manthorpe, J., Chew-Graham, C.A., Cattan, M., Goodman, C., Kirby-Barr, M., Whitehouse, J.H. and Walters, K. (2017) What do older people experiencing loneliness think about primary care or community based interventions to reduce loneliness? A qualitative study in England. *Health Soc Care Community* **25**, 1733-1742.

Khosravi, P., Rezvani, A. and Wiewiora, A. (2016) The impact of technology on older adults' social isolation. *Computers in Human Behavior* **63**, 594-603.

Kobayashi, L.C. and Steptoe, A. (2018) Social Isolation, Loneliness, and Health Behaviors at Older Ages: Longitudinal Cohort Study. *Ann Behav Med* **52**, 582-593.

Lauder, W., Mummery, K., Jones, M. and Caperchione, C. (2006) A comparison of health behaviours in lonely and non-lonely populations. *Psychol Health Med* **11**, 233-45.

Lee, P.H., Macfarlane, D.J., Lam, T.H. and Stewart, S.M. (2011) Validity of the International Physical Activity Questionnaire Short Form (IPAQ-SF): a systematic review. *The international journal of behavioral nutrition and physical activity* **8**, 115-115.

Leigh-Hunt, N., Bagguley, D., Bash, K., Turner, V., Turnbull, S., Valtorta, N. and Caan, W. (2017) An overview of systematic reviews on the public health consequences of social isolation and loneliness. *Public Health* **152**, 157-171.

Leist, A.K. (2013) Social media use of older adults: a mini-review. *Gerontology* **59**, 378-84.

Lelkes, O. (2013) Happier and less isolated: internet use in old age. *Journal of Poverty and Social Justice* **21**, 33-46.

Luo, Y., Hawkey, L.C., Waite, L.J. and Cacioppo, J.T. (2012) Loneliness, health, and mortality in old age: a national longitudinal study. *Soc Sci Med* **74**, 907-14.

Murray, C.J., Vos, T., Lozano, R., Naghavi, M., Flaxman, A.D., Michaud, C., Ezzati, M., Shibuya, K., Salomon, J.A., Abdalla, S., Aboyans, V., Abraham, J., Ackerman, I., Aggarwal, R., Ahn, S.Y., Ali, M.K., Alvarado, M., Anderson, H.R., Anderson, L.M., Andrews, K.G., Atkinson, C., Baddour, L.M., Bahalim, A.N., Barker-Collo, S., Barrero, L.H., Bartels, D.H., Basanez, M.G., Baxter, A., Bell, M.L., Benjamin, E.J., Bennett, D., Bernabe, E., Bhalla, K., Bhandari, B., Bikbov, B., Bin Abdulhak, A., Birbeck, G., Black, J.A., Blencowe, H., Blore, J.D., Blyth, F., Bolliger, I.,

Bonaventure, A., Boufous, S., Bourne, R., Boussinesq, M., Braithwaite, T., Brayne, C., Bridgett, L., Brooker, S., Brooks, P., Brugha, T.S., Bryan-Hancock, C., Bucello, C., Buchbinder, R., Buckle, G., Budke, C.M., Burch, M., Burney, P., Burstein, R., Calabria, B., Campbell, B., Canter, C.E., Carabin, H., Carapetis, J., Carmona, L., Cella, C., Charlson, F., Chen, H., Cheng, A.T., Chou, D., Chugh, S.S., Coffeng, L.E., Colan, S.D., Colquhoun, S., Colson, K.E., Condon, J., Connor, M.D., Cooper, L.T., Corriere, M., Cortinovis, M., de Vaccaro, K.C., Couser, W., Cowie, B.C., Criqui, M.H., Cross, M., Dabhadkar, K.C., Dahiya, M., Dahodwala, N., Damsere-Derry, J., Danaei, G., Davis, A., De Leo, D., Degenhardt, L., Dellavalle, R., Delossantos, A., Denenberg, J., Derrett, S., Des Jarlais, D.C., Dharmaratne, S.D., Dherani, M., Diaz-Torne, C., Dolk, H., Dorsey, E.R., Driscoll, T., Duber, H., Ebel, B., Edmond, K., Elbaz, A., Ali, S.E., Erskine, H., Erwin, P.J., Espindola, P., Ewoigbokhan, S.E., Farzadfar, F., Feigin, V., Felson, D.T., Ferrari, A., Ferri, C.P., Fevre, E.M., Finucane, M.M., Flaxman, S., Flood, L., Foreman, K., Forouzanfar, M.H., Fowkes, F.G., Fransen, M., Freeman, M.K., Gabbe, B.J., Gabriel, S.E., Gakidou, E., Ganatra, H.A., Garcia, B., Gaspari, F., Gillum, R.F., Gmel, G., Gonzalez-Medina, D., Gosselin, R., Grainger, R., Grant, B., Groeger, J., Guillemin, F., Gunnell, D., Gupta, R., Haagsma, J., Hagan, H., Halasa, Y.A., Hall, W., Haring, D., Haro, J.M., Harrison, J.E., Havmoeller, R., Hay, R.J., Higashi, H., Hill, C., Hoen, B., Hoffman, H., Hotez, P.J., Hoy, D., Huang, J.J., Ibeanusi, S.E., Jacobsen, K.H., James, S.L., Jarvis, D., Jasrasaria, R., Jayaraman, S., Johns, N., Jonas, J.B., Karthikeyan, G., Kassebaum, N., Kawakami, N., Keren, A., Khoo, J.P., King, C.H., Knowlton, L.M., Kobusingye, O., Koranteng, A., Krishnamurthi, R., Laden, F., Lalloo, R., Laslett, L.L., Lathlean, T., Leasher, J.L., Lee, Y.Y., Leigh, J., Levinson, D., Lim, S.S., Limb, E., Lin, J.K., Lipnick, M., Lipshultz, S.E., Liu, W., Loane, M., Ohno, S.L., Lyons, R., Mabweijano, J., MacIntyre, M.F., Malekzadeh, R., Mallinger, L., Manivannan, S., Marcenes, W., March, L., Margolis, D.J., Marks, G.B., Marks, R., Matsumori, A., Matzopoulos, R., Mayosi, B.M., McAnulty, J.H., McDermott, M.M., McGill, N., McGrath, J.,

Medina-Mora, M.E., Meltzer, M., Mensah, G.A., Merriman, T.R., Meyer, A.C., Miglioli, V., Miller, M., Miller, T.R., Mitchell, P.B., Mock, C., Mocumbi, A.O., Moffitt, T.E., Mokdad, A.A., Monasta, L., Montico, M., Moradi-Lakeh, M., Moran, A., Morawska, L., Mori, R., Murdoch, M.E., Mwaniki, M.K., Naidoo, K., Nair, M.N., Naldi, L., Narayan, K.M., Nelson, P.K., Nelson, R.G., Nevitt, M.C., Newton, C.R., Nolte, S., Norman, P., Norman, R., O'Donnell, M., O'Hanlon, S., Olives, C., Omer, S.B., Ortblad, K., Osborne, R., Ozgediz, D., Page, A., Pahari, B., Pandian, J.D., Rivero, A.P., Patten, S.B., Pearce, N., Padilla, R.P., Perez-Ruiz, F., Perico, N., Pesudovs, K., Phillips, D., Phillips, M.R., Pierce, K., Pion, S., Polanczyk, G.V., Polinder, S., Pope, C.A., 3rd, Popova, S., Porrini, E., Pourmalek, F., Prince, M., Pullan, R.L., Ramaiah, K.D., Ranganathan, D., Razavi, H., Regan, M., Rehm, J.T., Rein, D.B., Remuzzi, G., Richardson, K., Rivara, F.P., Roberts, T., Robinson, C., De Leon, F.R., Ronfani, L., Room, R., Rosenfeld, L.C., Rushton, L., Sacco, R.L., Saha, S., Sampson, U., Sanchez-Riera, L., Sanman, E., Schwebel, D.C., Scott, J.G., Segui-Gomez, M., Shahraz, S., Shepard, D.S., Shin, H., Shivakoti, R., Singh, D., Singh, G.M., Singh, J.A., Singleton, J., Sleet, D.A., Sliwa, K., Smith, E., Smith, J.L., Stapelberg, N.J., Steer, A., Steiner, T., Stolk, W.A., Stovner, L.J., Sudfeld, C., Syed, S., Tamburlini, G., Tavakkoli, M., Taylor, H.R., Taylor, J.A., Taylor, W.J., Thomas, B., Thomson, W.M., Thurston, G.D., Tleyjeh, I.M., Tonelli, M., Towbin, J.A., Truelsen, T., Tsilimbaris, M.K., Ubeda, C., Undurraga, E.A., van der Werf, M.J., van Os, J., Vavilala, M.S., Venketasubramanian, N., Wang, M., Wang, W., Watt, K., Weatherall, D.J., Weinstock, M.A., Weintraub, R., Weisskopf, M.G., Weissman, M.M., White, R.A., Whiteford, H., Wiebe, N., Wiersma, S.T., Wilkinson, J.D., Williams, H.C., Williams, S.R., Witt, E., Wolfe, F., Woolf, A.D., Wulf, S., Yeh, P.H., Zaidi, A.K., Zheng, Z.J., Zonies, D., Lopez, A.D., AlMazroa, M.A. and Memish, Z.A. (2012) Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* **380**, 2197-223.

Netz, Y., Goldsmith, R., Shimony, T., Arnon, M. and Zeev, A. (2013) Loneliness is associated with an increased risk of sedentary life in older Israelis. *Aging Ment Health* **17**, 40-7.

Nimrod, G. (2010) The Fun Culture in Seniors' Online Communities. *The Gerontologist* **51**, 226-237.

Office for National Statistics (2017) *Overview of the UK population*. Available online at <https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/articles/overviewoftheukpopulation/mar2017> [Accessed 25 March 2019].

Office for National Statistics (2018a) *Internet users, UK: 2018*. Available online at <https://www.ons.gov.uk/businessindustryandtrade/itandinternetindustry/bulletins/internetusers/2018> [Accessed 2 July 2018].

Office for National Statistics (2018b) *Overview of the UK population: November 2018*. Available online at <https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/articles/overviewoftheukpopulation/november2018> [Accessed 18 March 2019].

Patterson, A.C. and Veenstra, G. (2010) Loneliness and risk of mortality: A longitudinal investigation in Alameda County, California. *Social Science & Medicine* **71**, 181-186.

Peplau, L.A. 1985. Loneliness Research: Basic Concepts and Findings. In Sarason, I.G. and Sarason, B.R. (eds), *Social Support: Theory, Research and Applications*. Springer Netherlands, Dordrecht, 269-286.

Peplau, L.A. and Perlman, D. 1982. Perspectives on Loneliness. In Peplau, L.A. and Perlman, D. (eds), *Loneliness: a sourcebook of current theory, research, and therapy*. Wiley, 1-20.

Perissinotto, C.M., Stijacic Cenzer, I. and Covinsky, K.E. (2012) Loneliness in older persons: a predictor of functional decline and death. *Archives of internal medicine* **172**, 1078-1083.

Perlman, D. and Peplau, L.A. 1984. Loneliness research: A survey of empirical findings. In *Preventing the harmful consequences of severe and persistent loneliness*. National Institute of Mental Health, Rockville, MD, US, 13-46.

Petersen, J., Kaye, J., Jacobs, P.G., Quinones, A., Dodge, H., Arnold, A. and Thielke, S. (2016a) Longitudinal Relationship Between Loneliness and Social Isolation in Older Adults: Results From the Cardiovascular Health Study. *J Aging Health* **28**, 775-95.

Petersen, J., Thielke, S., Austin, D. and Kaye, J. (2016b) Phone behaviour and its relationship to loneliness in older adults. *Aging & mental health* **20**, 1084-1091.

Prince, S.A., Adamo, K.B., Hamel, M.E., Hardt, J., Connor Gorber, S. and Tremblay, M. (2008) A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity* **5**, 56.

Quintana, D., Cervantes, A., Sáez, Y. and Isasi, P. (2018) Internet Use and Psychological Well-Being at Advanced Age: Evidence from the English Longitudinal Study of Aging. *International Journal of Environmental Research and Public Health* **15**, 480.

Rico-Uribe, L.A., Caballero, F.F., Martín-María, N., Cabello, M., Ayuso-Mateos, J.L. and Miret, M. (2018) Association of loneliness with all-cause mortality: A meta-analysis. *PloS one* **13**, e0190033-e0190033.

Russell, D., Peplau, L.A. and Cutrona, C.E. (1980) The revised UCLA Loneliness Scale: Concurrent and discriminant validity evidence. *Journal of Personality and Social Psychology* **39**, 472-480.

Russell, D.W. (1996) UCLA Loneliness Scale (Version 3): reliability, validity, and factor structure. *J Pers Assess* **66**, 20-40.

Russell, D.W., Cutrona, C.E., McRae, C. and Gomez, M. (2012) Is Loneliness the Same as Being Alone? *The Journal of Psychology* **146**, 7-22.

Scharkow, M. (2016) The Accuracy of Self-Reported Internet Use—A Validation Study Using Client Log Data. *Communication Methods and Measures* **10**, 13-27.

Shankar, A., McMunn, A., Banks, J. and Steptoe, A. (2011) Loneliness, social isolation, and behavioral and biological health indicators in older adults. *Health Psychol* **30**, 377-85.

Smith, L., Gardner, B., Fisher, A. and Hamer, M. (2015) Patterns and correlates of physical activity behaviour over 10 years in older adults: prospective analyses from the English Longitudinal Study of Ageing. *British Medical Journal Open* **5**.

Steptoe, A., Breeze, E., Banks, J. and Nazroo, J. (2013a) Cohort profile: the English longitudinal study of ageing. *Int J Epidemiol* **42**, 1640-8.

Steptoe, A., Shankar, A., Demakakos, P. and Wardle, J. (2013b) Social isolation, loneliness, and all-cause mortality in older men and women. *Proc Natl Acad Sci U S A* **110**, 5797-801.

Sum, S., Mathews, R.M., Hughes, I. and Campbell, A. (2008) Internet use and loneliness in older adults. *Cyberpsychol Behav* **11**, 208-11.

Tsai, Y.-F., Wang, H.-H., Chang, Y.-C. and Chu, H.H. (2010) Videoconference program enhances social support, loneliness, and depressive status of elderly nursing home residents AU - Tsai, Hsiu-Hsin. *Aging & Mental Health* **14**, 947-954.

Turvey, C.L., Wallace, R.B. and Herzog, R. (1999) A revised CES-D measure of depressive symptoms and a DSM-based measure of major depressive episodes in the elderly. *Int Psychogeriatr* **11**, 139-48.

Victor, C.R. and Yang, K. (2012) The prevalence of loneliness among adults: a case study of the United Kingdom. *J Psychol* **146**, 85-104.

White, J., Zaninotto, P., Walters, K., Kivimäki, M., Demakakos, P., Biddulph, J., Kumari, M., De Oliveira, C., Gallacher, J. and Batty, G.D. (2018) Duration of depressive symptoms and mortality risk: The English Longitudinal Study of Ageing (ELSA). *British Journal of Psychiatry* **208**, 337-342.

Wilson, R.S., Krueger, K.R., Arnold, S.E. and et al. (2007) Loneliness and risk of alzheimer disease. Archives of General Psychiatry **64**, 234-240.

Tables

Table 1. Sample characteristics in relation to internet/email use

	Frequency of internet/email use							Chi-Square	
	All	Every day	Once a week	Once a month	Once every 3 months	Less than every 3 months	Never	P value	Cramer's V
	n=4492	n=3113 (69.3%)	n=384 (8.5%)	n=115 (2.6%)	n=32 (0.7%)	n=66 (1.5%)	n=781 (17.4%)		
Age (mean \pm SD)	64.3 \pm 13.3	62.9 \pm 8.8	67.6 \pm 11.3	68.5 \pm 12.3	66.5 \pm 9.5	65.9 \pm 13.3	67.5 \pm 24.0	<0.001	0.25
50-59	1436 (32.0%)	1265 (40.6%)	73 (19.0%)	12 (10.3%)	11 (36.0%)	18 (26.3%)	57 (7.3%)	<0.001	0.25
60-69	1543 (34.4%)	1176 (37.8%)	139 (36.3%)	48 (42.1%)	10 (30.9%)	23 (35.1%)	146 (18.7%)		
70-79	1003 (22.2%)	550 (17.7%)	115 (30.1%)	34 (29.2%)	6 (20.2%)	16 (24.5%)	281 (36.0%)		
80-89	429 (9.6%)	113 (3.6%)	53 (13.8%)	20 (17.1%)	4 (12.9%)	8 (12.5%)	232 (29.6%)		
90+	80 (1.8%)	10 (0.3%)	3 (0.8%)	1 (1.3%)	0	1 (1.5%)	65 (8.3%)		
Sex									
Men	2322 (51.7%)	1678 (53.9%)	191 (49.9%)	52 (45.7%)	14 (45.2%)	29 (43.1%)	357 (45.6%)	<0.001	0.07

Women	2170 (48.3%)	1435 (46.1%)	192 (50.1%)	62 (54.3%)	17 (54.8%)	38 (56.9%)	425 (54.4%)		
Marital status									
Unmarried	1274 (28.4%)	702 (22.5%)	113 (29.4%)	51 (44.7%)	9 (27.0%)	22 (33.7%)	376 (48.2%)	<0.001	0.22
Married	3218 (71.6%)	2411 (77.5%)	271 (70.6%)	64 (55.3%)	23 (73.0%)	44 (66.3%)	405 (51.8%)		
SES quintile									
1 (poorest)	782 (17.4%)	400 (12.9%)	54 (14.0%)	32 (27.5%)	5 (16.9%)	24 (36.4%)	266 (34.1%)	<0.001	0.15
2	837 (18.6%)	511 (16.4%)	79 (20.5%)	28 (24.1%)	4 (12.6%)	16 (24.0%)	200 (25.6%)		
3	935 (20.8 %)	636 (20.4%)	87 (22.8%)	25 (21.5%)	14 (44.8%)	9 (13.5%)	164 (21.0%)		
4	961 (21.4%)	712 (22.9%)	105 (27.3%)	21 (18.1%)	4 (11.3%)	12 (18.6%)	108 (13.9%)		
5 (richest)	976 (21.7%)	854 (27.4%)	59 (15.5%)	10 (8.7%)	5 (14.4%)	5 (7.5%)	43 (5.5%)		
Limiting Long-standing illness									
No	3046 (67.8%)	2321 (74.6%)	251 (65.4%)	65 (56.6%)	19 (60.3%)	34 (51.7%)	355 (45.4%)	<0.001	0.24

Yes	1446 (32.2%)	792 (25.4%)	113 (34.6%)	50 (43.4%)	13 (39.7%)	32 (48.3%)	426 (54.6%)		
Depression									
Low	2385 (53.1%)	1806 (58.0%)	182 (47.5%)	42 (36.3%)	19 (59.4%)	25 (37.9%)	311 (39.8%)	<0.001	0.16
High	2107 (46.9%)	1308 (42.0%)	201 (52.5%)	73 (63.7%)	13 (40.6%)	41 (62.1%)	471 (60.2%)		
Physical activity									
Inactive	932 (20.8%)	451 (14.5%)	81 (21.2%)	26 (22.4%)	7 (20.7%)	25 (37.2%)	343 (43.9%)	<0.001	0.28
Active	3559 (79.2%)	2663 (85.5%)	302 (78.8%)	89 (77.6%)	25 (79.3%)	42 (62.8%)	438 (56.1%)		
Loneliness									
Low	3619 (80.6%)	2573 (82.6%)	300 (78.3%)	90 (77.9%)	22 (68.4%)	49 (73.4%)	585 (74.9%)	<0.001	0.08
High	873 (19.4%)	540 (17.4%)	83 (21.7%)	25 (22.1%)	10 (31.6%)	18 (26.4%)	196 (25.1%)		
Social Isolation									
Not Isolated	3015 (67.1%)	2249 (72.2%)	265 (69.0%)	62 (54.1%)	12 (39.2%)	43 (65.2%)	384 (49.1%)	<0.001	0.20
Isolated	1476 (32.9%)	864 (27.7%)	119 (31.0%)	53 (45.9%)	19 (60.8%)	23 (34.8%)	398 (50.9%)		

Values are number of participants (percentages) within each category of internet/email frequency use unless otherwise stated

SD = standard deviation.

Table 2. Older adults' frequency of internet/email use in relation to self-reported loneliness.

High loneliness												
	OR*	95% CI	P value	OR**	95% CI	P value	OR***	95% CI	P value	OR****	95% CI	P value
Frequency of internet/email use												
Every day (69.3%)	1.00 (ref)			1.00 (ref)			1.00 (ref)			1.00 (ref)		
Once a week (8.5%)	0.63	0.52- 0.76	<0.001	0.76	0.63- 0.92	0.01	1.11	0.89- 1.37	0.36	1.16	0.94- 1.45	0.17
Once a month (2.6%)	0.83	0.62- 1.11	0.20	0.98	0.73- 1.32	0.91	1.24	0.91- 1.71	0.18	1.32	0.96- 1.81	0.09
Once every 3 months (0.7%)	0.85	0.53- 1.35	0.48	0.88	0.55- 1.42	0.59	0.89	0.54- 1.46	0.63	0.90	0.54- 1.48	0.67
Less than once every 3 months (1.5%)	1.38	0.64- 2.95	0.41	1.28	0.59- 2.78	0.54	2.49	1.05- 5.90	0.04	2.30	0.97- 5.45	0.06
Never (17.4%)	1.08	0.61- 1.90	0.79	1.25	0.70- 2.76	0.45	1.27	0.69- 2.33	0.44	1.34	0.73- 2.47	0.35

*Unadjusted

*Adjusted for social isolation.

***Adjusted for covariates sex, age, wealth, moderate-to-vigorous physical activity, marital status, limiting long-standing illness, depression

**** Adjusted for social isolation and covariates sex, age, wealth, moderate-to-vigorous physical activity, marital status, limiting long-standing illness, depression.

Table 3. Older adults' frequency of internet/email use in relation to self-reported social isolation.

High social isolation												
	OR*	95% CI	P value	OR**	95% CI	P value	OR***	95% CI	P value	OR****	95% CI	P value
Frequency of internet use												
Every day (69.3%)	1.00 (ref)			1.00 (ref)			1.00 (ref)			1.00 (ref)		
Once a week (8.5%)	0.37	0.32- 0.44	<0.001	0.39	0.33- 0.45	<0.001	0.60	0.50- 0.73	<0.001	0.60	0.49- 0.72	<0.001
Once a month (2.6%)	0.43	0.33- 0.56	<0.001	0.43	0.33- 0.56	<0.001	0.60	0.46- 0.81	0.001	0.60	0.45- 0.80	<0.001
Once every 3 months (0.7%)	0.82	0.55- 1.21	0.32	0.84	0.56- 1.25	0.38	0.94	0.61- 1.44	0.77	0.95	0.61- 1.45	0.80
Less than once every 3 months (1.5%)	1.50	0.73- 3.09	0.28	1.44	0.69- 3.01	0.34	2.96	1.34- 6.56	0.007	2.87	1.28- 6.40	0.01
Never (17.4%)	0.51	0.30- 0.87	0.01	0.50	0.29- 0.85	0.01	0.60	0.34- 1.07	0.09	0.59	0.33- 1.06	0.08

*Unadjusted

*Adjusted for loneliness

***Adjusted for covariates sex, age, wealth, moderate-to-vigorous physical activity, marital status, limiting long-standing illness, depression

**** Adjusted loneliness and covariates sex, age, wealth, moderate-to-vigorous physical activity, marital status, limiting long-standing illness, depression.

Table 4. Devices used to access the internet in the last three months categorised by internet/email usage.

	Frequency of internet/email use					Chi-Square	
	All	Every day	Once a week	Once a month	Once every 3 months	P value	Cramer's V
	n=4492	n=3113 (69.3%)	n=384 (8.5%)	n=115 (2.6%)	n=32 (0.7%)		
Desktop	1745 (38.9%)	1590 (51.1%)	123 (31.9%)	30 (26.3%)	3 (9.8%)	<0.0001	0.72
Laptop	2109 (47.0%)	1865 (59.9%)	185 (48.1%)	44 (38.6%)	16 (49.7%)	<0.0001	0.71
Tablet	2133 (47.5%)	1913 (61.4%)	170 (44.3%)	42 (36.2%)	9 (29.2%)	<0.0001	0.72
Smartphone	2127 (47.4%)	1992 (64.0%)	105 (27.4%)	24 (21.0%)	6 (19.9%)	<0.0001	0.73
Other	110 (2.5%)	101 (3.2%)	3 (0.7%)	5 (4.6%)	1 (4.0%)	<0.0001	0.71

Values are number of participants (percentages) within each category of internet/email frequency use unless otherwise stated

Table 5. Older adults' device use in relation to loneliness and social isolation.

	Loneliness		Chi-square		Social isolation		Chi-square	
	High	Low	P value	Cramer's V	High	Low	P value	Cramer's V
	n=873	n=3619			n=1476	n=3015		
Desktop (38.9%)	259 (29.7%)	1487 (41.1%)	<0.001	0.10	498 (33.7%)	1248 (41.4%)	<0.001	0.17
Laptop (47.0%)	355 (40.7%)	1754 (48.5%)	<0.001	0.08	605 (41.0%)	1505 (49.9%)	<0.001	0.17
Tablet (47.5%)	335 (38.4%)	1798 (49.7%)	<0.001	0.10	543 (36.8%)	1591 (50.4%)	<0.001	0.19
Smartphone (47.4%)	363 (41.6%)	1764 (48.7%)	<0.001	0.08	496 (33.6%)	1631 (54.1%)	<0.001	0.22
Other (2.5%)	21 (2.4%)	89 (2.5%)	<0.001	0.07	27 (1.8%)	83 (2.8%)	<0.001	0.17

Values are number of participants (percentages) within each category of loneliness/social isolation unless otherwise stated

Table 6. Internet activities in the last three months categorised by internet/email usage.

	Frequency of internet/email use					Chi-Square	
	All	Every day	Once a week	Once a month	Once every 3 months	P value	Cramer's V
	n=4492	n=3113 (69.3%)	n=384 (8.5%)	n=115 (2.6%)	n=32 (0.7%)		
Sending/receiving emails	3307 (73.6%)	2949 (94.7%)	280 (73.0%)	66 (57.8%)	12 (36.6%)	<0.001	0.75
Telephoning/video calls (via webcam)	1184 (26.3%)	1137 (36.5%)	37 (9.5%)	9 (7.5%)	2 (5.8%)	<0.001	0.72
Searching for information	3317 (73.8%)	2915 (93.6%)	309 (80.5%)	76 (66.3%)	17 (54.5%)	<0.001	0.73
Finances	2260 (50.3%)	2131 (68.4%)	113 (29.5%)	15 (13.3%)	1 (1.9%)	<0.001	0.74
Shopping/buying	2831 (63.0%)	2598 (83.4%)	182 (47.5%)	39 (33.9%)	12 (37.8%)	<0.001	0.75
Selling	413 (9.2%)	394 (12.6%)	14 (3.8%)	4 (3.3%)	1 (2.1%)	<0.001	0.71
Social Networking	1742 (38.8%)	1604 (51.5%)	110 (28.7%)	25 (21.5%)	3 (9.9%)	<0.001	0.72
Creating, uploading or sharing content	848 (18.9%)	391 (12.5%)	18 (4.8%)	4 (3.8%)	0	<0.001	0.71
News	1945 (43.3%)	1844 (59.2%)	83 (21.6%)	15 (13.1%)	2 (7.1%)	<0.001	0.74
Streaming/downloading	1653 (36.8%)	1595 (51.2%)	48 (12.6%)	6 (5.6%)	3 (10.2%)	<0.001	0.74

Games	1089 (24.2%)	982 (31.7%)	86 (22.3%)	14 (11.9%)	2 (6.5%)	<0.001	0.71
Job searching/ application	400 (8.9%)	376 (12.1%)	16 (4.2%)	4 (3.8%)	4 (13.5%)	<0.001	0.71
Using public services	899 (20.0%)	868 (27.9%)	25 (6.5%)	6 (4.8%)	0	<0.001	0.72
Other	267 (5.9%)	235 (7.5%)	20 (5.2%)	11 (9.5%)	1 (4.1%)	<0.001	0.71

Values are number of participants (percentages) within each category of internet/email frequency use unless otherwise stated

Table 7. Older adults' internet activities in the last three months in relation to loneliness and social isolation.

	Loneliness		Chi-square		Social isolation		Chi-square	
	High	Low	P value	Cramer's V	High	Low	P value	Cramer's V
	n=873	n=3619			n=1476	n=3015		
Sending/receiving emails (73.6%)	581 (66.6%)	2726 (75.3%)	<0.001	0.08	915 (62.0%)	2391 (79.3%)	<0.001	0.19
Telephoning/video calls (via webcam) (26.3%)	171 (19.6%)	1013 (28.0%)	<0.001	0.09	224 (15.2%)	959 (31.8%)	<0.001	0.22
Searching for information (73.8%)	583 (66.8%)	2734 (75.5%)	<0.001	0.08	919 (62.3%)	2398 (79.5%)	<0.001	0.19
Finances (50.3%)	362 (41.5%)	1897 (52.4%)	<0.001	0.09	616 (41.7%)	1644 (54.5%)	<0.001	0.18
Shopping/buying (63.0%)	486 (55.7%)	2345 (64.8%)	<0.001	0.08	778 (52.7%)	2053 (68.1%)	<0.001	0.18
Selling (9.2%)	55 (6.3%)	358 (9.9%)	<0.001	0.08	92 (6.2%)	321 (10.6%)	<0.001	0.18
Social Networking (38.8%)	323 (37.0%)	1419 (39.2%)	<0.001	0.07	427 (28.9%)	1315 (43.6%)	<0.001	0.19
Creating, uploading or sharing content (18.9%)	96 (11.0%)	317 (8.8%)	<0.001	0.08	90 (6.1%)	323 (10.7%)	<0.001	0.18
News (43.3%)	322 (36.9%)	1622 (44.8%)	<0.001	0.08	475 (32.2%)	1470 (48.8%)	<0.001	0.20
Streaming/downloading (36.8%)	257 (29.4%)	1396 (38.6%)	<0.001	0.09	420 (28.5%)	1233 (40.9%)	<0.001	0.18

Games (24.2%)	176 (20.1%)	913 (25.2%)	<0.001	0.08	294 (19.9%)	795 (26.4%)	<0.001	0.17
Job searching/ application (8.9%)	119 (13.6%)	281 (7.8%)	<0.001	0.12	139 (9.4%)	261 (8.7%)	<0.001	0.18
Using public services (20.0%)	174 (19.9%)	725 (20.0%)	<0.001	0.07	217 (14.7%)	682 (22.6%)	<0.001	0.18
Other (5.9%)	61 (7.0%)	206 (5.7%)	<0.001	0.08	77 (5.2%)	190 (6.3%)	<0.001	0.17

Values are number of participants (percentages) within each category of loneliness/social isolation unless otherwise stated