

Research Article

Internet Use and Loneliness of Older Adults Over Time: The Mediating Effect of Social Contact

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Abstract

Objectives: The internet is increasingly commonly used by older adults. However, it remains controversial in the literature on whether older people are more or less lonely with internet adoption. The current paper aims to test the longitudinal association of internet use and loneliness and to theorize the relationship by examining the mediating effect of social contact.

Method: This study employed data from 2006, 2010, and 2014 waves of the Health and Retirement Study. Loneliness was measured with the three-item UCLA loneliness scale, social contact was operationalized as contact frequency with family and friends, and internet use was measured using a self-assessed dichotomous item. Longitudinal associations and mediation effects were tested using hierarchical linear modeling.

Results: Internet use was associated with decreased loneliness over an 8-year period ($b = -0.049, p < .001$) and more social contact ($b = 0.285, p < .001$), which was related to lower perceived loneliness ($b = -0.088, p < .001$). On a scale ranges from 0 to 2 (0 = never lonely, 2 = often lonely), the total effect of internet use on loneliness was -0.060 , and the mediated effect was -0.025 .

Discussion: These findings imply that internet use may be an effective tool for reducing loneliness in older people by maintaining social contact.

Keywords: Internet adoption, Loneliness, Longitudinal methods, Multilevel models, Social network

Approximately one in four older adults in the United States self-identifies as suffering from loneliness (Ong, Uchino, & Wethington, 2016). Empirical evidence on loneliness shows that it is associated with multiple undesirable outcomes, including cognitive decline, psychological distress, and impaired immune system functioning (Cacioppo & Hawkey, 2009; Chiao, Wu, & Hsiao, 2015; Cloutier-Fisher, Kobayashi, & Smith, 2011; Cornwell & Waite, 2009; Park et al., 2014). A meta-analysis has indicated that loneliness is a mortality risk factor comparable to other traditional well-established risk factors, such as smoking, chronic disease, and sedentary lifestyle (Holt-Lunstad, Smith, Baker, Harris,

& Stephenson, 2015). Older adults who are lonely have a 26% greater likelihood of mortality (Holt-Lunstad et al., 2015). As global aging continues, loneliness is becoming an increasingly prominent social challenge.

Internet Use and Loneliness

Over the past decade, the internet has revolutionized how people communicate and access resources. Internet use has grown increasingly common among older adults (Gell, Rosenberg, Demiris, LaCroix, & Patel, 2015; Xie, Huang, & Watkins, 2013). In 2011, about 42.7% of adults aged

65 years and older had been using internet (Gell et al., 2015; Xie et al., 2013). A report by Pew Research Center also found increased internet use among older people in recent years (Anderson & Perrin, 2017).

The internet is a new option that older adults can use to connect with their families, peers, and society at large (Khvorostianov, 2016; Zickuhr & Madden, 2012). However, it has not been determined conclusively by previous studies, mainly using cross-sectional data, whether internet use is associated with lower levels of loneliness in older adults. Several inquiries have found internet use to be associated with reduced loneliness in the older adult population (Cotten, Anderson, & McCullough, 2013; Morris et al., 2014; Yu, Mccammon, Ellison, & Langa, 2016). By contrast, other studies have reported that internet use has no significant effect on perceived loneliness among older people (Aarts, Peek, & Wouters, 2015; Hill, Weinert, & Cudney, 2006; Slegers, Van Boxtel, & Jolles, 2008). The literature exhibits mixed results regarding the influence of internet use on perceived loneliness using cross-sectional evidence.

The authors identified only two previous studies that have investigated the influence of internet use on loneliness using longitudinal data. A randomized controlled trial of an internet-based intervention for older adults found a more significant reduction in perceived loneliness for the intervention group at six months, but this effect was not maintained at 12 months (Czaja, Boot, Charness, Rogers, & Sharit, 2018). Another study found that internet use for social purposes was associated with decreased loneliness in the following year, while the informational and instrumental use of internet was unrelated to loneliness (Szabo, Allen, Stephens, & Alpass, 2019). Current longitudinal evidence is still minimal, yet the existing evidence seems to imply that the effects of internet use on loneliness and the mechanisms through which it works have a complicated nature, warranting further research.

Social Contact as a Mediator

Previous conceptual papers have theorized that social contact may be a potential mediator for the association of internet use with loneliness, although this pathway has not been empirically tested (Nowland, Necka, & Cacioppo, 2018). For instance, the de Jong-Gierveld theory of loneliness indicates that social contact mediate the pathway from demographics (e.g., age, gender), living arrangement, and personality characteristics to perceived loneliness, even though internet use had not been determined as a relevant predictor for loneliness at the time that the theory was published (de Jong-Gierveld, 1987). A review of the literature on internet use and loneliness across the lifespan indicates that internet use only leads to reduced loneliness when it is used to enhance existing relationships and create new opportunities for social contact (Nowland et al., 2018). If the internet is used as a tool

to withdraw from social interactions, perceived loneliness levels increase (Nowland et al., 2018).

A previous study found that social support mediated the relationship between internet use and loneliness base on cross-sectional data (Heo, Chun, Lee, Lee, & Kim, 2015). While social support and social contact are closely related concepts, the two terms refer to two distinct aspects of interpersonal relationships. Social contact is the objective measure of the interaction with individuals in the social network (Martire, Schulz, Mittelmark, & Newsom, 1999). Social support is the perceived emotional, informational, and instrumental help that one has access to (Martire et al., 1999). Internet use might affect the frequency of social contact by adding a new avenue for people to get connected (Rice, Shepherd, Dutton, & Katz, 2009; Zhao, 2006), yet it is less likely that it would affect the perceived social support directly. Social contact is the more logical mediator in the longitudinal relationship. Several cross-sectional studies have separately reported the direct effect of internet use on increased social contact and its direct effect on reduced levels of loneliness (Cotten et al., 2013; Morris et al., 2014; Yu et al., 2016). However, no previous study has tested the mediation pathway of social contact, either in a cross-sectional study or with longitudinal data. This current manuscript intends to study the mediating effect of social contact use longitudinal data and to bridge the gap in the literature.

Hypothesis

The impact of internet use on perceived loneliness should be further investigated using longitudinally designed studies (Beneito-Montagut, Cassián-Yde, & Begueria, 2018). The use of a longitudinal analysis can allow trends in internet use and perceived loneliness to be portrayed, that is, the main effect of internet use on loneliness over time. The pathways that explain why internet use may have longitudinal impacts on loneliness have also not been sufficiently explored in the existing literature. Conducting longitudinal analysis of the mediation effects of social contact has the potential to reveal additional pathways from internet use to loneliness among older people. The inquiry of this paper was guided by the following two research questions (RQs). The authors posited hypotheses for each RQ base on the literature review:

- RQ1: Does internet use have a longitudinal impact on older adults' perceived loneliness?
- H1: Internet use is associated with less perceived loneliness longitudinally.
- RQ2: If internet use does impact loneliness over time, is this relationship mediated by changes in social contact?
- H2: The longitudinal association of internet use on loneliness is mediated by social contact. Specifically, internet use is positively related to increased social contact; social contact is negatively related to perceived loneliness.

Method

Data Set Description

HRS is a nationally representative longitudinal study that follows adults aged 50 years old and above in the United States at 2-year intervals since 1990. The HRS is sponsored by the National Institute on Aging (grant number NIA U01AG009740) and the Social Security Administration. This study analyzed 2006, 2010, and 2014 waves of the RAND-HRS (version 2) data merged with the corresponding waves of Leave-Behind data modules. The three waves were selected based on the availability of the key variables of interest, and the 2014 wave was the most up to date HRS data that had been finalized and made publically available.

The measures used by HRS to determine the psychosocial aspects of the respondents' lives were aggregated in the leave-behind survey, for example, loneliness and social contact. In each wave, half of the participants who were randomly selected to receive an Enhanced Face to Face interview could complete a printed survey left with them after the interview to mail back to the HRS research team. The leave-behind survey was first piloted in 2004 and has been continuously administered since 2006. Data from the 2004 wave were not employed here because the measurement items and sample selection method used in 2004 were different from those used in the following waves. Because only half of the sample has the chance to respond to the leave-behind survey for each wave, the longitudinal data arrived at 4-year intervals. The response rates for 2006, 2010, and 2014 waves were 87.7%, 78.1%, and 81.1%, respectively.

Those respondents not able to answer the leave-behind survey on their own could have it completed by a proxy. However, the proxies were requested not to answer those questions required participants' self-perceptions, such as perceived loneliness. Due to missing in the dependent variable, these participants were excluded from the analysis. HRS sampled individuals aged 50 years or above and their spouse despite their age. Because this paper focuses on studying the older adult population, individuals younger than 65 years old were excluded from the analysis. The three waves of leave-behind survey data were merged with the RAND-HRS longitudinal data set. In 2010, a new cohort, representing the Middle Baby Boomers (MBBs), born between 1954 and 1959, was recruited into the HRS study. The purpose of the current paper is to evaluate the time effects of internet use; therefore, the MBB cohort was excluded from the analysis because this group was not included at baseline. The working sample of the current study consists of 5,240 participants.

Measurements

Loneliness was measured using the three-item UCLA loneliness scale. The participants rated how often they felt that

they "lack companionship," are "left out," or are "isolated from others" (0 = hardly ever or never, 1 = some of the time, 2 = often). The mean score of the three items was calculated as the scale score of loneliness, which is a continuous outcome variable ranging from 0 to 2. The validity and reliability of this scale have been found satisfactory in a previous study (Hughes, Waite, Hawkey, & Cacioppo, 2004). The Cronbach's alpha coefficients of the scale were 0.82, 0.81, and 0.77 for 2006, 2010, and 2014 data, respectively.

Internet use was measured using a single item. The participants were asked whether they regularly used the internet. The responses were dichotomous (1 = yes, 0 = no).

Social contact was conceptualized as contact frequency with people in their social networks. A set of three items were presented three times to assess the participants' frequency of contact (including meetings, telephone conversations, or correspondence by mail or email) with children, other family, and friends. Social contact scores with children, other family, and friends were first obtained by averaging across three methods of social interactions. Then, the overall social contact score was calculated by taking the average of the three social category-specific scores. The possible scale score and the actual score range for the sample were from 1 to 6. Higher scores indicated more frequent social contact. The Cronbach's alpha coefficients for the scale were 0.70, 0.71, and 0.70 for 2006, 2010, and 2014 data, respectively. As indicated in the leave-behind survey codebook, social-category-specific contact scores were set to missing if more than one item was missing (Smith et al., 2013).

Control variables were demographic factors, including age, gender, race, education level, working status, marital status, income, living arrangement, and self-rated health, as these have all been reported in the literature as predictors for loneliness among older adults (Cattan, White, Bond, & Learmouth, 2005; Courtin & Knapp, 2017; Victor & Bowling, 2012). Age was measured in years old at the end of the interview month. The participants reported their gender dichotomously (1 = male, 2 = female). The race variable was recoded from the race and Hispanic indicator variables in the HRS data set. The recoded race variable has the following four categories: "non-Hispanic White," "non-Hispanic Black," "Hispanic/Latinx," and "Others." The marital status and educational level were coded dichotomously (marital statuses were "married" or "others". Educational levels were "has a college degree" or "does not have a college degree"). Working status was measured by whether the participant was working for pay (1 = yes, 0 = no). The household size was measured by the number of individuals living in the household. The participants rated their health with a single item, ranging from 1 (poor) to 5 (excellent). The income was measured using annual household income in U.S. dollars. Because the distribution of the income variable was positively skewed, a log transformation (income plus one) was performed.

Data Analysis

Figure 1 depicts the conceptual and analytical framework of the current study. Paths a and b show an indirect relationship between internet use and loneliness, mediated by social contact. Path c' reflects the direct effects of internet use on loneliness. The nature of longitudinal data is such that multiple observations of the same participants are all correlated with each other. Internet use, social contact, and loneliness are all at the observational level (level 1), nested within each individual (level 2).

The data analysis was conducted with Stata SE version 15.1, College Station, TX: StataCorp LLC. Hierarchical linear modeling (also known as multilevel modeling) was used to account for the fact that the multiple observations of the longitudinal study were nested within individuals. In order to address the first research question, mixed-effect models were run to test the longitudinal effects of internet use on loneliness. The authors chose to model the fixed effects of the year variable (i.e., year was considered as a categorical variable) because only three observation time points were used, and it was not considered a reasonable approach to coerce the relationship between loneliness and time as linear. Random coefficients (also known as random slopes) of internet use and social contacts were sequentially added to the model to capture the between-individual differences in internet use and social contacts on perceived loneliness. A series of likelihood ratio tests were conducted to test the necessity of the random coefficients of internet use and social contact variables.

To answer the second research question, longitudinal mediation analysis was conducted using the methods suggested in Bauer, Preacher, and Gil (2006). Before the longitudinal mediation analysis, the main effects of internet use on the outcome, that is, loneliness, and on the mediator, that is, social contact, were established. The main effects of the social contact on the outcome loneliness were also determined. Both the independent variable and the mediator were at level 1 (observational level), and the random coefficient for variable internet use and social contact were incorporated in the longitudinal mediation analysis in a stepwise manner (Bauer et al., 2006). Again, likelihood ratio tests were employed to determine whether random coefficients were needed. The longitudinal working data set

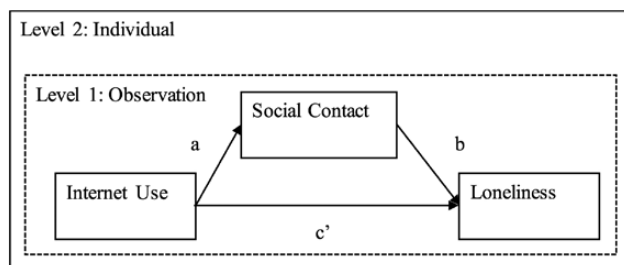


Figure 1. Conceptual and analytical framework of the longitudinal relationships among internet use, social contact, and loneliness.

incorporates about 17.3% of missing cases, with consideration for all variables of interest. The authors generated dichotomous variables for missing data and ran logistic regressions to test whether the missing cases were related to any of the variables in the model. None of the variables of interest were related to the missing variables, indicating that it is largely random where missing data appear. The missing at random hypothesis was supported. Multiple Imputation by Chained Equations (MICE) were employed to handle missing data (Allison, 2001). The number of imputations was determined by the largest FMI in the model estimation. Sixty iterations of imputations were performed.

Results

At baseline, the mean (*M*) age of the participants was 74.25 (standard deviation [*SD*] = 7.08, range 65–104). About 56.35% of the participants were female. The respondents were 77.96% non-Hispanic White, 12.73% non-Hispanic Black, 7.67% Hispanic/Latinx, and 1.64% Others. Overall, the participants in the study were highly educated: 18.53% had at least some college education or above.

Table 1 presents descriptive results of time-varying sample characteristics. The majority (60.09%) of the participants were married at baseline. However, this percentage dropped to 47.72% in 2014 primarily mostly due to death of spouses. The living arrangements measured as the number of individuals in the household, were stable from 2006 to 2010 (*M* = 1.98, *SD* = 0.94 in 2006, *SD* = 1.02 in 2010), with slight declines in 2014 (*M* = 1.92, *SD* = 0.99). The participants' self-rated health exhibited a declining trend. Over time, a decreasing number of participants were working for pay. The percentage of individuals who were working for pay was 19.13% in 2016, 13.93% in 2010, and 10.64% in 2014. The respondents' median incomes were US\$32,038, US\$30,626, and US\$31,440 in 2006, 2010, and 2014, respectively. The use of the internet increased over time, with 29.96%, 32.36%, and 34.19% of the respondents reporting regular use of the internet in 2006, 2010, and 2014, respectively. The social contact reported by the participants dropped slightly. On a scale of 1–6, where a higher score indicates more social contact, the average social contact scores were 3.92 (*SD* = 0.78) in 2006, 3.88 (*SD* = 0.79) in 2010, and 3.86 (*SD* = 0.80) in 2014; these scores correspond with contacting family and friends at least once or twice a month for each means of social contact on the scale (meet in person, telephone conversations, or correspondence by mail or email). Respondent reported loneliness decreased over time: on a scale from 0 to 2, the participants reported means of 0.47, 0.44, and 0.45 for levels of loneliness in 2006, 2010, and 2014, respectively, indicating an average of moderate level of loneliness. The correlation among key variables across three study waves can be found in Supplementary Appendix I. All correlations were statistically significant ($p < .05$).

Table 1. Descriptive Results of Time-Varying Variables of the Health and Retirement Study Sample (*N* = 5,240)

Year	2006		2010		2014	
	N, Mean or Median	(%) or (SD)	N, Mean or Median	(%) or (SD)	N, Mean or Median	(%) or (SD)
Married—yes	3,005	60.09	2,282	53.34	1,583	47.72
Household size (number of individuals in the household)	1.98	0.94	1.98	1.02	1.92	0.99
Self-rated health ^a	3.09	1.08	3.04	1.08	2.96	1.05
Working for pay—yes	956	19.13	594	13.93	352	10.64
Household income (median, in 1,000 USD) ^b	32.04	-	30.63	-	31.44	-
Internet use—yes	1,463	29.96	1,380	32.36	1,130	34.19
Social contact ^c	3.92	0.78	3.88	0.79	3.86	0.80
Loneliness ^d	0.47	0.53	0.44	0.52	0.45	0.52

Note: SD = standard deviation.

^aWith a range of 1–5, where higher scores indicate better self-rated health.

^bIncome range: 0–5,241,783 USD in 2006, 0–2,092,577 USD in 2010, and 0–2,521,388USD in 2014.

^cWith a range of 1–6, where higher scores indicate more social contact.

^dWith a range of 0–2, where higher scores indicate more loneliness.

Table 2 presents models with random intercepts for individuals and fixed year effects. The results of the likelihood ratio tests indicate that models with random coefficients of internet use, social contact, or both did not fit the data more accurately than models with random intercept only, indicating that the use random coefficients for internet use and social contact were not necessary. Because the range of outcomes was narrow (0–2), the coefficient estimations were small. Consequently, the results presented in Table 3 are given three significant digits following the decimal.

Model 1 addresses the first research question. For each time point, when controlling for potential confounding variables, the respondents who indicated regular internet use also described their loneliness as 0.049 points lower than that of those who did not (standard error [SE] = 0.013, $p < .0001$). The average perceived loneliness in 2010 was about 0.021 points lower than the baseline (SE = 0.009, $p = .02$). Participants' reported loneliness in 2014 was not significantly different from the baseline ($p = .10$). Cohen's f^2 was calculated to understand the effect size of internet use on loneliness (Selya, Rose, Dierker, Hedeker, & Mermelstein, 2012). The full model 2, including the covariant, explained 6% of the total variance of loneliness. Internet use alone explains about 0.3% of the total variance of loneliness, suggesting a small effect size. Intraclass correlation coefficients (ICC) suggest that 49.7% of the variance in loneliness was at between individual level.

Model 2 examined the direct relationships between internet use and social contact, the hypothesized mediator. Internet use was associated with increased social contact over time ($B = 0.244$, SE = 0.022, $p < .0001$), after controlling for demographics, social-economic status variables, and self-rated health. About 51.1% of the variance in social contact was at between individual level. Model 3 included

both internet use and social contact as predictors of loneliness. After controlling for social contact, it appeared that the association between internet use and loneliness was still significant, yet the p value increased ($b = -0.031$, SE = 0.013, $p = .02$). Higher social contact was correlated with lower perceived loneliness ($b = -0.072$, SE = 0.008, $p < .0001$). Adding social contact to the model predicting loneliness made the ICC decreased to 0.493, meaning 49.3% of the variance of loneliness was at between person level. This change in the significance of the association between internet use and loneliness suggested that social contact had a mediating effect.

Table 3 presents the longitudinal mediation model with individual random intercepts. A series of likelihood ratio tests showed that the two sets of random coefficients for social contact and internet use did not contribute to model fit ($\chi^2 = 0.77$, $p > .05$). Thus, the final model did not incorporate random coefficients. Internet use was found to be associated with a 0.285-unit increase in the social contact score (SE = 0.020, $p < .0001$). Increased social contact was associated with a 0.088 lower score for loneliness (SE = 0.007, $p < .0001$). Internet use was associated with a reduction in perceived loneliness; with the mediator, the direct effect of internet use on loneliness was -0.035 (SE = 0.013, $p = .01$).

Figure 2 illustrates the main findings shown in Table 3 and shows the conceptual model tested in this study. Internet use was negatively associated with increased feelings of loneliness over time. The total effect of internet use on loneliness was -0.060 . That is, relative to those who did not use the internet, the participants who did had a self-reported loneliness value that was 0.060 points lower on the scale from 0 to 2. The indirect effect (or mediated effect) of internet use on loneliness was -0.025 . The mediated effect accounts for 41.7% of the total effect.

Table 2. Longitudinal Mixed-Effect Models for Loneliness or Social Contacts with Random Intercepts of Individuals and Fixed Effects for Years ($N = 5,240$)

	Model 1	Model 2	Model 3
	Loneliness predicted by internet use	Social contact predicted by internet use	Loneliness predicted by both internet use and social contact
Internet use	-0.0486*** (0.0129)	0.244*** (0.0224)	-0.0307* (0.0129)
2010 ^a	-0.0206* (0.00882)	-0.0301 (0.0157)	-0.0226* (0.00881)
2014 ^a	-0.0182 (0.0110)	-0.0935*** (0.0196)	-0.0247* (0.0110)
Social contact	-	-	-0.0717*** (0.00754)
Age	0.000123 (0.00102)	-0.00648*** (0.00185)	-0.000326 (0.00103)
Sex-female	-0.00278 (0.0132)	0.341*** (0.0244)	0.0216 (0.0134)
Race-Black ^b	-0.0213 (0.0199)	0.117*** (0.0318)	-0.0129 (0.0197)
Race-Hispanic ^b	-0.0356 (0.0254)	0.0717 (0.0432)	-0.0300 (0.0251)
Race-Others ^b	-0.0460 (0.0484)	0.0235 (0.0805)	-0.0442 (0.0477)
Marital status—married	-0.234*** (0.0132)	-0.0280 (0.0220)	-0.235*** (0.0132)
Working for pay	-0.0139 (0.0144)	-0.00546 (0.0258)	-0.0137 (0.0144)
Education-college	-0.0386* (0.0169)	0.00797 (0.0292)	-0.0385* (0.0167)
Income	-0.00514 (0.00560)	0.00578 (0.00890)	-0.00484 (0.00557)
Household size	0.00877 (0.00655)	-0.0831*** (0.0106)	0.00288 (0.00641)
Self-rated health	-0.0685*** (0.00530)	0.0212* (0.00890)	-0.0678*** (0.00533)
Random effects			
Level 2 (individual)	0.353	0.559	0.346
Level 1 (observational)	0.357	0.534	0.356
ICC	0.497	0.511	0.493

Note: Standard errors in parentheses. ICC = intraclass correlation coefficient.

^aComparison year: 2006

^bComparison group: non-Hispanic White.

* $p < .05$, ** $p < .01$, *** $p < .001$.

Post-hoc Analysis

While internet use showed increases for each interval, we observed that the average social contact remained about the same over time. Is it possible that older people had decreasing social contact over the 8 years, but that internet use slowed this trend? We conducted post-hoc analysis to test this potential explanation. The trend test of the change of social contact was significant for non-internet users ($z = -4.07$, $p < .0001$), but was not significant for internet users ($z = -0.38$, $p = .10$). As shown in Figure 3, there was a trend of reduced social contact among older adults who

did not use the internet, whereas internet users maintained the same levels of social contact over time.

Discussion

Using three waves of data from the HRS, this study found that internet use was related to decreased loneliness among older adults over 8 years, after controlling for age, gender, race, educational level, working status, marital status, household size, self-rated health, and income. H1 was supported. This finding provides more robust evidence for

Table 3. Longitudinal Relationship Between Internet Use and Loneliness, Mediated by Social Contact (N = 5,240)

	Model 4
	Longitudinal mediation model
Path a: internet use on social contact	0.285*** (0.0199)
Path b: social contact on loneliness	-0.0877*** (0.00689)
Path c': direct effect of internet use on loneliness	-0.0347** (0.0129)
2010 ^a	-0.0180* (0.00840)
2014 ^a	-0.0467*** (0.0105)
Age	-0.00120 (0.000897)
Sex-female	0.125*** (0.0121)
Race-Black ^b	0.0552** (0.0182)
Race-Hispanic ^b	0.00980 (0.0225)
Race-Others ^b	-0.0471 (0.0460)
Marital status-married	-0.166*** (0.0116)
Working status-currently working for pay	-0.00396 (0.0126)
Education-had college education	-0.0291 (0.0150)
Number of individuals in the household	-0.0192*** (0.00546)
Self-rated health	-0.0445*** (0.00460)

Note: Standard errors in parentheses.

^aComparison year: 2006;

^bComparison group: non-Hispanic White;

* $p < .05$, ** $p < .01$, *** $p < .001$.

internet use as a protective factor against loneliness, in support of the results of other previous cross-sectional studies (Chopik, 2016; Cotten et al., 2013; Yu et al., 2016). The main effects of internet use on decreased loneliness were also consistent with some previous longitudinal evidence (Cotten et al., 2014; Szabo et al., 2019). Besides, this study tested the hypothesis that internet use alleviates loneliness through the mediating effects of social contact. In particular, the results indicated that, over time, internet users maintained more social contact with family and friends than nonusers, and such increased social contact was associated with lower levels of perceived loneliness longitudinally. H2 was supported.

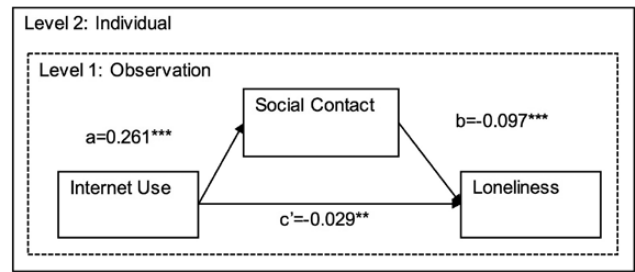


Figure 2. Tested longitudinal relationships among internet use, social contact, and loneliness. * $p < .05$, ** $p < .01$, *** $p < .001$.

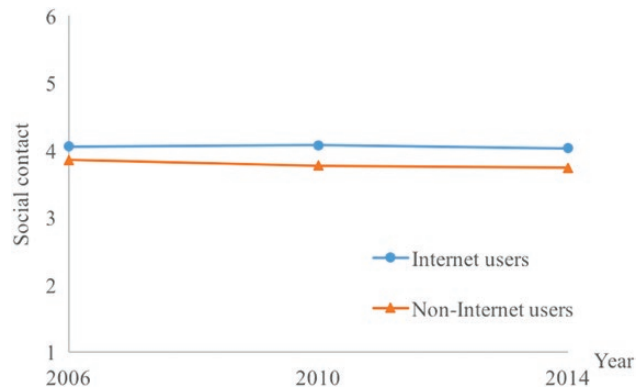


Figure 3. Social contact by internet users and nonusers.

This study provides evidence for the mediating effects of social contact on the association between internet use and loneliness using longitudinal data. The results suggested internet use can enhance the social contacts, possibly desired social contact by choice of older adults, and thus, alleviating loneliness. Socioemotional selectivity theory (STT) posits that because older adults expect less time left in life, they would choose to maintain contact with individuals with close relationships and focus on positive emotion experiences (Carstensen, 1992, 2006; Carstensen, Fung, & Charles, 2003). As a result of reducing contacts with acquaintance and contacts motivated by professional development needs, the size of the social network of older adults tends to decrease (Carstensen, 2006). The post-hoc analysis results showed that the frequency of social contact was kept at around the same level for internet users, while a decreasing trend was observed for nonusers. The decreasing trend of social contact also supports the inference of socioemotional selectivity theory (Carstensen, 1992). Nevertheless, STT did not explicitly discuss the case in which an older person does not always have the choice to have the level of social contacts desired. Maintaining social contacts could become increasingly challenging as individuals age, experiencing new health challenges, and dealing with reduced mobility. Despite the strong motivation an older person might have for maintaining meaningful social connections, health concerns and death of close family and friends might lead to a decrease in social contact that against one's socioemotional choices, and

hence, contributing to the experience of loneliness (Martire et al., 1999; Segrin & Passalacqua, 2010). Internet provides new avenues for older adults to access resources, communicate with family and friends. For example, older adults can meet with family and friends through video calls, albeit most health concerns and mobility constrains (Sum, Mathews, Pourghasem, & Hughes, 2008).

The findings of the current paper provide supportive evidence for intervention research that would employ technology to create new means of social contact and to alleviate loneliness. The internet can be particularly useful for enabling older people with reduced mobility due to their health conditions to stay socially connected (Heo et al., 2015). Future work may consider studying whether internet use moderates the adverse effects of health concerns on loneliness of older adults.

As shown in Figure 3, a gap in the frequency of social contact existed at baseline for internet users and nonusers, which implies the existence of some intrinsic characteristics of the two groups that would predict different levels of social contact, such as personality (Anderson, 1999; Cacioppo, Fowler, & Christakis, 2009). Internet-facilitated loneliness intervention might not be suitable for every older person. Future studies might consider contrasting the characteristics of older adult internet users and nonusers and develop person-centered interventions for loneliness. Internet use is also reported as being correlated with an increased sense of community, personal growth, and purpose in life among older adults (Sum, Mathews, Pourghasem, & Hughes, 2009; Zambianchi & Carelli, 2018). These positive psychological influences brought by internet use seem to support that older adult use internet with a focus on positive emotional experiences and meaningful interactions. Beyond social contact, these other benefits of internet could also explain decreased levels of loneliness, and future studies may investigate the mediating effects of the above mentioned mechanisms.

Although this study did conduct longitudinal analyses to establish a more robust relationship between internet use and perceived loneliness, the authors acknowledge that the relationships established in this study are not causal. Future studies may investigate relationships between internet use and loneliness with more sophisticated methods when more HRS study data points become available, such as survival analysis. Longitudinal experimental or quasi-experimental studies should be conducted to produce causal evidence.

The knowledge developed here was limited by the dichotomous measure of internet use in the HRS study. This measure may be insufficient for understanding the more complex relationship between internet use and loneliness. Previous studies have shown the importance that online activities, time spent online, and subjective perception of online experience have for perceived loneliness (Aarts et al., 2015; Cotten, Goldner, Hale, & Dreteña, 2011; Nowland et al., 2018; Sum et al., 2008; Szabo et al., 2019). Online activities have been divided into the informational, instrumental,

and social categories of internet use (Szabo et al., 2019). The social use of the internet, in particular, appears to be related to reduced loneliness (Sum et al., 2008; Szabo et al., 2019). While the informational and instrumental use of the internet may promote the well-being of older people by offering them increased opportunities for things to do, they have not been found to be associated with loneliness (Szabo et al., 2019). The current data set exhibits no ability to scrutinize how different purposes of internet use relate to perceived loneliness. Future studies may consider collecting longitudinal data including detailed measures of online activities, time spent online, and self-perceptions regarding online interactions to address these questions raised. Some analytical limitations should also be noted. Income was used as a proxy for social economic status of the retired sample, yet the older adults might not rely on income as much as younger adults, assets could be another important indicator. The distribution of the outcome variable—loneliness—was possibly zero-inflated. Many participants reported not feeling lonely at all. Nevertheless, HLM models are robust of the violation of the normal distribution assumption (Darandari, 2004). Zero-inflation in the outcome could lead to underestimated model parameter and missed significance, that is, higher risk of type 2 error (Perumean-Chaney, Morgan, McDowall, & Aban, 2013).

In conclusion, this paper found that internet use had a main effect on decreased perceived loneliness longitudinally, and this relationship was mediated by social contact. These findings imply that online activities may be an effective tool for reducing loneliness among older people by maintaining the levels of social contact. Intervention programs that aspire to use internet-based methods to reduce loneliness could consider guiding their participants to use the internet for social purposes and to create opportunities for social contact.

Supplementary Material

Supplementary data is available at *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences* online.

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Conflict of Interest

None reported.

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