It Does Matter for Us, Too: Implications of Digital Divide among Older Americans

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Abstract

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In the U.S., older adults have long overrepresented a digitally marginalized group who did not fully benefit from the digital lifestyle. Despite the rapid adoption of digital technology, the digital divide among older adults is still critical. About four out of ten older Americans, aged 65 or older do not have Internet access in 2021.

Nevertheless, relatively little public attention has been paid to the digital divide among older adults and its impacts since they were not the primary consumers in economic growth driven by digital technologies. This dissertation project aimed to expand knowledge in the determinants of older adults' engagement in digital lifestyle and the impacts of the digital divide on their wellbeing through a series of three cohesive research papers, analyzing data from the Health and Retirement Study (HRS).

The first part of the dissertation explored the digital divide among older Americans, seeking a better understanding of the role of stereotypes on older adults assimilated from surrounding cultures. Drawing on resources and appropriation theory and stereotype embodiment theory, paper one investigated the relationship between older adults' self-perception of aging and regular Internet use. The results from logistic regression show that the higher level of the

negative self-perception of aging was positively associated with no regular internet use. The results were in line with another critical argument from the resources and appropriation theory, indicating socioeconomically marginalized groups with limited resources were less likely to use the Internet.

Based on the implications from paper one, the study expanded its scope to the impacts of the digital divide on older adults' health and wellbeing. The second paper examined the association between older adults' regular Internet use and the likelihood of new-onset mild cognitive impairment (MCI), employing survival analysis techniques with longitudinal data from the HRS study waves from 2002 to 2016. Following the core arguments from the cognitive enrichment framework, the paper posited regular Internet use as a mentally stimulating activity that might help maintain or stimulate older adults' cognitive function. The study found that older adults who regularly used the Internet during the prior study year showed a lower likelihood of new-onset MCI than non-Internet users.

The last part of the current study investigated the relationship between digital technology as a social communication tool and older adults' subjective wellbeing. Specifically, paper three examined the association between older adults' social network services (SNS, i.e., Facebook, Skype, and Twitter) and perceived loneliness mediated by perceived social support and dispositional optimism. The study found that a more frequent SNS use might be associated with a lower level of loneliness, mediated by perceived social support. In addition, older adults with a higher level of dispositional optimism, indicating those who were optimistic toward their life, were more likely to frequently use SNS and perceive a higher level of social support from the SNS use than those who were pessimistic.

In brief, the current study found that the digital divide among older Americans was significant, while engagement in digital lifestyle might positively affect the population group's health psychological wellbeing. In addition, this study found that older adults' engagement in digital lifestyle might be affected by various psychological factors, indicating older adults might have a different level of willingness or reluctance to adopt digital technology based on their experiences over life.

Based on the findings, the current study provides policy and practice suggestions and future research to close the digital gap among older Americans. First, Digital technology training for older adults should be supported by policy and law. Second, Programs to support Internet connectivity of low-income groups, such as Emergency Broadband Benefits, a temporary program to mitigate economic hardship due to COVID-19, should be extended and further expanded to more population groups. Third, policymakers and practitioners need to understand psychological traits and attitudes toward digital technology shared by the older adult population groups to implement better the policy options mentioned above. Future research needs to investigate further psychological factors associated with older adults' reluctance or willingness to engage in digital lifestyle and causal relationships between digital technology uses and various health or psychological outcomes.

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INTRODUCTION

The Internet has increasingly shifted our daily life since its first advent in the late 1970s (Fagerberg, Mowery, & Nelson, 2005). Internet and information and communication technologies (ICTs) enabled more systematic and faster processing of information (Brown & Duguid, 2017) and increased social communications than any technology in human history (Wallace, 2015). Like the speed at which the Internet and ICTs have changed our lives, their spread has also been very rapid. Internet access reached a level between 80% and 90% in most Western societies for the last three decades (Van Dijk, 2020). About 93% of Americans have Internet access in 2021, which is a remarkable increase from 46% in 2000. Smartphone users in the U.S. have been even more dramatic. In 2021, about 85% of Americans use smartphones, which skyrocketed from 35% in 2012 (Pew Research Center, 2021a).

Nevertheless, the rapid adoption of the Internet and ICTs among Americans does not mean that individuals across different social groups commonly benefit from them (Robinson et al., 2015). Disparities in access to the Internet and the use of ICTs is popularly termed the digital divide, which refers to different levels of engagement in a wide range of digital lives (Castells, 2002). Studies commonly have shown the determinants of the digital divide, such as age, race, class, gender (Mesch, Mano, & Tsamir, 2012; Ono & Zavodny, 2008; Witte & Mannon, 2010). In the U.S., where broadband connectivity and smartphone adoption rate is very high, Internet inclusion still evades many economically and socially marginalized groups (Lai & Widmar, 2021).

Moreover, engagements in digital lifestyle might play critical roles in a range of health and psychological outcomes since those who function better in the Internet world and participate more fully in digitally mediated social life tend to enjoy advantages over their digitally

marginalized counterparts (DiPrete, Gelman, McCormick, Teitler, & Zheng, 2011). Access to digital technology and the Internet now means access to a wide array of services, including health information, open markets to purchase goods for a better price, and tools for communication (Van Dijk, 2020). Moreover, since the COVID-19 pandemic, Internet connectivity became a key to access to critical social services, and thus exacerbates the negative impacts of the digital divide (Eruchalu, 2021).

In the U.S., older adults have long overrepresented such a digitally marginalized group that has benefitted least from the digital lifestyle (Ramón-Jerónimo, Peral-Peral, & Arenas-Gaitan, 2013). For over three decades, older adults were generally considered the slowest and least motivated in adopting the digital lifestyle because of their reluctance, health, and cognitive issues (Friemel, 2016). Furthermore, relatively little public attention has been paid to older adults' engagement in digital life and its impacts on them since they were not the primary consumers in economic growth driven by digital technologies (Castellacci & Tveito, 2018). In this vein, while policy and research interests on the spread of the Internet have centered on the relatively younger generations, Internet use among older populations and its implication has been understudied (Wagner, Hassanein, & Head, 2010).

Although older Americans have historically been slow adopters of digital technology, their movement into digital life continues to accelerate. Internet access rates increased from 46% in 2000 to 96% in 2014 among U.S. adults aged 50–64. Among those aged 65 years or older, Internet access has risen from 14% in 2000 to 75% in 2021 (Pew Research Center, 2021a). There has also been a remarkable increase in online social communication tools such as social network services (SNS) among older Americans. The adoption rate of SNS among American Internet users aged 50–64 years has nearly doubled from 37% in 2010 to 73% in 2014 and has increased

more than six times from 7% in 2010 to 45% in 2021 among Internet users who are 65 years or older (Pew Research Center, 2021b).

Despite the rapid diffusion of broadband and smartphone, about 42% of older adults age over 65 years did not have broadband access to the Internet in 2021 (Rundlet, 2021). According to a report by Older Adults Technology Services (Older Adults Technology Services, 2021), age is one of the most vital determinants of Internet access, followed by poverty, indicating the digital divide is still prevalent among older Americans. While it is well documented that many older adults in the U.S. lack Internet access, only limited information about factors that might affect older adults' engagement in digital life is currently available. Lack of understanding of older Americans' digital divide could be problematic in several aspects. First, current research trends in Internet and ICTs could marginalize older adults since Internet access is relatively common among the general population. Studies on the digital divide have already shifted their focuses from physical access to gaps in Internet usage and detailed use patterns (Castells, 2004; Van Dijk, 2017), while a substantial number of older Americans are still not even online. Thus, determinants of older adults' Internet access and its impacts on their life are understudied (Yu, Ellison, McCammon, & Langa, 2016).

Second, despite empirical findings on how digital life affects various aspects of quality of life (Van Dijk, 2017; Van Dijk, 2020), the implications may not directly apply to older populations due to their distinct life circumstances from their younger counterparts (Vroman, Arthanat, & Lysack, 2015). On the other hand, significant later life transitions, such as retirement and family loss, may prompt older adults to communicate with their social support network online (Nimrod, 2009). These factors are rarely examined in digital life studies of older adults.

Third, among digital divide literature that focuses on demographic factors, most studies treat age itself as an independent explanatory variable (Robinson et al., 2015) that negatively affects the adoption of the Internet and ICTs. Because of this trend, relatively little attention has been paid to what other domains, such as psychological factors (e.g., stigma or anxieties of learning new technology), might foster or discourage active digital life participation among older adults (Calhoun, 2019). Thereby, a comprehensive understanding of older adults' Internet access and how these patterns vary by various psychological factors may expand our knowledge of the digital divide among older adults.

Scope of Research Questions

To address the limitations in the current research discussed above, this dissertation project aims to examine factors associated with older adults' digital technology adoption and the impacts of older adults' engagement in digital life on their health and psychosocial wellbeing with series of three cohesive research papers.

Figure 1. Range of research topic and structure of the three-paper dissertation

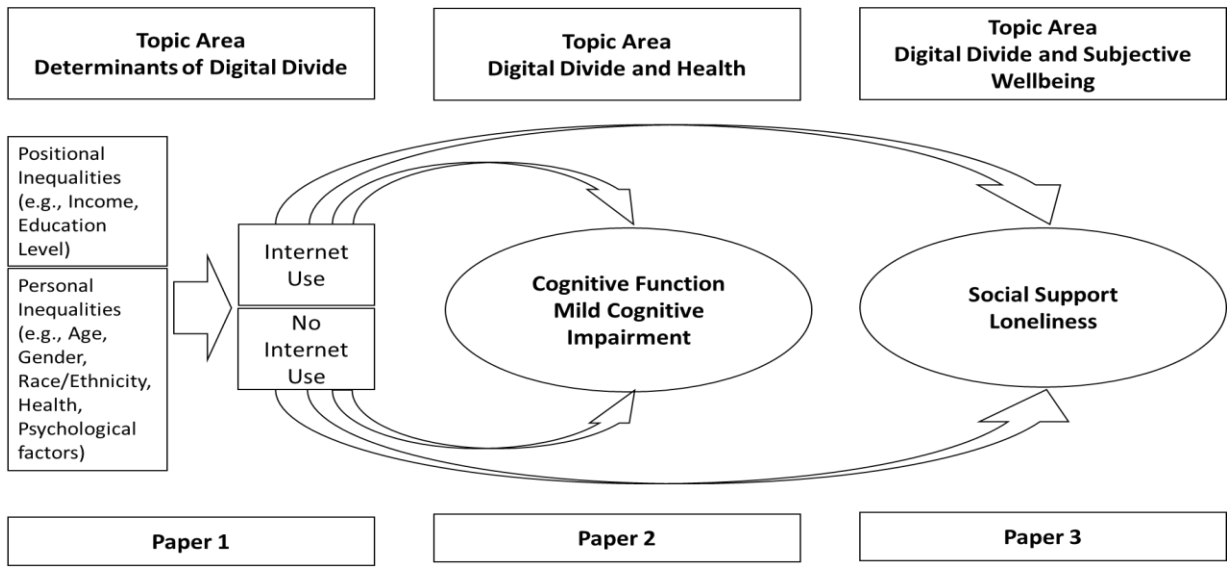

Figure 1 depicts the range and structure of this project and the main research questions for each paper. Using a three-paper dissertation format, the first paper explores the recent trend in Internet use among older Americans. It aims to expand knowledge on a psychosocial factor that might affect older adults' engagement in Internet use. With the social justice perspective, the first paper examines disparities in Internet access among older adults, focusing on the impact of institutional stereotypes, such as negative self-perception of aging.

Then, based on the implications from the first paper, the second and third papers further build on the impacts of the digital divide on older Americans' wellbeing with two different perspectives. The second paper examines how older adults' engagement in digital life might affect their health, focusing on their cognitive function. Under the assumption that Internet use could be a mentally stimulating activity for preserving cognitive function, the paper investigates how the likelihood of new-onset mild cognitive impairment (MCI) might differ between computer users and non-users.

The third paper explores the impact of using online social communications on older adults' subjective wellbeing, focusing on the association between social networking services (SNS) use and perceived loneliness among older adults and mediating effects of perceived social support and dispositional optimism.

All three papers from this dissertation analyzed data from the Health and Retirement Study (HRS), a biennial longitudinal study with a nationally representative sample of older Americans age 50 and older (Juster & Suzman, 1995). Each of the three projects employed data sets from different HRS waves between 2002 and 2018 in consideration of the specific research questions and data availability.

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PAPER 1: NEGATIVE PERCEPTION OF AGING, MULTI-LEVEL INEQUALITY AND REGULAR INTERNET USE AMONG OLDER AMERICANS: EVIDENCE FROM THE 2016 HEALTH AND RETIREMENT STUDY

Information and Communication Technologies (ICTs) have positively influenced older Americans' quality of life (Hunsaker & Hargittai, 2018; Smith & Olmstead, 2018). However, not all older adults fully share these benefits (Yoon, Jang, Vaughan, & Garcia, 2018). The term *digital divide* describes the disproportionate access to ICTs. The literature on the digital divide commonly highlights that the older, less educated, economically disadvantaged people with lower self-reported health, and those with more chronic conditions or disabilities, are more likely to experience limited or even no access to ICTs (A. J. Van Deursen & Van Dijk, 2019). The digital divide could result in further inequalities, including limited access to critical information, public service, social participation, and health service (DiMaggio & Hargittai, 2001). Given this, the digital divide deserves a place in the social justice discussion for older adults (Blank, 2017; Van Jaarsveld, 2020) . Furthermore, since the COVID-19 pandemic and corresponding preventive measures have limited people's access to a wide array of social services, digital technology has been widely adopted to provide alternatives to a vast multitude of day-to-day activities (Van Jaarsveld, 2020). In this context, recent studies increasingly discuss the need to recognize digital technology access as a vital social right (Sanders & Scanlon, 2021).

Older adults have been among the slowest to adopt digital lifestyles. The digital divide experienced by members of this demographic may be attributed to multi-level inequalities around a broader social context (A. J. Van Deursen & Van Dijk, 2019; A. J. Van Deursen, van Dijk, & Peters, 2011). While many studies on the subject have found a relationship between predisposed demographic characteristics and digital marginalization or nonuse, only a handful of studies have examined the potential impacts of psychological factors on the digital divide among

older adults. The current study examines the association between Internet use among older Americans and the psychological factor of self-perceptions of aging.

The association between self-perceptions of aging and the digital divide experienced by older adults has not been fully explored (Helsper & Reisdorf, 2013; Hunsaker & Hargittai, 2018). Older adults who develop negative self-perceptions toward their aging status may believe that they are "too old" for certain social behaviors or activities and are thus likely to readily withdraw from them or hesitate to adopt a new lifestyle altogether. Studies have found that a positive self-perception of aging is associated with having a healthier lifestyle, characterized by regular exercise performance, balanced nutrition intake, and regular trips to healthcare facilities. In contrast, a negative perception of aging is associated with withdrawing from various forms of social engagement (Levy and Myers, 2004, Sarkisian et al., 2005, Wurm et al., 2010). The current paper seeks to investigate the relationship between negative self-perceptions of aging and engagement in digital life. Based on the guiding theories and literature, the study posits that a higher level of negative self-perceptions of aging would be associated with little to Internet use among older adults.

Guiding Theories and Related Literature

While the current study's primary objective is to explore the role of a negative self-perception of aging on the digital divide among older adults, the study also includes the known determinants of the digital divide identified by previous studies. This study synthesizes relevant theories to include a wide range of variables from the literature and constructed a comprehensive framework that enables operationally defining negative self-perception of aging and socioeconomic contexts. For the first step, the study places the resources and appropriation theory as a main guiding framework for arranging multiple factors to predict the older adults'

Internet use. The present study then adopts the stress embodiment theory to conceptualize the negative self-perception of aging within the main framework. Finally, the study employs the intersectionality framework to explore potential interactions between the factors from the two different theoretical perspectives. Table 1.1 depicts the conceptual model and the conceptualization of variables used in this study.

(Table 1.1 around here.)

Resources and Appropriation Theory

Van Dijk's resources and appropriation theory portrays the digital divide as a consequence of social stratifications across mental, material, social, and cultural contexts (Fang et al., 2018; Van Dijk, 2012). The theory posits that Internet access is primarily predicted by the unequal distribution of resources caused by societal and individual features, namely personal and positional categorical inequalities. Personal categorical inequalities refer to the individual-level factors including, age, gender, race or ethnicity, personality, and health. Positional inequalities relate to one's position in the market economy and education attainment. The theory helps classify how the inequalities in a given population differ across socioeconomic classes in terms of Internet use, placing predictors of the digital divide within a single holistic frame (Van Dijk, 2013).

Supporting Evidence for the Resources and Appropriation Theory

The literature on the digital divide for both the general population and older adults has provided supporting evidence for each domain within the resources and the appropriation theory.

Education. Studies with large and population-representative samples of older adults provide empirical evidence for the positive relationship between education and Internet use (Atkinson, Black, & Curtis, 2008; Gell, Rosenberg, Demiris, LaCroix, & Patel, 2013; Gilleard &

Higgs, 2008; König, Seifert, & Doh, 2018). Higher education level, particularly college or higher degree, is a crucial predictor of being an Internet user (Graham, 2010; Hunsaker & Hargittai, 2018).

Position in the market economy. Position in the market economy takes a prominent position in the digital divide studies since income is a primary resource to purchase Internet access and hardware. Studies found that having a low income is the most potent deterrent of Internet access (Haight, Quan-Haase, & Corbett, 2014; Hunsaker & Hargittai, 2018). Given the fact that position in the market economy and education are often associated, critics point out that the influence of the two factors might be better understood when contextual intersectionality is considered (Duncan, Daly, McDonough, & Williams, 2002; Fang et al., 2018).

Age. Though Internet use among older adults has increased over the past decade (Anderson & Perrin, 2018), older adults continue to lag behind their younger counterparts (Hunsaker & Hargittai, 2018). Gazibara et al. (2015) highlight that the relationship between biological age and Internet use seems exponential rather than linear because the likelihood of being an Internet user has almost doubled by five years for the age group of 85 and older. Such results might imply that each age group or cohort shares a collective consciousness formulated by a public discourse of ICTs and has developed different perceptions towards Internet use depending on the necessity of learning Internet skills in daily life, the role of the Internet in different job categories, and retirement age among different cohorts (Fang et al., 2018). Therefore, age in the digital divide issue may be better understood across age groups as it relates to informing the policy about each group's familiarity with Internet technologies (Casado-Muñoz, Lezcano-Barbero, & Rodríguez-Conde, 2015).

Race and ethnicity. Among older Americans, African American and non-white Hispanic groups are less likely than their white counterparts to adopt Internet and health-related technology (Campos-Castillo, 2015). Moreover, such a disparity has continued despite the increasing Internet adoption across the two racial groups over the last two decades (Choi & DiNitto, 2013; Czaja et al., 2006; Yoon et al., 2018). However, the findings often rely on geographically limited data (Mitchell, Chebli, Ruggiero, & Muramatsu, 2018) and do not adequately address the complexities around some broader psychosocial contexts (Fang et al., 2018).

Health and physical/cognitive functionality. Health and functionality are crucial for the digital divide among older adults since poor health and reduced physical and/or cognitive functionality might impede going online (Gell et al., 2013; Greysen, Garcia, Sudore, Cenzer, & Covinsky, 2014). A better self-rated health status predicts a higher probability of being online (König et al., 2018), while needing help with instrumental activities of daily living (IADL) may be negatively associated with Internet use (Freese, Rivas, & Hargittai, 2006; Hamer & Stamatakis, 2014).

Limitations in Existing Research. Regardless of its inclusiveness, the resources and appropriation theory itself has limitations in elaborating on complexities embedded in each inequality category. Firstly, while the theory claims that individual traits could be critical for the digital divide, it does not specify an operational definition of core variables in the personal category, such as psychological characteristics. Secondly, since the theory primarily aims to explain the digital divide in the general population, further specification is required to identify traits that could capture older adults' appropriate characteristics (McDonough, 2016). Thirdly,

the theory does not fully account for potential social complexities and may overlook reciprocal actions among influential factors within the main inequality categories (Fang et al., 2018).

Stereotype Embodiment Theory

The current study synthesized Levy's (2009) stereotype embodiment theory within the resource and appropriation theory to elaborate on the self-perception of aging within the resource and appropriation framework. The theory introduces the negative perception of aging as negative stereotypes assimilated from surrounding cultures, including prejudice and discrimination towards people based on age, which might negatively influence older adults' self-esteem (Butler, 1969, 2009; Keita, 2014). Studies on the negative perception of aging point out that such internalized stereotypes might discourage older adults from actively engaging in a healthy lifestyle or social participation (Levy, Slade, Kunkel, & Kasl, 2002; Levy, Slade, Murphy, & Gill, 2012; Pascoe & Smart Richman, 2009; Vitman, Iecovich, & Alfasi, 2013). Based on the evidence, this study posits self-perception of aging as a personal-level psychological factor within the resource and appropriation theory. Accordingly, the current study hypothesized that older adults with more negative self-perception of aging would be less likely than their counterparts with intermediate or less negative self-perceptions of aging to be Internet users.

Intersectionality

Intersectionality is a research and policy paradigm (Hancock, 2007; Hankivsky, 2014) that claims that individual experiences could be better explained when taking account of complex social processes and structures (Hancock, 2007; Hankivsky & Cormier, 2011; Hankivsky, Cormier, & De Merich, 2009). The application of this perspective enabled this study to construct a multitude of barriers shared by socially, economically, and psychologically disadvantaged older adults. Guided by McCall's (2008) methodological guideline for

intersectionality research, the study synthesized the information gathered from each inequality category into a set of configurations.

Methods

Data

Introduced in 1990, the Health and Retirement Study (HRS) is a nationally representative biannual longitudinal study following adults of at least 50 years of age in the United States. This study analyzes the 2016 wave of the RAND-HRS data merged with the corresponding wave of Leave-Behind data. The HRS collected the psychosocial aspects of the respondents' lives, such as their self-perceptions of aging, from the Leave-Behind survey. In each HRS wave, half of the individual respondents were asked to complete a printed survey left with them after the primary interview and mail it back to the HRS research team. The final working sample of this study consisted of 5,945 participants and included the individuals who 1) completed the Leave-Behind questionnaire in 2016, 2) had no missing data on any of the variables included in the models, and 3) were not proxy interview cases.

Measures

Dependent variable.

Regular Internet use. The participants indicated having regular Internet use, including sending/receiving e-mails, shopping online, searching for information, or making travel reservations, in a binary response (0= no; 1 = yes).

Explanatory variable.

Negative self-perception of aging. Negative self-perceptions of aging were measured using a four-item scale from the Philadelphia Geriatric Center Morale Scale on one's attitudes

towards own aging (Lawton, 1975). For each item, six responses were available, ranging from (1) strongly disagree to (6) strongly agree, indicating the degree to which they agreed with the following statements: “Things keep getting worse as I get older,” “The older I get, the more useless I feel,” “The older I get, the more I have had to stop doing things that I liked,” and “Getting older has brought with it many things that I do not like.” A higher mean score based on these four items indicated a greater negative self-perception of aging, ranging from 1 to 6. Cronbach’s alpha for the overall scale was .72. Scores were first standardized and then divided into quartiles for regression analysis modeling to detect the threshold or discontinuous effects.

Socioeconomic status. This study used a socioeconomic status (SES) index by conducting a principal component analysis (PCA) to address the criticism toward considering education and position in the market economy to be single traits (Duncan et al., 2002; Fang et al., 2018). PCA is a widely used statistical method that can effectively compress multi-dimensional explanatory factors within a few dimensions and address potential multi-collinearity issues (Everitt, 2009); moreover, it has been validated as a robust method to describe SES differentiation (McKenzie, 2003; Vyas & Kumaranayake, 2006). The SES composite score includes disposable household income from all sources, the monetary value of each asset, debt, and years of education. From the PCA, one principal component, which carries about 82% of the variance and eigenvalue greater than 1 (2.43), was selected for the SES index. The computed principal component scores were weighted linear combinations of the original variables. Finally, the weighted scores were categorized into quartiles for analyses, and the highest SES group served as a reference category.

Other covariates.

Personal categorical inequality. This domain captures the demographic information, including biological sex, race/ethnicity, age groups, marital status, health status, and functionality. Self-rated health has two possible responses: poor/fair or good/excellent. Functionality was measured as difficulty with six activities of daily living (Haight et al.) and seven instrumental activities of daily living (IADL). They were then recoded as a binary response: having at least one difficulty in ADL and IADL (0=no, 1=yes), respectively.

Intersectionality.

This study placed three interaction terms in the post-logistic regression estimations of predicted probabilities of Internet use: negative self-perception of aging (SPA) with 1) age, 2) race/ethnicity, and 3) SES. An interaction term with negative SPA and race/ethnicity was constructed based on the findings of cross-culturally differentiated aspects of aging across racial and ethnic groups (North & Fiske, 2015; Tien-Hyatt, 1987). The other two interaction terms: 1) age and SPA and 2) SES and SPA, were created based on the evidence of positive correlations between them, respectively (Giasson, Queen, Larkina, & Smith, 2017; Rippon, Zaninotto, & Steptoe, 2015).

Analytic strategy

Descriptive statistics and multivariate logistic regression analyses were performed to identify trends in the older adults' Internet use and predict the likelihood of Internet use by negative self-perception of aging. Then, in consideration of the complexity involved in interpreting the interaction terms in non-linear models, the current study post-estimated interaction effects for race, age, and SES as the predicted probability of the Internet use based on the final logistic regression model. All statistical analyses were conducted in Stata (Version 15.1 Stata Corp., College Station, TX).

For logistic regression, all three were models constructed:

$$\text{Regular Internet use} \sim \textit{Bernoulli}\ (\text{logit}^{-1}\ (x_i\beta)),$$

where x_i is the vector of covariates consisting of the explanatory variables within the resources and appropriation theory (see Table 1), and β is the vector of logit coefficients. All estimates were accounted for in the HRS survey weights, using the *svy:* commands in Stata were implemented to account for the complex sampling features of HRS when computing weighted coefficient estimates and linearized standard errors.

The logistic regression analyses Model 1 were fitted to the predisposing variables introduced by the resources and appropriation theory and examined in previous studies. Model 2 attempted to determine the association between the negative SPA and Internet use while controlling for all covariates from Model 1 by adding the standardized negative self-perception of aging (SPA). The negative SPA in Model 2 supplemented a variable to personal-level inequalities based on the resource and appropriation theory, particularly a psychological aspect that suits explaining older adults' characteristics. Model 3, on the other hand, included the negative SPA as a factor variable (i.e., four-quartile categories of the standardized negative SPA) to detect the threshold effect and to calculate the predicted probabilities of Internet use, including the interaction terms (the negative SPA, age, SES, race/ethnicity, and health status). Results are shown in Table 3, and all coefficients are presented in terms of the odds ratio. Figures 1 to 4 show the predicted probabilities of Internet use by the categorized negative SPA and each intersectionality category.

Results

Descriptive Statistics

The mean age of participants was 67.38 years (SD: 10.75), and 71% were older than age 60. Female respondents (59.63%) were more numerous than males, and 56.28% were coupled. The largest racial/ethnic group was non-Hispanic white (64.68%), followed by African American (18.12%), Hispanic (7.96%), and others (9.24%). About 40% were non-Internet users, and the mean negative self-perception of aging was 3.24 (SD: .01).

(Table 1.2 around here.)

Table 1.2 reports sample characteristics stratified by regular Internet use status. Internet use dramatically varied across the age groups. Three-quarters (74.99%) of the youngest group (age 50–59) were Internet users, whereas only about a third (33.72) of the oldest group (age 80 or older) were. While 66.68% of non-Hispanic whites and 59.20% of all other racial/ethnic groups were regular Internet users, less than half of the African Americans (48.19%) and Hispanics (40.80%) were regularly accessing the Internet. There were considerable Internet use gaps across SES. The majority of older adults (87.21%) of the highest SES quartile regularly used the Internet, in contrast to about one-third in the lowest SES group (33.22%). For the negative self-perception of aging, 43.15% in the high level (most negative self-perception) were accessing the Internet regularly, while 57.83%, 65.25%, and 75.25% in moderate–high, low–moderate, and low groups did, respectively. Participants who evaluated their health status as fair or poor showed significantly lower regular Internet use rates (41.52%) than their healthier counterparts (67.80%). Of those without IADL difficulty, 63.03% reported using the Internet regularly, compared with the 32.60% who had one or more IADL difficulty.

(Table 1.3 around here.)

Logistic Regression for Predicting Internet Access

Table 1.3 presents the results of the logistic regression models. Model 1 confirms that the predisposing conditions introduced by the resources and appropriation theory showed statistical significance with regular Internet use for the current sample. Older age groups were less likely to access the Internet than their younger counterparts. The oldest group (age 80 or older) was .11 (p<.001) times less likely to use the Internet than the youngest (between ages 50 and 59). Similarly, the second (odds ratio = .58, p<.001) and third-oldest group (age 70–79, odds ratio = .27, p<.001) were less likely to access the Internet than the youngest group. Females were more likely to use the Internet (odds ratio = 1.83, p<.001) than males. African American (odds ratio = .45, p<.01) and older Hispanic adults (odds ratio = .37, p<.001) were significantly less likely to be regular Internet users than were their non-Hispanic white counterparts.

Older adults who rated their health fair or poor (odds ratio = .62, p<.001) were less likely to use the Internet regularly than those who evaluated their health to be good or excellent. Participants with at least one difficulty in instrumental activities of daily living (IADL) showed a significantly lower likelihood of Internet use (odds ratio = .57, p<.001) than those who did not have a condition. However, having at least one or more difficulties in daily living (Haight et al.) was not associated with regular Internet use.

The results from Model 1 support the existing literature in that the digital divide is largely attributed to stratification in SES. Though the coefficients' degrees vary, all three SES groups against the highest SES quartile showed a significantly lower likelihood of being a regular Internet user. The odds ratios of Internet use compared to the highest SES group for the lowest, the second-lowest, and the second-highest group were .10 (p<.001), .21 (p<.001), and .35 (p<.001), respectively.

Model 2 was developed by adding the negative self-perception of aging (SPA) to Model 1. The standardized negative SPA score showed a statistically significant association with regular Internet use adjusting for all relevant covariates. Specifically, one unit increase of standard deviation for the negative SPA scores on average meant a .88 times lower odds ratio for regularly accessing the Internet.

To detect the threshold effect of the negative self-perception of aging (SPA), Model 3 included the negative SPA as a factor variable. As discussed earlier, the categorized negative SPA variable was constructed by categorizing the standardized negative SPA by quartile. As in Model 2, the factor serves as a variable that explains the psychological aspects within the personal level inequalities. The final model shows a negative and statistically significant association between the higher level (most negative) of negative self-perceptions and Internet use, controlling for other covariates. Compared to the older adult group with a low negative self-perception of aging (mean: 1.69), the high group (mean: 4.86) and moderate-high group (mean: 3.73) showed odds ratios of .69 ($p<.05$) and .78 ($p<.05$), respectively, for being an Internet user. The low–moderate group (mean: 2.89) also showed an odds ratio of .81, though it was not statistically significant. All covariates had significant associations in both Model 1 and Model 2, exhibiting mostly similar coefficients and statistical explanatory powers as in Model 3.

(Figures 1.1 around here)

Figures 1.1 through 1.4 illustrate the predicted probabilities of being a regular Internet user under four different conditions, based on the coefficient estimations from Model 3. Figure 1 shows the probabilities of being an Internet user, stratified by the different levels of the negative

self-perceptions of aging (SPA). The low negative SPA showed the highest probability (.81, 95% CI: .79 to .83) of being an Internet user, followed by the low–moderate (.73, 95% CI: .71 to .76), moderate–high (.66, 95% CI: .64 to .69), and high (.51, 95% CI: .48 to .55) groups. The estimated probability difference between the low and high groups was about .3, indicating that the older adults with a high negative SPA level were 30% less likely to use the Internet than the low negative SPA group.

(Figures 1.2 around here)

Figure 1.2 shows the predicted probabilities of being an Internet user by the intersectionality of age and the negative self-perception of aging (SPA). While the probabilities significantly varied across different age groups, each age group also showed significantly different probabilities by its negative SPA level than others. Except for the oldest age group (age 80 or older), the other three groups showed approximately .20 probability gaps between the low and high negative SPA groups. The oldest age group's gap between the two different levels of negative SPA was about .15. The probability gap between the youngest and low negative SPA group (.88, 95% CI: .86 to .90) and the oldest and high negative SPA group (.28, 95% CI: .24 to .32) was about .60. The gap between the two groups indicates that the youngest and low negative SPA group was almost three times more likely to access the Internet than the oldest with higher negative SPA levels.

Figure 1.3 shows the predicted probabilities for being an Internet user by the intersectionality of race/ethnicity and the negative self-perception of aging (SPA). All four

racial/ethnic groups show probability gaps of approximately .30 between the low and high negative SPA groups. The gap in probabilities between the non-Hispanic white and low negative SPA groups (.84, 95% CI: .82 to .86) and Hispanic and high negative SPA groups (.29, 95% CI: .22 to .36) was approximately .55, more significant than the gap between the low and high negative SPA categories without interactions (about .30), as shown in Figure 1.

(Figures 1.4 around here)

Figure 1.4 shows the predicted probabilities for being an Internet user by the intersectionality of socioeconomic status (SES) and the negative self-perception of aging (SPA). The smallest gap between the low and high levels of negative SPA was found among the relatively higher SES groups. Specifically, the probability of being an Internet user among the low levels of negative SPA in the group with the highest SES index score was .93 (95% CI: .91 to .94). In comparison, the low levels of the negative SPA in the highest SES group showed a probability of .83 (95% CI: .79 to .87), and the probability gap between the two different groups with low levels of the negative SPA was about .10. However, gaps in probabilities by the negative SPA tend to be wider among lower SES groups. For example, within the lowest SES group, the results show a probability gap of .20 between low (.52, 95% CI: .46 to .57) and high negative SPA levels (.32, 95% CI: .28 to .37).

Discussion

Building on the resources and appropriation theory and drawing on the stereotype embodiment theory and intersectionality, this study uses data from the nationally representative samples of adults aged 50 or older to explore how the negative self-perception of aging (SPA)

affects older Americans' regular use of the Internet. The results from this study support most of the critical arguments from the resources and appropriation theory, adding new evidence to support the role of psychological factors and the intersectional inequality on the digital divide among older Americans.

This is one of the first studies to examine the role of psychological factors on the digital divide among older adults. As shown in the logistic regression of Models 2 and 3 from Table 3, negative self-perception of aging could be an independent predictor of Internet use among older adults while taking account of the social stratification that has been examined in the literature as predictors of the digital divide.

The findings provide additional insight into understanding that intersectional inequalities could occur with a negative self-perception of aging. The coefficient degrees of the relatively higher SPA levels were magnified when the negative SPA interacted with age, race/ethnicity, and SES. Specifically, probabilities of being an Internet user among those with relatively higher levels of the negative SPA tended to dramatically decrease when those individuals were of older age, racial/ethnic minority (African American and Hispanic ethnicity), or lower SES groups. These results confirm one of the core arguments of the stress embodiment theory, that negative self-perception towards aging could be strongly correlated with experienced material and societal disadvantages (Levy, 2009; McDonough, 2016). The results also support the intersectionality perspective, that inequalities could be explained with greater clarity when considering how an individual's experience of inequality could create new disadvantages when interacting with other experiences (McCall, 2008).

The significant disproportion in Internet users across age groups implies that a substantial number of older Americans currently not using the Internet might continue to deviate from

digital lifestyle unless substantial efforts are implemented (Seifert, Reinwand, & Schlomann, 2019). With the Worldwide Web as a central medium for the public since the 1990s, a large number of older adults—mainly aged 70 or older—might have had fewer opportunities for digital life, and their digital skills were not as necessary as became the case in the 2000s (DiMaggio & Hargittai, 2001). Therefore, older adults who were previously unfamiliar with the Internet are likely to remain non-users. However, the lack of digital life in the 2000s might lead older adults to experience disparities in various forms, including health outcome (Chambon, Herrera, Romaiguere, Paban, & Alescio-Lautier, 2014), social participation (Carpenter & Buday, 2007; Neves, Franz, Judges, Beermann, & Baecker, 2019), and psychological benefits (Erickson & Johnson, 2011; Heo, Chun, Lee, Lee, & Kim, 2015; Sum, Mathews, Hughes, & Campbell, 2008).

The dramatic decrease in the likelihood of being an Internet with lower SES provides two critical implications. First, older adults who experience financial troubles may not be able to afford any form of Internet access (e.g., broadband or mobile network) or related devices (e.g., computer or smartphone). Secondly, older adults with lower SES are likely to have fewer opportunities to adopt the Internet because the ICTs in earlier years were mostly enjoyed by individuals with high education attainment and specific job categories (i.e., white-collar occupations). Older adults who previously lacked Internet access might not have had the opportunities to equip themselves with essential digital lifestyle skills (Saunders, 2004; Xie & Bugg, 2009). Thus, older adults living without Internet access might remain non-users unless they are provided with affordable and accessible options to learn and realize its substantial benefits (DiMaggio & Hargittai, 2001; A. Van Deursen & Van Dijk, 2011). Therefore, it is crucial to recognize that access to affordable Internet is a basic human need in the information

society. As evidenced in Canada's case, recognizing Internet access as a social right is a vital starting point to implement policies to mitigate the digital divide with strategic investment in public sectors and culturally competent Internet-education content production (Haight, Quan-Haase, & Corbett, 2014; Howard, Busch, & Sheets, 2010).

The results also support previous research showing that Black and Hispanic groups have lower Internet use than their non-Hispanic white counterparts (Choi & DiNitto, 2013; Czaja et al., 2006; Yoon et al., 2018). The findings essentially follow the same lines as the discussions on SES, because lower SES is generally more prevalent among those groups than their white counterparts; therefore, Blacks' and Hispanics' technology adoption has also historically lagged behind the whites' (DiMaggio, Hargittai, Celeste, & Shafer, 2004). Another possible explanation is that lower Internet use among Hispanics might be attributed to their higher rates of limited English proficiency (Mitchell et al., 2018). However, as the results indicate, the "Other" category in which all other racial groups are aggregated showed significantly higher Internet use rates (59.20%) than the Hispanics (40.80%). For this reason, it may be too premature to conclude that language is a significant barrier to Internet access. Further investigation may need to explore how immigrant status and cultural factors affect older adults' attitudes towards Internet use in terms of the cross-cultural discourse of technology adoption.

Lastly, while Internet adoption is generally recommended for a better quality of life among older adults (Wagner, Hassanein, & Head, 2010), the results indicate that society and industries need to be mindful of certain socially disadvantaged groups' critical barriers to adopting a digital life. Improved health status and physical/cognitive functionality are significantly associated with Internet use (Freese et al., 2006; Hamer and Stamatakis, 2014). Notably, having difficulties with IADL could be one of the most critical barriers to being an

Internet user for older adults. Impediments to daily activities and cognitive impairment are likely to appear in later life (Hunsaker & Hargittai, 2018). For older adults with IADL difficulties or cognitive impairment, traditional services required for everyday tasking and communication may need to continue to be provided offline in consideration of the most digitally marginalized (Gell et al., 2013). Further research in health factors might shed light on what types of ICTs might be mostly associated with health and what advanced technologies are needed for better Internet access for older adults with such health problems.

The study has several limitations. Due to the convention of race/ethnicity measurement of the HRS, the study only captured three racial/ethnic identities (non-Hispanic white, African American, and Hispanic ethnicity) but had to aggregate all others into one category. Consequently, the study could not specify how being an "other" older minority (e.g., Asian or Native American) was related to Internet use. Thus, one must be careful with interpreting the impact of minority race/ethnicity, including interaction terms. Secondly, given the cross-sectional nature of the data, the interpretation of the negative self-perception of aging does not indicate any causal relations at all. It is still possible that Internet use could affect the self-perception of aging; as individuals engage in Internet activities, their self-efficacy could be improved. Finally, the dependent variables in this study rely on proxy measurement that did not ask about specific Internet usage but whether it was regular. Therefore, the measurement may suffer a validity problem.

Despite these limitations, this study provides valuable information on the digital divide in older Americans. Furthermore, the study sheds light on the role of multi-level inequalities and the self-perception of aging on older adults' Internet use from the intersectionality perspective. In modern society, the Internet is not merely a gate to more information but has been expanded to

various areas of our daily life. In this context, the digital divide among older adults may cause another dimension of social inequalities and call for policy and practice efforts to alleviate the digital divide in older Americans.

Table 1.1. *Conceptual model on the resources and appropriation theory & intersectionality*

Theory	Inequality categories	Descriptions	Related factors
Resources and appropriation theory	Positional inequalities	Inequalities by institutional factors	Socioeconomic status including: Position in labor market/market economy represented by income, and asset, education level
	Personal inequalities Supplementary theory: Stereotype embodiment theory for psychological trait	Inequalities contribute to individual characteristics	Age Gender Race/Ethnicity Health status: self-rated health & functionality Negative self-perception of aging based on the stereotype embodiment theory
Intersectionality	Inter-relation between factors in resource and appropriation framework	Inequalities by intersectionality	Age & negative self-perception of aging Race & negative self-perception of aging Socioeconomic status & negative self-perception of aging

Table 1.2. *Descriptive Statistics*

DV: Internet use (N=5,945)	%/Mean(SD)		
Variables	Total sample	No Internet use 39.29%	Internet use 60.71%
Age	67.39 (10.75)	71.31 (11.11)	64.85 (9.71)
Age category			
50–59	29.05%	25.01%	74.99%
60–69	30.58%	32.84%	67.16%
70-79	24.29%	46.61%	53.39%

80+	16.08%	66.32%	33.68%
Gender			
Male	40.47%	41.27%	58.73%
Female	59.53%	37.95%	62.05%
Marital status			
Married	56.30%	32.18%	67.82%
Not married	43.70%	48.46%	51.54%
Race/Ethnicity			
White	64.69%	33.13%	66.87%
African Americans	18.12%	51.81%	48.19%
Hispanic	7.96%	59.20%	40.80%
Others	9.23%	40.80%	59.20%
SES index			
Highest (1st quartile)	25.03%	12.77%	87.23%
Second highest (2nd quartile)	25.00%	29.95%	70.05%
Third highest (3rd quartile)	24.96%	47.71%	52.29%
Lowest highest (4th quartile)	25.01%	66.78%	33.22%
Negative Self-Perception of Aging (SPA)	3.24 (.01)	3.59 (.02)	3.01 (.01)
High (mean: 4.86, z-score: 1.32)	24.56%	56.85%	43.15%
Moderate-high (mean: 3.73, z-score: .40)	21.06%	42.17%	57.83%

Low-moderate (mean: 2.89. z-score: -.27)	28.01%	34.35%	63.65%
Low (mean: 1.69, z-score: -1.24)	26.38%	25.89%	74.11%
Self-rated health			
Fair to very poor	26.98%	58.48%	41.52%
Good to excellent	73.02%	32.20%	67.80%
ADL			
Have 1 or more difficulties	15.61%	60.13%	39.87%
None	84.39%	35.44%	64.56%
IADL			
Have 1 or more difficulties	7.64%	67.40%	32.60%
None	92.36%	36.97%	63.03%

Abbreviations: DV, dependent variable; SES, socioeconomic status; ADL, activities of daily living; IADL, instrumental activities of daily living.

Table 1.3. *Logistic regression models for predicting older adults' Internet use*

DV=Regular Internet Use	Model 1	Model 2	Model 2
N=5,945	OR [95% CI]	OR [95% CI]	OR [95% CI]
Personal inequality categories			
Demographic factor			
Age (ref: 50-59)			
60 - 69	.58*** [.47, .72]	.59*** [.47, .73]	.59*** [.47, .73]
70 - 79	.27*** [.21, .34]	.28*** [.22, .35]	.28*** [.22, .35]
80 +	.11*** [.09, .14]	.12*** [.09, .15]	.12*** [.09, .15]
Gender (ref: male)			
Female	1.83*** [1.52, 2.21]	1.81*** [1.52, 2.18]	1.81*** [1.51, 2.18]
Race (ref: white)			
African American	.45*** [.33, .60]	.43*** [.32, .58]	.43*** [.32, .58]
Hispanic ethnicity	.37*** [.25, .54]	.37*** [.25, .54]	.37*** [.25, .54]
Others	.79 [.57, .1.08]	.79 [.57, .1.08]	.79 [.57, 1.08]
Marital status (ref: unmarried)			
Married	1.19* [1.01, 1.42]	1.19* [1.01, 1.42]	1.19* [1.00, 1.42]
Psychological factor			
Standardized self-perception of aging (SPA)	-	.88* [.79, .98]	-
Negative Self-Perception of Aging (Ref: low)			
Low-moderate	-	-	.81 [.64, 1.04]
Moderate-high	-	-	.76*** [.62, .99]

High	-	-	.69*** [.52, .92]
Health &functionality			
Self-rated health (ref: good to excellent)			
Fair/poor	.57*** [.45, .71]	.61*** [.49, .76]	.61*** [.49, .76]
ADL (ref: no ADL condition)			
1 or more ADL condition	.96 [.74, 1.25]	1.00 [.77, 1.31]	1.00 [.77, 1.30]
IADL (ref: no IADL condition)			
1 or more IADL condition	.50*** [.37, .68]	.52*** [.38, .70]	.52*** [.39, .70]
Positional inequality category			
SES index (ref: the highest SES)			
Second highest SES	.35*** [.27, .45]	.36*** [.28, .46]	.36*** [.28, .46]
Second lowest SES	.21*** [.16, .27]	.22*** [.17, .28]	.22*** [.17, .28]
Lowest SES	.10*** [.07, .13]	.10*** [.07, .14]	.10*** [.07, .14]

*** $p<.001$., ** $p<.01$., * $p<.05$. *Abbreviations*: OR, Odds Ratio; CI, confidence interval; ADL, activities of daily living; IADL, instrumental activities of daily living.

Figure 1.1. Predicted probabilities by level of the Negative self-perception of aging with 95% confidential intervals

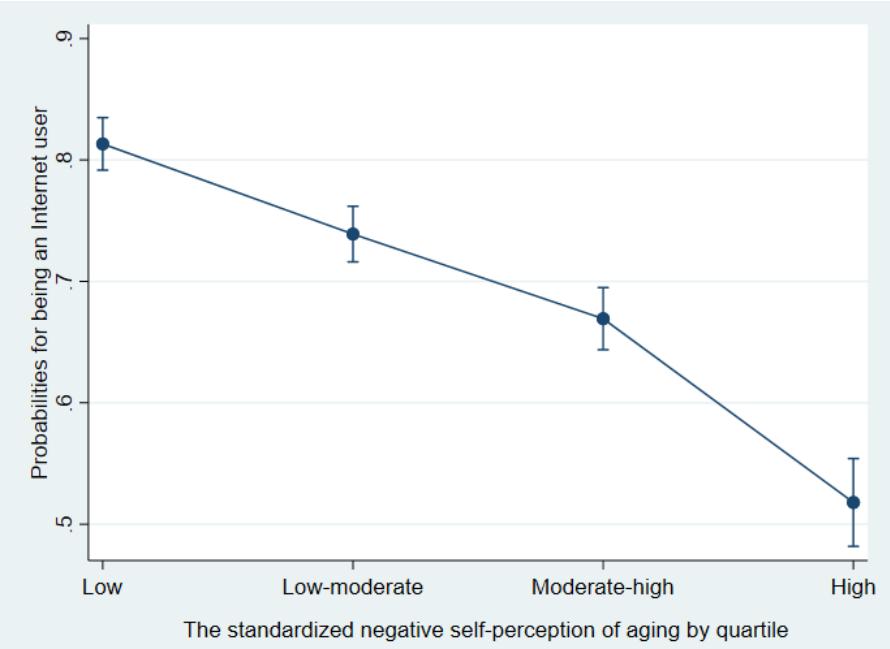


Figure 1.2. Predicted probabilities by Age & Negative SPA

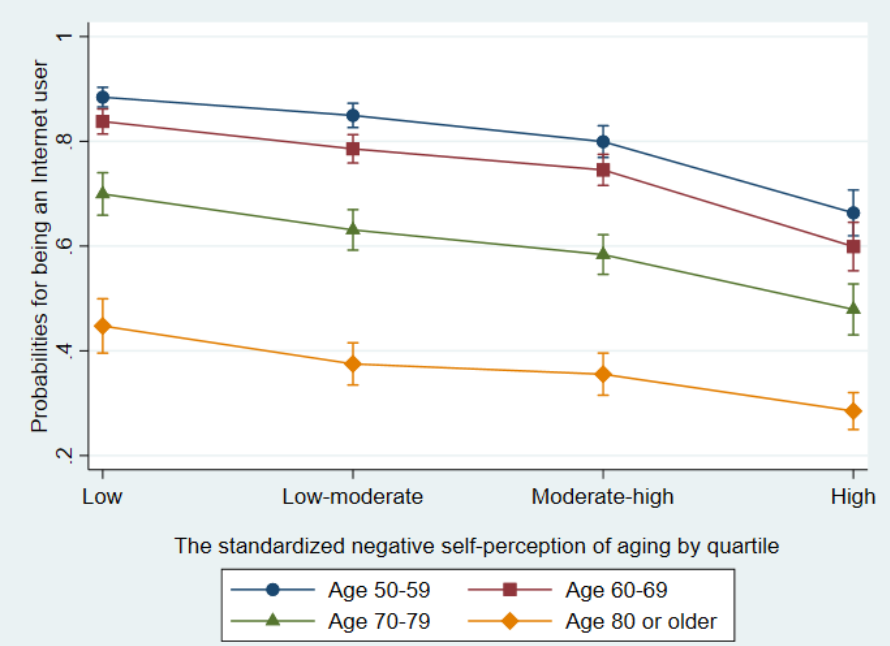


Figure 1.3. Predicted probabilities by Intersectionality: Race/Ethnicity & Negative SPA

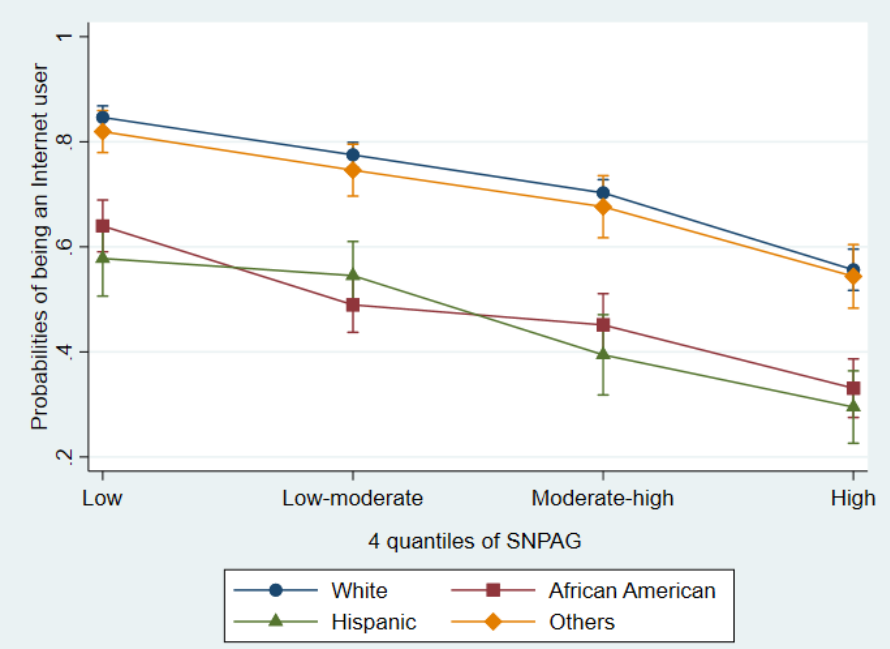
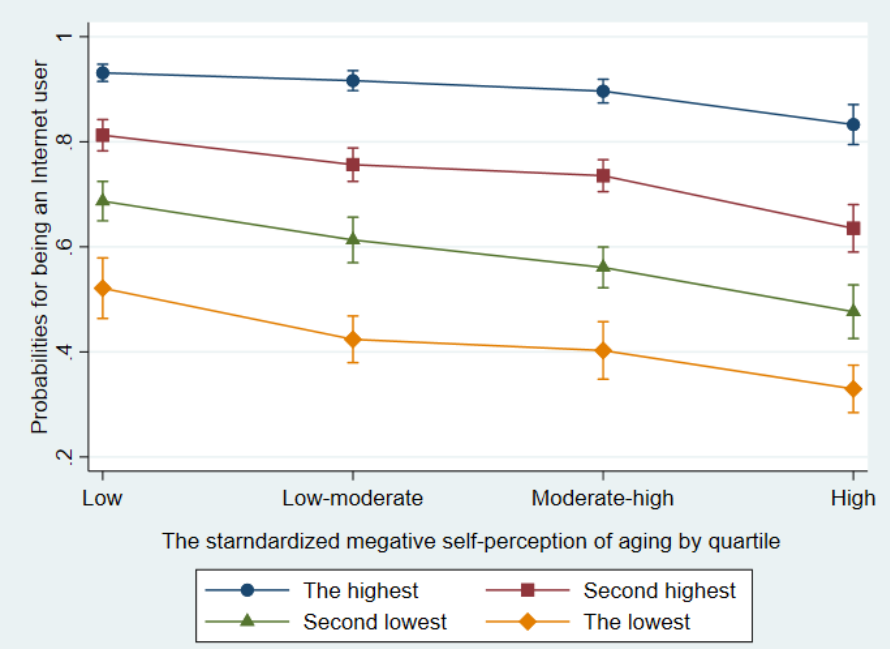


Figure 1.4. Predicted probabilities by Intersectionality: Socioeconomic status & Negative SPA



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PAPER 2: ASSOCIATION BETWEEN REGULAR INTERNET USE AND RISK OF DEVELOPING MILD COGNITIVE IMPAIRMENT AMONG OLDER AMERICANS: FINDINGS FROM A NATIONALLY REPRESENTATIVE SAMPLE

The decline of cognitive function is a significant risk factor for death, disability, and dementia, and it further threatens older adults' autonomy and functional independence (Krug, d'Orsi, & Xavier, 2019). With a rapid population structure change due to increased life expectancy and low fertility, preserving older adults' cognitive functions has become a critical public health agenda (Ihle, Bavelier, Maurer, Oris, & Kliegel, 2020; Suzman, Beard, Boerma, & Chatterji, 2015). Studies have shown that cognitively enriching activities might improve older adults' cognition by stimulating executive functioning, information processing, and memory performance (Akbaraly et al., 2009; Marioni et al., 2015; Then et al., 2013; R. Wilson et al., 2010; R.S. Wilson et al., 2002). Among the attempts to develop cognitive interventions to maintain and enhance older adults' cognition, methods using Information and Communication Technologies (ICTs) have attracted growing attention from healthcare professionals given ICT's potential to stimulate cognitive activity (Ihle et al., 2020; Krug et al., 2019). Longitudinal studies with population-representative samples of older adults have found that older adults' use of the Internet could be a protective factor that positively influences the maintenance of cognitive function (Almeida et al., 2012; Tun & Lachman, 2010; André J Xavier et al., 2014). A systematic review on clinical intervention studies that employed digital technologies showed that programs to train older adults to navigate the Internet were positively related to preserving older adults' cognition (Dardiotis et al., 2018) and even improving the memory of older adults who were already experiencing a cognitive decline (Ge, Zhu, Wu, & McConnell, 2018).

Although existing research on the subject provides evidence on the association between digital technology and better cognitive functioning (Kamin & Lang, 2020; Klimova, 2016), little

is known about how engaging in a digital lifestyle as a healthy behavior might be associated with the likelihood of new-onset mild cognitive impairment (MCI), the intermediate clinical status between normal cognitive aging and dementia across advanced adulthood (Ihle et al., 2020). The current study attempts to examine the association between regular use of the Internet and the likelihood of new-onset MCI among older adults using a nationally representative and longitudinal sample of older Americans aged 65 or older from the Health and Retirement Study (HRS).

Literature Review

Cognitive-Enrichment Framework

The primary assumption of the cognitive-enrichment framework is that individuals could experience both gains and losses in cognitive function beyond adulthood, but gains become less common and losses predominate with advancing age (Hertzog et al., 2008). Under the overarching premise, the cognitive-enrichment framework posits the human brain as a substrate that affords cognitive plasticity (Cacioppo et al., 2003), and thus, neurobiological status of cognitive function is considered influenced by accumulated individual, environmental, and contextual factors (Baltes, Reuter-Lorenz, & Rösler, 2006; Li & Lindenberger, 2002). A frequently used theoretical perspective in previous studies of older adults' cognition is the “use it or lose it” perspective (Tun & Lachman, 2010). The premise of the “use it or lose it” perspective is that the rate of aging-related cognitive decline will be less pronounced for more mentally active people (Hultsch, Hertzog, Small, & Dixon, 1999). Therefore, the “use it or lose it” perspective posits that different cognitive-functioning levels among people who vary in mental activity level will be more significant with increased age. While the association between mental activity and maintaining cognitive functioning is intuitively plausible and in line with established

neurobiological theories, the “use it or lose it” perspective fails to consider a wide range of factors that might affect cognition, such as predisposing socioeconomic factors, individual-level behaviors, and psychological wellbeing (Hertzog, Kramer, Wilson, & Lindenberger, 2008). The cognitive-enrichment framework complements such limitations of the “use it or lose it” perspective while subsuming its focal assumption on mental activity and cognition. With a wide array of theories and evidence, the cognitive-enrichment framework enables a comprehensive view of the factors from both individual and societal contexts that might have a meaningful impact on the level of effective cognitive functioning in advanced age. The cognitive-enrichment framework conceptualizes four main domains of older adults' lifestyle as substantial factors that could affect their cognitive performance: mentally stimulating activity, physical exercise, social engagement, and psychological wellbeing.

Mentally stimulating activity. The mentally stimulating activity premise is that older adults' cognitive function could remain better than previously predicted with activities that stimulate cognition (R.S. Wilson et al., 2002). Although older adults are slower than younger population groups to adopt intelligently challenging skills due to reduced neural plasticity that puts constraints on maximal levels of the cognitive performance with advancing age, evidence shows that mentally stimulating activities can still improve or at least maintain older adults' cognitive performance (Greenwood, 2007; Kempermann, 2008; Kramer, Bherer, Colcombe, Dong, & Greenough, 2004). Assessment of mentally stimulating activities in empirical studies has included a wide array of activities, such as crafting, reading books, learning new musical instruments, and playing games (Kelly et al., 2014). Studies have implied that such activities were associated with sustaining or upward movements in cognitive performance among older

adults maintaining such activities, even if the upward movements become more difficult with advancing age (Hertzog et al., 2008).

Use of digital technology as a mentally stimulating activity. An increasing number of studies have acknowledged the use of digital technology as one of such mentally stimulating activities (Ge et al., 2018). Learning how to operate and navigate information through digital devices is a modifiable behavior proven effective in protecting cognitive function (Hertzog et al., 2008; Ihle et al., 2020). Engaging in a digital lifestyle could provide older adults with mentally challenging activities that contribute to cognitive reserve accumulation, specifically with positive learning challenges in psychomotor ability and information processing, and executive function (Charness & Boot, 2009; Cullati, Kliegel, & Widmer, 2018; Dekhtyar et al., 2015), and opportunities for expanding lifelong learning (B. Lee, Chen, & Hewitt, 2011). Cognitive rehabilitation programs with digital technologies commonly reported that using the Internet through digital devices might improve creativity, cognitive flexibility, attention, and task performances (Diamond & Ling, 2016). The use of digital technologies might also indirectly influence the cognitive reserve by improving the practice of citizenship, health, education, work, leisure, socialization (Krug et al., 2019; Paiva & Del-Masso, 2013; Andre Junqueira Xavier et al., 2013).

Physical activities. The relation between physical activity and cognition in the cognitive-enrichment framework is well established in clinical studies (Hertzog et al., 2008). Evidence supports that physical activities could affect cognition in three ways. First, cardiorespiratory function was positively and directly associated with older adults' cognition. Maintaining normal-level oxygen saturation through physical exercises significantly impacted reestablishing cognition and motor skills (Moss, Franks, Briggs, Kennedy, & Scholey, 2005; Ortapamuk &

Naldoken, 2006). Second, physical activity might prevent or ease symptoms from chronic diseases positively associated with compromised cognitive function (Jia, Liang, Xu, & Wang, 2019). For instance, older adults doing regular physical exercise were less likely to have chronic conditions considered high-risk factors on older adults' cognitive function, such as cardiovascular diseases and type II diabetes (Mandolesi et al., 2018; White et al., 2017). Third, clinical studies on non-human animals increasingly showed that physical activity might induce structural changes in the brain and affect brain plasticity among non-human animals (Akbaraly et al., 2009; Y.-F. Liu et al., 2008; Vedovelli et al., 2011). Based on the results, the cognitive-enrichment theory assumes that physical activities might have positive effects on preserving the cognitive functions of human beings through morphological modifications that could result in better neuronal efficiency (Mandolesi et al., 2018).

Social engagement. Social engagement within the cognitive-enrichment framework refers to a status of being socially active and maintaining social connections (Bassuk, Glass, & Berkman, 1999). Studies on the subject have generally focused on relatively objective measurements indicating social relationships or participation, such as marital status, number of friends, regular contact with family members, and community services participation (Hertzog et al., 2008). It is well established that the incidence of dementia was lower among older adults who maintained close social networks, as indicated by being married or not living alone (H. Liu, Zhang, Choi, & Langa, 2020; Sundstrom, Westerlund, & Kotyrlo, 2016), and higher levels of social activity, such as volunteering, have also been positively associated with older adults' cognition (Fabrigoule et al., 1995; Krueger et al., 2009; Mackinnon, Christensen, Hofer, Korten, & Jorm, 2003; Seeman et al., 2011).

Psychological distress. Psychological distress within the cognitive-enrichment framework refers to perceived negative emotional or mental status. Research on the subject has shown a positive association between psychological distress and cognitive decline through negative emotional states. For instance, higher depressive symptomatology was associated with more rapid cognitive decline (Paterniti, Verdier-Tillefer, Dufouil, & Alperovitch, 2002; Sachs-Ericsson, Joiner, Plant, & Blazer, 2005; Wilson, Mendes de Leon, Bennett, Bienias, & Evans, 2004), a higher likelihood of incidence of mild cognitive impairment (Geda et al., 2006; Wilson, Schneider, et al., 2007), and dementia (Gatz, Tyas, St. John, & Montgomery, 2005; Wilson, Barnes, et al., 2002; Wilson, Krueger, et al., 2007).

Research Questions

The current study considers using the Internet in old age as a cognitive stimulus activity with the mental stimulation premises from the cognitive-enrichment perspective. Therefore, this study posits that regular Internet use is negatively associated with new MCI onset. In this background, the current study examined the following core research questions:

Research Question 1: Is regular Internet use positively associated with the likelihood of new-onset MCI among older adults?

Hypothesis 1-1: Older adults who regularly use the Internet are less likely to experience MCI than those who do not use the Internet.

Research Question 2: Do factors other than the stimulus activity within the cognitive-enrichment framework, including regular physical exercise, psychological wellbeing, and social engagement, have a positive effect on minimizing the risk of MCI among older adults?

Hypothesis 2-1: Older adults who regularly exercise are less likely to experience MCI than those who do not regularly exercise.

Hypothesis 2-2: Older adults who experience substantial depressive moods are more likely to experience MCI than those who do not experience depressive moods.

Hypothesis 2-3: Older adults who are socially engaging are less likely to experience MCI than those who are not socially engaging.

Methods

Data & Sample

This study used data from the Health and Retirement Study (HRS), a nationally representative longitudinal survey of Americans over the age of 50 conducted by the University of Michigan. The HRS's Core Survey, which has been conducted every two years since 1992, collects comprehensive data about the aging population in the United States, including information about physical and mental health, financial status, and retirement planning. The current study merged the HRS data from 2002 to 2016 with a RAND HRS longitudinal file that contains imputed variables for some of socioeconomic indicators, such as demographics, income, and health status (Bugliari et al., 2019). Then, the study captured respondent-level data on those who participated in all study waves from 2002 to 2016, completed cognitive measurement questions in each wave, did not indicate experience of mild cognitive impairment in 2002 based on the cognitive measurement, and non-proxy interview cases. This study's final sample consists of 5,962 individuals aged 65 or older in the HRS study year of 2002.

Measurement

Mild cognitive impairment (MCI). This study's primary outcome is a MCI status determined using the HRS cognitive function measurement indices. Each study year, the HRS measures the study participants' cognitive functions with indices including a total recall test with an immediate recall task (0–10), delayed recall task (0–10), and mental status index, and other tests involving serial 7s (0–5), backward count from 20 (0–2), object naming—scissors or cactus (0–2), president naming (0–1), vice president naming (0–1), and date naming (0–4). The maximum score from the indices is 35 points, and a total score of 12 or lower is considered mild cognitive impairment (Weir, 2017). The study participants younger than 65 were not invited to several index items, namely date naming, object naming (scissors or cactus), and naming the president or vice president (Ofstedal, Fisher, & Herzog, 2005), and thus the current study excluded those who were younger than 65 years in each study year.

Internet use. The primary predictor variable for the study is Internet use among the study participants. The HRS measured regular Internet/E-mail use as indicated by Yes (1) or No (0) responses to the question "I use Internet or E-mail: yes/no," which has been asked since the 2002 wave (Smith, Ryan, Fisher, Sonnega, & Weir, 2017).

Control variables. Guided by the cognitive-enrichment framework, the study included several critical control variables to examine the impact of Internet use on experiencing MCI. Regular physical activity is one factor that potentially maintains or enhances older adults' cognitive function within the framework. The HRS measured vigorous physical activities with the question "How often do you take part in sports or activities that are vigorous, such as running or jogging, swimming, cycling, aerobics or gym workout, tennis, or digging with a spade or shovel: more than once a week, once a week, one to three times a month, hardly ever, or never?" The variable re-categorized as doing regular exercise at the year of the interview (1) indicates

exercising at least one to three times a month, and no exercise (0) indicates hardly or never doing regular exercise (Smith et al., 2017).

Psychological distress is also a crucial factor in older adults' cognitive function within the cognitive-enrichment framework. The current study included depressive mood to indicate psychological distress. The HRS evaluates depression using a short version of the Center for Epidemiologic Studies—Depression Scale (CES-D) that consists of eight measurement questions from the full version of CES-D (Beekman et al., 1997; Steffick, 2000) with constantly high internal consistency (Steffick, 2000). The α of the short CES-D within the sample was 0.81. The sum of the mini CES-D score of ≥ 4 points was used to define cases of depression (Smith et al., 2017).

For social engagement, the current study included the study participants' status of living with a spouse or partner. When participants were living with a spouse or cohabitating with a partner, their status was coded as living with a spouse or partner (yes = 1). In the meantime, study participants who were divorced, widowed, never-married, or married but separated in each wave were considered to not be living with a spouse or partner (no = 0).

Covariates. The current study included functionality status, self-rated health, and chronic conditions from each study wave for additional covariates. Functionality included six activities of daily living (ADL) and seven instrumental activities of daily living (IADL). Both measurements were categorized into binary variables to indicate having at least one functional difficulty (1) or no difficulty (0). Response options for the self-rated health status were distributed among five categories, from poor to excellent, and recoded into binary values to indicate good to very good (1) or very poor to fair (0). As for chronic disease, diabetes and cardiovascular disease status were included (yes=1, no=0).

For demographic factors, gender, age (aged 75 or higher in each wave), race and ethnicity, income (yearly household income $40,000 or higher), and an education level (no high school, high school or equivalent, college +) were included to represent socioeconomic status.

Analytic Strategy

The current study employed a Kaplan-Meier estimation for bivariate survival estimation and logit discrete-time hazard model for fitting data throughout the discrete-time frame for multivariate analysis (Allison, 2014). The rationale of the analytical strategy choice considered three important natures of the Health and Retirement Study (HRS) and focal variables:

1. The HRS is a biannual survey administered every even-numbered year, and thus, the analysis must take into account the nature of the discrete-time frame;
2. This study's primary outcome is a binary variable to indicate the first mild cognitive impairment occurrence determined by the HRS's cognitive function indices. Therefore, a logit function estimation would be suitable to reflect the nature of the primary outcome and enables meaningful interpretations of results;
3. Including the main predictor, regular Internet use, several covariates of this study were time-varying while others were invariant. Therefore, the multivariate analysis must be able to process both variable types.

Model specification

The general logit discrete-time hazard function model, logit*(h)(tij)*, can be written as follows:

$$\textbf{logit}\ (h)(t_{ij}) = [\alpha_j D_{ij} + \alpha_j D_{ij} + \alpha_j D_{ij} + \ldots + \alpha_j D_{ij}] + [\beta_1 X_{1ij} + \beta_2 X_{2ij} + \ldots + \beta_p X_{pij}].$$

On the right side of the model, the first squared bracket denotes hazard function by the discrete time frame, where *D* is the standard dummy variable representation of each

measurement point, which also yields the time indicator *j, i* denotes individual value for each period *j* while α refers to the coefficient of each time dummy variables. In the second squared bracket, *X1ij*, *X2ij*, …, *Xpij* represent the *p* predictors, and *Xpij* denotes individual *i's* values for the *P*th predictor in the wave *j* that could be either time-invariant or time-varying. When the predictor is time-invariant, such as an individual education level, it would take on the same value in each period. In contrast, the value could be different when the predictor is time-varying, such as use of the Internet, vigorous physical activity, depression, and living with a spouse or partner status in each wave.

Based on the general model, the current study fitted the model using the four focal variables from the prior wave: Internet use, vigorous physical activity, living with a spouse or partner status, and depression. In line with the cognitive-enrichment framework, which asserts that cognitive function is considered the outcome of accumulated effects, the rationale of fitting those four variables from the prior wave is to examine the cognitive-enriching effect of the variables by minimizing the potential of reverse causality. For instance, the coefficient of regular Internet use in each study year *j* indicates how Internet use during the *j-2* wave (i.e., the 2002 HRS) was associated with the *j* wave's (i.e., the 2004 HRS) risk of new-onset mild cognitive impairment. Thus, the final logit discrete-time hazard model to reflect the modification is expressed as follows:

$$\textbf{logit}\ (h)(t_{ij}) = [\alpha_1 D_{1ij} + \alpha_2 D_{2ij} + \alpha_3 D_{3ij} + \ldots + \alpha_{16} D_{16ij}] + [\beta_1 \textbf{Regular Internet Use}_{ij-2} + \beta_2 \textbf{Regular Physical Activity}_{ij-2} + \beta_3 \textbf{Living with a spouse or partner Status}_{ij-2} + \beta_4 \textbf{Depression}_{4ij-2} + \ldots + \beta_p X_{pij}].$$

Four different models were fitted to data to estimate the association between regular Internet use and the likelihood of experiencing new-onset of mild cognitive impairment (MCI).

Model 1, the base model, estimated the hazard of experiencing MCI by regular Internet use with time dummies and socioeconomic characteristics. The further three models sequentially added an additional three focal cognitive-enriching factors to Model 1 to determine the significance of regular Internet use while controlling for other factors. Model 4, the final model, included all four focal variables: regular Internet use, vigorous physical activity, depressive mood, and living with a spouse or partner status, representing intellectually stimulating activity, physical activity, psychological wellbeing, social engagement, and psychological wellbeing, respectively.

Results

Descriptive Statistics

The descriptive statistics for the outcome, predictor, and control variables are presented in Table 2.1. Furthermore, independent t-tests and chi-squared tests were conducted to examine the bivariate effect of predictor variables and covariates on experiencing mild cognitive impairment (MCI). The results presented in Table 1 indicate that about one-fourth (25.65%) of the older adults in the study regularly used the Internet in the HRS study year of 2002. Among the regular Internet users in 2002, 7.46% experienced MCI, compared to the 19.42% of non-Internet users by the 2016 study wave ($p<.001$).

(Table 2.1 around here)

Figure 1 provides additional information on the bivariate association between Internet use and MCI from the Kaplan-Meier survival estimation. In the 2016 HRS wave, survival probability among non-Internet users was about .67, indicating that after 12 years from the year 2004, roughly one in three non-Internet users were likely to develop MCI. On the other hand, the

survival probability of MCI in older adults who used the Internet in least at one study wave was about .88 ($p<.001$), implying that approximately one in ten members of the group were likely to develop MCI.

(Figure 2.1 around here)

Older adults who were regularly doing vigorous physical activities or exercise showed a lower MCI prevalence (14.57%) than older adults who were not (17.79%) at a statistically significant level ($p<.01$). The prevalence of MCI was higher among study participants with a depressive mood (26.92%) than those who were not depressed (14.51%) ($p<.001$). Similarly, study participants who were living with a partner or spouse showed lower MCI prevalence (14.18%) than those who lived alone (20.48%) ($p<.001$).

Socioeconomic characteristics disproportionally distributed the prevalence of MCI. The mean age of older adults in 2002 who later experienced MCI through all study waves until 2016 (72.76, SD:.14) was slightly higher than that of the non-experiencing participants (71.09, SD: .06) ($p<.001$). In the same lieu, experiencing MCI was more prevalent among older adults in the advanced age group of 75 years old or older in 2002 (24.25%) than their younger counterparts (14.07%) ($p<.001$). More female participants (17.93%) had MCI than males (14.15%) ($p<.001$). Compared to the 12.66% in non-Hispanic whites, more than one-third of African Americans (34.98%) experienced MCI, followed by the group comprising all other racial/ethnic identities (28.40%) and Hispanic ethnicity (27.76%) ($p<.001$). The relatively low-income group, with household income less than $40,000, showed almost two times higher MCI prevalence (19.93%) than older adults with incomes of $40,000 or more (10.19%) ($p<.001$). The

prevalence of MCI was notably higher among low-education groups. About one-third (31.31%) of the no-high-school-diploma group had MCI. 13.52% of a high school diploma or the equivalent, and 8.51% of older adults with secondary education experienced MCI, respectively ($p<.001$).

Health status and functionality were associated with MCI prevalence. The percentages of individuals experiencing MCI were significantly higher among older adults who indicated relatively low self-rated health (24.38% vs. 13.78% in good to excellent), had at least one difficulty in ADL (23.55% vs. 15.36% in no difficulty) or IADL (31.95% vs. 15.36% in no difficulty), and had diabetes (20.95% vs. 15.34% in no diabetes), at the same statistically significant level ($p<.001$). The cardiovascular condition did not show a significant association with MCI.

Logit Discrete-time Hazard Models and Probability Estimation

Table 2.2 shows logit-hazards estimations from multivariate analysis. Model 1 included a binary variable to indicate the Internet use at the prior wave (j-2) and a total of seven time dummies (j year, ranged from 2004 to 2016) along with demographic factors. Results from Model 1 indicate that older adults who regularly used the Internet in the prior wave (j-2) were .33 times less likely to experience MCI at a statistically significant level ($p<.001$). Models 2, 3, and 4 were developed by sequentially adding three focal variables—physical exercise, depressive mood, and living with a spouse or partner status—constructed by the cognitive-enrichment framework. The logit-hazard coefficient of using the Internet was consistent across all models and statistically significant ($p<.001$) even after adding all three focal variables within Model 4. While hazard ratios of the first two time dummies, representing the 2006 and 2008 waves, were not statistically significant, the rest of the time dummies' hazard ratios ranged from 1.9 to 2.66

($p<.001$), indicating that the risk of experiencing MCI is likely to increase as one ages. Therefore, the results support Hypothesis 1-1 constructed based on the cognitive-enrichment framework that Internet use might be positively associated with reducing the risk of MCI.

(Table 2.2 around here)

Figure 2.2 illustrates the probability of experiencing MCI in each study wave (*j*) by regular Internet use of older adults at the *j-2* wave. Across all study waves included in the study, the non-Internet user group showed roughly three times higher probability of experiencing MCI than the Internet user group in each wave. For instance, in the study year of 2016, the probability of MCI within the non-Internet user group was .06, while the Internet user group's probability was .02 at a statistically significant level ($p<.001$).

(Figure 2.2 around here)

Figure 2.3 shows that the probability of MCI between the Internet users and non-users was more distant from each other within the advanced age group, aged 75 years or older, in 2002. In 2016, the probability of developing MCI for the non-Internet users aged 75 or older at the base year was .09, whereas the probability for the Internet users in the same age group was .03 ($p<.001$).

(Figure 2.3 around here)

The results partially support the hypotheses for other cognitive-enrichment framework dimensions under the second research question. In brief, physical activity and psychological distress were related to older adults' cognitive function but not social engagement. Older adults who regularly exercised in the *j-2* wave were less likely than the group of older adults who did not exercise to experience MCI (hazard ratio=.3, p<.001) in the *j* wave. On the other hand, depressive mood showed a positive and significant association with MCI. Older adults experiencing depression in the *j-2* wave were 1.53 times more likely to experience MCI in the *j* wave than those who did not have a depressive mood (p<.001). However, living with a spouse or partner that indicated social engagement in this study did not show a significant association with MCI (hazard ratio = 1.04, p>.05).

The result also highlighted that the risk of a new-onset of MCI was substantially higher among socioeconomically disadvantaged groups. All three racial or ethnic minority groups in the study showed a significantly higher risk of MCI than the non-Hispanic white group. For instance, the African American group showed a 2.66 (p<.001) times higher risk of MCI than non-Hispanic whites. Older adults with at least a high school diploma (hazard ratio: .51, p<.001) or some college experience (hazard ratio: .44, p<.001) showed a significantly lower risk of MCI than those who did not have a high school diploma. While no significant association was observed in most health status and functionality variables, older adults with at least one or more difficulties in terms of instrumental activities of daily living (IADL) showed a risk more than four times higher of experiencing MCI (hazard ratio = 4.29, p<.001) than those who had no difficulties.

Discussions

Based on a longitudinal analysis of a nationally representative sample of 5,962 older adults in the United States, and drawing on the cognitive-enrichment framework, this study examined how Internet use is associated with the risk of new-onset mild cognitive impairment (MCI) in individuals aged 65 and above. The cognitive-enrichment framework posits that mentally stimulating activities, physical activities, and social engagement might be positively associated with older adults' cognitive function, while psychological distress might be a risk factor of cognitive decline. The current study posited older adults' Internet use as a type of mentally stimulating activity and examined its association with the likelihood of new-onset MCI. Findings from the current study offer several vital insights in the era of population aging and digital technologies.

The findings from this study affirmed Hypothesis 1-1 drawn from the cognitive-enrichment framework: older adults who regularly use the Internet are less likely to experience mild cognitive impairment (MCI) than those who do not use the Internet, despite the downward trend of cognition that corresponds with aging. The main finding is in line with previous studies that have reported a protective effect of the use of digital technology as an effective mentally stimulating activity that is positively associated with enhanced capacities in psychomotor ability and information processing, and executive function (Charness & Boot, 2009; Cullati, Kliegel, & Widmer, 2018), but negatively associated with new-onset dementia (Dekhtyar et al., 2015). In the meantime, there has been a shortage of evidence on how Internet use is associated with the likelihood of new-onset MCI among older adults using a longitudinal and population-representative sample (Ihle et al., 2020; Krell-Roesch et al., 2017). Therefore, the current study

supplies further evidence on the potential of Internet use as a mentally stimulating activity that could be a protective factors of older adults' cognitive function (Ge et al., 2018).

The finding is consistent with existing literature on Internet use and cognitive function among older adults with panel data (Almeida et al., 2012; Tun & Lachman, 2010; Xavier et al., 2014) as well as intervention studies employing cognitive stimulation programs using digital technologies (Dardiotis et al., 2018; Ge, Zhu, Wu, & McConnell, 2018). Although direct comparisons of the degree of Internet use's impact on older adults' cognitive function is not straightforward due to different analytical strategies, a study conducted by Xavier et al. (2018) employed data from the English Longitudinal Study of Aging (ELSA), the English counterpart study of the HRS, and shares key measurement tools. Xavier et al. (2018) found that Internet use was positively associated with cognitive function among older adults aged 50 to 89. Specifically, current Internet users showed about 3.07% higher delayed recall test scores at each study wave. The current study provides additional evidence to the literature that even though the differences in cognitive function between Internet users and non-users (3.07%) might not seem large at each measuring point, non-users might still develop the heightened risk of MCI as they are entering advanced age.

The results from this study suggest that cognitive interventions based on digital technology could be more effective when providing other cognitively enriching factors simultaneously. Specifically, the results of this study support Hypothesis 2-1: older adults who regularly exercise are less likely to experience MCI than those who do not regularly exercise. The affirmation of Hypothesis 2-1 is accordant with existing literature on the positive impact of exercise on cognitive stimulations (Gregory, Parker, & Thompson, 2012; Vago & Lovecchio, 2014; Vedovelli et al., 2011). Moreover, confirmation of Hypothesis 2-2: older adults who

experience depressive moods are more likely to experience MCI than those who do not experience depressive mood highlights the impact of psychological wellbeing on maintaining older adults' cognition (Donovan et al., 2017). Thus, the findings support the cognitive-enrichment framework's core arguments on the role of physical activities and psychological wellbeing on the preservation of cognition. Therefore, practices that aim to maintain and enhance older adults' cognitive functions might consider holistic approaches to address all cognitively enriching factors simultaneously.

The results on the associations between the likelihood of new-onset MCI and socioeconomic variables of this study highlight that MCIs were more prevalent among the socially marginalized groups. In line with existing literature on the association between cognitive function and use of digital technology, the likelihood of new-onset MCI was significantly higher among Black and Hispanic (H. B. Lee et al., 2012), no-high-school-diploma (R. S. Wilson et al., 2009), and low-income groups. Research on the digital divide among older adults points out that such groups also overrepresented who among them did not have digital device, Internet access, or skills to navigate information online (Seifert et al., 2021; Yoon et al., 2020). Acknowledging that the lack of access to digital technology could be a health-risk factor in later life, policy efforts to deploy digital technology to mitigate potential disparities due to the digital divide are needed.

Aside from its direct effect on preserving older adults' cognition, Internet use could be a gateway that directs older adults toward other domains of cognitively enriching activities (Lifshitz, Nimrod, & Bachner, 2018). For instance, computer use through the Internet can provide older adults with a greater likelihood of maintaining relationships with social networking services, which might improve psychological wellbeing (Szabo, Allen, Stephens, & Alpass,

2018). Moreover, regular Internet users are more likely to access health-related information and services (Andre Junqueira Xavier et al., 2013; Yoon, Jang, Vaughan, & Garcia, 2020).

Engaging digital life has become more critical amid the recent COVID-19 pandemic, where physical contact is limited and many public services and social activities have migrated online (Seifert, Cotten, & Xie, 2021). Although Internet use among the older adult population has increased over the last decade, a substantial number of older adults still do not use digital devices nor go online (Friemel, 2016). Furthermore, older adults' digital lifestyles tend to be either intensive or inexistent, indicating that individuals who already engaged in a digital lifestyle are likely to continue their digital lifestyle and further benefit from it, whereas their counterparts who never or rarely use ICTs are likely to remain lagged (Calhoun & Lee, 2019). Based on the main finding on the role of Internet use on new-onset MCI, the digital divide might cause wider gaps in cognitive capacity between Internet users and non-users, leading to further health risks of MCI, dementia, and functional independence.

Implications for policy and practice

In 2000, the US Congress passed an amendment to the OAA that authorized federal grants under Title IV to "provide computer training and enhanced Internet access for older individuals" (Older Americans Act Amendments of 2000, 2000, Section 415). The statute gave priority to institutions and organizations offering services to older adults in rural areas and those with expertise in diverse training methods, including computer-based and Internet-based approaches (Older Americans Act Amendments of 2000, 2000). Despite the explicit attention given to computer training for older adults within the 2000 amendment of the OAA, there has been little evidence of significant federal support in this regard. Instead, Title IV of the OAA has

been subject to severe budgetary fluctuations from one year to the next, as new initiatives are introduced and others defunded (Napili & Colello, 2013; Wacker & Roberto, 2013).

Federal funding for computer training for older adults, as mandated by the OAA, has been abandoned without having achieved much nationwide impact. In the reauthorization of the OAA in 2016, the computer training section was repealed from the statute (Older Americans Act Reauthorization Act of 2016, 2016) and was not reinstated in its most recent reauthorization in 2020 (Older Americans Act Reauthorization Act of 2020, 2020).

Due to the absence of federal support and coordination, ongoing efforts to enhance older adults' computer-related skills in the United States have remained mostly small-scale and local. Nonprofit organizations such as the Older Adults Technology Services (OATS), based in New York City, SeniorNet, and the Oasis Institute—each with dozens of affiliate centers across the United States—meet some of the needs for training in computer and Internet use (Span, 2013). However, large gaps still exist in many parts of the country and geographic and demographic lines. Training programs offered by nonprofit organizations are generally located in or near cities. In addition, a survey by the Pew Research Center in 2017 found that Internet use varied by income and educational level for older adults (Anderson & Perrin, 2017). While 94% of individuals with an annual household income of more than $75,000 used the Internet, only 46% of those in households earning less than $30,000 per year did. Similarly, 92% of college graduates said they use the Internet compared to the 49% of those with a high school education or less (Anderson & Perrin, 2017). It will be essential to close these gaps in computer skills and Internet use among older adults, considering that computer use is positively associated with cognitive functioning, which, in turn, might benefit our society by reducing the overall cost of caring for older adults (Calhoun, Fraizer, Miramontes, Madjidi, & Watts, 2017). Moreover, in

the era of COVID-19, providing accessible Internet and training on navigating it and accessing government programs and services must be recognized as a social justice issue to reinforce independence and autonomy in older individuals (Seifert et al., 2021).

Limitations

Although the analyses for the current study attempted to minimize potential reverse causality by utilizing longitudinal panel data, lagged modeling, and employing a comprehensive theoretical framework (Leszczensky & Wolbring, 2019), none of the results from the statistical analyses may offer causal inferences between computer use and cognitive function among older adults but merely associations between them. Thus, future studies need to investigate the causal relationship between the use of digital devices and cognitive function, employing experimental research designs for better policy and practice implications. In addition, the Internet use measurement in the Health and Retirement Study provides limited information, primarily about their Internet access status. Therefore, further detailed information, such as Internet use frequency, most frequently used digital devices, and the primary purpose of Internet use, is needed to provide more comprehensive answers to the research questions on benefits of the digital lifestyle of older adults on their wellbeing. Future social surveys on older adults' digital life might need to develop comprehensive measurement tools to capture more detailed information on the population's digital lifestyles and their impacts on their wellbeing. Last but importantly, the study's social engagement measurement may not fully reflect the full operational definition of social engagement in the cognitive enrichment framework. The social engagement in the current study relied on a proxy measurement indicated by participants' couple status. Although the couple status is one of the critical aspects of social engagement in the cognitive-enrichment framework, it only captures part of various social engagement forms. In addition,

although the HRS has some comprehensive measurements of social engagement in their supplemental psychosocial questionnaire, popularly known as Leave-Behind, the current study could not fully utilize them for the following reason. The Leave-Behind invites only about 50% of the study participants who responded to core questions for the current study year and another 50% for the following year. Therefore, comprehensive social engagement data is not available for all participants across all study waves included in the current study. For these reasons, this study relies on the proxy measurement of social engagement to maintain as many participants as possible. Thus, interpretation of the role of social engagement in the results should be carefully made, acknowledging the limitation of the current social engagement measurement in the analyses.

Conclusion

The literature on the effect of Internet use on older adults' cognitive abilities has been growing steadily over the years and has suggested a positive connection between these two phenomena (Kueider et al., 2012). This study contributes to the field by analyzing a nationally representative dataset of 5,962 individuals from the HRS. If the strong associations found in this paper can be shown in future studies to be based on a causal relationship, it might imply the diffusion of digital technologies and related training for older adults may offer both individual and societal benefits. Individually, older adults may lower their risk of developing mild cognitive impairment and further ensure a better quality of life. At a societal level, providing older adults with digital devices with substantial training could be a method to provide cognitively stimulating activities and independence for older adults.

Table 2.1. *Descriptive Statistics at the baseline (the HRS 2002 wave)*

DV: Mild Cognitive Impairment (MCI) (N=5,962)	%/Mean(SD)			
Variables	Total sample	No MCI (Censored) 39.29%	MCI 60.71%	F/Chi^2
Age	71.36 (.05)	71.09 (.06)	72.76 (.14)	10.60***
Age category				
65–74	77.54%	85.93%	14.07%	78.77***
75-80	22.46%	75.75%	24.25%	
Gender				
Male	41.68%	85.58%	14.15%	15.12***
Female	58.32%	82.07%	17.93%	
Couple status				
Coupled	35.41%	85.82%	14.18%	38.96***
Not coupled	34.59%	79.53%	20.47%	
Race/Ethnicity				
White	81.00%	87.34%	12.66%	263.46***
African Americans	11.16%	65.02%	34.98%	
Latino	5.01%	72.24%	27.76%	
Others	2.83%	71.60%	28.40%	
Household income				
< $40,000	63.30%	80.07%	19.93%	95.93***
$40,000 or higher	36.70%	89.81%	10.19%	
Education level				
No high school degree	22.32%	68.69%	31.31%	297.66***
High school or equivalent	55.04%	86.48%	13.52%	
Some college or higher	22.64%	91.49%	8.51%	
Regular computer & Internet				

use				
Yes	25.65%	92.54%	7.46%	119.01***
No	74.35%	80.58%	19.42%	
Self-rated health				
Fair to very poor	24.29%	75.62%	24.38%	90.30***
Good to excellent	75.71%	86.22%	13.78%	
ADL				
Have 1 or more difficulties	12.18%	76.45%	23.55%	31.32***
None	87.82%	84.64%	15.36%	
IADL				
Have 1 or more difficulties	4.04%	68.05%	31.95%	44.66***
None	95.96%	84.30%	15.70%	
Cardiovascular disease				
Yes	26.70%	83.87%	16.83%	0.36
No	73.30%	83.82%	16.18%	
Diabetes				
Yes	18.10%	79.05%	20.95%	20.30***
No	81.90%	84.66%	15.34%	
Depression				
Yes	14.83%	73.08%	26.92%	84.76***
No	85.17%	85.49%	14.51%	
Regular physical activities/exercise				
Yes	44.67%	85.43%	14.57%	11.19**
No	55.33%	82.21%	17.79%	

*** $p<.001$., ** $p<.01$., * $p<.05$. *Abbreviations*: DV, dependent variable; ADL, activities of daily living; IADL, instrumental activities of daily living.

Figure 2.1. Kaplan-Meier Survival Estimation

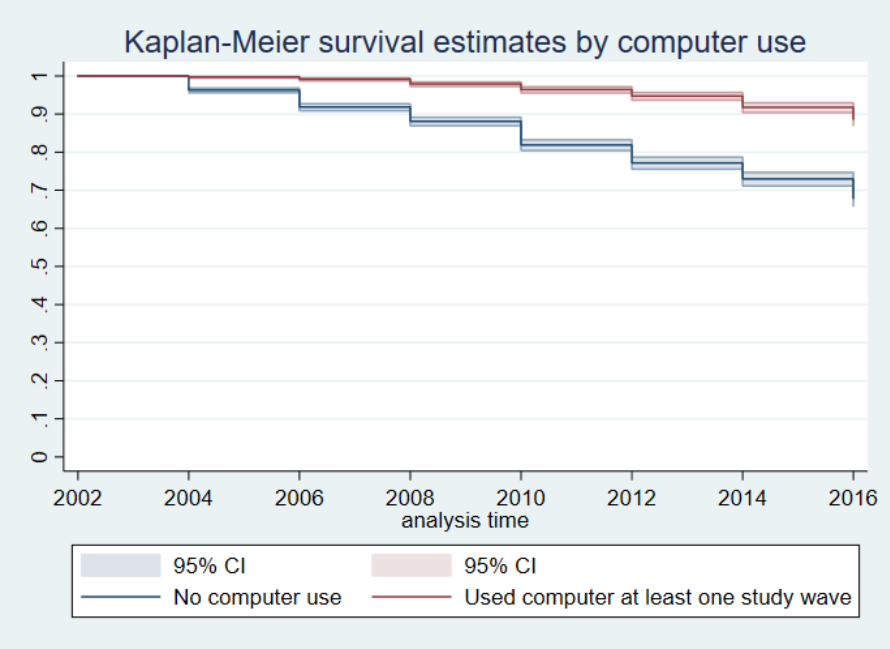


Table 2.2. *Logit discrete-time hazards models for predicting mild cognitive impairment*

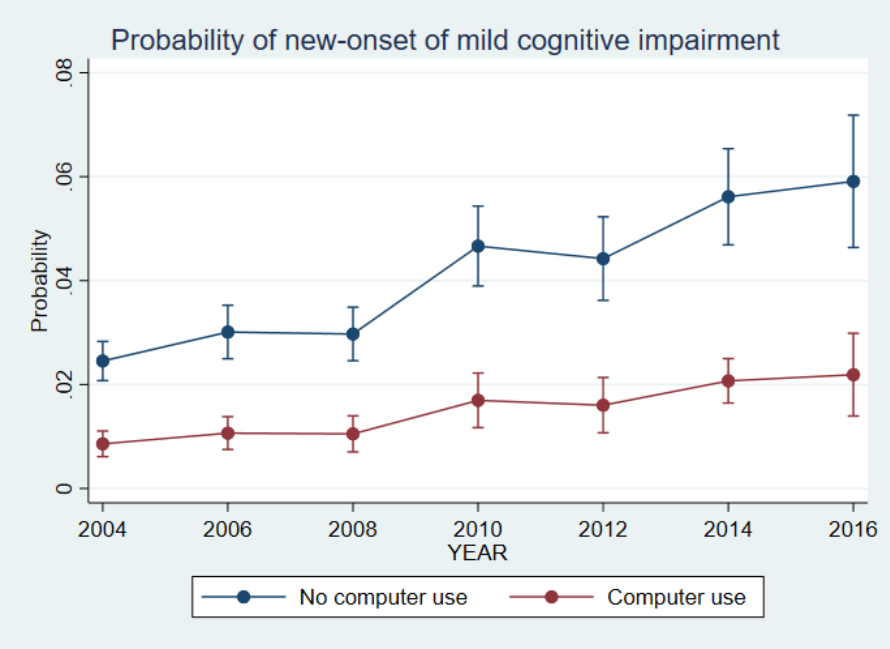
DV=Mild Cognitive Impairment	**Model 1**	**Model 2**	**Model 3**	**Model 4**
N=5,962	**HR [95% CI]**	**HR [95% CI]**	**HR [95% CI]**	**HR [95% CI]**
Focal variables				
Regular Internet use in the *j-2* wave (ref: no)				
Yes	.32*** [.25, .43]	.33*** [.25, .43]	.33*** [.25, .43]	.33*** [.25, .43]
Regular physical activities/exercise in the *j-2* wave (ref: no)				
Yes	-	.76* [.61, .95]	.76* [.62, .96]	.77* [.62, .96]
Depressive mood in the *j-2* wave (ref: no)				
Yes	-	-	1.53*** [1.30, 1.80]	1.53*** [1.30, 1.80]
Couple status (ref: no) in the *j-2* wave				
Yes	-	-	-	1.04 [.89, 1.21]
Demographic factors (time-invariant)				
Gender (ref: male)				
Female	1.08 [.95, 1.23]	1.06 [.93, 1.20]	1.03 [.91, 1.17]	1.05 [.91, 1.21]
Age (ref: 75 or older in 2000)				
65 – 74 in 2000	2.18*** [1.86, 2.56]	2.16*** [1.84, 2.53]	2.21*** [1.88, 2.59]	2.22*** [1.90, 2.59]
Race & Ethnicity (ref: non-Hispanic white)				
African Americans	2.69*** [2.23, 3.26]	2.70*** [2.23, 3.26]	2.65*** [2.20, 3.19]	2.66*** [2.21, 3.20]
Hispanic ethnicity	1.63** [1.18, 2.24]	1.63** [1.18, 2.25]	1.57** [1.13, 2.17]	1.56** [1.12, 2.17]
Others	1.76*** [1.29, 2.39]	1.76*** [1.30, 2.38]	1.72** [1.27, 2.32]	1.72** [1.28, 2.32]
Education level (ref: no high school)				

High school or equivalent	.50*** [.41, .61]	.50*** [.41, .61]	.51*** [.42, .62]	.51*** [.42, .62]
Some college or higher	.42*** [.33, .54]	.43*** [.34, .55]	.44*** [.35, .56]	.44*** [.35, .56]
Covariates (time-variant)				
Household income (ref: less than $40,000)				
Income equal to or more than $40,000	.79* [.63, .98]	.79* [.64, .99]	.81 [.65, 1.02]	.80 [.64, 1.01]
Self-rated health (ref: good to excellent)				
Poor to Fair	.84* [.71, .98]	.85 [.73, 1.00]	.89 [.76, 1.04]	.89 [.76, 1.04]
ADL (ref: no ADL condition)				
1 or more ADL condition	1.21* [1.01, 1.46]	1.18 [.99, 1.42]	1.16 [.96, 1.39]	1.16 [.96, 1.40]
IADL (ref: no IADL condition)				
1 or more IADL condition	4.47*** [3.65, 5.47]	4.45*** [3.64, 5.45]	4.29*** [3.51, 5.23]	4.29*** [3.51, 5.23]
Cardiovascular disease (ref: no)				
Yes	.92 [.74, 1.13]	.92 [.74, 1.13]	.90 [.73, 1.11]	.90 [.73, 1.11]
Diabetes (ref: no)				
Yes	.98 [.81, 1.19]	.97 [.80, 1.18]	.98 [.81, 1.18]	.98 [.81, 1.18]
Discrete-time dummies				
Study wave (ref: 2004 wave)				
2006 wave	1.28 [.99, 1.63]	1.23 [.96, 1.57]	1.27 [.97, 1.59]	1.24 [.97, 1.59]
2008 wave	1.25 [.96, 1.63]	1.21 [.92, 1.58]	1.22 [.93, 1.60]	1.23 [.94, 1.60]
2010 wave	2.01*** [1.57, 2.59]	1.93*** [1.51, 2.47]	2.02*** [1.58, 2.58]	2.03*** [1.59, 2.58]
2012 wave	1.88*** [1.39, 2.55]	1.82*** [1.34, 2.46]	1.90*** [1.39, 2.59]	1.91*** [1.41, 2.58]

2014 wave	2.46*** [1.96, 3.09]	2.38*** [1.89, 2.98]	2.49*** [1.99, 3.12]	2.51*** [2.00, 3.14]
2016 wave	2.61*** [1.91, 3.56]	2.53*** [1.85, 3.44]	2.64*** [1.93, 3.62]	2.66*** [1.94, 3.64]

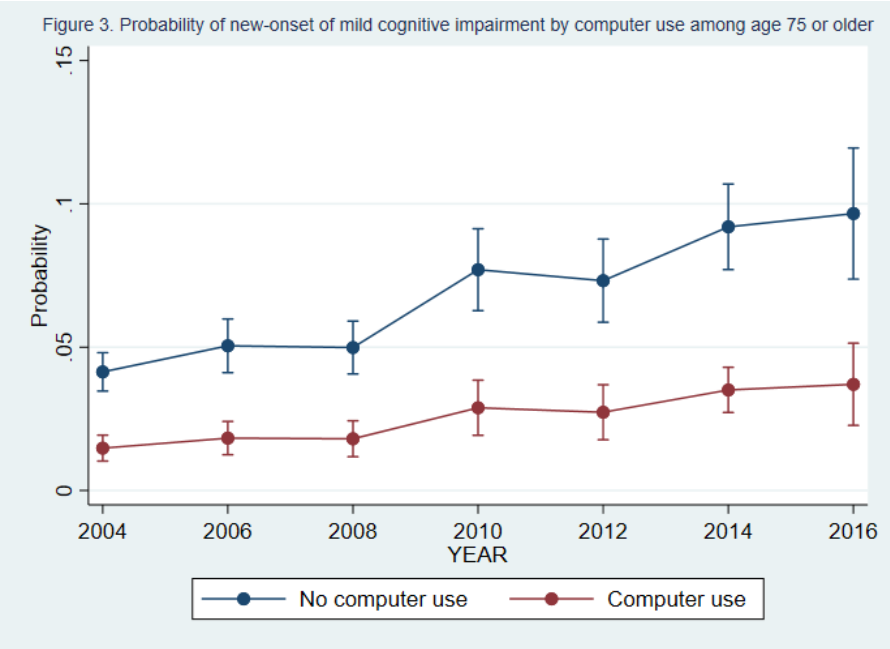
*** $p<.001$., ** $p<.01$., * $p<.05$. *Abbreviations*: HR, Hazard Ratio; CI, confidence interval; ADL, activities of daily living; IADL, instrumental activities of daily living.

Figure 2.2. Probability of new-onset of mild cognitive impairment by computer use



Note: To estimate the probability shown in the figure 2, mean values used for all continuous variables, while other categorical variables took the most frequent category (i.e., non-Hispanic white as a race/ethnic category).

Figure 2.3. *Probability of new-onset of mild cognitive impairment by computer use among age 75 or older*



Note: To estimate the probability shown in the figure 2, mean values used for all continuous variables, while other categorical variables took the most frequent category (i.e., non-Hispanic white as a race/ethnic category).

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PAPER 3: OLDER ADULTS' SOCIAL NETWORK SERVICES USE FOR SOCIAL CONTACT AND LONELINESS: THE MEDIATING ROLE OF SOCIAL SUPPORT AND DISPOSITIONAL OPTIMISM

Loneliness refers to a subjectively perceived status of being disconnected from significant others (Cacioppo, Grippo, London, Goossens, & Cacioppo, 2015), indicating the psychological contradiction between expected and actual quality of social relationships (Sum, Mathews, Hughes, & Campbell, 2008). Older adults are at higher risk of experiencing loneliness than other age groups for a variety of reasons (Savikko, Routasalo, Tilvis, Strandberg, & Pitkälä, 2005), such as loss of intimate relationships (i.e., death of a spouse, Carr, Kail, Matz-Costa, & Shavit, 2018), relocation (i.e., moving to a retirement home or being placed at a long-term care facility; O'Hora & Roberto, 2019), limited physical health (i.e., difficulties in activities of daily living; De Koning, Stathi, & Richards, 2017), and various psychosocial factors (i.e., less motivation to make new relationships; Cohen-Mansfield & Parpura-Gill, 2007). Furthermore, research has long reported that experiencing loneliness has negative impacts on psychological wellbeing (i.e., life satisfaction; Chopik, 2016), mental health (i.e., depression, cognitive decline; Singh & Misra, 2009), physical health (i.e., high blood pressure; Luanaigh & Lawlor, 2008; Ong et al., 2016), and even premature death (Trad, Wharam, & Druss, 2020). With a rapidly aging population, mitigating or preventing loneliness among older adults has become a vital public health issue (Sepúlveda-Loyola et al., 2020).

Among protective factors of loneliness, perceived social support has been regarded as a crucial factor associated with lower levels of loneliness among older adults (Jackson, Soderlind, & Weiss, 2000). Although the association between social support and loneliness has a long research history in gerontology, the relationship has received greater attention with the advancement of digital technology—particularly online communication and its potential to

enhance social support. (Cotten, Anderson, & McCullough, 2013). Of particular focus has been social networking services (SNS), with their potential to assist older adults in staying socially and emotionally connected, providing better social support by assisting the users in staying connected with others (Casanova, Zaccaria, Rolandi, & Guaita, 2021). An increasing number of older adults have adopted the digital technology as part of their daily communication tools, including SNS. SNS refers to online services that enable interactions between people online, including such popular platforms as Skype, Facebook, Twitter, and Instagram. According to Pew Research Center (2021), about 45% of Americans aged 65 and older used SNS in 2021, while the usage rates were generally higher among younger age groups (i.e., 73% between ages 50 and 64; 81% between ages 30 and 49; 84% between ages 18 and 29). Furthermore, because many social events have moved online since the onset of the COVID-19 pandemic, the role of SNS has become more critical than ever (Hajek & König, 2021).

Yet, findings on the impact of the use of SNS on loneliness have been inconclusive. While some studies found that people who regularly used SNS were less likely to feel lonely (Heo, Chun, Lee, Lee, & Kim, 2015; Szabo, Allen, Stephens, & Alpass, 2019), others have found the opposite—SNS use and loneliness might be positively associated (Kim, LaRose, & Peng, 2009; Turkle, 2017). Such different results may be attributed to the measurement issues presented. Some studies only asked whether or not the participants used SNS, while others measured the frequency of SNS use (i.e., how many times one uses SNS per week). On the other hand, some studies did not differentiate specific purposes of SNS use (e.g., communicating with others, entertainment). The SNS use may have different effects depending on its usage and primary purpose. For instance, the use of SNS might be negatively associated with psychological health when the primary purpose is entertainment or if one uses it too excessively (Erickson,

2011; Shakya & Christakis, 2017). On the other hand, SNS use has been found to be positively related to users' psychological wellbeing and mitigating social isolation when the primary purpose is social communication (Zhang, Kim, Silverstein, Song, & Burr, 2020). Therefore, it is crucial to differentiate the purpose of SNS use as well as its frequency to better understand the impacts of older adults' SNS use on their wellbeing.

While many studies attempted to examine the association between SNS use and loneliness, relatively little attention has been paid to the role of personality traits. Since loneliness is a subjective perception affected by personal and environmental factors (J. T. Cacioppo & Cacioppo, 2018), understanding the role of personality on the association between SNS use and loneliness can provide a better understanding of the role of SNS as a social communication tool. Dispositional optimism is an important predictor of a decrease in loneliness (Rius-Ottenheim et al., 2012) and is also known as a buffer of potential negative effects of SNS use (Liu et al., 2017). For instance, some SNS users often compared their social statuses with those of others exhibited on SNS, and such behaviors might be negatively associated with self-esteem (Krause, Baum, Baumann, & Krasnova, 2021). A study report that if an SNS user is pessimistic about his or her own life, the user was more likely to compare his or her life with that of others on SNS and would tend to think that other people's lives are comparatively better, eventually yielding a negative self-perception and further depressive symptoms (Liu et al., 2017). Since there has been a shortage of evidence in how different personalities among older adults might affect their SNS use and its outcome, it is important to examine the role of personality traits.

The current study draws upon prior studies and investigates the literature with advanced evidence on the relationship between SNS use and loneliness, using a measure to capture the

frequency of SNS use among older adults, specifically to communicate with their children, family, and friends. The present study also examines the association between SNS use for social communication, loneliness among older people, and the mediating effects of perceived social support and dispositional optimism, employing data from the Health and Retirement Study 2018 wave. This study's results have implications for policy and practice in using SNS to mitigate loneliness among older adults.

Literature Review

The current study aims to explore possible underlying mechanisms of the association between loneliness and SNS through perceived social support and dispositional optimism as mediating factors. Given the complexity of the focal research question, the study reviews various psychosocial theories. The study then reviews the empirical studies that employed the theories in the previous review stage and selects the most pertinent frameworks well supported by empirical evidence. Finally, the present study employs theories that could provide rationales for the operationalization of focal variables and formulates hypotheses to examine the essential associations shown in Figure 3.1.

(Figure 3.1 around here)

Social support and Social Network Services

Social support refers to the cognitive appraisal of being reliably connected to others (Cobb, 1976). Specifically, perceived social support comes from self-evaluations of accumulated social interactions and their qualities in terms of emotional support, instrumental aid, or mutually exchanged information (Rini & Dunkel Schetter, 2010). Literature has shown that a higher level of perceived social support is associated with positive psychological health outcomes (Newsom,

Nishishiba, Morgan, & Rook, 2003; Newsom, Rook, Nishishiba, Sorkin, & Mahan, 2005). On the other hand, the range of health outcomes that could be affected by social support is extensive, including depression, psychological distress, cancer, and others (Burleson, 2003).

Social capital theory. The association between communication and social support via SNS could be better understood by two core concepts in social capital theory: bonding social capital and bridging social capital. Bonding social capital refers to psychosocial support provided by social networks with closely tied people such as family members or intimate friends. In addition, bridging social capital indicates social relationships with a broader array of people with relatively weak social ties (Claridge, 2018). With bridging social capital, older adults might receive more up-to-date information about surrounding environments. For instance, SNS might help older adults keep updated with their family's current situation or life events and close friends and promote their sense of belonging (Lee, Noh, & Koo, 2013). SNS might also help older adults maintain broader relationships with their neighbors and communities, reducing their sense of isolation (Heo et al., 2015). In line with the theory and empirical findings, the current study posits that by using SNS for communicating with their family, children, and friends, older adults have a higher level of perceived support, yielding a lower level of loneliness.

Loneliness and Social Networking Services

Need to belong theory. The need to belong theory (Baumeister & Leary, 1995) claims that all human beings have an intrinsic need to pursue stable and positive interpersonal relationships. When this need is met, human beings develop a higher level of perceived psychological wellbeing, such as an optimistic attitude toward life. On the other hand, when the need is unsatisfied, the internal psychological rewarding mechanism might send signs of deficiency to one's brain, resulting in a negative perception of life such as loneliness, pessimism,

and low level of self-esteem (Baumeister, 2011). The theory also assumes that the sense of belonging might be greater through intimate relationships than casual social networks (Gere & MacDonald, 2010). Research reveals the potential of SNS to positively stimulate the brain's reward system and yield a better perception of subjective wellbeing (Meshi, Morawetz, & Heekeren, 2013). Several studies provide empirical evidence to support the theory. Older adults who communicate with family and friends via SNS tend to maintain social networks better and have a higher level of emotional support, reducing loneliness, than those who do not use SNS (Heo et al., 2015; Szabo et al., 2019; Williams & Lewis, 2009).

Dispositional optimism. Dispositional optimism refers to a stable personality trait and a generalized tendency toward positive outcome expectations, life engagement, and future orientation (Scheier et al. 1994). Dispositional optimism is one of the critical psychological traits that is negatively associated with loneliness (Rius-Ottenheim et al., 2012) and is also known as a protective factor against potential adverse effects of SNS use, such as upward comparison (Liu et al., 2017). Studies suggest that dispositional optimism may lead to a better social embedding and protect against loneliness. Higher optimism leads to a more positive appraisal of the existing social network or active pursuit of new social relationships to cope with adversities (Carver et al., 2010). In contrast, those with low levels of dispositional optimism are likely to experience loneliness over time (Jackson et al. 2000). Recent studies show that dispositional optimism might be a protective factor of possible negative impacts of the SNS use, such as upward social comparison, while increasing positive impacts of the SNS, such as enhanced perceived social support (Liu et al., 2017).

The mediating mechanism through social support and optimism. Although there is no single comprehensive framework that thoroughly explains the potential mediating effects of

social support and optimism, empirical evidence and theories reviewed in the present study could provide a reasonable conceptual model. Taken focal assumptions from the social capital theory and dispositional optimism perspective, the present study constructed the mediating mechanism of social support and dispositional optimism in the association between SNS use and loneliness. In brief, the current study posits that older adults' SNS use for communications with their family, children, and friends might be associated with a lower level of loneliness, mediated by perceived social support. In addition, dispositional optimism might associate with a more frequent SNS use among older adults, a higher level of perceived social support, and a decrease in loneliness. Figure 3.1 depicts the mediation mechanism through social support and optimism within the association between SNS use and loneliness.

Research questions and hypotheses

Drawing on the theories and supported by the relevant evidence, the current study examines the following research questions and hypotheses:

Research question 1: Is older adults' use of SNS negatively associated with the users' perception of loneliness?

Hypothesis 1: SNS use is negatively related to users' loneliness. Specifically, a higher level of the SNS use is associated with a lower level of loneliness.

Research question 2: What is the role of perceived social support in the association between older adults' SNS use and perception of loneliness?

Hypothesis 2: Perceived social support mediates the association between older adults' SNS use and loneliness.

Research question 3: What is the role of older adults' optimism on their use of SNS?

Hypothesis 3: Dispositional optimism is positively associated with older adults' SNS use. Specifically, a higher level of optimism is associated with a higher level of SNS use.

Research question 4: Is older adults' optimism negatively related to their loneliness?

Hypothesis 4: Dispositional optimism is negatively associated with older adults' loneliness. Specifically, a higher level of optimism is associated with a lower level of loneliness.

Methods

Sample

Data are from the Health and Retirement Study (HRS), a nationally representative panel survey study of community-dwelling Americans older than 50 years, conducted every two years since 1992 (Sonnega et al., 2014). Since 2006, the HRS asked a random subsample of 50% of participants to complete a self-administered Psychological and lifestyle questionnaire popularly known as "Leave-Behind." The Leave-Behind questionnaire includes various psychosocial indicators to measure participants' subjective well-being, social relationships, personality, lifestyles, and beliefs (Smith et al., 2017). Focal variables for this study are loneliness, Social Network Service (SNS) use, perceived social support, and optimism. The study excluded proxy interview cases, participants who were not community-dwelling and younger than 50, yielding a working sample size of 3,380 participants.

Measures

Loneliness. Loneliness was measured with an 11-item revised version of the UCLA Loneliness Scale (Russell, 1996). Participants were asked to rate how often they had the following seven positive feelings: (a) in tune with the people around you, (b) there are people you can talk to, (c) there are people you can turn to, (d) there are people who really understand you, (e) there are people you feel close to, (f) part of a group of friends, and (g) have a lot in

common with the people around you, as well as four negative feelings: (h) lack companionship, (i) being left out, (j) being isolated from others, and (k) feeling alone. The responses (1 = hardly ever or never, 2 = some of the time, and 3 = often; positive feelings were reverse-coded) were averaged to create the Loneliness Scale (range = 1–3; α = .88 for current wave); higher scores indicated higher levels of loneliness.

Social Network Services (SNS) use. SNS use communication was measured with an indicator of the frequency of communicating with children, other family members, and friends using such platforms as Skype, Facebook, or other social media. Responses were rated from 1 (hardly ever) to 6 (three or more times a week), and an average score was calculated from responses to these three social relationship types (range = 1–6; α = .87). The higher the score, the more frequent the social media communication with close social ties.

Perceived social support. Perceived social support operationalized with an index based on the average ratings of three questions across three social relationship types, children, other family members, and friends (total of nine items). The three questions were: "How much do they really understand the way you feel about things?", "How much can you rely on them if you have a serious problem?" and "How much can you open up to them if you need to talk about your worries?" The responses to these questions were rated from 1 (not at all) to 4 (a lot). An average score was first created for each relationship, and the overall perceived social support measure was calculated by averaging the scores of the three relationship types, with higher scores representing higher levels of perceived social support from social ties (range = 1–4; α = .82).

Optimism. Optimism was measured with the self-report six-item Life Orientation Test-Revised (LOT-R; Scheier et al., 1994). The LOT-R is a widely used measure of subjectively perceived optimism with good validity and reliability (Scheier et al., 1994; α = .76 in this study).

Participants used a 6-point Likert-type scale (1 = strongly disagree, 6 = strongly agree) to indicate the extent to which they agreed with six items such as "If something will go wrong for me, it will" (reverse-coded). Three items were reversed-scored, and responses were averaged (possible range: 1–6). Higher scores indicate greater optimism.

Analytical Strategies

Path models were estimated within a structure equation modeling to assess the relationship between older adults' SNS use and loneliness, as well as the mediation effects of social support and dispositional optimism. A two-step modeling procedure of the mediation effects with focal variables was employed to ensure good fits for both measurement and structural models. For the first step, each measurement model was examined to confirm each measurement model was well-represented by its indicators. In the second step, if each measurement model was satisfactory in terms of the goodness of the fit, the structural equation model would be tested by the maximum likelihood estimation method in STATA 15.1. The current study employed four goodness-of-fit indices widely used (Kline, 2015): (1) chi-square statistics; (2) Root Mean Square Error of Approximation (RMSEA); (3) Comparative Fit Index (CFI); (4) Standardized Root Mean Square Residual (SRMR). All analyses included socioeconomic variables as control variables: age, gender, marital status, race/ethnicity, education, and income. Confidence intervals for the estimates of the mediating effects were calculated through 1,000 bootstrap samples (MacKinnon, Lockwood, & Williams, 2004).

Results

Descriptive Statistics and Correlation Analysis

Table 3.1 presents the descriptive statistics for all variables including demographic factors and socioeconomic indicators. The bivariate correlations are shown in Table 3.2 SNS use was negatively correlated with loneliness ($r = -0.11$, $p < .001$) and positively correlated with social support ($r = 0.14$, $p < .001$) and dispositional optimism ($r = 0.03$, $p < .05$). Social support was positively correlated with dispositional optimism ($r = 0.10$, $p < .001$), and negatively correlated with loneliness ($r = -0.26$, $p < .001$). Dispositional optimism was negatively correlated with loneliness ($r = -0.36$, $p < .001$).

(Table 3.1 and 3.2 around here)

Testing for Mediated Association

Measurement model. Confirmatory factor analyses were conducted for focal variables (SNS use, social support, dispositional optimism, and loneliness) to test the goodness-of-fit of each measurement model. All factor loadings for the indicators on the focal variables were significant ($p < .001$).

Structural model. The direct path coefficient from SNS use to loneliness was significant ($\beta = -0.26$, $p < 0.01$). A mediated model (Model 1) fitted to the data. While most of the goodness of fit indices indicate good model fit, the chi-squared test was statistically significant, indicating a possibility of poor model fit (chi-squared: 563.86, RMSEA = 0.79, SRMR = 0.74, CFI = 0.97). In addition, the path coefficient from the SNS use to loneliness was not significant. Therefore, the path were removed and, the modified model (Model 2) was tested. Compared to Model 1, Model 2 also fitted well with the data except the chi-squared test (chi-squared: 559.71, RMSEA

= 0.78, SRMR = 0.78, CFI = 0.98). The log-likelihood test result was insignificant (p>.05) which indicates no significant difference between Model 1 and Model 2.

(Figure 3.2 around here)

The current study took Model 2 as the final model (see Figure. 3.2). The standardized parameter estimates for the main paths are displayed in Figure 2: First, frequent SNS use was associated with higher levels of social support (β = 0.26, p < .001). Second, higher perceived social support was associated with lower levels of loneliness (β = -0.40, p < .001). Third, higher dispositional optimism was associated with higher levels of SNS use (β = .04, p < .05). Fourth, dispositional optimism was associated with lower levels of loneliness (β = −0.30, p < .001). To test the indirect effects, the bootstrap procedure was used. The indirect effect of SNS use on loneliness mediated by social support was estimated at -.02 (p<.001), as illustrated in Table 3.3. Dispositional optimism's indirect effect on social support via the SNS use was -.002 (p<.05). The indirect effect of dispositional optimism on loneliness via social support was -.02 (p<.001).

(Table 3.3 around here)

Discussion

This study developed a structural equation model that drew on a comprehensive framework with relevant theories and empirical evidence to examine the relationship between older Americans' SNS use and loneliness and the mediating role of social support and dispositional optimism, using a nationally representative sample of Americans aged 50 and older.

A statistically significant association was found between more frequent SNS use to maintain social networks with family, children, and friends and a lower level of subjectively perceived loneliness. While the study found a positive association between SNS use and social support, the results also indicate that older adults with an optimistic attitude toward life may be more likely to use SNS more frequently than those who have pessimistic outlooks in line with the dispositional optimism perspective (Scheier et al., 1994).

SNS Use and Loneliness

A key finding of this study is the role of older adults' use of SNS on experiencing loneliness. Frequent SNS use of older adults was negatively associated with perceived loneliness. Thus, the finding supports hypothesis 1, which is consistent with the existing literature on the impact of SNS use on psychosocial adaptation in line with the need-to-belong theory (Meshi, Morawetz, & Heekeren, 2013).

Since social communication mediated via the Internet tends to require reduced contextual, visual, and auditory cues, individuals who interact with others online are likely to have fewer inhibitions in self-disclosing (Walther, 1996). Consequently, online communication might appear more intimate than conventional offline communication to users. In line with this argument, studies showed that online communication might be positively associated with higher self-disclosure levels, enhancing the users' perceived level of psychological wellbeing. (Deters & Mehl, 2013; Tidwell & Walther, 2002). In this context, SNS and other digital social media might be considered more accessible communication tools for individuals with difficulties in interpersonal skills.

It could also support communication for those who have difficulties with social activities offline due to limited mobility or physical health (Kraut et al., 2010). Given the evidence on

barriers to communication that many older adults are likely to have (Savikko, Routasalo, Tilvis, Strandberg, & Pitkälä, 2005), online-based social communication tools might provide older adults with more accessible tools to maintain social networks.

The Mediating Effect of Social Support

The results show that older adults' SNS use was positively associated with social support. Social support further mediated the relationship between SNS use and loneliness. Therefore, the study supports hypothesis 2, in line with the assumptions on the benefits of interpersonal communication to acquiring social capital (Canary et al., 1993; Coleman., 1988; Crocker and Canevello., 2008). With the perspective from social capital theory, the result indicates that SNS use might help older adults gain more social interactions (Mehdizadeh, 2010) and maintain social relationships (Canary et al., 1993), and accumulated bonding capitals from the social interactions and relationships provide older adults with increased level of perceive social support. The finding is also in line with previous research indicating that social support is a protective factor against loneliness (Jackson et al. 2002; Kong and You 2013; Perlman and Peplau 1981; Zhao et al. 2013).

Dispositional Optimism, SNS Use, Loneliness

The association between dispositional optimism and older adults' SNS use and self-esteem was significant. The result supports the focal idea of dispositional optimism put forth by Scheier, Carver, & Bridges (1994) that individuals who are optimistic about their lives were more likely to interact with others and actively engaging in social networks. Therefore, hypothesis 3 was supported. Additionally, dispositional optimism was negatively associated with loneliness, supporting hypothesis 4. Those results might provide important implications for practices designed to educate older adults with digital technology. While there have been active

discussions on how to deploy digital technology to older adults (Neves & Mead, 2020) as well as activities to help older adult population to learn and use the technology led by charitable organizations, such as Older Adults Technology Services (OATS), more policy supports are needed to boost impacts of such efforts (Huber & Watson, 2014). Since older adults generally have been digitally marginalized (Gatto & Tak, 2008), digital education programs for older adults must carefully consider how learning new communication methods would be viewed by them (Goodwin, 2013; Huber & Watson, 2014). In addition, an optimistic attitude toward one's life could buffer possible negative impacts from the SNS use, particularly from the tendency of upward social comparison (Liu et al., 2017). Future research might need to examine the role of social comparison orientation in older adults' SNS use and the role of optimism as a protective factor.

Nevertheless, the results do not indicate SNS use is beneficial only for older adults with relatively higher optimism. As shown in the structural equation model, the SNS use was positively associated with perceived social support and negatively related to loneliness while the paths coefficients through dispositional optimism were significant. Therefore, the results imply that using SNS could be an effective tool for mitigating older adults' loneliness while its impact might be greater among individuals with higher optimism.

Limitations

The study has several limitations. First, although this research's conceptual model was proposed based on empirical evidence and relevant theoretical models, no causal relationship between variables can be inferred due to the data's cross-sectional nature. Therefore, the study suggests that future studies need to employ experimental designs or longitudinal data to understand further the associations between SNS use, social support, dispositional optimism, and

loneliness. Second, despite the path model using structural equation modeling techniques built on comprehensive framework based on valid theories, one of the goodness of fit indicator (chi-squared: 563.86) indicates possibly poor fit of the model.

Conclusion and Implications

Despite the limitations, the current research has some important contributions to the literature. By testing the mediating roles of social support between SNS use specifically for contacting social networks and loneliness, this study contributes to the literature by adding evidence on how SNS use might mitigate the users' loneliness. In addition, the study examined what personality traits could affect the usage of SNS.

This research offers several suggestions for policymakers and practitioners. First, the finding that SNS and other social media are negatively associated with loneliness in older adults indicates that longitudinal research to establish causality is worthwhile as it may have implications for interventions that promote SNS. Specifically, SNS could be a viable option that promotes social networking of older adults with substantial strains, both mentally and physically, to interact with others offline (van Ingen, Rains, & Wright, 2017). Second, however, practitioners must be aware that attitudes toward digital technology and willingness to self-disclose vary by individuals, and thus the development of digital educations for older adults needs to carefully take account into personality traits (Cornejo, Weibel, Tentori, & Favela, 2015). Third, digital literacy training designed for older adults might be more beneficial if they introduce essential skills to utilize various social communication tools. Fourth, social media's benefits can be maximized when all society members have primary resources to go online.

During the COVID-19 pandemic, in-person social networking among older adults was particularly limited while they were already regarded as a population group marginalized in

digital social communication (Seifert, 2020). The situation that digital social communications have become a mainstream of social participation due to the COVID-19 might have the potential to exacerbate ageism, in which older adults who do not use social media could be viewed as lagged, in addition to the prevailing view of older adults as frail and physically isolated during the pandemic (Seifert, Cotten, & Xie, 2021). In the social context in which inclusion now includes active participation in the digital world, older adults who did not embrace the digital lifestyle, particularly those who did not have opportunities to learn online skills as part of their daily life, are at a high risk of exclusion (McDonough, 2016). Moreover, it is well reported that Internet use among older adults is influenced by various factors, such as age, gender, education, income, and health (Anderson, Perrin, Jiang, & Kumar, 2019; König, Seifert, & Doh, 2018). In this context, the digital divide among older adults needs to be seen as a multidimensional digital inequality that carefully considers the lack of resources to go online, proper usage, digital skills, social support, and self-perception across socioeconomically different older adults groups (DiMaggio, Hargittai, Celeste, & Shafer, 2004).

Taken together, the findings from this study imply that lack of primary resources and skills to participate in online social communication actively could yield inequalities in social support from online social networks and further negative self-perception (i.e., loneliness) among older adults. Therefore, policymakers should develop a comprehensive approach to address and prevent such problems in three ways: effective and efficient digital technology deployment, enhancing basic digital skills to navigate Internet with accessible training, and raising public awareness of the need for digital literacy among older adults.

Table 3.1. *Descriptive statistics*

Variables	Mean/%	SD	Range
Predictor			
Social Network Service Use	2.76	1.69	1-6
Mediators			
Social support	3.04	.47	1-4
Dispositional optimism	4.62	1.09	1-6
Outcome			
Loneliness	1.42	.50	1-3
Covariates			
Age	67.79	10.27	50-102
Female, %	59.23%	-	-
Race, %			
Non-Hispanic White	67.66%		
Non-Hispanic Black	16.12%		
Non-Hispanic other	7.10%		
Hispanic	9.11%		
Income	90681.50	171047.5	0-3316800
Marital status			
Married	72.93%		
Divorced	10.31%		
Widowed	14.28%		
Never Married	2.49%		

Table 3.2. *Correlations of the variables*

Variables	1	2	3	4
Social Network Service Use	-			
Social support	0.14***	-		
Dispositional optimism	0.03*	0.09***		
Loneliness	-0.11***	-0.26***	-0.36***	-

***$p < .001$. *$p < .05$.

Table 3.3. *Indirect effects*

Variables	Estimate	[95% CI]
SNSs → Social Support → Loneliness	-.02***	[-.01, -.03]
Dispositional optimism → SNSs → Social support	-.002*	[-.001, -.003]
Dispositional optimism → SNSs → Loneliness	-.02***	[-.01, -.03]

Notes. Confidence intervals (CIs) for direct and indirect effects were estimated using bootstrapping. Path parameters are standardized coefficients. ***$p < .001$. *$p < .05$.

Figure 3.1. Conceptual model for the association between SNS use and loneliness

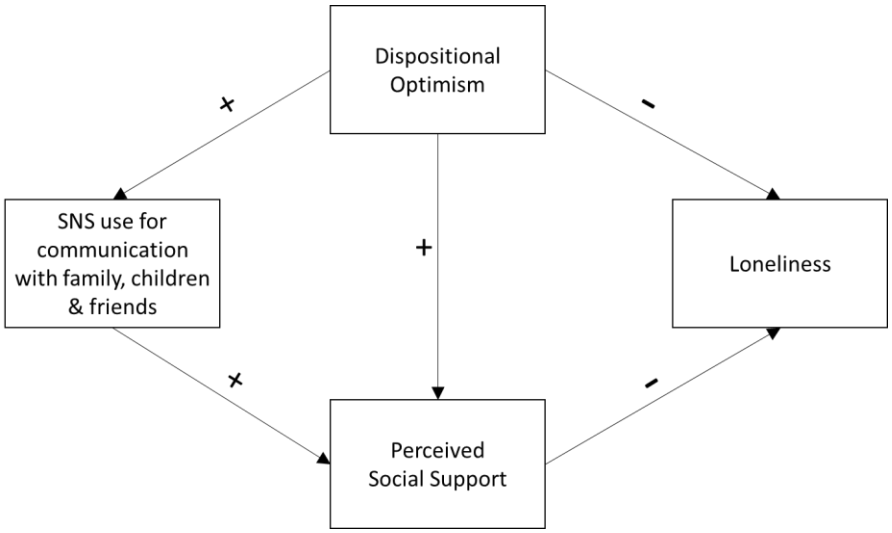
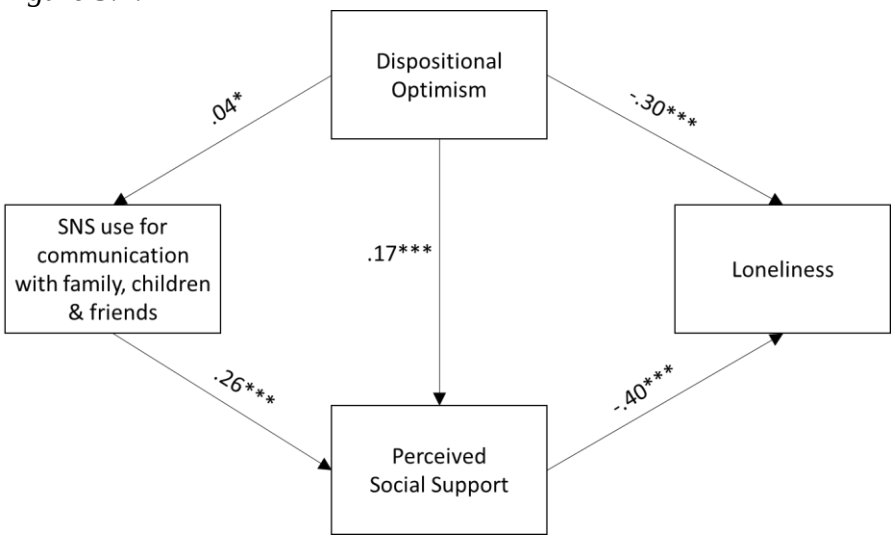


Figure 3.2. Final Path Model and Direct Coefficient



***$p < .001$. *$p < .05$.

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CONCLUSION

This dissertation sought a better understanding of the determinants of the digital divide among older adults and its implications on their health and subjective wellbeing by analyzing data from the HRS, population-representative data of adult Americans aged 50 or older. Drawing on the research and theoretical frameworks used in this dissertation, I began by exploring factors associated with the digital divide among older Americans, focusing on the role of negative self-perception of aging. The first paper contributes to the literature by providing a novel finding that negative self-perception of aging might be associated with Internet use. Based on the implications from the first paper, paper two streched its scope to investigate the impact of the digital divide on health among older adults, by examining the association between regular computer use and the likelihood of new-onset MCI among older adults. Lastly, paper three examined the relationship between the digital divide and older adults' subjective wellbeing, focusing on the role of online social communication. The summary of each paper is provided as follows.

Summary of Findings

The paper one's primary purpose was to investigate the role of negative stereotypes assimilated from surrounding cultures, such as ageism, on older adults' Internet use. The study examined the association between negative perception of aging and older adults' regular Internet use with the synthesized conceptual framework based on resources and appropriation theory and stereotype embodiment theory. Results from logistic regression using the HRS 2016 data indicated that the higher level of the self-perceived negative perception of aging was associated with no regular internet. Paper one also supported most of the critical arguments from the resources and appropriation theory that inequalities in positional (e.g., income, education level)

and personal (e.g., age, gender, race/ethnicity) inequalities might negatively affect Internet use of older adults, indicating the digital divide is a matter of social justice.

Based on the social justice implications from paper one, paper two examined the association between older adults' regular computer use and the likelihood of new-onset mild cognitive impairment (MCI), employing survival analysis techniques with longitudinal data from the HRS waves from 2002 to 2016. Following the core arguments from the cognitive enrichment perspective, the paper posited that regular computer use could be a mentally stimulating activity and might affect preserving or stimulating older adults' cognition. The results showed that regular computer use during the prior study year might be negatively associated with the likelihood of new-onset MCI in the current study year. In addition, older adults who were socioeconomically marginalized, who did not regularly exercise, and had depressive moods were more likely to develop MCI, supporting other core arguments from the cognitive enrichmant perspective.

Last but importantly, paper three investigated the potential benefits of Internet use for older adults, focusing on its function as a social communication tool. The study examined the relationship between older adults' social network service (SNS, i.e., Facebook, Skype, and Twitter) use and loneliness, mediated by perceived social support and dispositional optimism on the association. Paper three employed path analysis using the structural equation modeling technique to examine hypotheses from the conceptual framework based on social capital theory, the need to belong theory, and dispositional optimism perspective. The study found that that older adults' internet use might be associated with decreased perception of loneliness, mediated by perceived social support. The results from the paper three indicated that an older adult who

were optimistic toward life were likely to use SNS more frequntly and percieve more social support from SNS use than those who were pessimistic.

Implications

The Digital Divide was Prevalent among Older Adults

The findings from this dissertation add a piece of evidence to the literature that the digital divide is still prevalent among older Americans. In the first paper, consistent with other surveys on Internet use (Older Adults Technology Services, 2021; Pew Research Center, 2021), about 40% of older adults indicated they did not go online in 2016. The results show that while Internet adoption reaches a saturation point among younger populations, disparities in Internet access remain in older populations (Pew Research Center, 2021). Similar to the previous research, Internet access among older adults was stratified by socioeconomic factors, such that those who are older, racial/ethnic minorities, less educated, and have lower income are less likely to be online (van Deursen & Helsper, 2015; Elliot, Mooney, Douthit, & Lynch, 2013; Selwyn, Gorard, Furlong, & Madden, 2003). The Internet access stratification among older adults indicates the digital divide already has become an issue of equity, and the gap must be closed by policy efforts.

Given the essential role of the Internet in our life, closing the digital divide has become a fundamental issue of equity and social justice—and it must be seen as such by policymakers and the public alike.

The Role of Self-Perception of Aging on Digital Technology Adoption

A unique contribution of this work to the literature is providing new evidence on the association between negative stereotypes and older adults' Internet use. The first paper identifies that subjective perception of aging might be associated with older adults' Internet use. It implies

that motivating older adults to learn new digital technology might need careful approaches based on how they perceive themselves when introducing them to new technologies they are not familiar with. As research has shown, the embodiment of negative perception of oneself might discourage oneself from attempting new tasks in life, which might lead to adverse psychological outcomes. Studies on the digital divide have primarily focused on internal characteristics at the individual level (e.g., perceived usefulness, discomfort, and computer literacy) as predictors of technology use (McDonough, 2016). The findings on self-perception of aging's role in digital technology adoption might also contribute to the existing theoretical frameworks on digital technology adoption because they offer special consideration to understand the digital divide among older adults. Older adults who evaluate themselves as useless might be less motivated to learn or use digital technologies, thinking they are unsuitable for the technologies.

The Cognitive Benefit from Digital Technology Use

The association between regular computer use and new-onset MCI from paper two contributes to the literature by providing evidence of undemonstrated needs for digital technology training as one of the practical mentally stimulating activities that might enhance capacities in psychomotor ability and information processing, and executive function (Charness & Boot, 2009; Cullati, Kliegel, & Widmer, 2018). In the meantime, it should be noted that if the digital divide remains unresolved, it might cause even wider gaps in cognitive function and further health disparities among older adults by their digital technology adoption status.

Social Network Services as a Tool for Connectivity and Social Support

An important finding from paper 3 is that older adults' SNS use can reduce loneliness, particularly when its primary purpose is to stay connected with their intimate social networks, including family, child, and friends. While there have been inconclusive results from the

previous research, the finding provides a more comprehensive understanding of when older adults' SNS use could be beneficial. The finding is consistent with the previous research highlighting the necessity of SNS's function to connect older adults to family or to contacts with whom the user wants to maintain a quality relationship.

The use of SNS could also be affected by psychological factors. This paper shows that individuals who were optimistic about their lives were more likely to use SNS to stay connected with others in line with the dispositional optimism perspective (Scheier, Carver, & Bridges, 1994; Adersson, 2012). The result indicates that SNS use might not be a panacea to mitigate older adults' social isolation, and the adaptation of SNS among older adults should be understood based on various personalities.

Future Research Directions

This paper suggests several directions to further understand the digital divide's impact on older adults and implement better digital technology training and education for them. First, policymakers and researchers will need to explore more psychological factors, such as attitude toward digital technology, that possibly contribute to older adults' reluctance to participate in digital lifestyle in order to develop effective policy options and programs to assist vulnerable older adults in participating in digital lifestyle. Second, studies on the digital divide among older adults are in need of longitudinal designs and causal inference methods to understand better causal relationships between digital technology use and cognitive functions. Finally, more intervention studies are required to evaluate their efficacy in reducing the technological gap within the older generation and what additional supports could facilitate digital technologies among the population.

Concluding Remarks

The results from this study indicates that digital divide among older Americans is significant. Socioeconomically marginalized older adults are unlikely to afford Internet access and digital devices to navigate online, thereby fewer opportunities to learn how to utilize the technology (Carlson et al., 2006; Xie & Bugg, 2009). Given the potential benefits from engagement in the digital lifestyle examined in this dissertation project, such as the lower risk of MCI and decreased loneliness, the digital divide might yield unexpected health and psychosocial disparities. Moreover, the impacts of the digital divide have been more significant during the COVID-19 pandemic. Because of social distancing and limited access to social services during the pandemic, all population groups increasingly relied on the Internet for essential activities for a living (Lai & Widmar, 2021). While all members of society have struggled with the adjustment, older adults have been a group who most struggled, particularly for those with limited Internet access. Taken together, the digital divide among older adults calls for urgent policy intervention to provide Internet access, digital devices, and training specially designed for older adults.

Currently, there are no explicit legal provisions to provide such programs, except a few temporary benefits to support Internet connectivity for low-income households during the COVID-19 pandemic, such as Emergency Broadband Benefit. Although there was a specific statute under the Older Americans Act (OAA) used to authorize the federal government's responsibility to fund computer training and Internet access for older adults under the law, congress repealed the statute from its 2016 reauthorization without substantial program implementation. Due to the removal of the statue, organizations that provide computer education for older adults, such as the Older Adults Technology Services (OATS) and SeniorNet, primarily

rely on funds from private sectors (Calhoun, 2019). Policymakers should support such efforts either by reinstating the statute within the OAA or implementing new policies to close gaps in digital technology adaptation among older adults. Though it is a temporary, Emergency Broadband Benefit program already has helped a number of Americans to be connected to essential socia services online during the COVID-19 pandemic (Rundlet, 2021). Policy makers should see such a program as a milestone to recognize Internet accessbility as one of the criticial basic resources for living in the U.S and make efforts to extend such progrmas even after the pandemic and further expand them, while they develop a comprehensive set of policy options to close digital gaps among Americans.

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