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Research Article

Internet Use and Cognitive Functioning in Later Life: Focus on Asymmetric Effects and Contextual Factors

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Abstract

Background and Objectives: Despite emerging literature linking Internet usage and cognitive functioning in later life, research seldom takes changes in older adults' Internet use into account. How changes in Internet use influence older adults' cognitive decline over time, particularly in the context of sociodemographic factors that shape Information and Communication Technology (ICT) use, remains an open question.
Research Design and Methods: Using 9 waves of panel data from the *Health and Retirement Study* (2002–2018), we examined within-person asymmetric effects of transitioning into and out of Internet use on cognitive functioning, and whether the associations vary across birth cohorts and by living arrangement.
Results: Transitioning into Internet use (i.e., Internet use onset) was associated with improved cognitive functioning at a given wave and decelerated cognitive decline over time. Transitioning out of the Internet (i.e., Internet use cessation) was associated with worse cognitive functioning at a given wave and accelerated cognitive decline over time. Furthermore, birth cohort and living arrangement moderated these associations. The detrimental effect of transitioning out of Internet use was worse for older adults born in 1941 or before. The cognitive benefits of transitioning into Internet use were greater for those older adults who live alone.
Discussion and Implications: These findings highlight the interplay between technology, social environment, and cognitive functioning in later life. The salubrious effects of using the Internet, as well as the deleterious effects of ceasing to use such technology, underscore the importance of promoting digital literacy and access to ICT among the older adult population.

Keywords: Cognition, Information technology, Technology, Health and Retirement Study

There are now decades of research on Internet use and cognitive functioning in later life (Cotten, 2021; Fingerman et al., 2020). While earlier studies focused on how cognitive functioning plays a key role in older adults' use of the Internet, a growing body of recent studies focuses on the Internet as an antecedent of cognitive health, based on the idea that the Internet offers a rich array of activities that may be cognitively stimulating for older adults (Firth et al., 2019; Ihle et al., 2020). However, we are still at an early stage in our understanding of the topic. Little is known about how changes in Internet use and nonuse *across* time influence cognitive functioning, and how such linkages may vary depending upon the sociodemographic context in which the Internet is used across individuals. These represent important gaps in the literature because the pattern of engagement with the Internet changes over time, and older adults are not a homogeneous group in their reasons for use/nonuse of the Internet (Levine et al., 2018; Rikard et al., 2018; van Deursen & van Dijk, 2014). Such complexities, in turn, are likely to influence the cognitive benefits derived from using the Internet in later life.

This study investigated within-person associations between changes in Internet use and cognitive functioning in later life. In exploring changes in older adults' Internet use, we distinguished the transition *into* Internet use (i.e., Internet use onset) from the transition *out of* Internet use (i.e., Internet use cessation) to assess their unique associations with individuals' cognitive functioning over time. We further investigated how such Internet–cognition nexus varies by birth cohorts and living arrangement, which are known to influence older adults' engagement with the Internet. By examining how patterns of technology use influence the health and well-being of U.S. older adults and identifying the effects of contextual factors, this study aims to expand our understanding of the consequences of digital inequalities in later life.

Changes in Internet Use and Cognitive Functioning in Later Life

The term "digital inequality" or "digital divide" is commonly used to describe a division between individuals who have access to and use various information and communication technologies (ICTs) and those who do not (van Dijk, 2020). The age-related digital divide in *accessing* online information appears to be narrowing at a steady rate, with more than two thirds of community-dwelling U.S. older adults aged 65 years and older having access to the Internet as of 2019 (Pew Research Center, 2021). However, the divide persists when it comes to *using* the Internet over time. Many older adults report not using the Internet due to health reasons (e.g., vision impairment, disability; Gell et al., 2015), as well as nonhealth reasons (e.g., lacking confidence or interest; van Deursen & Helsper, 2015; financial strain; König & Seifert, 2020).

An aspect of health relevant to using the Internet is cognitive functioning. Although some level of cognitive capacity is necessary to engage with various online activities, empirical research is increasingly finding that Internet use may entail cognitive benefits as well (Kamin & Lang, 2018; Klimova, 2016). This is in keeping with the concept of cognitive reserve, where the accumulation of cognitively stimulating experiences may bring about resilience to age- or disease-related changes to the brain (Ihle et al., 2020; Stern, 2009). The Internet offers a rich avenue for social and cognitive engagement; from social networking sites to banking, the World Wide Web affects every aspect of modern society, enabling communications and information sharing. Evidence from observational and experimental studies dovetails well with this view. For example, engaging in social activities using online face-to-face communication programs or social networking sites has been associated with improved cognitive functioning among healthy older adults (Dodge et al., 2015; Myhre et al., 2017). Studies employing general indicators of Internet use also find that using the Internet improves cognitive performance (Kamin & Lang, 2018; Klimova, 2016) or mitigates the overall cognitive decline over time in later life (Ihle et al., 2020; Xavier et al., 2014).

Yet, the extant literature tends to overlook the changes in older adults' Internet use over time and how such changes may influence cognitive functioning. Although the overall number of older Internet users has been increasing in past years, many individuals cease to use the Internet in later life (König & Seifert, 2020; Rikard et al., 2018). Older adults' use of the Internet could thus be characterized in terms of the continued use or nonuse, as well as the transition *into* Internet use (i.e., the onset of usage) and *out of* Internet use (i.e., the cessation of usage). Few studies to date have focused on transitions around Internet use in later life (Levine et al., 2018; Rikard et al., 2018), and the evidence for their influence on cognitive functioning is largely limited to the onset of Internet usage (Klimova, 2016). Given ongoing initiatives to promote technology-based interventions among older adults, more research is needed to understand the determinants and consequences of changes in Internet use (Levine et al., 2018). Without the informational and social benefits of the Internet, it is possible that Internet use cessation negatively affects cognitive functioning in later life.

Contextual Factors That Influence the Internet–Cognition Nexus

The consequences of Internet use/nonuse likely depend on contextual factors that influence digital literacy and Internet use in later life. The digital divide framework posits that divide is a multidimensional phenomenon that arises as a combination of inequality in access (i.e., the first level), inequality of use (i.e., the second level), and inequality in outcome (i.e., the third level) regarding information technology (van Deursen & van Dijk, 2014; Van Dijk, 2020). In this view, each level of the digital divide cumulates to a subsequent inequality in the next level. To assess how transitions around Internet use may affect cognitive functioning in later life, it is thus important to recognize factors related to interindividual differences in access and use of the Internet among the older adult population.

One of the known determinants of older adults' regular use of and attitudes toward the Internet, as well as the type of online activities they engage in, is birth cohorts (Friemel, 2016; van Deursen & Helsper, 2015). Birth cohorts locate the point in individuals' life course that corresponds with the timing of technological developments (Cotten, 2021). For instance, studies demonstrate that older adults born during or after World War II are more likely to have access to and use the Internet in later life, possibly due to their experiences using a computer in their career (Cotten, 2021; Friemel, 2016). Informational use of the Internet, such as the use of e-government services, depends on the level of traditional literacy (van Deursen & Helsper, 2015), suggesting that earlier-born cohorts may further be limited in their use of the Internet than the later-born cohorts. In this context, learning to use the Internet is likely to be a more cognitively stimulating experience for earlier-born cohorts than later-born cohorts of older adults, and the cognitive detriments of Internet use cessation may have similar cohort differences.

Individuals' social surroundings could also alter how Internet use/nonuse affects cognitive functioning in later life. Older adults frequently cite staying in touch with family and friends as the primary reason for learning new online features like social media, and as such, older adults living alone may actively utilize the Internet to increase social connectivity (Cotten, 2021; Silva et al., 2020). Moreover, online information-seeking behaviors could vary by living arrangement. One of the main reasons for Internet nonuse in later life is attributed to proxy Internet use, in which Internet users complete online tasks on behalf of Internet nonusers (Grošelj et al., 2019). Without other Internet users in the household, older adults living alone have more incentive to use the Internet to compensate for the lack of indirect access to online information. Such autonomy in usage, in turn, may result in more cognitive benefits. Similarly, stopping Internet use may lead to a greater loss of social and intellectual engagement for older adults living alone than it is for older adults residing with others.

Study Aims

Building upon a multilayered digital divide framework, this study examines how within-person changes in Internet use are associated with the cognitive trajectory in later life. Specifically, we employed a methodological approach that allowed us to investigate whether the transition *into* Internet use (i.e., the onset of use) and the transition *out of* Internet use (i.e., the cessation of use) distinctly influence older adults' cognitive functioning in the context of birth cohorts and living arrangement. This study tests four hypotheses using nine waves of biennial panel data from the *Health and Retirement Study* (HRS; 2002–2018).

H1: The transition *into* Internet use is associated with improved cognitive functioning at a given wave and decelerated cognitive decline over time.

H2: The transition *out of* Internet use is associated with worse cognitive functioning at a given wave and accelerated cognitive decline over time.

H3: The associations between within-person changes in Internet use and cognitive functioning are moderated by individuals' birth cohorts, such that the associations will be stronger for earlier-born cohorts (i.e., before 1942) compared to later-born cohorts (i.e., 1942 or after).

H4: The associations between within-person changes in Internet use and cognitive functioning are moderated by individuals' living arrangements, such that the associations will be stronger when individuals are living alone compared to when individuals are living with others.

Method

Data and Study Sample

HRS is a nationally representative panel survey of individuals older than age 51 and their spouses (of any age) in the United States. The initial HRS cohort (b. 1931–1941) was interviewed in 1991, which was later merged with a subsequent study known as Asset and Health Dynamics Among the Oldest Old (b. 1890–1923). Two new cohorts—the Children of the Depression (b. 1924–1930) and the War Babies (b. 1942–1947)—were further recruited in 1998. The HRS replenishes the sample every 6 years; Early Baby Boomers (b. 1948–1953) and Mid Baby Boomers (b. 1954–1959) were added in 2004 and 2010, respectively (Sonnega et al., 2014). Blacks and Hispanic participants were oversampled in the HRS.

We analyzed nine waves of data from 2002 to 2018 because information on Internet use was not available before the 2002 wave. Measures for Internet use and basic sociodemographic information were taken from the core public-use file (Sonnega et al., 2014). Other study variables such as living arrangement, cognitive functioning, the number of depressive symptoms, employment status, household income, and the number of chronic conditions were taken from a longitudinal file constructed by the Rand Corporation, which accounted for inconsistencies and missingness across waves. Between 2002 and 2018, 34,318 nonproxy respondents who were part of the targeted HRS cohorts were interviewed. Among 34,318 nonproxy respondents, we restricted our sample to 18,646 individuals who were 65 or older and had completed the full cognitive battery at a given wave; accordingly, "baseline" in this study refers to the first wave in which an individual was at least 65 years old during the study period. Of 18,646 respondents, we further excluded 54 individuals (0.3%) who were missing information on the key study variables. The final study included 18,592 respondents (respondent-wave observation N = 78,289).

Measures

Cognitive functioning at each wave was assessed using the widely adopted 35-point modified Telephone Interview for Cognitive Status (Crimmins et al., 2011). This included a test of immediate and delayed recall (range = 0–20), serial-7 subtraction (range = 0–5), backward counting (range = 0–2), object (range = 0–2), date (range = 0–4), and President/Vice President naming (range = 0–2), with the higher score indicating better cognitive functioning.

Internet use at each wave was assessed with the following question: "Do you regularly use the World Wide Web, or the Internet, for sending and receiving e-mail or for any other purpose, such as making purchases, searching for information, or making travel reservations?" The response was coded dichotomously (1 = *yes*; 0 = *no*).

Birth cohort and living arrangement were considered as contextual factors. The study sample included five different HRS-designed birth cohorts, as described earlier. We created a binary variable to indicate individuals born after World War II (1 = *born in 1942 or after*, 0 = *born in 1941 or before*). Self-report of the number of residents in the household at each wave was utilized as a measure of living arrangement (1 = *living alone*, 0 = *not living alone*).

We included a set of covariates that may confound the link between transitions around Internet use and cognitive functioning at each wave (Berner et al., 2019; Fingerman et al., 2020). These included marital status (1 = *currently married*, 0 = *not married*), household income (log-transformed), the number of health conditions (physician-diagnosed high blood pressure, diabetes, cancer, lung disease, heart disease, stroke, psychiatric problems, and arthritis), the number of activities of daily living difficulties (self-reported any difficulty with bathing, dressing, eating, getting in/out of bed, and walking across a room), and the number of depressive symptoms (eight-item version of the Center for Epidemiologic Studies—Depression scale), which were treated as time-varying covariates. We also considered key sociodemographic characteristics as time-invariant covariates, which included age at first wave (in years), gender (1 = *female*, 0 = *male*), race and ethnic background (1 = *minority*, 0 = *non-Hispanic White*), and education (high school [reference group], less than high school, some college, college).

Analytic Strategy

We adopted the recently proposed asymmetrical fixed effects approach (Allison, 2019) that separates individuals' record of Internet use into a positive (i.e., changing from nonuse to use; transitioning *into* Internet use) and a negative (i.e., change from use to nonuse, transitioning *out of* Internet use) component. Given that the fixed-effects models do not produce estimates for time-invariant characteristics, the asymmetrical effects approach was incorporated into the within–between random effects (REWB) modeling framework. REWB models decompose all time-varying predictors to a between-person (BP; Level 2) component, calculated as the person-specific mean across the observation period, and a within-person component (WP; Level 1), calculated as the deviation from one's person-specific mean at each occasion (Bell & Jones, 2015; Hamaker & Muthén, 2020). In this study, the WP component of the transition *into* Internet use compared the cognitive functioning of a person who did not use the Internet at one time to the same person at the subsequent wave when the person transitioned to using the Internet. Similarly, the WP component of the transition *out of* Internet use compared the cognitive functioning of a person who used the Internet at one time to the same person at the subsequent wave when the person transitioned out of Internet use. We included random effects for time (i.e., time elapsed from baseline) to allow for interindividual variability in how cognitive functioning changes over time. Additional details on the current analytic approach are given in Supplementary Material.

We first estimated whether the transitions into and out of Internet use were associated with cognitive functioning at a given wave (Model 1A). We then added an interaction term between the transitions and time to investigate whether the onset or the cessation of Internet use leads to differences in the rate of cognitive decline over time (Model 1B). Next, we investigated the contextual effects of birth cohorts and living arrangement by stratifying the aforementioned models into each group of interest (i.e., earlier-born cohort vs. later-born cohort, living with others vs. living alone; Models 2A and 3A). Finally, we tested the group differences by including two-way interaction terms between the transitions and contextual factors (i.e., birth cohort, living arrangement), as well as three-way interaction terms between the transitions, contextual factors, and time using the whole sample (Models 2B and 3B). All analyses were performed using the MIXED function in Stata 16. Standard errors were allowed for intragroup correlation to account for the nonindependence at the household level.

Results

At baseline, study participants on average were 71 years old and reported about two health conditions: almost no difficulty with activities of daily living and a little more than one depressive symptom (Table 1). The majority of participants were non-Hispanic White, female, married, had completed high school, and about 33% reported using the Internet at the initial observation.

Approximately 13% of the participants (n = 2,376) reported transitioning into Internet use, and about 14% (n = 2,525) reported transitioning out of Internet use during the 16-year period (not shown in tables). About 2% of participants transitioned *into* (n = 375) or transitioned *out of* (n = 324) Internet use 2 or 3 times. In total, there were 5,647 transitions around Internet use over the study period. The intraclass correlation coefficients for cognitive functioning were 0.64, indicating a considerable degree of correlation within individuals.

Associations Between Internet Use/Nonuse and Cognitive Functioning

Table 2 presents the results pertaining to the associations between the transitions around Internet use and the level of cognitive functioning. As expected, transitions *into* Internet use were associated with an increase in the level of cognitive functioning at a given wave (b = 0.40, p < .001; Model 1A), while transitions *out of* Internet use were associated

Table 1. Study Sample Characteristics at Baseline

Variables	*M*/% (*SD*)	Min	Max	ICC
Cognitive functioning[a]	22.07 (5.27)	0	35	0.64
Internet use[b]	33			—
Sociodemographic characteristics				
Age	70.69 (6.97)	65	109	—
Female, %	58			—
Married, %	63			—
Living alone, %	26			—
Race/ethnicity, %				
Non-Hispanic White	74			—
Non-Hispanic Black	15			—
Non-Hispanic other	2			—
Hispanic	9			—
Education, %				
Less than high school	26			—
High school graduation	34			—
Some college	20			—
College degree and more	20			—
Household income[c]	10.36 (1.20)	0.00	15.80	0.61
Health status				
Depressive symptoms[d]	1.47 (1.94)	0	8	0.56
Health conditions[e]	2.12 (1.41)	0	8	0.82
Activities of daily living[f]	0.31 (0.83)	0	5	0.55
Self-rated memory[g]	1.90 (0.92)	0	4	0.54

Notes: ICC = intraclass correlation. Respondent N = 18,592.

[a]Sum of total 35-point modified Telephone Interview for Cognitive Status.

[b]Coded as regularly using the World Wide Web, or the Internet, for sending and receiving e-mail or for other purpose (1 = *yes*, 0 = *no*).

[c]Log-transformed sum of all income in a household.

[d]Count of eight endorsed items from the Center for Epidemiologic Studies—Depression scale.

[e]Count of eight diagnosed health conditions.

[f]Count of limitations in five activities of daily living.

[g]Individuals' rating of their memory at the present time, ranging from 0 (*poor*) to 4 (*excellent*).

with a decrease in the level of cognitive functioning at a given wave (b = −0.37, p < .001). In Model 1B, we added an interaction term between time and the Internet use transitions to assess their effect on the rate of cognitive decline. The transition *into* Internet use mitigated the rate of cognitive decline (b = 0.16, p < .001), and the transition *out of* Internet use worsened the rate of cognitive decline over time (b = −0.25, p < .001).

In Models 2A and 2B (Table 3), we estimated the asymmetric REWB models separately for those born before 1942 (i.e., earlier-born) and those born in or after 1942 (i.e., later-born). For the earlier-born cohort, transitioning *into* Internet use was associated with an increase in the level of cognitive functioning at a given wave (b = 0.43, p < .001; Model 2A), and transitioning *out of* Internet use was associated with a decrease in the level of cognitive functioning at a given wave (b = −0.43, p < .001). Moreover, transitioning *in* and *out of* Internet use mitigated (b = 0.18, p < .001) and exacerbated (b = −0.24, p < .001) the rate of cognitive decline for the earlier-born cohort, respectively (Model 2B). In contrast, transitions around Internet use were unrelated to the level of cognitive functioning among the later-born cohort. Adding interaction terms to the full sample indicated that the concurrent cognitive detriments associated with the transition *out of* Internet use were significantly greater for the earlier-born cohort than they were for the later-born cohort (p = .039).

Results regarding the role of living arrangement are presented in Table 4. When individuals were living with others, transitioning *into* Internet use was associated with a higher level of cognitive functioning (b = 0.32, p < .001; Model 3A), and transitioning *out of* Internet use was associated with a lower level of cognitive functioning at a given wave (b = −0.37, p < .001). Similarly, when individuals were living alone, transitioning *into* and *out of* Internet use was associated with a higher (b = 0.51, p < .001) and a lower (b = −0.39, p < .001) level of the cognitive functioning at a given wave, respectively. The same pattern emerged regarding the rate of cognitive decline (Model 3B). Transitions *into* Internet use attenuated the rate of cognitive decline (living with others b = 0.15, p < .001; living alone b = 0.21, p < .001), while transitions *out of* Internet use accelerated the rate of cognitive decline (living with others b = −0.26, p < .001; living alone b = 0.23, p < .001).

Table 2. Asymmetric Within-Between Random Effects Model of Internet Use and Cognitive Functioning

Variables	Model 1A: Main effects	Model 1B: Moderation effects
	b (*SE*)	*b* (*SE*)
Fixed effects		
Intercept	26.24*** (0.61)	26.21*** (0.62)
Internet use: Transition in[a]	0.40*** (0.06)	−0.05 (0.11)
Internet use: Transition in[a] × Time[b]	—	0.16*** (0.03)
Internet use: Transition out[c]	−0.37*** (0.07)	0.48*** (0.11)
Internet use: Transition out[c] × Time[b]	—	−0.25*** (0.03)
Time[b]	−0.66*** (0.01)	−0.65*** (0.01)
Covariates (WP; Level 1)		
Married	0.10 (0.06)	0.09 (0.06)
Household income[d]	0.09*** (0.02)	0.09*** (0.02)
Depressive symptoms[e]	−0.03** (0.01)	−0.03** (0.01)
Health conditions[f]	−0.13*** (0.03)	−0.13*** (0.03)
Activities of daily living[g]	−0.49*** (0.02)	−0.48*** (0.02)
Self-rated memory[h]	0.18*** (0.02)	0.18*** (0.02)
Covariates (BP; Level 2)		
Age at baseline	−0.21*** (0.00)	−0.21*** (0.00)
Female	0.88*** (0.06)	0.88*** (0.06)
Minority[i]	−2.09*** (0.07)	−2.09*** (0.07)
Education (ref. high school graduation)		
Less than high school	−2.23*** (0.08)	−2.23*** (0.08)
Some college	0.75*** (0.07)	0.75*** (0.07)
College degree or more	1.60*** (0.07)	1.60*** (0.07)
Random effects		
Time variance	0.29*** (0.01)	0.29*** (0.01)
Intercept variance	8.64*** (0.16)	8.64*** (0.16)
Residual variance	7.82*** (0.07)	7.81*** (0.07)
−2 log likelihood	419,738.9	419,643.4

Notes: WP = within-person; BP = between-person. Respondent N = 18,592. Respondent-wave observation N = 78,245.
[a]Transitioning from Internet nonuse to Internet use.
[b]Time elapsed from baseline.
[c]Transitioning from Internet use to Internet nonuse.
[d]Log-transformed sum of all income in a household.
[e]Count of eight endorsed items from the Center for Epidemiologic Studies—Depression scale.
[f]Count of eight diagnosed health conditions.
[g]Count of limitations in five activities of daily living.
[h]Individuals' rating of their memory at the present time, ranging from 0 (*poor*) to 4 (*excellent*).
[i]Self-identifying as non-Hispanic Black, Hispanic, or non-Hispanic other.
$^{**}p < .01$, $^{***}p < .001$.

A difference between living arrangement types emerged regarding the effect of transitioning *into* Internet use; the concurrent cognitive benefits associated with the transition *into* Internet use were greater when individuals were living alone as opposed to living with others (p = .044).

Discussion

The Internet has become an essential, if not an indispensable, aspect of daily living for most Americans. In addition, the recent coronavirus disease 2019 pandemic highlighted the significance of digital participation for older adults when physical distance became the recommended practice. While evidence often supports the benefit of using new technologies (e.g., Internet, smartphones) in later life, research seldom explores the potential detriments of use cessation. The present study found evidence for cognitive benefits and losses that are unique to transitioning *into* and *out of* Internet use, respectively. Furthermore, more nuanced findings emerged across birth cohorts and living arrangements.

Internet Use Transitions and Cognitive Functioning

As expected, transitioning *into* Internet use was associated with improved cognitive functioning at a given wave and a slower rate of cognitive decline over time. The finding

Table 3. Asymmetric Within-Between Random Effects Model of Internet Use and Cognitive Functioning by Birth Cohorts

Variables	Model 2A: Main effects			Model 2B: Moderation effects		
	Earlier-born[a]	Later-born[b]	Diff	Earlier-born[a]	Later-born[b]	Diff
	b (*SE*)	*b* (*SE*)	*p*	*b* (*SE*)	*b* (*SE*)	*p*
Fixed effects						
Intercept	21.81*** (0.74)	31.07*** (4.21)	.029	21.72*** (0.75)	31.09*** (4.22)	.027
Internet use: Transition in[c]	0.43*** (0.07)	0.15 (0.19)	.14	−0.14 (0.11)	−0.05 (0.38)	.81
Internet use: Transition in[c] × Time[d]	—	—		0.18*** (0.03)	0.09 (0.15)	.56
Internet use: Transition out[e]	−0.43*** (0.07)	−0.02 (0.18)	.039	0.39** (0.12)	0.02 (0.34)	.32
Internet use: Transition out[e] × Time[d]	—	—		−0.24*** (0.03)	−0.03 (0.14)	.16
Time[d]	−0.69*** (0.01)	−0.27*** (0.03)	.000	−0.68*** (0.01)	−0.27*** (0.03)	.000
Covariates (WP; Level 1)						
Married	0.05 (0.07)	0.37 (0.19)	.11	0.04 (0.07)	0.37 (0.19)	.11
Household income[f]	0.10*** (0.02)	0.04 (0.04)	.24	0.10*** (0.02)	0.04 (0.04)	.24
Depressive symptoms[g]	−0.03** (0.01)	0.01 (0.03)	.16	−0.03** (0.01)	0.01 (0.03)	.16
Health conditions[h]	−0.13*** (0.03)	−0.14 (0.08)	.87	−0.12*** (0.03)	−0.14 (0.08)	.84
Activities of daily living[i]	−0.49*** (0.03)	−0.22** (0.08)	.001	−0.49*** (0.03)	−0.22** (0.08)	.001
Self-rated memory[j]	0.17*** (0.02)	0.23*** (0.07)	.40	0.17*** (0.02)	0.23*** (0.07)	.40
Covariates (BP; Level 2)						
Age at baseline	−0.18*** (0.01)	−0.22*** (0.06)	.55	−0.18*** (0.01)	−0.22*** (0.06)	.54
Female	0.75*** (0.07)	1.06*** (0.10)	.012	0.75*** (0.07)	1.07*** (0.10)	.010
Minority[k]	−2.20*** (0.08)	−1.93*** (0.12)	.07	− 2.20*** (0.08)	−1.93*** (0.12)	.06
Education (ref. high school graduation)						
Less than high school	−2.16*** (0.08)	−2.30*** (0.17)	.46	−2.15*** (0.08)	−2.30*** (0.17)	.44
Some college	0.65*** (0.08)	0.83*** (0.13)	.25	0.64*** (0.08)	0.83*** (0.13)	.23
College degree or more	1.28*** (0.09)	2.14*** (0.13)	.000	1.28*** (0.09)	2.14*** (0.13)	.000
Random effects						
Time variance	0.29*** (0.01)	0.20*** (0.06)		0.29*** (0.01)	0.19*** (0.06)	
Intercept variance	8.74*** (0.18)	7.78*** (0.30)		8.74*** (0.18)	7.78*** (0.30)	
Residual variance	7.87*** (0.07)	7.30*** (0.17)		7.86*** (0.07)	7.31*** (0.17)	
−2 log likelihood	355,680.8	63,502.6		355,590.6	63,499.8	

Notes: Diff = cohort difference; WP = within-person; BP = between-person. Respondent N = 18,592. Respondent-wave observation N = 78,245. All models adjusted for the between-person differences (Level 2) of time-varying variables.
[a]Birth cohort born in 1941 or earlier, respondent n = 13,771.
[b]Birth cohort born in 1942 or after, respondent n = 4,821.
[c]Transitioning from Internet nonuse to Internet use.
[d]Number of completed waves.
[e]Transitioning from Internet use to Internet nonuse.
[f]Log-transformed sum of all income in a household.
[g]Count of eight endorsed items from the Center for Epidemiologic Studies—Depression scale.
[h]Count of eight diagnosed health conditions.
[i]Count of limitations in five activities of daily living.
[j]Individuals' rating of their memory at the present time, ranging from 0 (*poor*) to 4 (*excellent*).
[k]Self-identifying as non-Hispanic Black, Hispanic, or non-Hispanic other.
$^{**}p < .01$, $^{***}p < .001$.

supports the view that holds Internet as a source of positive cognitive stimulation for older adults (Firth et al., 2019; Kamin & Lang, 2018). Possible mechanisms by which online activities improve cognitive abilities in later life have been proposed. For instance, in studies involving older adults, using online search engines has been linked to activation of neural circuitry related to complex reasoning and decision making (Small et al., 2009), and playing video games designed to train multitasking performance has been associated with enhanced working memory and sustained attention (Anguera et al., 2013). Our finding further indicates that there may be lasting cognitive benefits. While earlier experimental studies contributed to the literature by teasing out detailed linkages between specific online tasks and cognitive outcomes, the observation period in these studies rarely extends beyond few sessions (Ihle et al., 2020; Kamin & Lang, 2018). This study contributed to the literature by assessing changes in cognitive functioning over a decade, finding that transitioning *into* using the Internet may lead to a slower rate of cognitive decline in later life.

Table 4. Asymmetric Within-Between Random Effects Model of Internet Use and Cognitive Functioning by Living Arrangement

Variables	Model 3A: Main effects			Model 3B: Moderation effects		
	Living with others[a]	Living alone[b]	Diff	Living with others[a]	Living alone[b]	Diff
	b (*SE*)	*b* (*SE*)	*p*	*b* (*SE*)	*b* (*SE*)	*p*
Fixed effects						
Intercept	26.54*** (0.72)	25.15*** (1.01)	.80	26.51*** (0.72)	25.12*** (1.01)	.78
Internet use: Transition in[c]	0.32*** (0.07)	0.51*** (0.13)	.044	−0.05 (0.13)	−0.22 (0.22)	.98
Internet use: Transition in[c] × Time[d]	—	—		0.15*** (0.03)	0.21*** (0.05)	.55
Internet use: Transition out[e]	−0.37*** (0.08)	−0.39** (0.13)	.21	0.46*** (0.14)	0.43 (0.24)	.36
Internet use: Transition out[e] × Time[d]	—	—		−0.26*** (0.03)	−0.23*** (0.05)	.41
Time[d]	−0.60*** (0.01)	−0.78*** (0.02)	.000	−0.60*** (0.01)	−0.78*** (0.02)	.000
Covariates (WP; Level 1)						
Married	0.44*** (0.10)	0.15 (0.23)	.23	0.43*** (0.10)	0.15 (0.23)	.24
Household income[f]	0.06** (0.02)	0.12*** (0.03)	.06	0.06** (0.02)	0.12*** (0.03)	.07
Depressive symptoms[g]	−0.04** (0.01)	−0.02 (0.02)	.77	−0.04** (0.01)	−0.02 (0.02)	.77
Health conditions[h]	−0.12*** (0.03)	−0.09 (0.06)	.29	−0.12*** (0.03)	−0.09 (0.06)	.30
Activities of daily living[i]	−0.48*** (0.03)	−0.48*** (0.04)	.66	−0.47*** (0.03)	−0.48*** (0.04)	.63
Self-rated memory[j]	0.19*** (0.03)	0.12** (0.04)	.020	0.19*** (0.03)	0.12** (0.04)	.019
Covariates (BP; Level 2)						
Age at baseline	−0.21*** (0.01)	−0.21*** (0.01)	.56	−0.21*** (0.01)	−0.21*** (0.01)	.56
Female	0.79*** (0.06)	1.11*** (0.10)	.001	0.79*** (0.06)	1.11*** (0.10)	.001
Minority[k]	−2.01*** (0.08)	−2.23*** (0.12)	.25	−2.01*** (0.08)	−2.23*** (0.12)	.25
Education (ref. high school graduation)						
Less than high school	−2.21*** (0.09)	−2.21*** (0.12)	.71	−2.21*** (0.09)	−2.21*** (0.12)	.73
Some college	0.69*** (0.08)	0.82*** (0.12)	.25	0.69*** (0.08)	0.82*** (0.12)	.25
College degree or more	1.59*** (0.08)	1.48*** (0.13)	.17	1.59*** (0.08)	1.48*** (0.13)	.16
Random effects						
Time variance	0.28*** (0.02)	0.23*** (0.02)		0.28*** (0.02)	0.23*** (0.02)	
Intercept variance	8.21*** (0.17)	9.43*** (0.29)		8.22*** (0.17)	9.43*** (0.29)	
Residual variance	7.60*** (0.08)	8.27*** (0.14)		7.59*** (0.08)	8.26*** (0.14)	
−2 log likelihood	294,182.4	127.241.6		294,116.8	127,215.6	

Notes: Diff = living arrangement difference; WP = within-person; BP = between-person. Respondent N = 18,592. Respondent-wave observation N = 78,245. All models adjusted for the between-person differences (Level 2) of time-varying variables.
[a]Living arrangement—living with others, respondent-wave observation n = 54,999.
[b]Living arrangement—living alone, respondent-wave observation n = 23,290.
[c]Transitioning from Internet nonuse to Internet use.
[d]Number of completed waves.
[e]Transitioning from Internet use to Internet nonuse.
[f]Log-transformed sum of all income in a household.
[g]Count of eight endorsed items from the Center for Epidemiologic Studies—Depression scale.
[h]Count of eight diagnosed health conditions.
[i]Count of limitations in five activities of daily living.
[j]Individuals' rating of their memory at the present time, ranging from 0 (*poor*) to 4 (*excellent*).
[k]Self-identifying as non-Hispanic Black, Hispanic, or non-Hispanic other.
$^{**}p < .01$, $^{***}p < .001$.

Furthermore, transitioning *out of* Internet use was associated with worse cognitive functioning at a given time, and it accelerated cognitive declines over time. The findings mirror the known benefits of Internet use in later life; if the complexities of online activities confer cognitive benefits in later life, the absence of a similar level of cognitive stimulation may have detrimental consequences. While relatively less attention has been paid to the reasons and consequences of stopping Internet use in later life, the existing research points out various circumstances in which older adults may transition from Internet use to nonuse. For example, completing basic online tasks such as sending or receiving emails could become challenging when individuals experience vision loss or decline in fine motor skills (Gell et al., 2015). Individuals who are less skilled in navigating the ever-changing online space may transition out of Internet use, particularly if there is someone else who can complete online tasks on behalf (Grošelj et al., 2019). Our findings indicate that stopping Internet use in these circumstances could have cognitive costs. However, because our study relied on self-reports of general Internet use, it is unclear whether stopping a specific online task contributed to the changes more than others. We also note that more fine-grained information and time points are needed to determine causal relationships between Internet use transitions and cognitive change. Future research should seek to clarify how reasons or patterns of individuals' disengagement from the Internet affect cognitive functioning in later life. Identifying risk factors for Internet use cessation in later life represents another fruitful area of future research.

Contextual Effects of Birth Cohorts and Living Arrangement

As expected, we found that the aforementioned associations between the transitions around Internet use and cognitive functioning were more prominent among individuals born before 1942. This suggests that cognitive benefits of adopting the Internet may be more pronounced for those who have limited prior experiences. The earlier-born cohorts in this study were in their 50s or older when the World Wide Web opened to the public in 1991 (Cotten, 2021), suggesting that they lack the experience or the training the later-born cohorts likely obtained earlier in the life course. While it is true that these barriers deterred earlier-born cohorts from using the Internet in the first place (Friemel, 2016; Matthews et al., 2019), those who are able to overcome such challenges may reap greater cognitive benefits from initiating Internet use in later life. Although there is limited research on how specific cohorts or generations utilize the Internet over the life course, recent studies indeed indicate that the oldest old use the Internet to better manage their health or sustain independence, which contributed to their overall well-being (Schlomann et al., 2020; Sims et al., 2017). More research is needed here, including how the effects of Internet use in later life are confounded by related cohort or period effects (e.g., formal education or prevalence of a computer at home).

The pattern of results linking transitions around Internet use and cognitive functioning was similar when individuals were living alone versus with others, thereby supporting the initiatives to encourage older adults' continued Internet use, regardless of the living arrangement. However, the significant moderating effects of living arrangements indicate that the positive effect of the transition *into* Internet use was greater for those who were living alone. Research consistently shows that Internet use improves the mental health of those older adults who live alone by reducing a sense of social isolation, loneliness, and depression (Cotten, 2021; Silva et al., 2020). Our finding contributes to this body of research by demonstrating that those who live alone reap greater cognitive benefits, likely from informational and communicative resources available to them in the online environment. In light of these findings, future studies should examine whether other contextual factors that shape one's social environment and source of information (e.g., urban/rural residence, social network characteristics) also influence how Internet use influences cognitive functioning in later life, especially among older adults living alone.

Limitations

The one-item measure of Internet use in this study is less than optimal to capture the wide variation in older adults' online engagement. Recent research on older adults' Internet use particularly highlights how older adults are not a monolith in their skills or usage of the Internet and the importance of evaluating specific types of online activities (van Deursen & Helsper, 2015; van Deursen & van Dijk, 2014). For instance, evidence shows that older adults with a racial/ethnic minority background and a low socioeconomic status report substantially reduced probability of using technology to manage their health (Mitchell et al., 2019). In this study, we were not able to explicate the impact of accumulated socioeconomic disadvantages in relation to Internet use, in part because the data do not allow us to understand in what capacity older adults used the internet. Relatedly, the present approach does not model cognitive outcomes as a function of the duration of continued Internet use/nonuse, and the question of how the duration of dis(use) affects cognitive functioning over time remains to be answered in a future study. We further note that the age–period–cohort effects represent important and unique forces that could shape how Internet use may influence cognitive functioning. The current research design did not account for period effects, in part due to the identification problem associated with the linear relationship between age, period, and cohort. As such, this study assumed that period effects of sociohistoric events that occurred during the observation period (i.e., a wider Internet availability) manifested through cohort succession, rather than influencing Internet use behaviors of different cohorts in an identical manner (Ang, 2019). Finally, the data for this study come from a relatively healthy group of community-dwelling older adults. Residents of assisted living facilities or nursing homes are typically more cognitively and physically impaired than community-living older adults, and relocation to residential facilities is one of the key predictors of technology nonuse on a daily basis (Levine et al., 2018). Given that ICT use among older adults in long-term care facilities remains an important, yet understudied area of research (Seifert et al., 2017), extending the present work to investigate the contextual role of different living environments would be a plausible next step. Finally, we are unable to claim causality in our findings in part because Internet use may also be influenced by one's cognitive capacities.

Conclusions

This study contributes to the literature by examining how transitions *into* and *out of* Internet use in later life are uniquely associated with cognitive functioning over an observation period spanning 16 years. To the best of our knowledge, this is the first study that uncovered cognitive detriments of Internet use cessation in addition to the cognitive benefits of starting Internet use. Identifying the roles of birth cohorts and living arrangements represents another key contribution of this study. In particular, older adults born in 1941 or before reported cognitive decline when they stopped using the Internet, and individuals living alone reaped cognitive benefits when they started using the Internet, thus underscoring how sociodemographic characteristics contextualize the Internet–cognition nexus. These findings strongly support policy endeavors and intervention efforts aimed at promoting digital engagement and technology use in later life, especially for sectors of the older population deemed to be on the "wrong" side of the digital divide.

Supplementary Material

Supplementary data are available at *The Gerontologist* online.

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Conflict of Interest

None declared.

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