Computers in Human Behavior 111 (2020) 106388

Contents lists available at ScienceDirect

Computers in Human Behavior

journal homepage: http://www.elsevier.com/locate/comphumbeh

Social media use improves executive functions in middle-aged and older adults: A structural equation modeling analysis

Shuna Shiann Khoo [1], Hwajin Yang [*,1]

Singapore Management University, Singapore

ARTICLE INFO

Keywords:
Social media use
Executive functions
Social support
Perceived constraints
Older adults

ABSTRACT

Given the paucity of research on the cognitive implications of social media use in middle and late adulthood, we sought to understand the relations between middle-aged and older adults' social media use and their executive functions (EF)—a set of domain-general cognitive control processes—and the underlying mechanism. By analyzing a nationally representative cohort ranging from ages 40s–70s from the MIDUS Refresher Survey and Cognitive Project, we tested a serial mediation model with perception of social support and sense of control (i.e., personal mastery and perceived constraints) as sequential mediators in a structural equation modeling analysis. We found that perceived social support and constraints fully and serially mediated the relation of middle-aged and older adults' social media use for interpersonal interactions with EF. Our study demonstrates that middle-aged and older adults' social media use for social connection can be a useful medium that protects against age-related cognitive decline in EF.

1. Introduction

The explosive growth of social media—the internet-based applications (e.g., Facebook, Twitter, and WhatsApp) that enable communication and social interaction via the creation and exchange of user-generated content (Kaplan & Haenlein, 2010)—offers new ways for older adults to connect and engage in meaningful social interactions with family and friends. With respect to this the majority of studies on older adults' social media use document its beneficial impact on socio-emotional variables such as loneliness, daily stress, and life satisfaction (Leist, 2013; Sims, Reed, & Carr, 2017; White et al., 1999). Despite social media's potential for cognitive stimulation at older ages, less is known about whether these socioemotional implications extend into cognitive domains (Myhre, Mehl, & Glisky, 2016; Quinn, 2018). Importantly, given that socioemotional support for older adults longitudinally predicts better cognitive functions (Seeman, Lusignolo, Albert, & Berkman, 2001), older adults' social media use, which tends to invigorate social sharing and ties, likely confers benefits on their cognitive functioning.

In view of the paucity of research on this subject, we sought to examine the relation between middle-aged and older adults' social media use for social connections and executive functions (EF)—a domain-general set of cognitive control processes that facilitate goal-oriented mental processes such as planning, attention control, memory updating, multitasking, reasoning, and problem solving (Hedden & Gabrieli, 2004). Given that EF contributes to important life outcomes such as life satisfaction and purpose in late adulthood (Lewis, Turiano, Payne, & Hill, 2017; Toh, Yang, & Hartanto, 2019), which are regarded as vital aspects of healthy aging, investigating the cognitive implications of social media use in mid and later life is therefore both timely and crucial.

1.1. Social media and EF

Our research is guided by two objectives. Our primary goal is to examine whether middle-aged and older adults' social media use for interpersonal interactions would positively predict their EF. Three lines of evidence lend support to our premise. First, given that aging inevitably leads to decline in many, if not all, cognitive processes (van Hooren et al., 2007), social media use—which requires considerable information processing—likely offers opportunities for older adults to exercise and sharpen their cognitive abilities. Second, based on literature showing the positive effects of supportive interactions on older adults' crucial cognitive abilities, such as executive functioning, global cognition,

* Corresponding author. School of Social Sciences, Singapore Management University, Level 4, 90 Stamford Rd. , 178903, Singapore.
E-mail address: hjyang@smu.edu.sg (H. Yang).
[1] Both authors contributed equally to this work.

https://doi.org/10.1016/j.chb.2020.106388
Received 13 October 2019; Received in revised form 13 March 2020; Accepted 13 April 2020
Available online 14 April 2020

memory, and spatial processing (e.g., Derksen et al., 2015; Ellwardt, Aartsen, Deeg, & Steverink, 2013; Kelly et al., 2017; Seeman et al., 2001), social media use—which facilitates socializing with busy or distant family members and friends—should stimulate and promote cognitive activities. This, in turn, would protect their EF from age-related decline. Indeed, longitudinal and meta-analytical studies suggest that greater social support is positively associated with general cognitive functioning in older adults (Ellwardt et al., 2013; Kelly et al., 2017). Third, since social media serves as a channel for older adults to stay in close contact with their family and friends (for a review, see Leist, 2013), those who actively use social media might become more receptive to seeking help and thereby feel greater empowerment and sense of control, which would in turn improve their cognitive control. With respect to this notion, previous studies suggest that older adults' sense of control is closely linked to various cognitive processes (e.g., Infurna & Gerstorf, 2013; Lachman & Agrigoroaei, 2012).

Despite the empirical importance of this subject, scant research has investigated the relation between middle-aged and older adults' social media use and EF. Further, in view of the multifaceted characteristics of EF (i.e., inhibition, shifting, and updating; Miyake et al., 2000), prior studies have only identified associations of social media use with limited aspects of EF. For instance, Myhre et al. (2016) found that older adults (aged 75 and above) who learned to use Facebook through an intervention program demonstrated significant improvements only in the updating aspects of EF, as measured by the Letter Memory and Keep Track tasks, and not in other aspects of EF (i.e., inhibition and shifting). More recently, Quinn (2018) found that social media training (2 h per week for 4 weeks on messaging, photo sharing, status updates, and information gathering) on various apps (e.g., Facebook or Twitter) had a positive effect on older adults' (aged 65 and above) inhibition, as assessed by the modified Stroop task, but not on other facets of EF (i.e., processing speed, attention, and working memory).

Although these intervention studies suggest that older adults' social media use benefits EF, their findings are not conclusive due to several drawbacks. First, most EF tasks have been shown to have inherent task-impurity issues, since they tend to tap not only the task's target EF ability but also non-EF abilities (Miyake et al., 2000). For instance, although the Stroop task is a widely used measure of inhibition, it not only implicates the ability to inhibit the prepotent response but also the ability to identify and discriminate colors. Given that these task-specific measurement errors may obscure genuine relations between social media use and EF, a more rigorous latent variable approach based on multiple tasks of EF is needed to circumvent the task-impurity issue in EF tasks.

Second, given that previous studies (Myhre et al., 2016; Quinn, 2018) are based on the three-factor model of EF (inhibition, updating, and shifting; Miyake et al., 2000), it is notable that the multi-factor structure of EF may not be applicable to other populations, such as children or older adults. For instance, studies pertaining to older adults suggest that either unidimensional or two-factor models fit the data well (Adrover-Roig, Sesé, Barceló, & Palmer, 2012; de Frias, Dixon, & Strauss, 2006; Ettenhofer, Hambrick, & Abeles, 2006; Hull, Martin, Beier, Lane, & Hamilton, 2008), which implies that the postulated three factors of EF may not be clearly differentiated from each other in older adults (Hull et al., 2008). Specifically, Adrover-Roig et al. (2012) suggest that shifting and updating factors can be treated as a single process in older adults, without the inhibition factor. Given this, it is essential to determine how the theoretical structure of EF unfolds in older adults.

Third, the small sample size of previous studies (less than 20 per condition) hinders generalizing their findings. Fourth, these studies did not control for potential confound variables such as health, education, and income that have been shown to affect executive functioning (for a review, see Hartanto & Yang, 2019). Fifth, given that the interventions used in previous studies are tailored to promote social media use in older adults, it is not clear whether older adults' self-motivated social media use, as it naturally occurs in everyday contexts, would confer the same benefits on executive functioning. In view of these limitations, more research is warranted to replicate previous findings and address their limitations by employing a larger and more representative sample and a more rigorous analytic approach—i.e., structural equation modeling.

1.2. A psychosocial mechanism

Our second primary objective is to examine the mechanism that drives the relation between social media use and EF in middle and late adulthood. Although studies have shed light on the directionality of the relation between social media use at older ages and EF (Myhre et al., 2016; Quinn, 2018), the specific mechanism underlying the link has not been investigated. Notably, recent studies suggest that younger and older adults have different goals and motivations for their social media use; older adults use social media primarily for social purposes (Leist, 2013), while younger adults leverage social media for both informational (Aillerie & McNicol, 2018) and social (Barker, 2009) purposes. Given that socioemotional goals become more perceptible with aging, it is plausible that socioemotional factors might play profound roles in the psychosocial mechanism that drives the link between social media use and EF. Despite the importance of the subject, it has attracted scant attention from researchers and further investigation is essential. Hence, we propose that two important psychosocial variables—perceived social support and sense of control—would serially mediate the relation between social media use for interpersonal interactions and EF in middle-aged and older adults.

First, we propose that social media use would facilitate middle-aged and older adults' receipt of social support, since social media enables those who are socially isolated or physically constrained to remain connected to their social networks (Leist, 2013). For instance, Bell et al. (2013) found that older adults who regularly used Facebook reported a higher level of social satisfaction than their counterparts, primarily because Facebook enabled them to maintain close connections with family and friends. Moreover, given that social support can take the form of either emotional or instrumental aid (Walen & Lachman, 2000), social media can be an effective outlet through which older adults elicit various types of social support and strengthen social bonds across multiple social networks (e.g., family and friends; Xie, 2008). Thus, older adults' increased social media use should help them stay in contact with loved ones and promote feelings of being supported and cared for—which, in turn, would positively influence their perception of social support by their social network (Walen & Lachman, 2000).

Second, we propose that middle-aged and older adults' enhanced perception of social support would serially influence their sense of control (Antonucci, 2001; Lang, Featherman, & Nesselroade, 1997). Sense of control refers to one's feeling of control over environmental events (Lachman & Weaver, 1998; Robinson & Lachman, 2017) and implicates two facets: personal mastery (beliefs about one's self-efficacy) and perceived constraints (beliefs about the presence of uncontrollable external barriers and obstacles; Lachman & Firth, 2004). While sense of control declines as one ages (Lachman, Rosnick, & Röcke, 2009), studies suggest that social support can buffer this decline (Antonucci, 2001). According to the support-efficacy model (Antonucci & Jackson, 1987), social support for older adults strengthens the internalization of their self-efficacy (Lang et al., 1997) and ultimately fosters an internal control belief about their ability to overcome constraints and generate satisfactory outcomes (Lachman & Weaver, 1998). In line with this theoretical account, a longitudinal study found that individuals who received stable and predictable social support over time experienced a stronger sense of control (Lang et al., 1997). Thus, it is reasonable to believe that social media use would facilitate more stable social support for middle-aged and older adults, which would in turn strengthen their sense of control.

Third, it is notable that sense of control is instrumental in promoting older adults' cognitive performance (e.g. Albert et al., 1995; Infurna & Gerstorf, 2013; Lachman & Agrigoroaei, 2012; Soederberg Miller &

Lachman, 2000). An enhanced sense of control implicates a cognitive-behavioral mechanism (Bandura, 1997) and motivates one to feel more confident and, in turn, undertake problem-solving activities, use more effective cognitive strategies, and eventually achieve better cognitive performance (Hertzog, McGuire, & Lineweaver, 1998; Lachman & Andreoletti, 2006, pp. P88–P94; Soederberg Miller & Gagne, 2005). For instance, studies have found that older individuals with higher control beliefs performed better on a recall task because they were motivated to strategically encode words by clustering (Lachman & Andreoletti, 2006, pp. P88–P94; Soederberg Miller & Gagne, 2005), which in part indicates better working memory (i.e., updating) for mentally storing, sorting, and categorizing words (Gaultney, Kipp, & Kirk, 2005). Similarly, a cross-lagged study has also found that higher control beliefs are subsequently related to better cognitive abilities, such as reasoning and perceptual speed (Neupert & Allaire, 2012). It is, therefore, plausible that middle-aged and older adults who develop stronger sense of control will likely achieve better performance on cognitively challenging EF tasks. Taken together, we propose a serially mediated mechanism in which enhanced perception of social support and sense of control mediate the relation between middle-aged and older adults' social media use for interpersonal interactions and EF.

1.3. The present study

To understand the relation between middle-aged and older adults' social media use for social connections and EF and the underlying mechanism, we focused on the following key research questions and hypotheses. First, we examined whether middle-aged and older adults' use of social media to contact family and friends would change their perception of social support from their network of family and friends. Given that older people typically value family ties and prefer to spend time with family more than friends, social support from family may be more meaningful (Procidano & Heller, 1983) for influencing the perception of social support. Thus, we hypothesized that middle-aged and older adults' social media use would have different repercussions for their perception of social support, depending on the target group for their contacts (family or friends).

Second, we investigated whether middle-aged and older adults' enhanced perception of social support through social media use would foster a stronger sense of control, and whether their improved sense of control would in turn predict better executive functioning. In line with literature that supports positive relations between perceived social support and sense of control (Antonucci, 2001; Lachman & Weaver, 1998; Lang et al., 1997) and between sense of control and cognitive performance in older adults (Infurna & Gerstorf, 2013; Lachman & Andreoletti, 2006, pp. P88–P94; Neupert & Allaire, 2012), we expect that enhanced perception of social support via social media use would boost sense of control in middle-aged and older adults and, in turn, contribute to better cognitive performance on EF tasks.

Using structural equation modeling, we conducted separate serial mediation analyses with respect to family and friends. To verify the order of the two mediators (perceived social support and sense of control), we tested another serial mediation model in which sense of control preceded perceived social support. In light of our goals, we analyzed a nationally representative adult cohort ranging from ages 40s–70s from the MIDUS Refresher Survey and Cognitive Project while controlling for notable covariates such as age, sex, education, daily functioning level, health, and income, which have been suggested to influence an individual's social media use or EF (Correa, Hinsley, & de Zúñiga, 2010; Vroman, Arthanat, & Lysack, 2015).

2. Methods

2.1. Participants

Of the representative and diverse national sample of 3577 U.S. adults (aged 25 to 74) who took part in the Midlife in the United States Refresher (MIDUS-R) study (2011–2014), a subset of 2673 participants was recruited to be part of the MIDUS-R Cognitive Project, which administered a comprehensive battery of cognitive assessments (Ryff et al., 2016; Ryff & Lachman, 2016). For the purpose of our study, we only analyzed data from 1735 participants who were aged 40 years and above. Participants' demographic, psychosocial, physical, and mental health information were collected during the MIDUS-R study, and data from a series of cognitive measures were collected from the MIDUS-R Cognitive Project. Of the participants, 85.6% were White, 6.3% Black, 1.3% Native American, 0.9% Asian, 0.2% Native Hawaiian or Pacific Islander, and 5.3% Other (see Table A1 in the Appendix for descriptive statistics and zero-order correlations).

2.2. Measures

2.2.1. Social media use

Using an 8-point Likert scale (1 = *Several times a day*, 4 = *About once a week*, 8 = *Never or hardly ever*), participants self-reported how often they used social media (e.g., Facebook, Twitter, Myspace, Skype, text messages, chat rooms, etc.) to contact distant family members (e.g., brothers, sisters, parents, or children) who had not lived with them in the past year. Using the same item, participants also rated the frequency of social media use to contact friends in the past year. The two items were reverse coded so that higher scores denote greater frequency of social media use to contact participants' family and friends.

2.2.2. Perceived social support

Using a four-item questionnaire (e.g., "How much do they care about you?") on a 4-point scale (1 = *A lot*, 4 = *Not at all;* $\alpha = 0.838$), participants rated the extent of social support they received from family. Participants also answered the same questions with reference to friends ($\alpha = 0.879$). Items were reverse coded, with higher scores denoting greater perceived social support.

2.2.3. Sense of control

Participants' sense of control was assessed by a 12-item questionnaire (Lachman & Weaver, 1998) on a 7-point Likert scale (1 = *Strongly Agree*, 7 = *Strongly Disagree*). The scale consisted of two subscales: (a) personal mastery (four items; $\alpha = 0.739$) to assess self-efficacy in carrying out personally important goals (e.g., "I can do just about anything I really set my mind to") and (b) perceived constraints (eight items; $\alpha = 0.866$) to assess one's perception of uncontrollable obstacles that interfere with goal achievement (e.g., "There is little I can do to change the important things in my life"). Items were reverse coded, with higher scores reflecting higher standing in each dimension.

2.2.4. Executive functions (EF)

EF abilities were assessed by a 30-min Brief Test of Adult Cognition by Telephone (BTACT), which consists of several cognitive tasks. Five of these tasks, which have been shown to tap executive functions, were included in the study (Ryff & Lachman, 2016) and are described below.

The digit backward span was designed to assess working memory (updating) capacity. Participants were presented with a series of numbers and asked to repeat them in reverse order. The maximum number of digits recalled up to eight was used to index working memory performance. The category fluency task measured participants' verbal fluency (Baldo, Shimamura, Delis, Kramer, & Kaplan, 2001) and processing speed, which have been shown to be associated with executive functioning (Adrover-Roig et al., 2012). Participants were asked to name as many things that belong to a given category as possible in 1 min, and the number of items listed was used to index performance. Similarly, the backward counting task assessed speed of processing by asking participants to count backward from 100 as fast as possible for 1.5 min. The number of correctly reported numbers was used to index performance. The number series task assessed participants' fluid intelligence and

reasoning, which are typically correlated with working memory. Participants were asked to infer what the next number (e.g., 12) would be in a series of given numbers (e.g., 2, 4, 6, 8, 10), and the number of correct answers was used to index performance. Lastly, the Stop and Go Switch Task (SGST) was designed to assess participants' task-switching and inhibition abilities. Participants were asked to respond according to verbal cues, which were either "normal" (i.e., congruent) or "reverse" (i.e., incongruent). For instance, when prompted with a normal cue, participants should answer "stop" and "go," respectively, in response to the verbal targets "RED" and "GREEN." When prompted with a reverse cue, participants should say "go" and "stop," respectively, in response to "RED" and "GREEN." The two types of cues were intermixed and presented randomly during the task, and participants were required to switch their responses according to normal or reverse cues. Participants' mean response times on switch (i.e., different cues were given consecutively) and nonswitch (i.e., the same cue was given consecutively) trials were used to index performance. Longer response times indicate poorer performance.

2.2.5. Health status

Participants' ability to carry out daily activities was measured by the 7-item Instrumental Activities of Daily Living Scale adapted from the 36-item Short-Form Health Survey (SF-36; Ware & Sherbourne, 1992). Using a 4-point scale (1 = *A lot*, 4 = *Not at all*; α = 0.946), participants evaluated their independence with respect to daily living activities (e.g., "How much does your health limit you in lifting or carrying groceries?"). Items were reverse coded such that higher scores denote greater difficulties in performing each activity of daily living (i.e., poorer health). Second, participants reported the number of chronic conditions they had experienced in the past 12 months from a list of 39 chronic conditions. Individuals who suffered from a greater number of chronic conditions were considered to be in poorer health.

3. Results

3.1. Analysis plan

Structural equation modeling was conducted using M*plus* 7.4 (Muthén & Muthén, 1998) with full information maximum likelihood estimation. The variables of social media use to connect with family and friends (i.e., predictor) were modeled as indicators, while perception of social support (for family and friends), personal mastery, perceived constraints, and EF were modeled as latent variables. Scale items were used as indicators for the latent variables of perception of social support, personal mastery, and perceived constraints, while the five cognitive tasks served as indicators of EF. To ensure that the indicators represent the intended constructs, we first fitted individual measurement models to the data, using confirmatory factor analysis (see Table 1 and Figure A1 in the Appendix). Thereafter, we performed separate structural equation modeling while including age, sex, daily functioning, health, education, and income as covariates, and examined the mediational relation between social media use and EF via social support and sense of control. Given that sense of control consists of two facets (i.e., personal mastery and perceived constraints), we conducted separate structural modeling analyses with respect to each facet. Model fit indices were evaluated based on Hu and Bentler's (1999) criteria: root mean square error of approximation (RMSEA) < 0.05; confirmatory fit index (CFI) > 0.95; and standardized root mean square residual (SRMR) < 0.08. All reported path coefficients are standardized estimates that are indicative of effect sizes (Muthen, 2019).

3.2. Measurement models

Confirmatory factor analysis showed that the measurement model of perceived social support from family showed good model fit to the data (see Table 1). All factor loadings of four scale items as indicators were significant, $ps < .001$ (see Figure A1 in the Appendix for factor loadings). Likewise, the measurement model of perceived social support from friends showed good model fit, with all factor loadings being significant, $ps < .001$. Similarly, we evaluated measurement models for each facet of sense of control. Measurement models of both personal mastery and perceived constraints showed good fit (see Table 1), and all factor loadings were significant, $ps < .001$ (see Figure A1 in the Appendix).

Table 1
Fit indices for measurement and structural models.

	$\chi 2$	*df*	RMSEA	CFI	SRMR
Measurement models					
Perceived family support	3.69	1	.039	1.00	.006
Perceived friends support	7.79**	1	.063	1.00	.007
Perceived constraints	68.66***	14	.047	.99	.017
Personal mastery	0.66	1	.000	1.00	.003
Executive Functions (EF)					
Two-factor model	4.33	3	.016	1.00	.007
One-factor model	2.44	1	.029	1.00	.005
Full measurement model	784.66	252	.035	.97	.028
Structural models					
Family support and perceived constraints as mediators	815.77***	211	.041	.95	.041
Friends support and perceived constraints as mediators	840.80***	211	.041	.95	.042

Note. The two-factor model of EF consists of two latent factors: Factor 1 (category fluency and backward counting) and Factor 2 (number series, digit backward, and Stop and Go Switch task). *$p < .05$; **$p < .01$; ***$p < .001$.

Next, we tested the measurement model for the construct of EF, which was used as an outcome variable. Given that previous studies suggest that either one-factor or two-factor models of EF fit older adults' data well (Adrover-Roig et al., 2012; de Frias et al., 2006; Ettenhofer et al., 2006; Hull et al., 2008), we tested both models to identify the best fitting model. The one-factor model (i.e., a unidimensional construct of EF) consisted of a single factor, while the two-factor model comprised two latent factors that corresponded to (a) processing speed/goal maintenance and (b) updating/shifting. We found that the model fit indices for both models were excellent (see Table 1), and a chi-square difference test indicated that the two models did not significantly differ from each other. Hence, we chose the more parsimonious one-factor model, which is aligned with Adrover-Roig et al.'s (2012) empirical findings that processing speed and goal maintenance share a significant amount of variances with either shifting or updating (i.e., working memory). Finally, we tested the full measurement model with the predictor, mediators, and outcome variable and its model fit indices were excellent (see Table 1).

3.3. Social media use to connect with family

When the variable of social media use for social interaction with family was used as a focal predictor in our structural modeling analysis, with social support and sense of control as mediators and EF as an outcome variable, we found that perceived support from family and perceived constraints—but not personal mastery—serially mediated the relation between social media use to contact family and EF (see Fig. 1). The indirect effect involving personal mastery as a mediator was not significant ($\beta = -0.001$, $SE = 0.001$, $p = .27$). Thus, personal mastery was not considered for subsequent analyses. On the other hand, the indirect effect of social media use on EF via perceived support from family and perceived constraints was significant ($\beta = 0.006$, $SE = 0.002$, $p = .003$). Our post hoc power analysis (Schoemann, Boulton, & Short, 2017) indicated that the statistical power to detect this indirect effect was sufficient (>0.99). Further analyses of path coefficients showed that the use of social media to contact family positively predicted one's perception of family support ($\beta = 0.222$, $SE = 0.024$, $p < .001$), which in turn negatively predicted perceived constraints ($\beta = -0.274$, $SE = 0.025$, $p < .001$), which then negatively predicted EF ($\beta = -0.100$, $SE =$

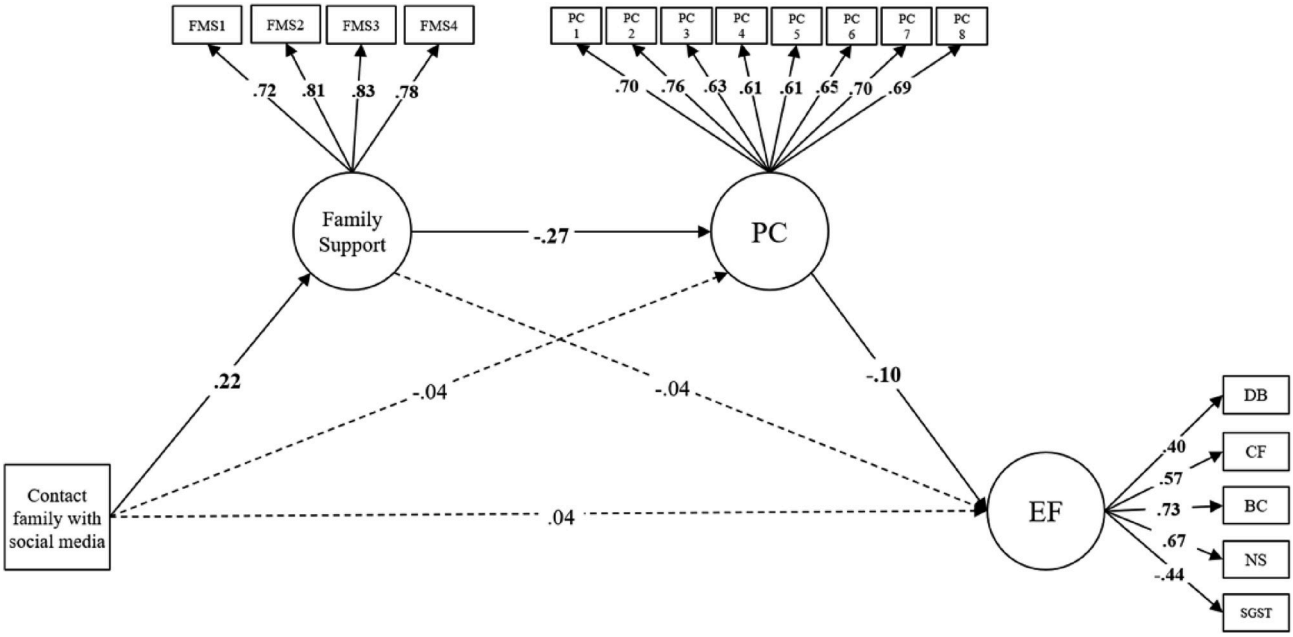

Fig. 1. Structural equation model for the relation between social media to contact family and EF. Circles represent latent variables. Squares and rectangles represent indicators (manifest variables). Longer solid and dotted lines signify statistically significant (at the 0.05 level) and nonsignificant standardized path coefficients, respectively. Values next to single-headed arrows connecting latent variables and indicators signify standardized factor loadings, which are all significant (at the 0.05 level). FMS = Family support; PC = Perceived Constraints; DB = Digit Backward; CF = Category Fluency; BC = Backward Counting; NS = Number Series; SGST = Stop and Go Switch Task.

0.030, $p = .001$). Notably, the direct effect of social media use on EF was not significant ($\beta = 0.041$, $SE = 0.024$, $p = .088$). These results imply that the association between social media use to contact family and EF was fully mediated by perceived family support and perceived constraints. Further analyses showed that results from the two separate nested mediation models, which tested a single mediator of either perception of social support from family ($\beta = -0.009$, $SE = 0.006$, $p = .140$) or perceived constraints ($\beta = 0.004$, $SE = 0.003$, $p = .130$), were not significant.

To verify our theoretical model, we performed another serial mediation analysis with the order of the two mediators (perceived family support and perceived constraints) reversed. The indirect effect via perceived constraints and then family support was not significant ($\beta = -0.002$, $SE = 0.001$, $p = .158$). These results are consistent with the

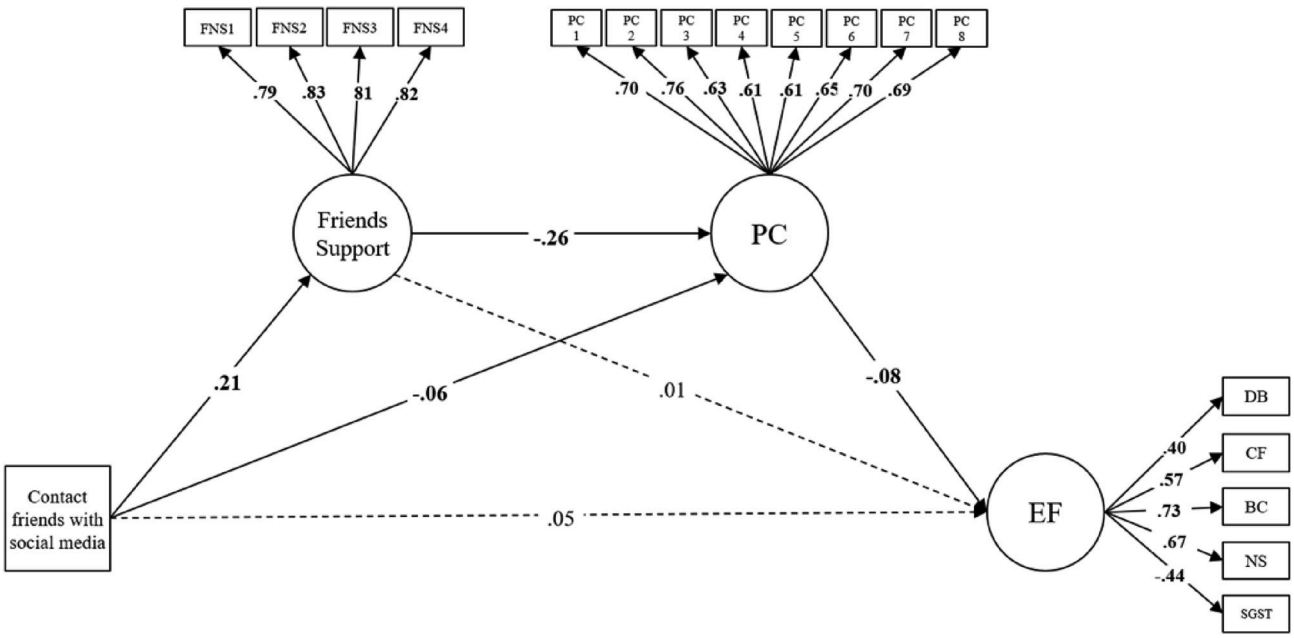

Fig. 2. Structural equation model for the relation between social media use to contact friends and EF. Circles represent latent variables. Squares and rectangles represent manifest variables (indicators). Longer solid and dotted lines signify statistically significant (at.the 05 level) and nonsignificant standardized path coefficients, respectively. Values next to single-headed arrows connecting latent variables and indicators signify standardized factor loadings, which are all significant (at the 0.05 level). FNS = Friends support; PC = Perceived constraints; DB = Digit Backward; CF = Category Fluency; BC = Backward Counting; NS = Number Series; SGST = Stop and Go Switch Task.

support-efficacy model (Antonucci & Jackson, 1987), which postulates that social support is a factor that strengthens sense of control. Together, these results support our hypothesis that the frequent use of social media to contact family members would indirectly predict executive functioning serially through enhanced perception of family support and reduced perceived constraints.

3.4. Social media use to connect with friends

When a similar serial mediation analysis was performed for middle-aged and older adults' social media use to contact friends, we found that the indirect effect of social media use for interactions with friends on EF via perceived support from friends and perceived constraints was significant ($\beta = 0.005$, $SE = 0.002$, $p = .011$; see Fig. 2). Post hoc power analysis (Schoemann et al., 2017) indicated that the statistical power to detect this effect was adequate (0.88). Specifically, the use of social media to contact friends positively predicted one's perception of social support from friends ($\beta = 0.213$, $SE = 0.025$, $p < .001$), which in turn negatively predicted perceived constraints ($\beta = -0.262$, $SE = 0.025$, $p < .001$), which then subsequently predicted EF ($\beta = -0.083$, $SE = 0.030$, $p = .006$). The direct effect of social media use to contact friends on EF was not significant ($\beta = 0.049$, $SE = 0.025$, $p = .051$), indicating that the relation between social media use to contact friends and EF was fully mediated by perceived support from friends and perceived constraints. Further analyses revealed that results from the two separate nested mediation models with perceived support from friends ($\beta = 0.002$, $SE = 0.006$, $p = .748$) and perceived constraints ($\beta = 0.005$, $SE = 0.003$, $p = .067$) as a single mediator, respectively, were not significant. Notably, however, the serial mediation effect involving personal mastery was not significant ($\beta = -0.002$, $SE = 0.001$, $p = .21$).

To verify our theoretical model, we ran a similar analysis with the order of the two mediators (perceived support from friends and perceived constraints) reversed. We found that the indirect effect of social media use on EF, via perceived constraints and then support from friends (reversed order), was not significant ($\beta = 0.000$, $SE = 0.001$, $p = .749$), which confirms our proposed serial mediation model in which perceived social support precedes perceived constraints in explaining the association between social media use and EF. Taken together, these results support our hypothesis that frequent use of social media to contact friends would positively predict EF serially through enhanced perception of support from friends and reduced perceived constraints.

4. Discussion

Using a large representative sample, a comprehensive battery of cognitive tasks, and rigorous structural equation modeling, we found that the use of social media for interpersonal interactions with family and friends positively predicts executive functioning in middle and old age indirectly via perceived social support and constraints. Corroborating and extending previous research (Myhre et al., 2016; Quinn, 2018), our study sheds light on the sequential mechanism underlying the relation between social media use for social connection and EF via enhanced perception of social support and reduced constraints. Below, we discuss the findings that are particularly worthy of further consideration.

First, our findings reconcile, in part, the mixed findings of previous studies. In view of the indirect effect of social media use on EF via perceived social support and perceived constraints, Myhre et al.'s (2016) null finding of the relation between social media intervention and inhibition and shifting aspects of EF may be due to the lack of social support received from social media use. Given that participants in Myhre et al.'s (2016) intervention condition were instructed to use social media to seek social support from new acquaintances—while excluding close family and friends—their intervention method may have resulted in a limited extent of social support, which in turn impaired the mediation link between social media use and EF. In contrast, Quinn (2018) found that social media training positively enhanced inhibition, but not other cognitive abilities—i.e., processing speed, attention, and working memory. Given that Quinn (2018) reported a significant decrease in social media use between the period of intervention and the 4-month follow-up study, our findings suggest that the positive indirect effect of social media use on EF may require a relatively longer and persistent use of social media (e.g., 1 year in our study), since changes in the perception of social support and perceived constraints require time to settle and show their full effects. Hence, the short-term use of social media, as in Quinn's (2018) study, could have a limited effect on EF.

Second, given that the socioemotional selectivity theory maintains that older adults are keenly motivated to enhance positive and more satisfying emotional experiences by devoting time to emotionally rewarding social networks (Carstensen, 1992; Lansford, Sherman, & Antonucci, 1998), we expected that the indirect effect of social media use for family would be more pronounced than that for friends. We found, however, that the use of social media to connect with family and friends significantly predicted EF via enhanced perception of social support and attenuated perceived constraints. These results suggest that social media use for interactions with conceivably broader social networks (i.e., friends) is as beneficial as social media use to connect with family for improving middle-aged and older adults' perception of social support and, in turn, attenuating perceived constraints. Future studies are needed to examine whether the indirect effect of social media use to connect with friends on EF is specific to very close friends or casual acquaintances.

Third, we found that only perceived constraints, and not personal mastery, significantly contributed to the serial mediation model for the relation between social media use for interpersonal interactions and EF. Given that perceived constraints are more relevant to success in one's daily life (e.g., "I often feel helpless in dealing with the problems of life"), it is reasonable that social media, through which older adults can solicit help from family and friends, reduces perceived constraints in middle-aged and older adults. On the other hand, since personal mastery reflects one's competence in achieving long-term goals (e.g., "I can do just about anything I really set my mind to"), the use of social media may do little to enhance one's personal mastery at older ages. This finding corroborates with previous findings that perceived constraints have a greater influence on older individuals' mental and physical health than personal mastery (Infurna & Mayer, 2015).

Our study is not without limitations, which require caution in interpreting the findings. First, notwithstanding the use of a mediational analysis, it is difficult to establish a causal relation between social media use and EF due to the correlational nature of the analysis (Pirlott & MacKinnon, 2016). That is, it is still possible that those who are high in executive functioning tend to use social media more frequently as a tool to elicit social support from family and friends and experience less constraints, instead of the hypothesized direction whereby social media use predicts EF via social support and perceived constraints.

Second, given that there are different types of social support (shallow vs. deep), our study is limited because it does not differentiate the specific type of social support that plays a mediating role in the relation between social media use and EF. According to Pfeil, Zaphiris, and Wilson (2009), social media is effective for facilitating shallow social support and not deep social support. Similarly, Lewandowski, Rosenberg, Parks, and Siegel (2011) suggest that when it comes to facing adversity in life, people still prefer face-to-face support over support received through social media. Given this, it is possible that social media as a medium to promote social support may not be an effective channel to evoke social support for those who are experiencing adversities. Future studies are needed to understand this subject in depth.

Third, our assessment of social media use is limited to its use for interpersonal interactions and does not account for other possible uses, such as information gathering (Leist, 2013). Thus, further studies are required to understand whether the broader use of social media would have similar benefits for middle-aged and older adults. Fourth, although

a large sample size might inflate some predictive relations and lead to spurious findings, we argue that this is less likely since (a) we employed a latent variable approach to control for measurement errors, (b) we chose a well-refined theoretical framework, and (c) our findings are in line with previous empirical findings. Finally, given that we focused on a unidimensional construct of EF based on the five tasks, our findings are relevant to middle-aged and older adults' general control functioning but not to specific facets of EF. Future research should therefore employ more EF tasks to examine the relation of social media use to specific aspects of EF.

Our study contributes to the literature by expanding previous research on the impact of social media use on middle-aged and older adults' general cognitive functioning (Myhre et al., 2016; Quinn, 2018). Our findings are novel, in that they demonstrate the specific pathway by which social media use impacts EF. Our findings that middle-aged and older adults reap benefits in domain-general control functioning through their social media use have important and practical implications. First, with an increasing aging workforce, there is a pressing need for older workers to maintain (or even maximize) their cognitive abilities during extended working years. Given this, an effective use of social media that enhances middle-aged and older adults' perception of social support and reduces perceived constraints can serve as a useful strategy to buffer against possible age-related cognitive decline (van Hooren et al., 2007).

Second, given that social support, perceived constraints, and EF are all instrumental for successful aging (Albert et al., 1995; Infurna & Mayer, 2015; Lewis et al., 2017; Toh et al., 2019), our findings imply that constructive social media use is important for middle-aged and older adults' well-being in later years. Further, our findings have important implications for social policies and community interventions to promote healthy aging in a rapidly aging society. Specifically, given that the spread of social media is pervasive and can be used for meaningful purposes, middle-aged and older adults' social media use as a mode of communication and social interaction has great potential to improve important psychological functioning that supports healthy aging.

5. Conclusion

This study offers insights into how social media use with family and friends can benefit middle-aged and older adults' EF serially through enhanced perceived social support and reduced perceived constraints. Prior research has not provided a clear mechanistic explanation of how social media use influences middle-aged and older adults' EF. Our findings show that social media use with family or friends positively predicts one's perceived social support, which in turn negatively predicts perceived constraints, which in turn supports EF. Our findings are both timely and crucial to facilitate more research on the role of social media use to improve cognitive abilities in middle and late adulthood and to inform policy makers on interventions to promote healthy aging.

Appendix

Table A1
Descriptive Statistics and Bivariate Zero-order Correlations

	M	*SD*	1	2	3	4	5	6	7	8	9	10	11	12
1. Executive Functions (EF)	−0.5	0.3	1.00											
2. Social media use (family)	4.1	2.6	**0.08**	1.00										
3. Social media use (friends)	4.1	2.6	**0.16**	**0.70**	1.00									
4. Family Support	0.5	0.1	−0.05	**0.22**	0.05	1.00								
5. Friends support	0.3	0.2	**0.06**	**0.11**	**0.21**	**0.39**	1.00							
6. Perceived Constraints	−0.2	0.4	**−0.16**	**−0.11**	**−0.12**	**−0.33**	**−0.32**	1.00						
7. Personal Mastery	0.0	0.4	0.05	0.01	−0.04	**0.21**	**0.24**	**−0.66**	1.00					
8. Age (years)	58.6	10.3	**−0.34**	**−0.09**	**−0.18**	**0.10**	0.00	**−0.07**	−0.04	1.00				
9. Sex[b]	1.5	0.5	−0.04	**0.19**	**0.16**	**0.11**	**0.23**	**−0.11**	−0.04	**−0.09**	1.00			
10. Chronic Diseases[c]	3.1	3.2	**−0.08**	−0.03	−0.04	**−0.11**	**−0.08**	**0.21**	**−0.07**	−0.02	**0.14**	1.00		
11. Daily Activities[c]	1.9	0.9	**−0.17**	**−0.06**	**−0.06**	**−0.02**	**−0.06**	**0.22**	0.01	**0.25**	**0.16**	**0.49**	1.00	
12. Education[d]	7.9	2.5	**0.41**	0.02	**0.09**	−0.04	0.04	**−0.13**	−0.04	0.00	**−0.08**	**−0.19**	**−0.29**	1.00
13. Income[e]	53.6	53.0	**0.14**	**0.07**	**0.06**	0.03	0.04	**−0.09**	**0.08**	−0.01	**−0.28**	**−0.17**	**−0.25**	**0.40**

Note.

>a Sense of control is based on two subtests of personal mastery and perceived constraints.

[b] Sex (1 = Male, 2 = Female).

[c] Higher score indicates poorer health.

[d] Education is reported on a scale of 1 (*No school*) to 12 (*Doctoral or other professional degree*).

[e] Income includes wages, salaries, stipends from all jobs (including self-employment), pension accounts, social security, tips, commissions, financial assistance, etc. Income is reported based on the measurement unit of $1000.

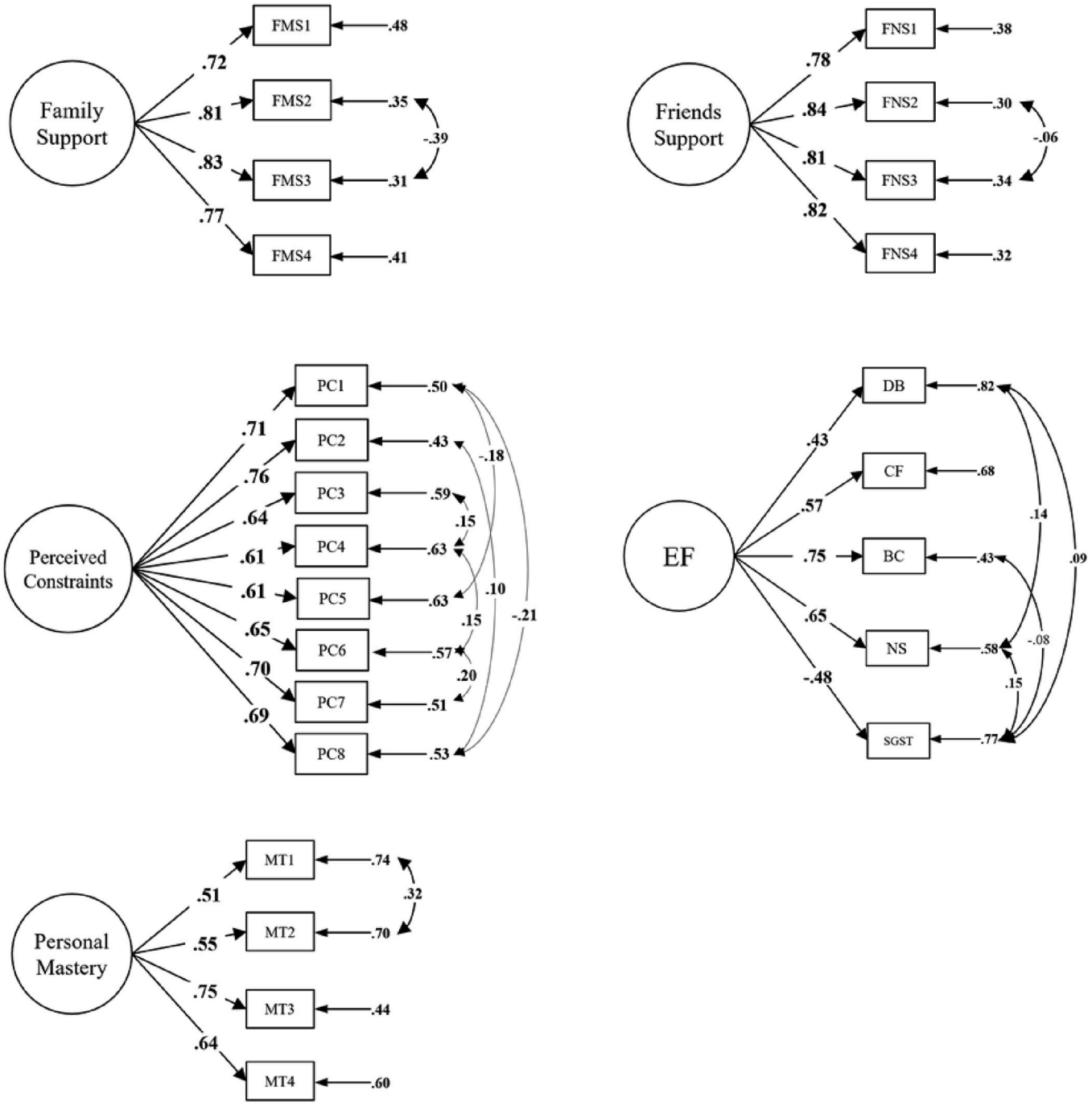

Fig. A1. Individual measurement models of EF, Perceived Constraints, Perceived Family Support, Perceived Friends Support and Personal Mastery, with standardized estimates. Circles represent latent variables. Rectangles represent indicators (manifest variables). Values for long single-headed arrows signify factor loadings and those for short single-headed arrows represent error variances. Values for curved, double-headed arrows indicate interfactor correlations. FMS = Family support; FNS = Friends support; PC = Perceived Constraints; DB = Digit Backward; CF = Category Fluency; BC = Backward Counting; NS = Number Series; SGST = Stop and Go Switch Task; MT = Personal mastery. All bolded statistics are statistically significant at the .05 level.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chb.2020.106388.

References

Adrover-Roig, D., Sesé, A., Barceló, F., & Palmer, A. (2012). A latent variable approach to executive control in healthy ageing. *Brain and Cognition, 78*(3), 284–299. https://doi.org/10.1016/j.bandc.2012.01.005.

Aillerie, K., & McNicol, S. (2018). Are social networking sites information sources? Informational purposes of high-school students in using SNSs. *Journal of Librarianship and Information Science, 50*(1), 103–114. https://doi.org/10.1177/0961000616631612.

Albert, M. S., Jones, K., Savage, C. R., Berkman, L., Seeman, T., Blazer, D., et al. (1995). Predictors of cognitive change in older persons: MacArthur studies of successful

aging. *Psychology and Aging, 10*(4), 578–589. https://doi.org/10.1037/0882-7974.10.4.578.
Antonucci, T. C. (2001). Social relations: An examination of social networks, social support, and sense of control. In J. E. Birren, & K. W. Schaie (Eds.), *Handbook of psychology of aging* (pp. 427–453). Academic Press.
Antonucci, T. C., & Jackson, J. S. (1987). Social support, interpersonal efficacy, and health: A life course perspective. In *Handbook of clinical gerontology* (pp. 291–311). Pergamon Press.
Baldo, J. V., Shimamura, A. P., Delis, D. C., Kramer, J., & Kaplan, E. (2001). Verbal and design fluency in patients with frontal lobe lesions. *Journal of the International Neuropsychological Society, 7*(5), 586–596. https://doi.org/10.1017/S1355617701755063.
Bandura, A. (1997). *Self-efficacy: The exercise of control*. Freeman. https://psycnet.apa.org/record/1997-08589-000.
Barker, V. (2009). Older adolescents' motivations for social network site use: The influence of gender, group identity, and collective self-esteem. *CyberPsychology and Behavior, 12*(2), 209–213. https://doi.org/10.1089/cpb.2008.0228.
Bell, C., Fausset, C., Farmer, S., Nguyen, J., Harley, L., & Fain, W. B. (2013). Examining social media use among older adults. *Proceedings of the 24th ACM Conference on Hypertext and Social Media - HT, '13*, 158–163. https://doi.org/10.1145/2481492.2481509.
Carstensen, L. L. (1992). Social and emotional patterns in adulthood: Support for socioemotional selectivity theory. *Psychology and Aging, 7*(3), 331–338.
Correa, T., Hinsley, A. W., & de Zúñiga, H. G. (2010). Who interacts on the Web?: The intersection of users' personality and social media use. *Computers in Human Behavior, 26*(2), 247–253. https://doi.org/10.1016/j.chb.2009.09.003.
Derksen, B. J., Duff, M. C., Weldon, K., Zhang, J., Zamba, K. D., Tranel, D., et al. (2015). Older adults catch up to younger adults on a learning and memory task that involves collaborative social interaction. *Memory, 23*(4), 612–624. https://doi.org/10.1080/09658211.2014.915974.
Ellwardt, L., Aartsen, M., Deeg, D., & Steverink, N. (2013). Does loneliness mediate the relation between social support and cognitive functioning in later life? *Social Science & Medicine, 98*, 116–124. https://doi.org/10.1016/j.socscimed.2013.09.002.
Ettenhofer, M. L., Hambrick, D. Z., & Abeles, N. (2006). Reliability and stability of executive functioning in older adults. *Neuropsychology, 20*(5), 607–613. https://doi.org/10.1037/0894-4105.20.5.607.
de Frias, C. M., Dixon, R. A., & Strauss, E. (2006). Structure of four executive functioning tests in healthy older adults. *Neuropsychology, 20*(2), 206–214. https://doi.org/10.1037/0894-4105.20.2.206.
Gaultney, J. F., Kipp, K., & Kirk, G. (2005). Utilization deficiency and working memory capacity in adult memory performance: Not just for children anymore. *Cognitive Development, 20*(2), 205–213. https://doi.org/10.1016/j.cogdev.2005.02.001.
Hartanto, A., & Yang, H. (2019). Does early active bilingualism enhance inhibitory control and monitoring? A propensity-matching analysis. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 45*(2), 360–378. https://doi.org/10.1037/xlm0000581.
Hedden, T., & Gabrieli, J. D. E. (2004). Insights into the ageing mind: A view from cognitive neuroscience. *Nature Reviews Neuroscience, 5*(2), 87–96. https://doi.org/10.1038/nrn1323.
Hertzog, C., McGuire, C. L., & Lineweaver, T. T. (1998). Aging, attributions, perceived control, and strategy use in a free recall task. *Aging, Neuropsychology, and Cognition, 5*(2), 85–106. https://doi.org/10.1076/anec.5.2.85.601.
van Hooren, S. A. H., Valentijn, A. M., Bosma, H., Ponds, R. W. H. M., van Boxtel, M. P. J., & Jolles, J. (2007). Cognitive functioning in healthy older adults aged 64–81: A cohort study into the effects of age, sex, and education. *Aging, Neuropsychology, and Cognition, 14*(1), 40–54. https://doi.org/10.1080/138255890969483.
Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal, 6*(1), 1–55. https://doi.org/10.1080/10705519909540118.
Hull, R., Martin, R. C., Beier, M. E., Lane, D., & Hamilton, A. C. (2008). Executive function in older adults: A structural equation modeling approach. *Neuropsychology, 22*(4), 508–522. https://doi.org/10.1037/0894-4105.22.4.508.
Infurna, F. J., & Gerstorf, D. (2013). Linking perceived control, physical activity, and biological health to memory change. *Psychology and Aging, 28*(4), 1147–1163. https://doi.org/10.1037/a0033327.
Infurna, F. J., & Mayer, A. (2015). The effects of constraints and mastery on mental and physical health: Conceptual and methodological considerations. *Psychology and Aging, 30*(2), 432–448. https://doi.org/10.1037/a0039050.
Kaplan, A. M., & Haenlein, M. (2010). Users of the world, unite! the challenges and opportunities of Social Media. *Business Horizons, 53*(1), 59–68. https://doi.org/10.1016/j.bushor.2009.09.003.
Kelly, M. E., Duff, H., Kelly, S., McHugh Power, J. E., Brennan, S., Lawlor, B. A., et al. (2017). The impact of social activities, social networks, social support and social relationships on the cognitive functioning of healthy older adults: A systematic review. *Systematic Reviews, 6*(1), 259. https://doi.org/10.1186/s13643-017-0632-2.
Lachman, M. E., & Agrigoroaei, S. (2012). Low perceived control as a risk factor for episodic memory: The mediational role of anxiety and task interference. *Memory & Cognition, 40*(2), 287–296. https://doi.org/10.3758/s13421-011-0140-x.
Lachman, M. E., & Andreoletti, C. (2006). Strategy use mediates the relationship between control beliefs and memory performance for middle-aged and older adults. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 61*(2), P88–P94. https://doi.org/10.1093/geronb/61.2.P88.
Lachman, M. E., & Firth, K. M. P. (2004). The adaptive value of feeling in control during Midlife. In O. G. Brim, C. D. Ryff, & R. C. Kessler (Eds.), *The john D. and catherine T. Macarthur foundation series on mental health and development. Studies on successful midlife development. How healthy are we? A national study of well-being at midlife*. University of Chicago Press.
Lachman, M. E., Rosnick, C. B., & Röcke, C. (2009). The rise and fall of control beliefs and life satisfaction in adulthood: Trajectories of stability and change over ten years. In *Aging and cognition: Research methodologies and empirical advances* (pp. 143–160). American Psychological Association. https://doi.org/10.1037/11882-007.
Lachman, M. E., & Weaver, S. L. (1998). The sense of control as a moderator of social class differences in health and well-being. *Journal of Personality and Social Psychology, 74*(3), 763–773. https://doi.org/10.1037/0022-3514.74.3.763.
Lang, F. R., Featherman, D. L., & Nesselroade, J. R. (1997). Social self-efficacy and short-term variability in social relationships: The MacArthur Successful Aging Studies. *Psychology and Aging, 12*(4), 657–666. https://doi.org/10.1037/0882-7974.12.4.657.
Lansford, J. E., Sherman, A. M., & Antonucci, T. C. (1998). Satisfaction with social networks: An examination of socioemotional selectivity theory across cohorts. *Psychology and Aging, 13*(4), 544–552. https://doi.org/10.1037/0882-7974.13.4.544.
Leist, A. K. (2013). Social media use of older adults: A mini-review. *Gerontology, 59*(4), 378–384. https://doi.org/10.1159/000346818.
Lewandowski, J., Rosenberg, B. D., Parks, J. M., & Siegel, J. T. (2011). The effect of informal social support: Face-to-face versus computer-mediated communication. *Computers in Human Behavior, 27*(5), 1806–1814. https://doi.org/10.1016/j.chb.2011.03.008.
Lewis, N. A., Turiano, N. A., Payne, B. R., & Hill, P. L. (2017). Purpose in life and cognitive functioning in adulthood. *Aging, Neuropsychology, and Cognition, 24*(6), 662–671. https://doi.org/10.1080/13825585.2016.1251549.
Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*, 49–100. https://doi.org/10.1006/cogp.1999.0734.
Muthen, B. O. (2019 August 28). *Effect size of serial mediation model*. Mplus Discussion. http://www.statmodel.com/discussion/messages/11/27351.html?1567031326.
Muthén, L. K., & Muthén, B. O. (1998). *Mplus user's guide* (7th ed.). Muthén & Muthén.
Myhre, J. W., Mehl, M. R., & Glisky, E. L. (2016). Cognitive benefits of online social networking for healthy older adults. In *The journals of gerontology series B*. Psychological Sciences and Social Sciences. https://doi.org/10.1093/geronb/gbw025. gbw025.
Neupert, S. D., & Allaire, J. C. (2012). I think I can, I think I can: Examining the within-person coupling of control beliefs and cognition in older adults. *Psychology and Aging, 27*(3), 742–749. https://doi.org/10.1037/a0026447.
Pfeil, U., Zaphiris, P., & Wilson, S. (2009). Older adults' perceptions and experiences of online social support. *Interacting with Computers, 21*(3), 159–172. https://doi.org/10.1016/j.intcom.2008.12.001.
Pirlott, A. G., & MacKinnon, D. P. (2016). Design approaches to experimental mediation. *Journal of Experimental Social Psychology, 66*, 29–38. https://doi.org/10.1016/j.jesp.2015.09.012.
Procidano, M. E., & Heller, K. (1983). Measures of perceived social support from friends and from family: Three validation studies. *American Journal of Community Psychology, 11*(1), 1–24.
Quinn, K. (2018). Cognitive effects of social media use: A case of older adults. *Social Media + Society, 4*(3). https://doi.org/10.1177/2056305118787203, 205630511878720.
Robinson, S. A., & Lachman, M. E. (2017). Perceived control and aging: A mini review and directions for future research. *Gerontology, 63*(5), 435–442. https://doi.org/10.1159/000468540.
Ryff, C., Almeida, D., Ayanian, J., Binkley, N., Carr, D. S., Coe, C., et al. (2016). *Midlife in the United States (MIDUS refresher), 2011-2014*. https://doi.org/10.3886/ICPSR36532.v3. Inter-university Consortium for Political and Social Research [distributor].
Ryff, C. D., & Lachman, M. E. (2016). *Midlife in the United States (MIDUS refresher): Cognitive Project, 2011-2014*. https://doi.org/10.3886/ICPSR37081.v1. Inter-university Consortium for Political and Social Research [distributor].
Schoemann, A. M., Boulton, A. J., & Short, S. D. (2017). Determining power and sample size for simple and complex mediation models. *Social Psychological and Personality Science, 8*(4), 379–386. https://doi.org/10.1177/1948550617715068.
Seeman, T. E., Lusignolo, T. M., Albert, M., & Berkman, L. (2001). Social relationships, social support, and patterns of cognitive aging in healthy, high-functioning older adults: MacArthur studies of successful aging. *Health Psychology, 20*(4), 243–255. https://doi.org/10.1037/0278-6133.20.4.243.
Sims, T., Reed, A. E., & Carr, D. C. (2017). Information and communication technology use is related to higher well-being among the oldest-old. *The Journals of Gerontology: Series B, 72*(5), 761–770. https://doi.org/10.1093/geronb/gbw130.
Soederberg Miller, L. M., & Gagne, D. D. (2005). Effects of age and control beliefs on resource allocation during reading abstract. *Aging, Neuropsychology, and Cognition, 12*(1), 129–148. https://doi.org/10.1080/13825580590925161.
Soederberg Miller, L. M., & Lachman, M. E. (2000). Cognitive performance and the role of control beliefs in Midlife. *Aging, Neuropsychology, and Cognition, 7*(2), 69–85. https://doi.org/10.1076/1382-5585(200006)7:2;1-U;FT069.
Toh, W. X., Yang, H., & Hartanto, A. (2019). Executive function and subjective well-being in middle and late adulthood. *Journals of Gerontology, 9*.
Vroman, K. G., Arthanat, S., & Lysack, C. (2015). "Who over 65 is online?" Older adults' dispositions toward information communication technology. *Computers in Human Behavior, 43*, 156–166. https://doi.org/10.1016/j.chb.2014.10.018.
Walen, H. R., & Lachman, M. E. (2000). Social support and strain from partner, family, and friends: Costs and benefits for men and women in adulthood. *Journal of Social*

and Personal Relationships, 17(1), 5–30. https://doi.org/10.1177/0265407500171001.

Ware, J. E., & Sherbourne, C. D. (1992). The MOS 36-item short-form health Survey (SF-36): I. Conceptual framework and item selection. *Medical Care, 30*(6), 473–483. JSTOR.

White, H., McConnell, E., Clipp, E., Bynum, L., Teague, C., Navas, L., et al. (1999). Surfing the net in later life: A review of the literature and pilot study of computer use and quality of life. *Journal of Applied Gerontology, 18*(3), 358–378. https://doi.org/10.1177/073346489901800306.

Xie, B. (2008). Multimodal computer-mediated communication and social support among older Chinese internet users. *Journal of Computer-Mediated Communication, 13*(3), 728–750. https://doi.org/10.1111/j.1083-6101.2008.00417.x.