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Association of social isolation and smartphone use on cognitive functions

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A R T I C L E I N F O

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A B S T R A C T

Background: The number of socially isolated older adults has increased owing to the coronavirus disease pandemic, thus leading to a decrease in cognitive functions among this group. Smartphone use is expected to be a reasonable preventive measure against cognitive decline in this social context. Thus, this study aimed to investigate the influence of social isolation and smartphone use on cognitive functions in community-dwelling older adults.
Methods: We divided 4,601 community-dwelling older adults into four groups based on their levels of social isolation and smartphone use. Then, we conducted cognitive functions tests including a word list memory task, trail-making test, and symbol digit substitution task. Social isolation was defined when participants met two or more of the following measures: domestic isolation, less social contact, and social disengagement. We used an analysis of covariance adjusted by background information to measure between-group differences in levels of cognitive functions and social isolation. A linear regression model was used to analyze the association of standardized scores of cognitive function tests with smartphone use.
Results: Smartphone users' scores of the symbol digit substitution task were superior compared with both non-users with social isolation and without. All cognitive functions were associated with smartphone use among non-socially and socially isolated participants. Socially isolated older adults showed an association only between trail making test- part A and smartphone use.
Conclusions: Smartphone use was associated with cognitive functions (memory, attentional function, executive function, and processing speed) even in socially isolated community-dwelling older adults.

1. Introduction

In 2021, the World Health Organization (WHO) referred to social isolation as "the objective state of having a small network of kin and non-kin relationships and thus few or infrequent interactions with others" (Organization, 2021). Results from a nationwide internet survey in Japan revealed that the prevalence of social isolation was 21.2% (20.7–21.7%) and 27.9% (27.3–28.4%) before and during the pandemic, respectively (Yamada, Wakaizumi, Kubota, Murayama, & Tabuchi, 2021). Additionally, the number of socially isolated older adults is expected to increase worldwide in the future because of the spread of the novel coronavirus disease (Bland et al., 2020). Therefore, while social distancing prevents infections, it leads to fewer social interactions. Moreover, social isolation during the COVID-19 pandemic has been linked to a decline in cognitive function (Noguchi et al. 2021). Thus, social isolation in older adults has recently become a more serious social issue.

In addition, social isolation may have harmful consequences on cognitive health. The WHO posed social isolation as a risk factor for physical health (e.g., cardiovascular disease, stroke) and mental health conditions (e.g., cognitive decline, dementia, depression, anxiety, suicidal ideation, and suicide) (Organization, 2021). Specifically, one risk factor across all these geriatric illnesses is cognitive decline (Inouye, Studenski, Tinetti, & Kuchel, 2007), as it interferes with independent daily activities (Urwyler et al., 2017). A meta-analysis found that some aspects of social isolation are significantly associated with poor cognitive function in later life (Evans, Martyr, Collins, Brayne, & Clare, 2019). Another recent meta-analysis confirmed the effect of structural and functional aspects, as well as the combination of both, on cognitive decline (Piolatto et al., 2022). Accordingly, cognitive decline induced by

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social isolation threatens health longevity in socially isolated older adults and requires intervention that aims to maintain cognitive functions.

Smartphones are information and communication technology devices that are portable and have high accessibility to various built-in functions. In 2016, approximately 42% of older adults aged over 65 reported owning smartphones, up from just 18% in 2013. In addition, there are substantial differences in technology adoption within the older adult population based on factors such as age, household income, and educational level (Perrin, 2017). Smartphones' built-in functions enable interactions with people through email, phone calls, social media, and video calls. A survey conducted in the US revealed that 34% of older adults aged 65 and over use social networking sites (Perrin, 2017). A randomized-control trial reported that access to technology and the Internet may provide opportunities to reduce the risk of social isolation and loneliness among older adults (Czaja, Boot, Charness, Rogers, & Sharit, 2018).

Additionally, smartphone use may contribute to cognitive maintenance in socially isolated older adults. Indeed, a recent systematic review explored how smartphone and tablet use could aid cognitive and memory function, which were enhanced by pre-existing familiarity with and early adoption of these devices in older adults with cognitive impairment (Wilson, Byrne, Rodgers, & Maden, 2022). Moreover, a previous cross-sectional study showed that among community-dwelling older adults, smartphone users maintained higher cognitive functions, compared with non-users (Yuan et al., 2019). A dose-response relationship was confirmed between smartphones' functions use and the levels of cognitive functions (Yuan et al., 2019). In addition, in a longitudinal intervention study, scholars used a smartphone to encourage self-management in the daily lives of community-dwelling older adults (Hiroyuki Shimada et al., 2019). Thus, smartphone use is considered a positive factor for maintaining cognitive functions in socially isolated community-dwelling older adults. Thus, as smartphone users can interact while maintaining physical distance, smartphones could be useful tools for intervention, especially during a pandemic.

Therefore, this study aimed to investigate the influence of social isolation and smartphone use on cognitive functions in community-dwelling older adults. We proposed a hypothesize that older adults who use smartphones would have higher cognitive functions even in social isolation, compared with non-users.

2. Materials and Methods

2.1. Study design and participants

The participants were recruited from a sub-cohort of the National Center for Geriatrics and Gerontology Study of Geriatric Syndrome. This sub-cohort targeted all older adults aged 65 years or more on March 31, 2017, who lived in Tokai, Aichi Prefecture, Japan; and all were without long-term-care needs or support at the start of the study. An invitation letters for the baseline assessment was sent to all older adults (n=20,248), 5,563 of them participated in it. We excluded: participants who were diagnosed with brain diseases such as stroke, dementia, and Parkinson's disease, those who scored 23 or lower mini-mental state examination, those who needed help from others for basic daily activities and those who missed answering about possession of smartphone or social lifestyle. Finally, we had 4,601 participants in our study. We conducted measurements (see section 2.2) on these participants from 2017–2018. The ethics committee of the National Center for Geriatrics and Gerontology approved this study (approval number: 1067-3).

Participants performed all cognitive function tests using the National Center of Geriatrics and Gerontology-Functional Assessment Tool (NCGG-FAT) (Makizako et al., 2013). NCGG-FAT consists of four cognitive domains, including to memory, attention and executive function, and processing speed. These domains assessed by word list memory I-II, trail-making test- part A, trail making test part-B, and symbol digit substitution task. This tablet PC-based tool is equipped with a multidimensional neurocognitive task battery with sufficient reliability (the intraclass coefficient ranged from 0.764–0.942) and moderate and high validity. We used electrical tablet devices (Apple Inc., Cupertino, CA, USA) to measure participants' scores.

2.2. Measurements

2.2.1. Cognitive functions

Wordlist memory I-II was originally derived from a subset of the Alzheimer's disease assessment scale–cognitive subscale (Graham, Cully, Snow, Massman, & Doody, 2004). The word list memory I-II comprised two parts that examined immediate and delayed recognition levels. In the first part, each word was displayed on the screen for 2 seconds successively. Meanwhile, we instructed participants to memorize as many words as possible. Immediately afterwards, participants were asked to select a memorized word from a word list of 30 words. Twenty minutes after part 1, the participants wrote down as many words as they could remember on paper as part 2. We considered the total number of correct answers in both parts as each participant's representative performance score.

In the trail-making test - part A, numbers from 1–15 were displayed irregularly scattered on the screen, and we instructed participants to select the numbers in order as quickly as possible (Lezak, Howieson, Loring, & Fischer, 2004). In the trail-making test part B, 15 numbers and letters (Japanese Kana characters) were displayed on the screen in an irregular pattern, and we instructed participants to select numbers and letters alternately in order as quickly as possible. For both trail-making tests, we used participants' total time taken to finish the test as a performance representative value.

In the symbol digit substitution task (Wechsler, 1955), a correspondence table that comprised both nine figures and numbers was displayed at the top of the screen. Next, at the bottom of the screen, a specific figure was displayed with a list of numbers from 1–9. Participants had to select the number that matched with the figure from the correspondence table. We counted the total correct answers registered in 90 seconds as participants' performance representative value. After practice sessions, we double-checked whether participants correctly understood all tasks' goals.

2.2.2. Social isolation and smartphone use

To assess participants level of isolation, we used three measures of social isolation with a questionnaire based on a previous study (Philip et al., 2020), which included domestic isolation, less social contact, and social disengagement. We defined social isolation when participants met two or more of these measures. We considered participants in domestic isolation when they lived alone, and considered less social contact when they answered "No" to both of the following questions: "Do you have face-to-face conversations with acquaintances/friends other than family members?" and "Do you talk on the phone with acquaintances/friends other than family members?". We considered participants as socially disengaged if they answered, "No" to both the questions "Do you participate in a group exercise circle?" and "Do you participate in meetings of senior citizen associations, neighborhood associations, or other groups?".

2.2.3. Social isolation and smartphone use

We assessed smartphone use with face-to-face interviews. The survey form included an illustration of a full-screen smartphone, and participants were asked to indicate whether or not they used a smartphone. We defined participants who answered "No" to the question "Do you use a smartphone?", as non-users and those who answered "yes" as smartphone users.

2.2.4. Background information

We used age, sex, body height, body mass, body mass index, number of used medications, disease history for hypertension, diabetes, heart disease, eyesight, smoking condition, education history, household annual income, gait speed, and the Geriatric Depression Scale (GDS) as background information. To assess eyesight, we asked participants whether they could or not read newspapers or read-only headlines. We divided household annual income into four categories (i.e., < 5 million, ≥ 5 million to <7 million, > ≥ 7 million to <5 million, > and ≥ 10 million yen) according to a previous study (Kurita et al., 2021). We measured gait speed on the ground level for 6.4 meters by asking participants to walk at a normal speed. To obtain their walking speed, we set up infrared light-emitting devices at 2.4 m and 4.4 m from the starting point, respectively. Then, we measured the time taken to walk 2.4 meters. We finally divided the time by 2.4. We used a 15-item version of the GDS to quantify depressive symptoms in older adults (Yesavage, 1988). Higher scores indicate more depressive symptoms.

2.2.5. Statistical analysis

We established four groups of participants according to smartphone use and their level of social isolation: i) socially isolated non-users, ii) non-socially isolated non-users, iii) socially isolated smartphone users, and iv) non-socially isolated smartphone users. To determine the difference in all measured items among groups, we used analysis of variance (ANOVA) for ratio scale and Pearson's chi-square test for the nominal scale. As post hoc analysis, multiple comparisons with Bonferroni correction and residual analysis were conducted respectively for each type of scale.

For the four groups, and both socially and non-socially isolated groups respectively, we conducted an analysis of covariance (ANCOVA) to compare the estimated value of each cognitive functions test score. We adjusted for all background information variables (see section 2.2.4), except diseases background history, body height, and mass.

We built a linear regression model (Model 1) with standardized

Table 1
Characteristics of group and their statistical comparisons.

	Overall (n = 4,601)	Social isolation & non-users (n = 660)	Non-social isolation & non-users (n = 2,748)	Social isolation & smartphone users (n = 180)	Non-social isolation & smartphone users (n = 1,013)	p-Value	Post hoc
Women, n (%)	2,613 (56.8)	334 (50.6)	1616 (58.8)	101 (56.1)	562 (55.5)	**<0.001**[a]	SN<NN
Age, years	73.63 ± 5.41	74.82 ± 5.92	74.36 ± 5.38	70.66 ± 4.57	71.37 ± 4.35	**<0.001**[b]	SN>SS, SN>NS, NN>SS, NN>NS
Body mass index, m/kg^2	23.24 ± 3.14	23.02 ± 3.26	23.19 ± 3.15	23.36 ± 3.71	23.47 ± 2.91	**0.022**[b]	SN<NS
Medication use, n/day	3.03 ± 2.79	3.54 ± 3.09	3.11 ± 2.81	2.73 ± 2.51	2.55 ± 2.50	**<0.001**[b]	SN>NN, SN>SS, SN>NS, NN>NS
Medical history, n (%)							
Hypertension	2130 (46.3)	331 (49.6)	1,294 (47.0)	74 (41.1)	438 (43.2)	**0.031**[a]	not significant
Diabetes mellitus	605 (13.1)	99 (14.9)	340 (12.4)	23 (12.8)	146 (14.4)	0.257[a]	N/A
Heart disease	842 (18.3)	125 (18.8)	531 (19.3)	31 (17.2)	158 (15.6)	0.073	N/A
Eyesight, n (%)							
Cannot read newspaper/can read only headline	25 (0.5)	3 (0.5)	19 (0.7)	0 (0.0)	3 (0.3)	0.342[a]	N/A
Former smoker/smoker, n (%)	1603 (34.8)	257 (38.5)	887 (32.2)	78 (43.3)	387 (38.2)	**<0.001**[a]	SN<NN, NN<SS, NN<NS
Education history, years	11.79 ± 2.28	11.37 ± 2.42	11.65 ± 2.21	12.11 ± 2.17	12.37 ± 2.27	**<0.001**[b]	SN<NN<SS, SN<NS, NN<NS
Household annual income, n (%)							
< 5 million	3589 (78)	579 (88.9)	2,137 (80.5)	158 (89.8)	725 (73.0)	**<0.001**[a]	SN>NN>NS, NN<SS, SS>NS
>=5 million to <7 million	443 (9.6)	36 (5.5)	279 (10.5)	8 (4.5)	121 (12.2)	**<0.001**[a]	SN<NN, SN<NS, NN>SS, SS<NS
>=7 million to <5 million	300 (6.5)	28 (4.3)	162 (6.1)	7 (4.0)	103 (10.4)	**<0.001**[a]	SS<NS, NN<NS
>= 10 million	133 (2.9)	8 (1.2)	78 (2.9)	3 (1.7)	44 (4.4)	**<0.001**[a]	SN<NS
Gait speed, m/s	1.22 ± 0.20	1.16 ± 0.21	1.21 ± 0.19	1.24 ± 0.21	1.25 ± 0.18	**<0.001**[b]	SN>NN, SN>SS, SN<NS, NN<NS
Geriatric depression scale, score	2.42 ± 2.40	3.73 ± 3.03	2.28 ± 2.22	2.93 ± 2.79	1.85 ± 2.00	**<0.001**[b]	SN<SS<NN<NS
Cognitive function							
Word memory	11.05 ± 3.15	10.27 ± 3.20	10.84 ± 3.16	12.05 ± 2.78	11.95 ± 2.93	**<0.001**[b]	SN<NN<SS, SN<NS, NN<NS
Trail making test-part A	21.14 ± 6.84	22.87 ± 8.94	21.50 ± 6.91	19.93 ± 5.53	19.26 ± 4.45	**<0.001**[b]	SN>NN>SS, SN>NS, NN>NS
Trail making test-part B	43.07 ± 24.66	50.07 ± 32.14	44.41 ± 25.18	36.91 ± 17.89	35.97 ± 14.81	**<0.001**[b]	SN>NN>SS, SN>NS, NN>NS
Symbol digit substitution test	44.24 ± 9.59	40.96 ± 9.83	43.22 ± 9.23	48.15 ± 9.23	48.47 ± 8.87	**<0.001**[b]	SN<NN<SS, SN<NS, NN<NS

[a]: Chi-squared test; [b]: One-way analysis of variance; SN: social isolation & non-users; NN: non-social isolation & non-users; SS: social isolation & smartphone users; NS: non-social isolation & smartphone users; N/A: not applicable.

[a] = P-values obtained by Pearson's chi square test.

[b] = P-values reported from one-way ANOVA.

[c] =Statistically significant association by adjusted standardized residual > 1.96 [P <0.05].

[d] = Statistically significant association by adjusted standardized residual < 1.96 [P <0.05].

scores of each cognitive function test, where social isolation, smartphone use, and background information were added as independent variables. For Model 2, an interaction term for smartphone use x social isolation was added as the independent variable. We also built two linear regression models showing the association between the standardized score of each cognitive function and smartphone use while controlling for background information, in both the non-socially and socially isolated groups.

We performed statistical analyses using Statistical Package for the Social Sciences (version 27.0; SPSS Japan Inc., Tokyo, Japan). The level of statistical significance was $p < 0.05$.

3. Results

Of the 4,601 participants, 840 (18.4%) were defined as socially isolated and 1,193 (25.9%) were smartphone users. The number of socially-isolated smartphone users, socially isolated non-users, non-socially isolated smartphone users, and non-socially isolated non-users were 660 (14.3%), 2,748 (59.7%), 180 (3.9%), and 1,013 (22.0%), respectively. Table 1 shows the characteristics of group and their statistical comparisons. The ANOVA showed significant differences in all items, except for the prevalence of diabetes mellitus, heart disease, and eyesight among the four groups divided by social isolation and smartphone use ($p<0.05$). All cognitive function tests did not differ in smartphone users, regardless of whether they were socially isolated or not. However, there were significant differences in all cognitive function tests among non-users, with lower scores for socially-isolated participants. Additionally, geriatric depression scores were systematically higher in the order socially isolated & non-users, socially isolated & smartphone users, non-socially isolated & non-users, and non-socially isolated & smartphone users.

The ANCOVA showed significant differences of trail-making test A and B and symbol digit substitution task score between the socially-isolated and non-socially-isolated groups ($F=4.508$; $p=0.034$, $F=4.953$; $p=0.026$, $F=6.877$; $p=0.009$). Estimates ± standard errors of cognitive functions tests for socially isolated and non-socially isolated groups were 11.0±0.10 and 11.1±0.05 for word list memory, 21.4 ± 0.22 and 20.9 ± 0.10 for trail-making test- part A, 44.0 ± 0.77 and 42.0 ± 0.36 for trail-making test- part B, and 43.9 ± 0.27 and 44.7 ± 0.13 for symbol digit substitution task, respectively.

The ANCOVA showed significant differences among the four groups in all cognitive function tests (see Fig. 1). For the symbol digit substitution task, smartphone users had significantly higher scores (i.e., higher processing speed) than non-users, in the socially isolated group.

Table 2 shows the results of the linear regression model analysis associated with cognitive functions in all participants. In Model 1, social isolation was significantly associated with the trial making test- part A and symbol digit substitution task. Additionally, smartphone use was also associated with all scores of the cognitive function tests. However, there was no significant modifying effect of social isolation x smartphone use on any cognitive function. Table 3 shows the results of the linear regression model analysis for cognitive functions in non-socially and socially isolated participants. Among non-socially isolated participants, smartphone use was significantly associated with the word list memory, trail making test- part B, and symbol digit substitution task, while among socially isolated participants, it was significantly associated with all cognitive function tests.

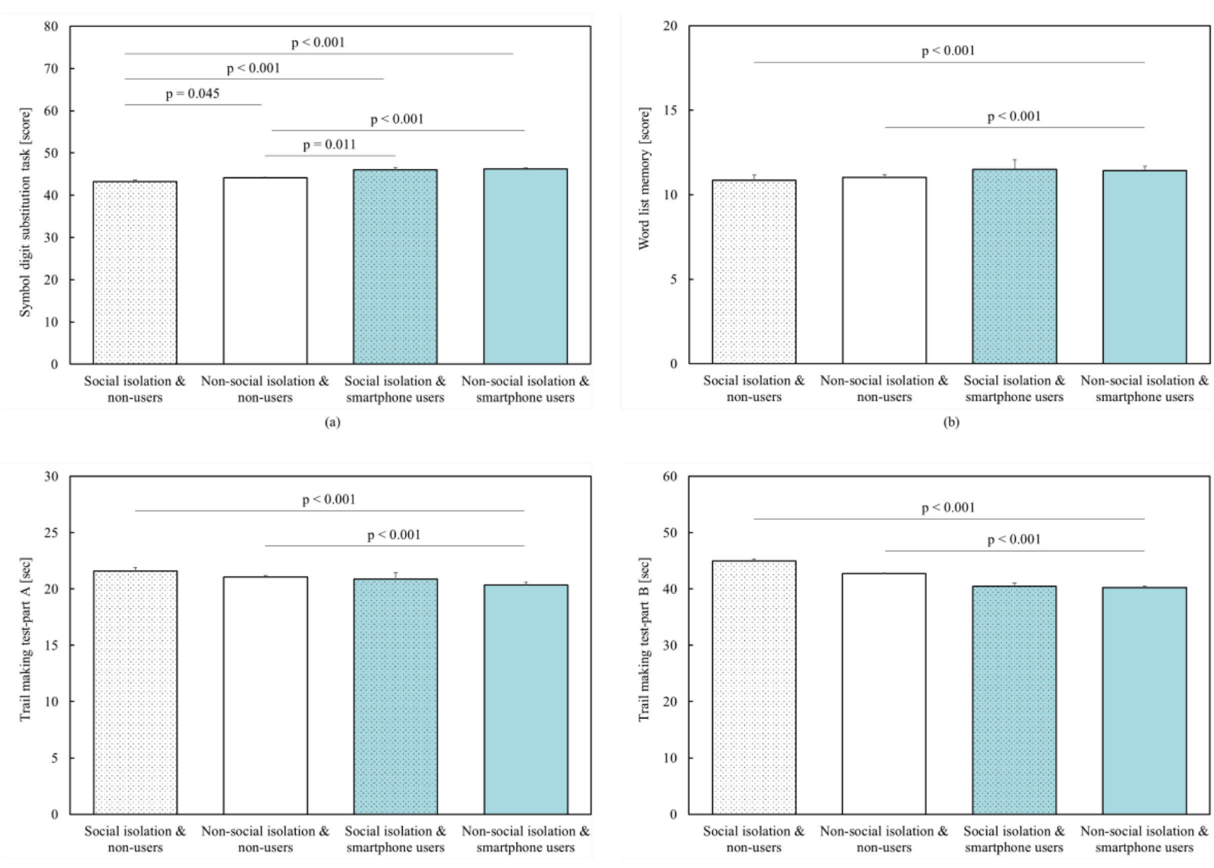

Fig. 1. Results of the analysis of covariance of the cognitive tests adjusted with background information. Note. (a) word memory, (b) trail making test- part A, (c) trail making test- part B, (d) symbol digit substitution task. Background information: sex, age, body mass index, eyesight, gait speed, education level, smoking, geriatrics depression score, household annual income, number of used medications.

Table 2
The results of linear regression model analysis for cognitive functions in all participants

	Model 1				Model 2			
	B	95% CI	β	p-Value	B	95% CI	β	p-Value
Standardized score of word list memory								
Standardized social isolation	-0.014	(-0.039 – 0.012)	-0.015	0.297	-0.013	(-0.038 – 0.013)	-0.014	0.325
Standardized smartphone use	0.064	(0.038 – 0.09)	0.069	**<0.001**	0.064	(0.038 – 0.09)	0.068	**<0.001**
Interaction term of social isolation x smartphone use	-	-	-	-	0.011	(-0.013 – 0.035)	0.012	0.378
Standardized score of trail making test- part A								
Standardized social isolation	0.022	(0.004 – 0.041)	0.033	**0.019**	0.023	(0.004 – 0.041)	0.034	**0.017**
Standardized smartphone use	-0.035	(-0.054 – -0.016)	-0.051	**<0.001**	-0.035	(-0.054 – -0.016)	-0.052	**<0.001**
Interaction term of social isolation x smartphone use	–	–	–	–	0.007	(-0.011 – 0.025)	0.011	0.435
Standardized score of trail making test- part B								
Standardized social isolation	0.014	(-0.005 – 0.033)	0.02	0.157	0.014	(-0.005 – 0.033)	0.02	0.160
Standardized smartphone use	-0.038	(-0.057 – -0.018)	-0.053	**<0.001**	-0.038	(-0.057 – -0.018)	-0.053	**<0.001**
Interaction term of social isolation x smartphone use	–	–	–	–	-0.001	(-0.019 – 0.017)	-0.002	0.900
Standardized score of symbol digit substitution test								
Standardized social isolation	-0.030	(-0.051 – -0.008)	-0.033	**0.007**	-0.029	(-0.051 – -0.008)	-0.033	**0.008**
Standardized smartphone use	0.089	(0.068 – 0.111)	0.099	**<0.001**	0.089	(0.067 – 0.111)	0.099	**<0.001**
Interaction term of social isolation x smartphone use	–	–	–	–	0.003	(-0.017 – 0.024)	0.004	0.739

Model 1: adjusted for age, sex, body mass index, medication, eyesight, smoking history, education level, income level, gait speed, geriatric depression scale; Model 2: Model 1 + interaction term of social isolation x smartphone use. B: partial regression coefficient; CI: confidence interval; β: standardized partial regression coefficient.

Table 3
The results of linear regression model analysis for cognitive functions in participants in non-socially and socially isolated participants.

	Non-socially isolated participants				Socially isolated participants			
	B	95% CI	β	p-Value	B	95% CI	β	p-Value
Standardized score of word list memory	0.209	(0.094 – 0.325)	0.100	**<0.001**	0.128	(0.058 – 0.197)	0.059	**<0.001**
Standardized score of trail making test- part A	-0.073	(-0.15 – 0.004)	-0.054	0.065	-0.083	(-0.135 – -0.031)	-0.051	**0.002**
Standardized score of trail making test- part B	-0.09	(-0.179 – -0.001)	-0.056	**0.047**	-0.086	(-0.138 – -0.034)	-0.053	**0.001**
Standardized score of symbol digit substitution test	0.207	(0.107 – 0.308)	0.103	**<0.001**	0.201	(0.143 – 0.259)	0.097	**<0.001**

B: partial regression coefficient; CI: confidence interval; β: standardized partial regression coefficient.

4. Discussion

This study intended to understand the impact of smartphone use on social isolation in community-dwelling older adults. Socially isolated community-dwelling older adults had a lower processing speed assessed by symbol digit substitution task than those that were non-socially isolated. However, smartphone users had a higher processing speed than non-users, even in social isolation. Additionally, there were significant associations between all cognitive functions and smartphone use, regardless of whether participants were socially isolated or not. In particular, the association with attentional function assessed in the trail making test- part A was found only for socially isolated participants. These results suggest that using a smartphone could positively influence processing speed and attention for socially isolated community-dwelling older adults. Although a future longitudinal study could contribute to establishing a causal direction for the latter relationship, smartphone use would be a potential tool for maintaining cognitive functions even during the current pandemic.

The population of community-dwelling older adults with social isolation was small (n=840, 18.4%), compared with those in the non-socially isolated group. Furthermore, the proportion of socially-isolated smartphone users accounted for 21.4% of the socially isolated group at the study period. However, it is important to consider that in the future, the number of smartphone users in the older Japanese population is expected to increase (Department of Business Statistics Economic and Social Research Institute Cabinet Office, 2021). Thus, while the number of older adults in social isolation was estimated to increase, it is speculated that those with smartphones would become a common demographic. According to a previous report, the top cause of functional disability in Japan was dementia (18.7%) in 2020 (Office, 2021). Furthermore, non-face-to-face interactions through digital devices (e.g., smartphones) contributed to decreasing the risk of onsets of functional disability (Katayama et al., 2022). Thus, in the future, smartphone use could be useful to prevent cognitive decline.

One possible explanation for the difference in higher processing speed and attentional function among the socially isolated groups could be the difference in depressive symptoms between smartphone users and non-users. Living alone, which is one criterion for social isolation in our study, was reported to be associated with lower processing speed and more severe depressive symptoms (Gow, Corley, Starr, & Deary, 2013). And attentional function assessed by trail making test- part A was associated with depressive symptoms in Japanese older adults with social frail (Kume et al., 2022). Depressive symptoms are also known to mediate a decrease in serum brain-derived neurotrophic factor concentrations and brain volume, resulting in a decrease in processing speed as assessed by the symbol digit substitution task (H. Shimada et al., 2014). Additionally, depressive symptoms were milder in smartphone users compared with non-users (Hwang, Rabheru, Peisah, Reichman, & Ikeda, 2020). Accordingly, smartphone users could likely avoid depressive symptoms that would in turn negatively influence cognitive functions. Thus, they could maintain their processing speed capacity, compared with non-users.

The study found no interaction between smartphone use and cognitive functions. This was seemingly contrary to the hypothesis that cognitive decline due to social isolation would be remediated by smartphone use. However, there are further considerations to be made before concluding as such. For example, we were unable to distinguish between participants who had recently begun using smartphones and those who had previously used them but did not currently possess them. We also do not know how much they used their smartphones for the purpose of communicating. Thus, we believe that future prospective studies should consider participants' experience with smartphones, their use history, and the purposes for which they use them, to examine the relationship between smartphone use and cognitive function in more detail.

The strength of this study is showing that socially isolated community-dwelling older adults who use smartphones could better maintain processing speed than non-users in the large cohort. However, we could not assure the causal relationship between social isolation and smartphone use owing to the cross-sectional design of this study. Thus, it is unclear whether smartphone use directly prevents cognitive decline due to social isolation among community-dwelling older adults. Another limitation is that we missed collecting more detailed information on smartphone use. For example, a previous study collected information about the number of smartphone functions used to discuss the dose-response relationship between smartphone use and cognitive functions (Yuan et al., 2019). Furthermore, in future, more detailed analyses may consider a sensitivity model aimed at determining which social isolation measures are more likely to be associated with cognitive functions and which cognitive functions are ameliorated by smartphone use. Moreover, although a significant difference was found in cognitive function score (e.g.: symbol digit substitution test) between smartphone users or non-users among socially isolated community-dwelling older adults in this study, the clinical meaning was still unclear. Therefore, future studies should focus on the effect of smartphone use on cognitive impairment in socially isolated older adults.

Conclusion

Regarding symbol digit substitution task, socially isolated community-dwelling older adults had lower scores, compared with the non-socially isolated group. However, among the socially isolated group, only the symbol digit substitution task in the cognitive function test was superior (i.e., higher processing speed) for smartphone users than non-users, regardless of social isolation. Additionally, smartphone use was associated with all scores of cognitive function tests (word list memory, trail making test- part A and B, and symbol digit substitution task). Smartphone use could help maintain processing speed among socially isolated community-dwelling older adults.

CRediT authorship contribution statement

Masanori Morikawa: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. **Sangyoon Lee:** Conceptualization, Data curation, Investigation, Methodology, Writing – review & editing. **Keitaro Makino:** Conceptualization, Data curation, Investigation, Methodology, Writing – review & editing. **Seongryu Bae:** Data curation, Investigation, Writing – review & editing. **Ippei Chiba:** Data curation, Investigation, Writing – review & editing. **Kenji Harada:** Data curation, Investigation, Writing – review & editing. **Kouki Tomida:** Writing – review & editing. **Osamu Katayama:** Data curation, Investigation, Writing – review & editing. **Hiroyuki Shimada:** Funding acquisition, Methodology, Project administration, Resources, Writing – review & editing.

Declaration of Competing Interest

The authors declare no conflict of interest.

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