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Nudge-Based Interventions on Health Promotion Activity Among Very Old People: A Pragmatic, 2-Arm, Participant-Blinded Randomized Controlled Trial

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ABSTRACT

Objectives: Social distancing due to the coronavirus disease 2019 crisis can exacerbate inactivity in older adults. Novel approaches for older adults must be designed to improve their activity and maintain their health. This study examined the effect of nudge-based behavioral interventions on health-promoting activities in older adults in Japan.
Design: Two-arm, participant-blinded randomized controlled trial.
Setting and Participants: Japanese continuing care retirement community residents (n = 99, median age 82 years, 73% women)
Intervention: Two-step nudge-based behavioral intervention promoting tablet usage.
Methods: We enrolled participants from an ongoing Internet of Things project in a retirement community in Japan. For the health promotion program, tablet computers were installed in a common area for participants to receive information about their health. The intervention group received a 1-time loss-emphasized nudge (first step), followed by asking questions about when they planned to use it again (second step). The control group used the tablet computers without being asked those questions. The main outcome was the participants' mean daily tablet activity every 4 weeks for the next 16 weeks.
Results: Ninety-nine individuals were randomly assigned to the intervention or control group. The rate ratios for tablet use were significantly higher in the intervention group in the second and third periods. The subgroup analysis showed that these effects were largely attributable to men.
Conclusions and Implications: Nudge-based interventions can be effective in promoting activities for older adults, especially older men. The finding of this study indicates a possible intervention to engage people who are socially isolated.

The social distancing policy established because of the coronavirus disease 2019 (COVID-19) reduced physical and social activities worldwide,[1,2] raising concerns about harmful health consequences, especially for older adults.[3–5] As the damage to health resulting from inactivity increases with age,[6,7] changing the sedentary lifestyle of older adults is an urgent and important public health issue. Although there is evidence of effective interventions to promote healthy behavior in older adults, such as educational counseling,[8–10] resources are usually needed for each targeted individual for short-term success.

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SF has received salary as a part-time physician from the clinic attached to the CCRC since April 2021. TU received a salary as a part-time worker from the CCRC between July 2019 and March 2021. The other authors declare no conflicts of interest.

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Nudge theory, a less costly approach that can lead to behavioral changes, has received widespread attention in research and policy making.[11,12] Nudge is defined as "an aspect of choice architecture that predictably alters people's behavior without forbidding any options or significantly changing their economic incentives."[13] Nudge can guide people to personally and socially desirable choices by targeting their subconscious biases and routines that are present in human decision-making processes. In theoretical frameworks, humans tend to prefer avoiding losses to acquiring equivalent gains[14]; thus, behavioral changes could be encouraged by emphasizing losses rather than benefits ("loss-emphasized nudge").[15] Humans also tend to procrastinate on important tasks,[16] and declaring their planned execution date could reinforce their intention to change their behaviors[17] ("commitment nudge"). Nudge-based interventions have been adopted for a wide range of behaviors, such as chronic disease management, and social distance promotion.[13,18,19] However, few studies have assessed the effect of nudge-based interventions on the very old population (aged ≥80 years); therefore, the usefulness of nudge-based messages in a highly aging society remains unclear. As it is hypothesized that physical and social changes during the aging process can influence the underlying mechanism of how nudges affect people's behaviors, in this study, we intentionally targeted the very old population and examined whether nudge-based interventions resulted in behavioral changes to promote their levels of activity using a senior-friendly communication device.

Methods

Study Design

This trial was conducted as part of an ongoing research project in a continuing care retirement community (CCRC) in Kyoto, Japan.[20] The research project, which started in 2018, aimed to promote the health of older adults through a senior-friendly Internet of Things. It has 30 beacon sensors covering the site and voluntary participants carry a low-energy Bluetooth beacon. Given the infrastructure, older adults do not need additional operations and receive a feedback sheet showing their walking distance, the areas they visited, and the time they spent in the common areas. The project also involved the installation of tablet computers in the common areas intended to guide participants out of their rooms. The tablet computer senses a beacon approaching and starts an individually customized talk flow with audio assistance, allowing older users to navigate easily. The talk flow consists of, but is not limited to, a greeting message according to the extent of daily walking distance, questions about daily health status, and rock-paper-scissors games with the CCRC staff's photos. They use a touchscreen stylus of either their own or one provided at the site with an alcohol disinfectant (Supplementary Figures 1 and 2).

Data derived from beacons and the tablet computers were linked by research ID to participants' administrative data, including frailty status defined by an annual CCRC self-report survey using the Kihon checklist (Supplementary Table 1).[21] Participants provided written consent for participation in the project, and the Institutional Review Board approved the study (R1669). We randomized the project participants on July 1, 2021, and compared daily activities of tablet computer use from July 13, 2021, for 16 weeks between those who received a series of nudge-based messages and those who did not.

Study Population

We assessed the eligibility of all study participants who carried their beacon card daily based on beacon-detected data during the 3 months prior to randomization (ie, from April 1, 2021, to June 30, 2021). Because habituality of tablet computer usage strongly influences the outcome of interest of this study, we excluded participants whose tablet computer use during the same period was defined as an outlier after transforming to a standard normal distribution.[22]

Randomization and Masking

To address possible contaminations in intervention status caused by cohabitation, we excluded one of the cohabitants from the randomization process if both were study participants. Furthermore, we stratified the participants by their history of tablet computer use (yes/no). They were then separately randomized to either group in a 1:1 ratio using computer-generated random numbers. After randomization, the excluded participants were assigned to the same group as their cohabitant. The first author generated a random allocation sequence and assigned the participants to the intervention. Participants and care providers at the site were blinded to interventions.

Intervention

The intervention was constructed based on previous studies showing that classic nudges work better when combined with reflective elements[23] and that older adults may benefit from game-based interventions.[24] Our nudge-based intervention consisted of 2 steps: a loss-emphasized message and a commitment device. The first step was the provision of information on the time-limited special content available on tablet computers ("Time-limited special quizzes made by Kyoto University are available from July 13 for a week! Don't miss it!"). The message was printed on a regular feedback sheet for the intervention group and posted in their individual CCRC mailboxes on July 12, 2021. The second step was designed to reinforce users' intentions to promote their activity. When using tablet computers during the week after the first step was administered, only those in the intervention group received a simple question on the tablet computer: "When would you use the tablet computer next time?" They were asked to select one of the options: "today or tomorrow," "within a week," or "after one week." The control group received the regular feedback sheet without the additional message and used the time-limited special quizzes on tablet computers but did not receive the additional question. Supplementary Table 2 summarizes the content delivered to the intervention and control groups.

The possibility of participants knowing their intervention status was limited in 2 senses. First, because the regular feedback sheet was in an envelope and posted in their mailbox, they were unlikely to share it with others. Second, tablet computers were expected to be used individually, as the simultaneous presentation of multiple beacons near the tablet computers would cause confusion in detecting individuals.

Outcomes and Follow-up

The outcome measure was the participants' mean daily activity using tablet computers every 4 weeks for the following 16 weeks. The daily activity was counted as the number of responses recorded on tablet computers. The responses to the commitment question were not included as they were only recorded in the intervention group.

Statistical Methods

We conducted an intention-to-treat analysis; all participants were analyzed in the group to which they were allocated, regardless of whether they received the second step of the intervention. First, we drew a time series graph of the rolling average of 3 days of the mean daily use of the tablet computer according to the groups. Second, differences in the means of tablet computer use every 4 weeks

Table 1
Baseline Characteristics of Participants

	Intervention (n = 52)	Control (n = 47)	All (N = 99)
Demographics			
Median age (Q1, Q3),* y	83.8 (78.3, 87.4)	81.6 (78.1, 86.3)	82.1 (78.1, 87.2)
<75	4 (7.7)	5 (10.6)	9 (9.1)
≥75 and <80	11 (21.2)	11 (23.4)	22 (22.2)
≥80 and <85	17 (32.7)	18 (38.3)	35 (35.4)
≥85	20 (38.5)	13 (27.7)	33 (33.3)
Females	33 (63.5)	39 (83.0)	72 (72.7)
No cohabitant	37 (71.2)	39 (83.0)	76 (76.8)
Frailty status†			
Physical function and strength domain	29 (55.8)	23 (48.9)	52 (52.5)
Malnutrition domain	3 (5.8)	4 (8.5)	7 (7.1)
Oral function and eating	29 (55.8)	26 (55.3)	55 (55.6)
Socialization and housebound domain	14 (26.9)	10 (21.3)	24 (24.2)
Cognitive and memory domain	24 (46.2)	20 (42.6)	44 (44.4)
Depression and mood domain	33 (63.5)	33 (70.2)	66 (66.7)
Beacon-derived activities, mean (SD)‡			
Daily social relation, h	1.01 (0.81)	1.24 (0.89)	1.12 (0.85)
Daily distance, m	698.89 (418.33)	796.05 (722.17)	745.02 (581.60)
Daily visited spots, n	4.49 (2.76)	4.91 (3.04)	4.69 (2.89)

Values are presented as numbers (percentages), unless stated otherwise.

*As of June 30, 2021.

†Obtained from the Kihon checklist taken in the CCRC in February 2021, developed by the Japanese Ministry of Health, Labour and Welfare as a publicly used screening tool to identify signs of frailty. Detailed items and cutoff values are available in Supplementary Table 1.

‡Obtained from beacon logs between April 1 and June 30, 2021.

between the groups were analyzed as a whole and separately by sexes. Lastly, we regressed daily usage on an interaction term of the intervention status with dummy variables for the elapsed period since the intervention (ie, 0, pre-period; 1, first period, including the intervention week; and 2, second period) to obtain a period-specific differentiated effect of the intervention status as a whole and separately by sexes. A generalized estimating equation model assuming a Poisson distribution with an exchangeable correlation structure was used as panel data clustered by participants with count outcomes (log-link) using a bootstrap estimation.

The results of the sensitivity analyses of those living alone and those defined as tablet computer users in the previous 3 months were used to determine any unintended bias caused in the randomization sequence. Furthermore, sex and mean daily count of tablet computer use during the preintervention period were included separately as covariates in the main analysis as a control for the potentially disproportional distribution of participants' characteristics between the groups.

All analyses were performed with Stata, version 15.0 (StataCorp).

Results

Study Population

A total of 110 residents who provided valid informed consent as of June 30, 2021 were selected for eligibility; 99 met the eligibility criteria. All randomized participants completed the trial (Supplementary Figure 3). Table 1 shows participants' basic characteristics by group. The median age was 82.1 years (interquartile range, 78.1-87.2), and 72 participants (73%) were women. The prevalence of frailty status defined by the annual self-report survey indicated that the study participants were similar in frailty to the corresponding age groups of the general population of the community (Supplementary Table 3).[25] Their walking distances inside the CCRC were slightly less than 1 km, and they spent an average of approximately 1 hour in the common areas per day.

Main Outcomes

Figure 1 shows the 3-day rolling average of the mean daily activity of the tablet computer. The activities were similar between the groups before the intervention and then increased during the intervention week (gray shade), with more drastic increases observed in the intervention group than in the control group (red line). There were no differences between the groups immediately after the intervention week; however, approximately a month later, some differences were observed between the groups, which continued for 12 weeks. Similar trends were observed in both men and women, with a larger difference observed among men than among women.

Figure 2 shows the primary outcomes expressed as the differences in the mean daily activities of the tablet computers of the participants every 4 weeks between the groups (intervention minus control). The daily activities of the intervention group were significantly higher in the second and third periods than those of the control group ($P = .003$ and .047, respectively). Men were more responsive to the intervention than women. Detailed results are provided in Supplementary Table 4.

The rate ratios of the intervention group for daily activities of the tablet computers compared to the preintervention period and the control group also showed that the likelihood of the intervention group using tablet computers during the second and third periods was more than twice the control group (mean rate ratio = 2.38, 95% CI 1.21, 4.71; and 2.16, 95% CI 1.14, 4.08, respectively). A subgroup analysis by sex revealed that the effect of the intervention was mainly in men (Supplementary Table 5).

Sensitivity Analyses

Sensitivity analyses with only those living alone and those with a history of tablet computer use showed results similar to the main analyses. The models including sex or previous tablet computer activities showed they were not significant covariates and did not change the main results (Supplementary Table 6).

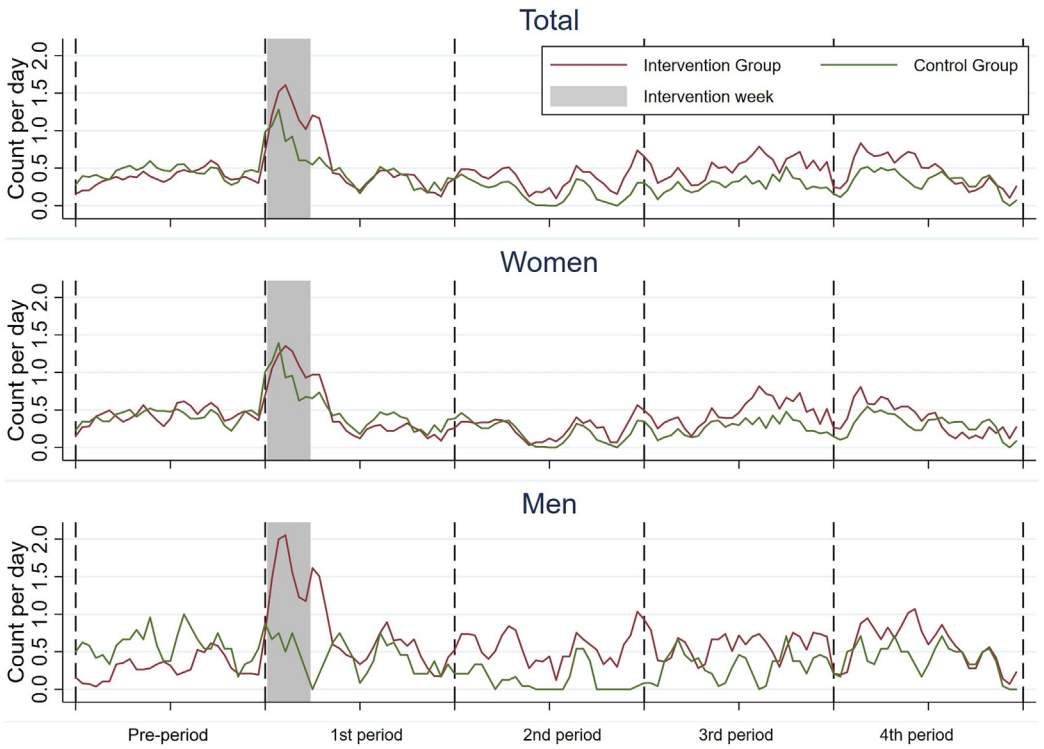

Fig. 1. Three-day rolling average of daily tablet activity. n = 52 for the intervention group, n = 47 for the control group. Dot lines indicate a 4-week interval.

Discussion

Our results indicate that our 2-step behavioral intervention, which involved loss-emphasized nudge and commitment nudge, made a difference by increasing older adults' health promotion activities in the following 12 weeks. The findings indicated that nudges can be effective in the short and long term when combined appropriately. Promoting older adults' activities is the key to designing health services for them. Therefore, the findings of this study will help improve the health outcomes of older adults.

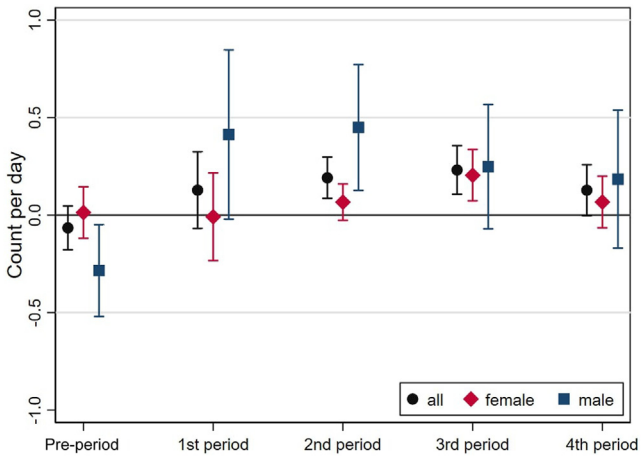

Fig. 2. Differences in daily count of tablet computer usage every 4 weeks between intervention and control group. Bars indicate 95% CIs. Positive value indicates the intervention group used tablet more frequently than the control group. Pre-period: June 15 to July 12, 2021; first period: July 13 to August 9, 2021; second period: August 10 to September 6, 2021; third period: September 7 to October 4, 2021; fourth period: October 5 to November 1, 2021.

The initial large effect of the nudges in the intervention group disappeared quickly; however, the intervention group experienced a subtle but consistent increase in their activities after a few weeks, and the increase persisted for at least 8 weeks. These findings suggest the 2-step nudge-based intervention worked as expected, highlighting that loss of opportunity generates short-term behavioral change through an automatic and affective system that influences immediate behavioral decisions (heuristics)[26] and that the provision of commitment devices facilitates the translation of newly evolved behavior into regular behaviors (deliberation).[23] Additionally, the findings are partially consistent with an experimental study suggesting the "temporal spillover effect" of nudges, in which aimed behavioral changes were observed subsequently without the presence of a nudge.[27] In this study, the underlying mechanism was hypothesized to be that the initial behavioral change mediated the effect of nudges, resulting in a prolonged effect.

The magnitude of the effect varied with sex; men were more responsive to the intervention. The exact element of our intervention that prompted older men to promote their activity could not be determined, but our intervention involving technology and affirmation (eg, "Kyoto University—made quizzes") might have worked better for men than women among older adults.[28] Women are more likely than men to engage in social and physical activity, especially in older age[29,30]; thus, our study findings may be novel for indicating a possible intervention to engage socially isolated people.

The limitations of this study include sampling bias due to the reliance on participants in an existing project in a CCRC. We chose the CCRC because the Internet infrastructure we created enabled us to examine older adults' immediate and detailed behaviors in response to the message delivered and to offer high-quality, low-cost, rapid trials even during the COVID-19 pandemic, where safety measures would have prevented us from conducting any trials targeting older adults. Another limitation is the outcome that is not a direct indicator of health behaviors. We assessed nudge-based messages to promote

tablet usage and found its effect in this study. Then it is presumable that nudges to promote physical activity promote older adults' physical activity. Future alternative studies could be conducted using a wearable device to assess the effect of nudge-based interventions directly on physical activity in older adults.

Conclusions and Implications

This study revealed that nudge-based interventions can be effective in promoting activities for older adults, especially older men. This finding indicates a possible intervention to engage socially isolated people.

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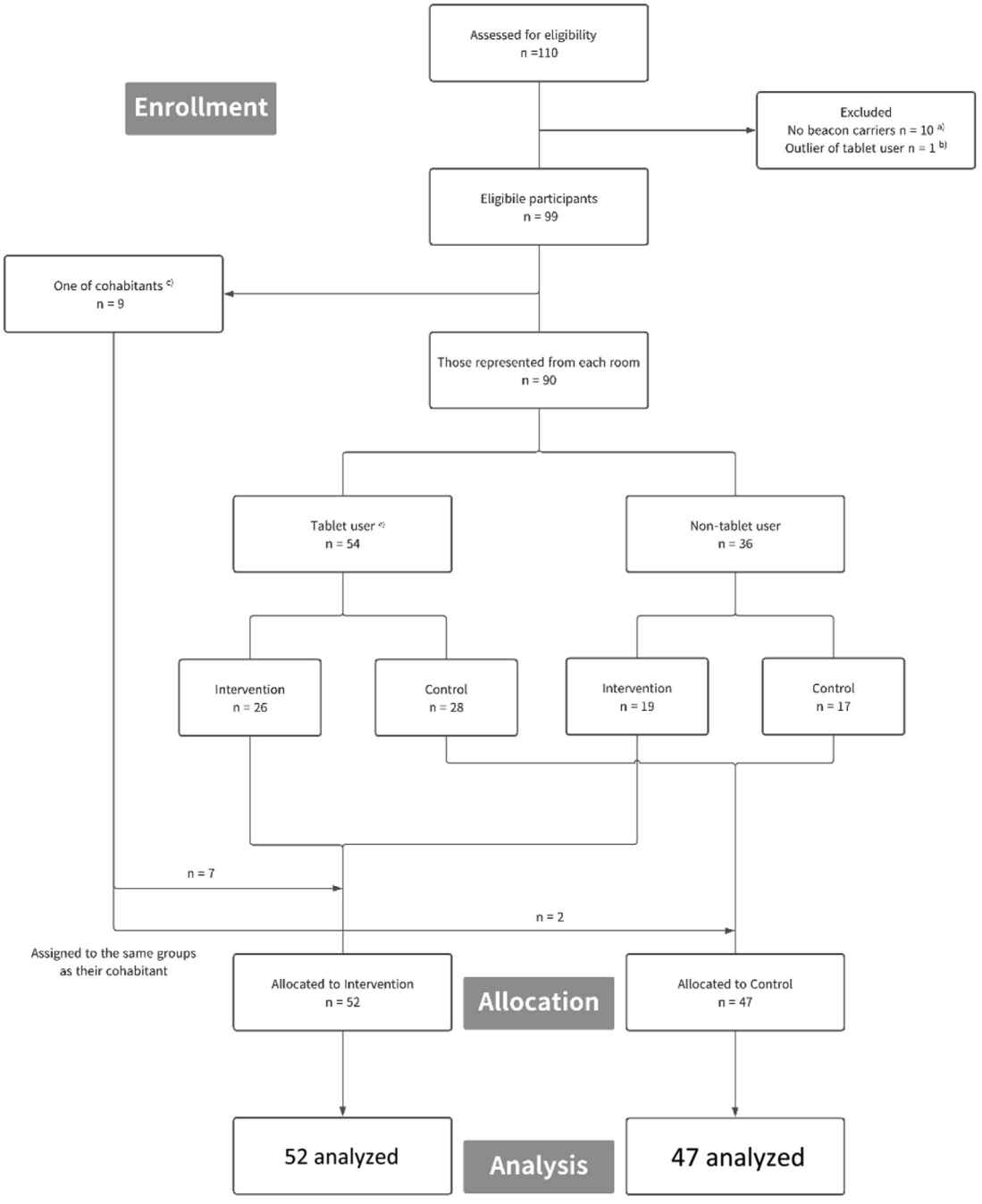
Supplementary Fig. 1. Onsite photos. Photograph of a tablet computer site.

A ballpoint ben with a touch rubber tip with the project logo printed on the side

Supplementary Fig. 2. A ballpoint pen with a touch rubber tip with the project logo printed on the side.



Supplementary Fig. 3. Enrollment.
• Those whose beacons were not sensed between April 1 and June 30, 2021, were excluded from the 110 residents with valid informed consent as of June 30, 2021.
• Outliers of tablet use in the previous 3 months were defined using the Grubbs test (Pearson/df = 11.146, with a threshold of $\alpha = 2$).
• If a participant lived with someone who was also eligible, the one with a lower research ID number was removed temporarily at this point. They were assigned to the same group as their cohabitants after randomization.
• Those who used the tablet at least once between April 1 and June 30, 2021, were thought to be tablet users.

Supplementary Table 1
Detailed Items of Self-Reported Questionnaire (Kihon Checklist)

1	Do you go out by bus or train by yourself?	0. Yes	1. No
2	Do you go shopping to buy daily necessities by yourself?	0. Yes	1. No
3	Do you manage your own deposits and savings at the bank?	0. Yes	1. No
4	Do you sometimes visit your friends?	0. Yes	1. No
5	Do you turn to your family or friends for advice?	0. Yes	1. No
6	Do you normally climb stairs without using handrails or wall for support?	0. Yes	1. No
7	Do you normally stand up from a chair without any aids?	0. Yes	1. No
8	Do you normally walk continuously for 15 minutes?	0. Yes	1. No
9	Have you experienced a fall in the past year?	1. Yes	0. No
10	Do you have a fear of falling while walking?	1. Yes	0. No
11	Have you lost 2 kg or more in the past 6 months?	1. Yes	0. No
12	Height: __ cm, weight: __ kg, BMI: __kg/m^2. If BMI is less than 18.5, this item is scored	1. Yes	0. No
13	Do you have any difficulties eating tough foods compared to 6 months ago?	1. Yes	0. No
14	Have you choked on your tea or soup recently?	1. Yes	0. No
15	Do you often experience having a dry month?	1. Yes	0. No
16	Do you go out at least once a week?	0. Yes	1. No
17	Do you go out less frequently compared to last year?	1. Yes	0. No
18	Do your family or your friends point out your memory loss? Eg, "You always ask the same question over and over again"?	1. Yes	0. No
19	Do you make a call by looking up phone numbers?	0. Yes	1. No
20	Do you find yourself not knowing today's date?	1. Yes	0. No
21	In the last two weeks have you felt lack of fulfilment in your daily life?	1. Yes	0. No
22	In the last two weeks have you felt a lack of joy when doing the things you used to enjoy?	1. Yes	0. No
23	In the last two weeks have you felt difficulty in doing what you could do easily before?	1. Yes	0. No
24	In the last two weeks have you felt helpless?	1. Yes	0. No
25	In the last two weeks have you felt tired without a reason?	1. Yes	0. No

Physical function/strength domain is applicable if 3 or more of questions 6-10 were rated 1.
Malnutrition domain is applicable if 2 or more of questions 11-12 were rated 1.
Oral function and eating domain is applicable if 2 or more of questions 13-15 were rated 1.
Socialization and housebound domain is applicable if either 16 or 17 was rated 1.
Cognitive and memory domain is applicable if 2 or more of questions 18-20 were rated 1.
Depression and mood domain is applicable if 2 or more of questions 21-25 were rated 1.

Supplementary Table 2
Contents Delivered to Intervention and Control Groups

	Intervention Group	Control Group
Received a routine feedback sheet on 12th July	X	X
Received a loss-framed message printed on the feedback sheet (“Time-limited special Kyoto University–made quizzes are available from July 13 for a week! Don’t miss it!”)	X	
Enjoyed the special quizzes on tablet computers between 13th and 20th July	X	X
Answered to the question “When would you use the tablet computer next time?” on tablet computers between 13th and 20th	X	

Supplementary Table 3
Percentages of Frailty Status: Comparison of the Study Participants With an Available Statistic From the General Community-Dwelling Older Population

Sex	Comparative General Population*						Study Population		
	Men			Women					
Age	75-79	80-84	85-89	75-79	80-84	85-89	75-79	80-84	85-89
n	1149	664	254	1368	861	393	22	35	33
Physical function/strength domain	23.4	31.0	44.0	34.2	50.4	61.2	31.8	44.1	72.7
Malnutrition domain	2.1	4.5	7.6	3.5	3.8	5.8	9.0	2.9	9.0
Oral function/eating	21.8	28.0	41.1	26.7	35.4	35.4	31.8	58.8	63.6
Socialization/housebound domain	38.4	46.9	60.9	45.1	59.3	61.9	40.9	25.7	18.2
Cognitive/memory domain	18.1	27.6	40.7	15.5	22.6	29.3	50.0	37.1	51.5
Depression/mood domain	32.5	41.1	50.3	36.9	46.3	46.3	54.5	60.0	78.8

*Adapted from Kameoka study participants who are without the long-term care insurance certificate. Yamada Y, Nanri H, Watanabe Y, et al. Prevalence of frailty assessed by Fried and Kihon checklist indexes in a prospective cohort study: design and demographics of the Kyoto-Kameoka Longitudinal Study. *J Am Med Dir Assoc*. 2017;18:733.e7−733.e15.

Supplementary Table 4
Daily Count of Tablet Computer Use of Groups

	Intervention	Control	Mean Difference (95% CI)	*P* Value*
All	n = 1456 person-day	n = 1316 person-day		
Preintervention period	0.383 (0.040)	0.448 (0.040)	−0.066 (−0.178, 0.047)	.087
First period	0.635 (0.081)	0.508 (0.055)	0.128 (−0.069, 0.324)	.30
Second period	0.376 (0.046)	0.185 (0.025)	0.191 (0.086, 0.296)	.003
Third period	0.506 (0.053)	0.275 (0.032)	0.231 (0.107, 0.355)	.047
Fourth period	0.445 (0.054)	0.318 (0.031)	0.127 (−0.003, 0.258)	.68
Females	n = 924 person-day	n = 1092 person-day		
Preintervention period	0.435 (0.054)	0.422 (0.041)	0.013 (−0.119, 0.1448)	.26
First period	0.514 (0.100)	0.523 (0.063)	−0.009 (−0.234, 0.217)	.005
Second period	0.264 (0.040)	0.198 (0.028)	0.066 (−0.027, 0.160)	.50
Third period	0.470 (0.061)	0.266 (0.034)	0.204 (0.073, 0.336)	.14
Fourth period	0.445 (0.054)	0.318 (0.031)	0.067 (−0.066, 0.200)	.89
Males	n = 532 person-day	n = 224 person-day		
Preintervention period	0.291 (0.058)	0.576 (0.124)	−0.285 (−0.520 to −0.049)	.16
First period	0.846 (0.137)	0.433 (0.102)	0.413 (−0.022, 0.848)	.18
Second period	0.570 (0.104)	0.121 (0.053)	0.449 (0.126, 0.772)	.001
Third period	0.570 (0.099)	0.321 (0.088)	0.248 (−0.071, 0.567)	.38
Fourth period	0.577 (0.109)	0.393 (0.102)	0.184 (−0.170, 0.539)	.77

Values are presented as mean (SE), unless stated otherwise.
Preintervention period: June 15 to July 12, 2021; first period: July 13 to August 9, 2021; second period: August 10 to September 6, 2021; third period: September 7 to October 4, 2021; fourth period: October 5 to November 1, 2021.
*Two-sample Wilcoxon rank-sum test.

Supplementary Table 5
Mean Rate Ratios and 95% CIs of Intervention Status for Daily Tablet Computer Use According to Sex

	All (N = 99)	Females (n = 72)	Males (n = 27)
First period	1.47 (0.86, 2.50)	0.95 (0.41, 2.20)	**3.86 (1.84, 8.09)**
Second period	**2.38 (1.21, 4.71)**	1.30 (0.68, 2.47)	**9.34 (4.24, 20.59)**
Third period	**2.16 (1.14, 4.08)**	1.72 (0.91, 3.25)	**3.50 (1.21, 10.15)**
Fourth period	1.64 (0.76, 3.54)	1.18 (0.55, 2.57)	**2.90 (1.20, 7.00)**

The values are exponentiated coefficients of the interaction term between the intervention status and the period. The references are the preintervention period and control group. First period: July 13 to August 9, 2021; second period: August 10 to September 6, 2021; third period: September 7 to October 4, 2021; fourth period: October 5 to November 1, 2021. The bold values indicate statistically significant results with 95% confidence intervals.

Supplementary Table 6
Rate Ratios and 95% CIs of Intervention Status for Daily Tablet Usage in the Sensitivity Analyses

	Only Those Living Alone (n = 76)	Only Those With History of Tablet Use in the Previous 3 mo ahead of the Intervention (n = 56)	Adjusted by Sex (N = 99)	Adjusted by Pre Tablet Activity (N = 99)
First period	1.49 (0.77, 2.87)	1.48 (0.78, 2.80)	1.47 (0.82, 2.62)	1.47 (0.89, 2.42)
Second period	2.27 (0.96, 5.38)	2.39 (1.00, 5.69)	2.38 (1.08, 5.66)	2.38 (1.15, 4.94)
Third period	1.58 (0.78, 3.17)	2.15 (1.05, 4.38)	2.16 (1.12, 4.16)	2.16 (1.16, 4.00)
Fourth period	1.29 (0.49, 3.43)	1.64 (0.71, 3.79)	1.64 (0.72, 3.74)	1.64 (0.83, 3.23)
Men			1.71 (0.27, 11.07)	
Pre tablet activity				1.02 (1.01, 1.03)

The values are exponentiated coefficients of the interaction term between the intervention status and the period. References are the preintervention month and the control group.