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Digital Nudging for Enhanced Well-Being: Development and Evaluation of a 21-Day Self-Healing Intervention for Older Adults

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Abstract
In today's increasingly digital environment, technology presents considerable opportunities for enhancing well-being among older adults, who demonstrate growing engagement with smartphones and social media platforms. This study developed and evaluated a "21-Day Self-Healing and Well-Being Guide," a digital intervention specifically designed for older adults. The intervention employed digital nudging techniques targeting five core well-being dimensions identified through previous research: physical health, gratitude expression, religious faith, family relationships, and financial security. The three-group experimental study compared two distinct push notification intervention models with a non-intervention control group. The behavior modification group received interventions based on the Fogg Behavior Model, with targeted behavioral prompts focused on health management and gratitude practices. The positive phrase group received affirmative messages designed to improve emotional states and enhance life satisfaction. Both intervention groups received daily digital engagement throughout the 21-day program period. Intervention effectiveness was assessed through pre-post measurements of life satisfaction, quality of life, and self-healing capacity among 603 participants aged 55 and above. Results demonstrated significant improvements across all outcome measures in both intervention groups compared to controls, with the behavior modification group exhibiting more substantial improvements in physical well-being and self-healing capacity. Qualitative data confirmed high intervention acceptability and perceived value of digital engagement. These findings suggest that evidence-based digital interventions can effectively enhance older adults' well-being by leveraging their increasing digital literacy and social media engagement. Future research should examine the long-term sustainability of these behavioral changes and explore applications across diverse older adult populations with varying levels of technological familiarity.

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Keywords Digital intervention · Older adults · Well-being · Self-healing · Behavioral nudging

The rapid integration of smartphones and social media into daily life has created new opportunities for enhancing the well-being of older adults. Recent studies indicate that social media usage among older adults not only improves their digital health literacy (Choukou et al., 2022) but also positively impacts their quality of life (Nam, 2021). Additionally, research has identified that older adults' core interpretations of well-being encompass physical health and gratitude, with extensions into three distinct perspectives: religious faith and inner peace, spousal relationships and children's achievements, and life goals and financial security (Hsu et al., 2025). The present study aims to develop and evaluate a "21-Day Self-Healing and Well-Being guide" digital intervention for older adults. This program integrates digital nudging techniques with key elements of well-being enhancement identified in previous research (Hsu et al., 2025). The intervention's effectiveness is assessed through measures of life satisfaction, quality of life, and self-healing capacity, with exploration of its long-term application potential.

Literature Review

Digital Nudging

The nudge theory, introduced by Thaler and Sunstein (2008), recognizes that individuals may fail to make optimal choices despite awareness of their best interests due to irrational behavior patterns. The theory emphasizes that subtle behavioral interventions through positive reinforcement or indirect suggestions can effectively influence decision-making processes and facilitate desirable behavioral changes. These interventions modify the choice architecture without restricting autonomy, supporting healthy behavioral patterns through non-coercive methods. For instance, incorporating descriptive social norms in tax notification letters has been shown to increase tax payment rates by 15% (Behavioural Insights Team, 2012).

Digital nudging extends this theory to digital environments, particularly mobile applications and online platforms, leveraging technological features to promote better decision-making and behaviors. Examples include activity trackers encouraging physical activity or warning prompts designed to reduce unnecessary online purchases (Esposito et al., 2017; Mele et al., 2020). These digital nudges utilize predictable human behavior patterns to design targeted interventions, enhancing user engagement and satisfaction. Researchers have further developed various approaches for implementing digital nudging, such as the "Digital Nudging Process Model," which emphasizes goal setting, user understanding, nudge design, and effectiveness evaluation (Meske & Potthoff, 2017; Schneider et al., 2018). Since digital nudges directly influence human behavior, the design and implementation must adhere to ethical standards, respecting user autonomy and interests while avoiding manipulation (Lembcke et al., 2019; Paunov et al., 2019).

In educational contexts, particularly for older adults, digital nudging has proven effective in promoting task completion, discussion participation, and sustained learning engagement (Motz et al., 2021; Nguyen & Vo, 2021; van Oldenbeek et al., 2019). Digital nudges can also influence cognitive processes by encouraging content review and skill practice (Dawood et al., 2013), while affecting emotional dimensions through positive feedback and recognition, fostering accomplishment and pride that sustain long-term engagement (Edwards & Li, 2020). This study utilized these principles by implementing segmented push notifications as digital nudges to enhance the well-being in older adults, offering a non-intrusive yet effective means of promoting positive behavioral changes through tailored interventions. Furthermore, a systematic review of digital nudge interventions has shown promising results in promoting health screening behaviors among high-risk individuals (Wang et al., 2025). Collectively, this evidence demonstrates the versatility and effectiveness of digital nudging across educational and health domains, establishing a strong foundation for investigating their potential to improve well-being outcomes in older adult populations.

Push Notifications as Digital Nudge

Push notifications in social media function as digital intervention tools that enhance user engagement through subtle behavioral stimuli (Jensen et al., 2019). These notifications can be categorized by their nature and purpose, including reminder-based push notifications (nudges), informational push notifications (nudges), and push notifications based on social comparison (nudges). Reminder-based push notifications are designed to remind users to complete specific activities or tasks, such as taking medication or attending a scheduled meeting. Informational push notifications provide real-time news updates, weather changes, or other relevant information, improving users' efficiency in information access (Kim & Dennis, 2020). Push notifications based on social comparison leverage peer activities or achievements to encourage users to be more competitive or to mimic others, which can lead to positive changes in behavior, like adopting healthier (Patel & Lal, 2021).

Research demonstrates that push notifications can effectively promote behavior change by providing timely reminders and necessary information that reinforce consistency and sustainability. In health promotion applications, scheduled health reminders and motivational messages significantly increase adherence to healthy behaviors (Choi et al., 2021). Studies indicate that effective push notification strategies should consider individual differences, contextual suitability, and information timeliness, with personalization enhancing user acceptance and strengthening behavior change outcomes (Lee & Nguyen, 2021).

Enhancing Nudge Effectiveness Via Segmentation

Segmented push technology, or adaptive push notifications, represent an advanced data-driven strategy that tailors notifications based on users' behaviors, preferences, and past interactions. This approach delivers personalized, relevant content to enhance engagement, making it valuable in digital marketing and customer relationship management. The core of this technology utilizes big data and machine learning

algorithms to identify user interests and deliver attractive, attention-capturing messages. Li and colleagues (2019) demonstrated that analyzing users' behavioral data enables creation of precise user profiles, facilitating customized message delivery that increases engagement and improves conversion rates.

Research across multiple domains demonstrates that segmented push notifications are tailored to users' specific characteristics and needs significantly enhance intervention effectiveness for diverse populations. In health promotion, Jones et al. (2022) highlighted the potential of segmented push notifications tailored to users' health data and behavioral patterns in encouraging healthier lifestyle adoption, particularly for chronic disease management. Wang and Zheng (2020) found that segmented push notifications significantly enhanced user experience by reducing information overload and minimizing disruptions from irrelevant messages, a strategy crucial for sustaining long-term engagement. In digital education, Andersen and Lee (2021) demonstrated that segmented push notifications effectively boost student learning motivation in online environments by providing tailored resources based on progress and preferences, enhancing outcomes and participation. The heterogeneous nature of the older adult population makes segmented push notifications especially valuable for addressing their diverse well-being needs and preferences. According to the Socioemotional Selectivity Theory (SST) (Charles & Carstensen, 2010), older adults prioritize meaningful experiences and prefer investing time in activities and relationships offering personal benefit, making personalized notifications especially relevant for this age group.

The Fogg Behavior Model (FBM)

The Fogg Behavior Model (FBM) provides a structured framework for understanding and implementing behavioral changes, particularly in health promotion. Proposed by Fogg (2009), this model has been successfully applied across various domains, including corporate safety culture (Scott & Al, 2020), child sexual education (Wang & Xu, 2022), social policy (Oe & Yamaoka, 2021), digital marketing (Wang et al., 2023), stress management (van Eijk, 2015), and response to the pandemic (Harbisher, 2022). The FBM posits that behavior change occurs only when three core elements (motivation, ability, and a prompt) are simultaneously present at sufficient levels. It has been suggested that one of the elements is absent when a behavior does not occur.

Behavior = MAP (at the same moment).

Motivation (M)

Encompasses intrinsic and extrinsic behavioral drivers, including pleasure-seeking, pain avoidance, reward pursuit, and punishment avoidance. Ly and collegues (2013) demonstrated how motivational factors enhance public health interventions, while Robinson et al. (2013) identified emotions like pride and achievement as significant in encouraging healthy eating behaviors.

Ability (A)

Refers to possessing or easily acquiring necessary resources to perform a behavior, including time, money, physical capability, and mental capacity. Mohr et al. (2014) emphasized that simplifying behavior execution significantly increases change likelihood, particularly crucial when designing health interventions for older adults.

Prompts (P)

Function as direct behavioral catalysts, ensuring that reminders appear at opportune moments when individuals possess sufficient motivation and ability to act. Effective triggers must be immediate and contextually appropriate (Schultz et al., 2007), such as health app push notifications reminding users to exercise or take medication.

Fogg also introduced the "Tiny Habits" approach, which is to begin with small behaviors that gradually expand into significant changes. This method attaches new small habits to existing routines (e.g., flossing one tooth after brushing teeth) and reinforces them with positive feedback (Fogg, 2020). According to Fogg, because tiny habits are easily executed, they readily integrate into daily life and evolve into lasting behavioral patterns. The ABC's of forming a habit was further introduced, which include 1) Anchor (A): A triggering moment based on an existing routine, when individuals are more willing to initiate new behaviors after completing familiar tasks; Behavior (B): A behavior that one wants to change but broken down into a very small and simple action; Celebrate (C): Reinforcing behavior through positive emotions by celebrating its completion.

Celebrating small successes enhances positive emotions, further solidifying new habits. This approach has demonstrated effectiveness across multiple fields. Gardner et al. (2021) developed assessment questions based on Fogg's theory for designing and evaluating health behavior change interventions. Researchers have applied the Tiny Habits approach to address pandemic-related lifestyle changes (Rafique, 2022; Husseiny & Al-Zahraa Mohammad Soliman, 2023), social media management (Sussman, 2022), and healthy eating promotion (Januraga et al., 2020).

The theoretical foundation for behavior changes interventions can be further strengthened by considering the complementary relationship between Fogg's MAP Behavior Model and established value-expectancy theories. The Theory of Planned Behavior (TPB), one of the most widely applied frameworks in health behavior research, proposes that behavioral intention and the subsequent behavior are predicted by three key constructs: attitudes toward the behavior, subjective norms, and perceived behavioral control (Ajzen, 1991). However, one of the most documented limitations of TPB is that behavioral intentions don't always translate into actual behavior (Hauslbauer et al., 2022). This study addresses this limitation by implementing environmental prompts (push notifications) as an additional component to activate pre-existing behavioral intentions. By combining TPB's predictive framework with Fogg's practical design principles, interventions can simultaneously build the psychological foundations for behavior change (intentions, attitudes, control beliefs) while optimizing the behavioral design elements (simplicity, triggers, motivation) that facilitate successful implementation.

Positive Language and Emotional Resilience in Older Adults

Given the demonstrable potential effectiveness of segmented push notifications, this study further incorporates positive language to leverage its established effects on emotional resilience among older adults. Taherkhani and colleagues (2023) found that structured positive language programs combined with self-reflection potentially produce long-term positive effects on emotional resilience and psychological health. Studies show that after exposure to positive language, older adults tend to focus more on positive aspects of life while reducing attention to negative experiences (Lima et al., 2023). Positive language may impact on the emotional resilience in older adults, helping them adopt more effective thinking patterns and emotional regulation strategies, thereby promoting psychological well-being and life satisfaction.

The phenomenon "positivity effect" indicates that older adults have a greater propensity to remember positive events or emotions compared to younger individuals. This effect was first established through tests of hypotheses based on SST (Carstensen & DeLiema, 2018). Researchers suggested this effect may stem from strengthened neural connections between the amygdala and prefrontal cortex, potentially aiding older adults in more effective emotion management and psychological balance maintenance (Petro et al., 2021). This study aimed to employ continuous examination on how positive language affects older adults' emotional resilience via segmented push notification, in order to maximize the potency of this intervention.

Current Study

Based on these theoretical and research foundations, the proposed study designed two types of push notification intervention models: a behavior modification group based on the FBM utilizing specific behavioral prompts (health management and gratitude exercises) to develop positive daily habits, and a positive-phrase group focused on delivering brief positive phrases to stabilize emotional states and enhance life satisfaction and psychological health. Both intervention groups provided digital companionship. By comparing these interventions with a non-intervention control group, the researchers aimed to assess the effectiveness of push notification strategies in enhancing well-being among older adults and determine which approach yields greater benefits. This study advances the application of digital technology in promoting well-being and behavioral change in older adults, exploring new pathways for enhancing their quality of life and psychological well-being through sustainable behavioral interventions.

Methodology

This study employed an experimental design involving random assignments within a self-selected sample. Participants were recruited through public online announcements and voluntarily enrolled, resulting in a sample of older adults with basic digital literacy and a demonstrated willingness to engage in digital intervention. Enrolled individuals were randomly assigned to one of three groups: the Behavior Change

(BC) group, the Positive Phrase (PP) group, or the control group. Pre-test and post-test assessments were administered to evaluate the effectiveness of the 21-day "Self-Healing Well-Being Guide" in enhancing participants' overall well-being.

Participants

A total of 603 participants aged 55 and above were recruited through social media platforms. According to Taiwan's government policy, the minimum age requirement for participation in older adult learning programs is 55 years old; therefore, this study adopted this age as the minimum threshold for participant recruitment. While formal assessments of basic literacy, social media operation skills, and cognitive function were not administered as part of the study protocol, participation requirements implicitly presupposed these capabilities. Specifically, all participants were required to complete an online registration form independently and engage with digital push notifications delivered via social media platforms over a 21-day period. This pre-screening condition inherently excluded individuals with substantial literacy challenges, severe cognitive impairments, or insufficient digital operation skills.

In the BC group and the PP group, 503 participants completed both the pre-test and post-test and engaged in at least 80% of the interactions, with an attrition rate of 53%. In the control group, 100 participants completed both the pre-test and post-test, with an attrition rate of 51%. Participant background information is shown in Table 1.

Research Design and Procedure

Based on the experimental design, after recruitment, participants were randomly assigned to three groups: the BC group, the PP group, and the no-intervention control group. The first two groups underwent a 21-day intervention program following the pre-test, while the no-intervention control group did not receive any intervention. The primary difference between the BC group and the PP group lies in the presence or absence of behavior-prompt designs. The BC group received content designed using FBM to facilitate behavioral change, while the PP group received positive languages such as inspirational phrases without behavior prompts. For example, "Reclaim the doctor within you—its name is self-healing!", and "Showing gratitude to others is a way of being kind to yourself." Both the BC group and the PP group received two systematic push notifications per day. The first notification was delivered at 7:00 AM, while the second one was at 5:00 PM. In the BC group, the content of the first daily notification was personalized based on participants' self-identified well-being priorities provided during registration. The PP group also received affirmations tailored to their well-being priorities. The second daily notification for the BC group included encouragement for participants who had achieved their daily behavior goals, or reminders and informational nudges for those who had not yet completed their goals, while the PP group received another positive phrase in their second daily notification. An example of the push notification interface is shown in Fig. 1, followed by a translated version.

The research process in this study consists of four stages, which are further described in Table 2.

Table 1 Descriptive statistics of participants

		Behavior Change Group		Positive Phrase Group	Control Group
Number of Participants		268		235	100
Age		67.54(6.58)		68.24(5.90)	67.07(6.05)
Percentage of Females		86%		89%	90%
Residing in Northern Region		81%		82%	73%
Education Level					
College/University		69%		72%	72%
High School/Vocational		26%		25%	18%
Regarding Well-Being, Aside from Physical Health and Mobility, Which of the Following is Most Important?					
Spirituality/Religion		41%	40%	45%	
Life Goals		45%	41%	39%	
Partner/Children		14%	19%	16%	
Living Alone		16%		20%	20%
Going Out More than 5 Days per Week		65%		68%	78%
Frequency of using social media					
	For advice or recommendations	3.23		3.42	3.11
	To learn new knowledge	3.59		3.76	3.5
	To search for news and information	3.67		3.80	3.56
	To communicate with others	3.66		3.76	3.64
	To maintain existing relationships	3.65		3.70	3.56
	To seek companionship when feeling lonely	1.85		1.83	2.00
I can solve most problems independently.		3.09		3.16	2.99
I usually handle challenging and complex tasks well.		2.90		2.86	2.73
Despite difficulties, i can trust my abilities.		3.02		3.00	2.93

Note. Numbers in parentheses indicate standard deviations

Research Tools

This study designed the intervention program based on the FBM and the Tiny-Habits approach. According to FBM, behavior change occurs when the three elements: Motivation (M), Ability (A), and Prompt (P) happen simultaneously. Therefore, the intervention plan simultaneously considers the concept of both FBM and Tiny Habits approach. In this study, tiny tasks were designed across different themes, ensuring they are achievable for older adults by considering physical ability, financial cost, time, and space constraints. The prompts were delivered immediately after participants engage in routine activities, and celebration messages were sent each evening to encourage participants who completed their daily task. The push notification content was customized based on the previous study of the research team (Hsu et al., 2025), which identified that physical health and gratitude are important consensus factors for older adults' well-being. Additionally, three unique perspectives include:

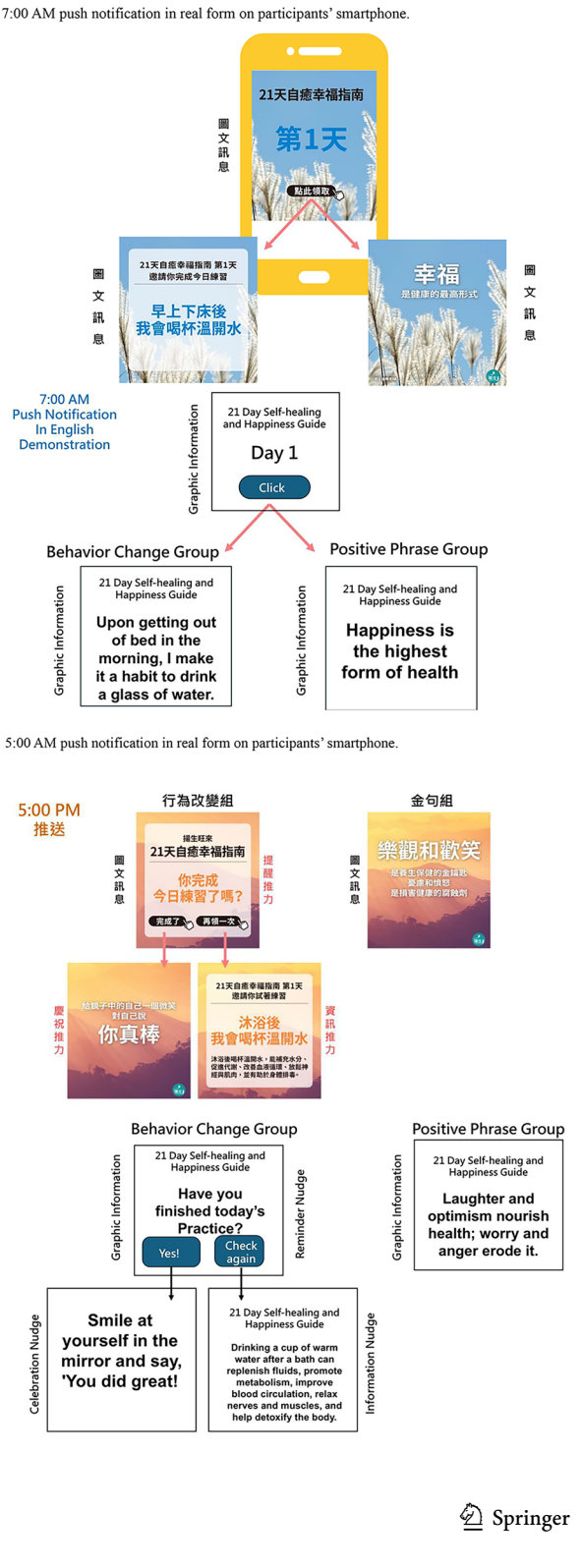


Fig. 1 Illustration of Push Notification Content for the BC Group and PP Group

Table 2 Study procedure

No.	Stage Theme	Procedure
1	Tool development, script design, and practical revisions	An initial draft of the research tools was written by an expert and then revised through multiple rounds of feedback with four academic scholars in the field until a consensus was reached. Following this, three practitioners in elderly care were invited to provide suggestions for improving the clarity and expression of the content and further adjust the content accordingly. The final content was designed as visually friendly and engaging graphic materials to ensure suitability for push notifications.
2	Pilot testing and content adjustment	The research tools developed in Stage 1 were tested through a pilot study involving 30 older adults aged 60 and above to assess the feasibility of the tools and content. Feedback from the pilot study led to several adjustments, for example: (1) Avoiding push notifications at 5:00 PM, as many participants were busy preparing dinner. (2) Using a square-shaped font rather than handwritten styles, as it was easier to read. (3) Including "completed" visual messages, which encouraged participants when they finished tasks.
3	Participant recruitment and group assignment	Participants were recruited through online advertisements, and those interested were required to complete a pre-test questionnaire during registration. Participants were randomly assigned to one of the three groups: the behavior change group, the positive affirmation group, or the control group. The behavior change group and the positive affirmation group received push notifications via social media for 21 consecutive days, while the control group did not receive any intervention.
4	Post-test questionnaire	At the end of the 21-day intervention period, all participants were invited to complete a post-test questionnaire. To encourage full participation, those who completed both the pre-test and post-test questionnaires were entered into a lottery for a NT$100 gift voucher. Finally, data from the pre-test, post-test, and participants' interaction behaviors during the intervention were collected and analyzed.

Table 3 "21-Day Self-Healing Well-Being guide" theme plan

Well-Being Category	Theme	Days	Sub-Themes
Common themes (essential)	1. Physical Health	10	Mobility, Sleep, Habits, Diet, Cognition
General push notification	2. Gratitude	5	
Unique themes (choose one of the three)	1. Inner Peace/Religious Faith	6	Spiritual, Religious, Both Equally Important
Adaptive push notification	2. Spousal Relationship/Children's Achievements	6	Spouse, Children, Both Equally Important
	3. Life Goals/Sense of Control	6	

Religious Faith/Inner Peace, Spousal Relationship/Children's Achievements, and Life Goals/Economic Security. Table 3 outlines the detailed intervention plan, with higher push frequency for themes that older adults commonly associate with well-being. Based on the need for novelty in the digital domain and its tendency to fatigue easily (Małecka et al., 2022), the 21-day intervention features entirely unique content without repetition.

Research Instruments

This study collected participants' background variables, including birth year, biological sex, educational level, place of residence, social media usage efficacy, self-efficacy, weekly outing frequency, and whether they live alone (see Table 1). Additionally, to facilitate segmented push notifications, this study investigated participants' views on well-being. Besides physical health, mobility, and gratitude, participants were asked to identify which of the following three individualized aspects is most important to them: religious faith/inner peace, spousal relationship/children's achievements, or life goals/sense of control. Further segmentation was conducted based on whether participants have a spouse or children and their emphasis on religious faith versus inner peace. Well-being measure included the following scales: Chinese Happiness Inventory-Short Form (CHWB) (Lu, 2006), Satisfaction with Life Scale-Short Form (SWLS) (Diener et al., 1985; Wu & Yao, 2006), Self-Healing Scale (SHS) (Wu et al., 2021), and EuroQol Visual Analogue Scale (EQVAS) (EuroQol Group, 1990). Both quality of life (as a multidimensional construct encompassing physical, social, and psychological domains) and psychological well-being (focusing specifically on emotional states, life satisfaction, and psychological functioning) were collected to provide a comprehensive assessment of intervention effects on older adults' overall well-being.

All questionnaires were administered during both the pre-test and post-test stages. In the post-test, participants were also interviewed after completing the "21-Day Self-Healing and Well-Being Guide." All scales used a 5-point Likert scale for responses, where 1 represented strongly disagree/very rarely and 5 represented strongly agree/very frequently. The EQ-VAS was a 0–100 visual analog scale, where participants marked their current perceived quality of life, with 0 indicating the lowest and 100 the highest quality of life. For the full list of survey items, please refer to Table 4.

Results

This study examined the effects of different intervention programs on older adults' well-being using an experimental method with three groups: the BC group receiving health-related push notifications, the PP group receiving motivational messages or phrases, and a no-intervention control group. The research aimed to determine whether digital media notifications promoting behavior change were more effective than those fostering positive emotions in enhancing well-being among older adults. This study followed a three-stage approach, beginning with a pre-intervention comparison to establish baseline measurements, followed by a post-intervention analysis to assess improvements across groups, and concluding with qualitative interviews to provide deeper context for the quantitative findings. This comprehensive methodology was designed to offer evidential support for the effectiveness of digital interventions for improving older adults' well-being.

The baseline demographic characteristics across the three groups from Table 1, BC group ($n=268$), PP group ($n=235$), and control group ($n=100$), were examined to ensure group comparability prior to the intervention. The average ages were 67.54

Table 4 Sources and sample items of research instruments

Category	Sample Item	Source
Self-Healing Scale (SHS)	1. I can live independently. 2. I maintain a healthy lifestyle. 3. I can feel inner peace. 4. I have good interpersonal relationships. 5. I can seek help when I need it.	Wu et al. (2021)
Satisfaction with Life Scale (SWLS)	1. In most ways, my life is close to ideal. 2. The conditions of my life are excellent. 3. I am satisfied with my life. 4. So far, I have gotten the important things I want in life. 5. If I could live my life over, I would change almost nothing.	Diener et al. (1985); Wu and Yao (2006)
EuroQol Visual Analogue Scale (EQVAS)	1. On a scale from 1 to 100, how would you rate your quality of life?	Euro-Qol Group (1990)
Chinese Happiness Inventory (CHWB)	1. I like my life. 2. I feel that life has meaning and purpose. 3. The events in my past life were pleasant. 4. I feel energetic. 5. I am hopeful about the future. 6. I can understand the meaning of life	Lu (2006)

years ($SD = 6.58$), 68.24 years ($SD = 5.90$), and 67.11 years ($SD = 6.10$), respectively. One-way ANOVA indicated no statistically significant differences in age among the groups, $F(2, 600) = 1.41$, $p = .24$.

Gender distributions were also similar, with 87.3% of participants identifying as female in the BC group, 88.1% in the PP group, and 90.0% in the control group. A chi-square test confirmed no significant difference in gender distribution, $\chi^2(2) = 0.50$, $p = .78$.

Regarding educational attainment, the percentage of participants with a college degree or higher (education levels 4 or 5) was 68.7%, 71.9%, and 72.0%, respectively. No significant differences were observed among the groups, $\chi^2(8) = 12.05$, $p = .15$. These results support the assumption that the random assignment resulted in demographically comparable groups.

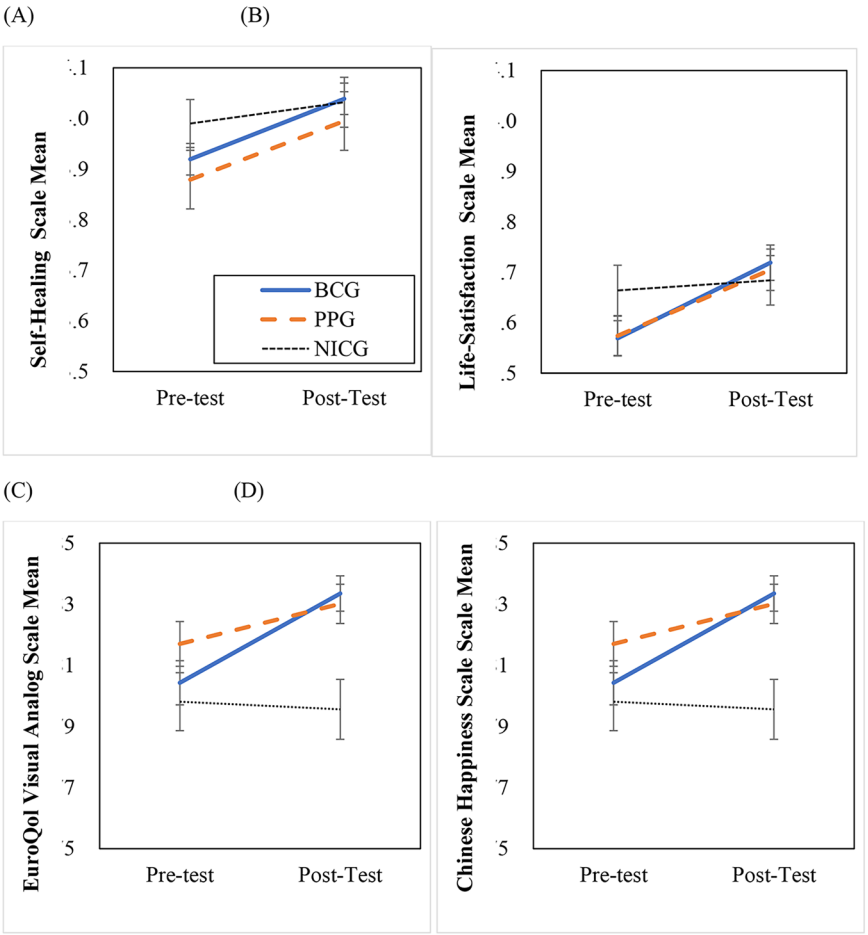
Comparison of Well-Being among Groups before Intervention

One-way ANOVA was conducted to compare pre-test scores on the Self-Healing Scale (SHS), Satisfaction with Life Scale (SWLS), EuroQol Visual Analog Scale (EQVAS), and Chinese Happiness Scale (CHWB). Levene's test confirmed homogeneity of variances for SHS, SWLS, and EQVAS, but not for CHWB, which required the use of the Brown-Forsythe statistic and Games-Howell post hoc tests for correction. The ANOVA results showed no significant differences among the three groups on all indicators before the intervention (SHS: $F(2, 600) = 1.63$, $p = .196$; SWLS: $F(2, 600) = 1.12$, $p = .327$; EQVAS: $F(2, 600) = 1.29$, $p = .280$; CHWB: $F(2,$

498.662) = 0.16, p = .850). These findings suggest that the groups were comparable in well-being at baseline, ensuring a stable foundation for assessing intervention effects.

Improvement in Well-Being after Intervention

To explore the changes in well-being among the three different groups, a 3 (groups: BC group, PP group, and the control group) × 2 (time points: pre-test, post-test) mixed-design ANOVA was conducted on various well-being indicators. The results are presented in Supplementary Table s1 and Fig. 2. The findings for each indicator are described sequentially below.



Note. BCG= Behavior Change Group, PPG= Positive Phrase Group, NICG= No-Intervention Control Group.

Fig. 2 Pre-test and Post-test Mean Scores of the Three Groups

For the SHS, the group effect was not significant ($F(2, 600) = 0.95$, $p = .388$), but the time effect was significant ($F(1, 600) = 23.01$, $p < .001$), suggesting an overall increase in self-healing regardless of the group. Similarly, for the SWLS, the group effect was not significant ($F(2, 600) = 0.16$, $p = .856$), but the time effect was significant ($F(1, 600) = 28.98$, $p < .001$). The significant group × time interaction ($F(2, 600) = 3.65$, $p = .027$) indicated that improvements in life satisfaction were greater in the BC and PP groups compared to the control group.

The CHWB showed a similar pattern: no significant group effect ($F(2, 600) = 0.34$, $p = .71$), but significant time ($F(1, 600) = 42.67$, $p < .001$) and interaction effects ($F(2, 600) = 3.29$, $p = .038$). Post-hoc tests confirmed that both the BC and PP groups experienced greater increases in happiness compared to the control group.

For the EQVAS, the group effect was not significant ($F(2, 600) = 2.79$, $p = .063$), but the time effect was significant ($F(1, 600) = 12.96$, $p < .001$). A significant group × time interaction ($F(2, 600) = 5.98$, $p = .003$) suggested that improvements in quality of life were more pronounced in the intervention groups.

Effect size analyses indicated that the observed impacts, while statistically significant, were relatively small ($\eta_p^2 > 0.01$). These results suggest that the interventions effectively enhanced well-being, but the magnitude of these effects was limited. Further analysis is needed to explore differences in the extent of improvement among the three groups.

Comparison of Improvement in Well-Being across Different Interventions

One-way ANOVA was used to compare improvements in well-being among the three groups based on the SWLS, EQVAS, and CHWB. Improvement was calculated by subtracting pre-test scores from post-test scores for each scale (see Table 5).

Levene's test confirmed homogeneity of variances for life satisfaction ($F(2, 600) = 0.22$, $p = .802$) and quality of life ($F(2, 600) = 1.16$, $p = .313$) but not for happi-

Table 5 Comparison of improvement magnitudes on different Well-being indicators across three groups

Indicator	Group	Mean	SD	F value	post hoc comparisons
Self-Healing Scale improvement magnitudes	1. BCG	0.12	0.37	1.29	
	2. PPG	0.12	0.51		
	3. NICG	0.04	0.38		
Satisfaction with Life Scale improvement magnitudes	1. BCG	0.15	0.41	3.65*	1 > 3
	2. PPG	0.13	0.42		($p = .030$)
	3. NICG	0.02	0.42		
EuroQol Visual Analog Scale improvement magnitudes	1. BCG	2.92	8.33	5.98**	1 > 3
	2. PPG	1.31	8.62		($p = .005$)
	3. NICG	-0.25	7.03		
Chinese Happiness Scale improvement magnitudes	1. BCG	0.17	0.35	3.37[a]*	1 > 3[b]
	2. PPG	0.11	0.42		($p = .025$)
	3. NICG	0.06	0.36		

Note. BCG = Behavior Change Group, PPG = Positive Phrase Group, NICG = No-Intervention Control Group

ness ($F(2, 600) = 4.13$, $p < .05$), requiring Brown-Forsythe and Games-Howell corrections. ANOVA results showed no significant differences in self-healing improvement ($F(2, 600) = 1.29$, $p = .276$). However, significant group effects were found for improvements in life satisfaction ($F(2, 600) = 3.65$, $p = .027$), quality of life ($F(2, 600) = 5.98$, $p = .003$), and happiness ($F(2, 439.979) = 3.37$, $p = .035$).

Post hoc tests revealed that the BC group showed significantly greater improvements in life satisfaction, quality of life, and happiness compared to the control group ($p < .05$), while no significant differences were observed between the PP group and the other groups. These results suggest that the BC group was more effective in enhancing well-being than the other groups.

To further interpret the intervention effects, we calculated Cohen's d values for between-group differences using pooled standard deviations. Compared to the control group, participants in the BC group showed small-to-moderate improvements in subjective health (EuroQol VAS, $d = 0.38$), life satisfaction (SWLS, $d = 0.31$), and happiness (CHWB, $d = 0.31$). These effect sizes exceed the commonly accepted threshold of 0.3 for minimal clinically meaningful group differences in well-being-related interventions (Franceschini et al., 2023), suggesting the observed gains are not only statistically significant but also practically relevant.

Correlation among Indicators

To examine the associations among the four well-being indicators used in this study—Self-Healing Scale (SHS), Satisfaction with Life Scale (SWLS), EuroQol Visual Analog Scale (EQ-VAS), and Chinese Happiness Scale (CHWB)—Pearson correlation coefficients were calculated using post-test data from all participants across groups. All four variables were significantly and positively correlated, with correlation coefficients ranging from 0.60 to 0.81. The strongest correlation was observed between SWLS and CHWB ($r = .81$), suggesting a high degree of shared variance in life satisfaction and happiness. Moderate-to-strong associations were also found between SHS and CHWB ($r = .72$), and between EQ-VAS and the other well-being indicators ($r = .60$ to 0.70). These findings indicate that while the measures are distinct, they tap into related dimensions of subjective well-being among older adults.

Correspondence of Qualitative Data

Participants' feedback during the post-test was analyzed thematically, revealing several insights regarding the effectiveness of the intervention. For the BC group (Supplementary Table s2), the results indicated improvements in psychological well-being, habit formation, and self-awareness. Participants reported experiencing more positive thinking, a greater sense of gratitude, and a stable psychological state. The intervention also helped them establish or reinforce healthy habits such as regular exercise and gratitude practices, while fostering deeper self-reflection on their behaviors, life goals, and values. The daily push notifications effectively enhanced focus and engagement, and the perceived supportive atmosphere contributed to participants feeling accompanied and encouraged. However, some participants noted a lack of

Table 6 Individual level change summary

	Self-Healing	Life Satisfaction	EQ-VAS	Happiness (CHWB)
Unchanged	61%	57%	70%	57%
Improved	27%	29%	20%	31%
Deteriorated	12%	14%	10%	13%

personalized challenges, suggesting that the content could benefit from more novelty and difficulty maintaining engagement.

In contrast, the PP group's feedback was summarized into three themes (Supplementary Table s3): enhancement of well-being, a gratitude attitude, and positive energy. Participants reported increased positive emotions and overall happiness, along with a stronger sense of gratitude toward daily activities, other people, and life in general. They also perceived positive changes in their behavior and mindset, enabling them to face life more proactively. These findings imply that simple positive phrases can effectively boost emotional well-being and foster a positive outlook. Overall, the qualitative data not only corroborates the quantitative results but also provides a deeper understanding of the mechanisms through which the interventions impacted well-being, highlighting both strengths and areas for improvement, such as the need for more personalized and challenging content.

Individual-level Change Situation

To further illustrate the distribution of individual-level changes, we classified each participant's score trajectory based on a commonly used threshold of 0.5 standard deviations (*SD*) from the pre-test value (Norman et al., 2003). Participants whose post-test scores improved or declined by at least 0.5 SD were categorized as "Improved" or "Deteriorated," respectively, while those whose scores remained within ±0.5 *SD* were considered "Unchanged."

As shown in Tables 6 and 27% of participants demonstrated meaningful improvement on the self-healing measure, 12% deteriorated, and 61% remained unchanged. For life satisfaction, 28.5% improved, 14.3% deteriorated, and 57.2% remained unchanged. On the EQ-VAS health rating, 20.2% improved, 9.6% deteriorated, and 70.2% remained stable. In the happiness scale (CHWB), 30.8% improved, 12.6% deteriorated, and 56.6% showed no significant change.

These findings complement the group-level significance tests and suggest that while average effects were moderate, a substantial proportion of participants experienced individually meaningful improvements in well-being outcomes.

Discussion

The results of this study underscore the differential effectiveness of digital intervention programs in promoting well-being among older adults. Pre-intervention analysis confirmed the comparability of well-being levels across all groups, establishing a robust baseline for evaluating intervention outcomes. The significant improvements observed in the BC group highlight the potential of behavior-triggering digital nudges

to enhance life satisfaction, quality of life, and happiness more effectively than motivational messages alone. In contrast, while the PP group also showed significant improvements on the SWLS, EQVAS, and CHWB, the analysis of the magnitude of improvement indicated no significant differences between this group and the no-intervention control group. This suggests that the digital push notifications featuring positive phrases require further investigation to establish their efficacy in enhancing well-being among older adults.

Qualitative feedback revealed that participants in the BC group experienced substantial gains in psychological well-being, habit formation, and self-awareness, which reinforce the effectiveness of behavior-specific digital nudges. However, the lack of challenging content was a recurrent theme, indicating the need for personalized and progressively challenging tasks in future interventions. In contrast, the PP group's improvements were predominantly emotional, underscoring the supplementary role of positive messaging in digital interventions.

Micro-Behavior Change Design and the Promotion of Positive Cycles

The pronounced improvements observed in the BC group substantiate the efficacy of a 21-day micro-behavior change approach grounded in the FBM (Fogg, 2009, 2020). By simplifying health-promoting actions and utilizing timely digital triggers, the intervention successfully transformed micro-behaviors into sustainable habits. This process not only reinforced life satisfaction and overall well-being but also demonstrated the scalability of micro-behavior strategies in digital health interventions for older adults.

According to the FBM, successful micro-behavior changes hinge on reducing the complexity of behaviors and deploying timely triggers to maintain action continuity. The push notification design in this study effectively combined health management behaviors with gratitude practices, converting small-scale actions into routine habits. This structural mechanism was instrumental in enhancing life satisfaction and quality of life. These findings align with previous studies, which suggest that sustained micro-behavior adjustments can significantly bolster psychological resilience and well-being (Michie et al., 2011; Lyubomirsky & Layous, 2013).

Additionally, the content of the push notifications was strategically designed based on prior research (Hsu et al., 2025), focusing predominantly on health and gratitude—core themes deemed highly relevant by older adults. Approximately 70% of the push notifications addressed these themes, while about 30% were personalized through segmented push strategies. The high engagement rate, evidenced by over 85% of participants clicking on the push notifications, underscores the importance of content relevance in sustaining user interaction. This observation is consistent with the findings of Bidargaddi et al. (2018), which emphasize that alignment between digital intervention content and user needs is crucial for maximizing engagement. Conversely, irrelevant or generic content was shown to significantly diminish participation rates.

Moreover, focusing on core issues that resonate with the values and priorities of older adults can enhance empathy and acceptance of intervention, thereby further promoting improvements in well-being (Khan et al., 2024). The integration of per-

sonalized and contextually relevant content not only heightened the perceived usefulness of the intervention but also facilitated a greater sense of digital companionship and support, which are essential for maintaining user motivation in long-term digital health programs.

The Effectiveness of Digital Push Notifications in the BC Group

The results of the BC group indicate that specific guidance on health behaviors and gratitude practices can significantly enhance participants' well-being, life satisfaction, and quality of life. Furthermore, the extent of improvement observed in this group was significantly greater than that of the control group. These findings suggest that well-designed behavior prompts can not only facilitate psychological adjustment but also drive positive changes in lifestyle. Prior research has shown that engaging in behavior change can create a positive feedback loop between psychological and behavioral adjustments, thereby enhancing self-efficacy and psychological resilience among older adults (Michie et al., 2011). The health behavior guidance provided through digital push notifications enabled participants to establish positive habits effectively in the short term, demonstrating the efficacy of digital interventions.

In contrast, although the PP group showed significant improvements in well-being, life satisfaction, and quality of life, the extent of these improvements was not significantly different from the control group. This suggests that relying solely on psychological cues through positive language might be insufficient to produce substantial improvements in well-being-related indicators. Research in positive psychology has demonstrated that positive language input can indeed enhance emotional stability and a sense of life meaning (Fredrickson, 2013; Lyubomirsky & Layous, 2013). However, the effects observed in the PP group seemed to be more focused on providing short-term emotional support rather than driving deeper behavioral changes or psychological internalization.

The core value of digital push notifications lies in their ability to provide regular and relevant interventions, which can offer consistent psychological support to older adults and create a sense of digital companionship (Amundsen, 2021; Nieves et al., 2024). The significant effects observed in the BC group further highlight that when push notification content is combined with specific behavioral guidance, its impact can extend beyond emotional support to encompass comprehensive improvements in lifestyle habits and psychological adjustment. Recent studies have emphasized that the relevance of content and interactive design are critical factors in determining the success of digital interventions (Hernández-Reyes et al., 2020; Rocha et al., 2023). Therefore, future efforts should focus more on refining the design of behavior change programs by integrating health behaviors and positive psychological support to enhance the effectiveness and broader applicability of digital push notifications.

Limitations of Information Push, Celebration Push, and Enhancement of Self-Healing Ability

The integration of information nudge (providing explanations about the benefits of practices) and celebration nudge (offering encouraging and complimentary messages

upon completion) in the BC group did not significantly increase the click-through rate. This outcome may reflect the limited marginal benefit of push notification details for participants. Related research suggests that excessive information output can lead to information fatigue, which may, in turn, diminish the effectiveness of the intervention (Rypdal et al., 2020). Therefore, it is essential to consider this factor carefully in the design of future push notification programs for older adults.

The analysis of the SHS revealed different levels of findings depending on the statistical methods used. The results of the two-way mixed-design ANOVA indicated that neither the main effect of the group nor the interaction effect between group and time was significant. This suggests that the three types of interventions did not differ significantly in terms of their impact on the enhancement of self-healing ability. However, the main effect of time was significant, indicating that the post-test self-healing scores were higher than the pre-test scores for all participants. This improvement might be attributed to time effects or to increased psychological attention resulting from participation in the study.

Further post hoc comparisons revealed that the self-healing ability of the BC group and the PP group significantly improved between the pre-test and post-test ($p < .001$), while the control group did not show a significant difference ($p = .057$). These findings suggest that the push notifications provided some short-term benefits for the BC group and the PP group, particularly in terms of behavioral and emotional support. However, the short-term nature of the intervention was insufficient to produce significant differences between the groups. These results imply that the enhancement of self-healing ability is influenced both by a general time effect and by the specific effects of push notification interventions. Future research should consider extending the duration of the intervention and combining multidimensional indicators with qualitative research to explore how external support can be internalized into long-term psychological mechanisms, thereby achieving a more stable improvement in self-healing ability.

In general, our findings support the complementary nature of Fogg's MAP Behavior Model and value-expectancy theories such as the TPB. The success of our tiny habits approach suggests that interventions can simultaneously address TPB constructs (attitudes, subjective norms, perceived behavioral control) while leveraging Fogg's behavioral design principles, specifically on providing effective triggers to activate behavior. By reducing the ability threshold required for behavior performance, our intervention may have enhanced participants' perceived behavioral control, while the meaningful content of our prompts likely influenced attitudes toward well-being behaviors.

Research Limitations and Recommendations for Future Studies

The participants in this study were primarily older adults with a certain level of digital proficiency, most of whom resided in urban areas. This sample composition may limit the generalizability of the findings to older adults with lower digital device usage rates or those living in different contexts, such as rural areas or disadvantaged groups. Future research should consider expanding the sample to include a more diverse range of participants, especially those who are less digitally skilled

or come from underserved communities, to enhance the representativeness of the sample. Although the initial recruitment target was 1,286 participants, the final effective sample size was 603, reflecting a 50% attrition rate. However, in the context of digital interventions, such an attrition rate is generally considered acceptable and, in practical terms, can even be regarded as relatively high. Unlike in-person courses, participants in digital environments tend to have greater freedom of choice without the influence of social obligations. Therefore, maintaining such a proportion of participants throughout the 21-day digital push notification program suggests a considerable level of attractiveness and engagement in the intervention.

Further analysis indicated that 80% of participants in the BC group completed at least 80% of the intervention content, while 66% of those in the PP group reached the same standard. This finding implies that despite the post-test response rate declining to 50%, the overall acceptance and satisfaction with the intervention were still high. Additionally, the level of engagement in the BC group was significantly higher than in the PP group, suggesting that the design of the BC intervention was more appealing and provided greater practical benefits. Regarding the duration of the intervention, future studies could consider extending the intervention period and conducting multiple assessments at different time points to observe the dynamic impact on well-being. The current design of the BC group aimed to promote well-being-related behaviors through push notifications; however, it remains uncertain whether participants performed the micro-behaviors or if the observed improvements in well-being were merely due to a positive psychological response to the push notification content. Therefore, it is recommended that future studies incorporate behavior-tracking technologies, such as wearable devices or behavior logs, to more accurately assess participants' adherence to the suggested behaviors. Lastly, uncontrolled external factors, such as family events, changes in social support, or health status fluctuations, might have influenced participants' well-being during the study period, potentially confounding the effects of the push notifications (Sanfey, 2020; Ziemann, 2019). Future research could address this issue by conducting qualitative interviews or using open-ended questionnaires to document external events during the study, thereby providing supplementary information for interpreting the results.

To sum up, future research should investigate optimal strategies for maintaining intervention effects through several approaches. First, studies should examine the effectiveness of different booster intervention formats and frequencies, such as adaptive reminder systems, graduated support protocols, or periodic re-engagement sessions (Bouton, 2014; Foxx, 2013). Second, research should explore how the novelty effect of new technology impacts long-term engagement, as initial enthusiasm may diminish over time without reinforcement strategies (Tsay et al., 2020). Third, future studies should investigate barriers and facilitators to health technology adoption by older adults, as understanding factors that promote or hinder initial uptake are crucial for designing more accessible and sustainable interventions (Bertolazzi et al., 2024). Finally, longitudinal studies extending beyond our 21-day intervention period are needed to track well-being impacts over months rather than weeks, allowing researchers to identify optimal timing and dosage for these maintenance interventions.

Conclusion

This study provides compelling evidence that well-designed digital push notifications can significantly enhance well-being, life satisfaction, and quality of life among older adults. The substantial improvements observed in the BC group underscore the effectiveness of actionable prompts and personalized content in fostering positive behavior changes and psychological well-being. These findings suggest that integrating health-related behaviors with positive psychological support in a digital format can serve as a practical and scalable solution for enhancing well-being in aging populations.

However, the observed limitations, such as the limited impact of positive language alone in the PP group, emphasize the importance of combining behavior-specific guidance with motivational elements to achieve meaningful and sustained improvements in well-being. For developers and health practitioners, our results highlight the need to design digital interventions that are not only personalized but also grounded in evidence-based behavior change theories. Future research should focus on extending intervention durations, enhancing content relevance, and exploring the use of advanced analytics and behavior-tracking technologies to optimize the effectiveness of digital push notifications on well-being in older adults. With aging populations worldwide, accessible technology-based solutions for psychological health are becoming essential. This work adds to growing evidence that well-designed digital interventions can meaningfully support successful aging and improve quality of life for older adults in their daily lives.

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Data Availability The present study's data is available upon request to the corresponding author.

Declarations

Conflict of interest The authors have no conflicts of interest to disclose.

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