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INFORMATION AND COMMUNICATION TECHNOLOGIES TO PROMOTE HEALTHY AGEING: A RURAL COMMUNITY INTERVENTION DURING COVID-19 PANDEMIC

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Abstract: *This pilot study evaluates a community intervention using information and communication technologies (ICT) to enhance cognitive activity and subjective well-being in older adults. Conducted during the final phase of the COVID-19 pandemic with a pre-test and post-test design, the study involved Group 1 (n = 11) and Group 2 (n = 12), who participated in a learning program using ICT to stimulate autobiographical memory and social interaction. In addition, Group 1 received training on stress coping strategies based on mindfulness-based cognitive therapy, while Group 2 reflected on the digital inclusion of older people. Following the intervention, Group 1 demonstrated significant improvements in performance on the Trail-Making-A Time and Stroop Words tasks, while Group 2 showed improvement on the Trail-Making-B Time task; all of these measures are related to executive function. Depression decreased in both groups. Most indicators of positive well-being remained stable after the intervention, with some showing a tendency to improve. These findings suggest that this community intervention is suitable for older adults and contributes to improved cognitive abilities and subjective well-being. Complementing the quantitative evaluation, a subsequent qualitative study was conducted with 20 older adults who had participated in the learning program, utilizing a participatory approach to gain deeper insights into their experiences and needs. The results indicated that the most valued aspects of the intervention were the in-person opportunities to learn how to use technology in daily life and to share reminiscences. Participants also emphasized the importance of practice opportunities and the empathetic support provided by facilitators throughout the activities.*

Keywords: *older adults, healthy ageing, information and communication technologies (ICT), cognitive abilities, subjective well-being, community intervention.*

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INTRODUCTION

Healthy ageing is defined by the World Health Organization (WHO, 2015) as the "process of developing and maintaining the functional ability that enables well-being in older age" (p. 28). Functional ability consists of intrinsic capacity, a composite of an individual's physical and mental capacities, and environments, which comprise all the external factors that shape the context of an individual's life. From this perspective, environments can promote healthy ageing by reducing risks, encouraging healthy behaviours, removing barriers, and providing targeted services. Several models highlight that maintaining cognitive abilities (such as processing speed, working memory, executive functions, attention, and inhibition) and high levels of well-being (including happiness, satisfaction, and fulfilment) are key determinants of healthy ageing. Although normative ageing (i.e., non-pathological ageing) may involve a decline in cognitive abilities, such decline can be delayed or even reversed through healthy lifestyles, supportive environments, and appropriate interventions (Baltes & Baltes, 1990; Carstensen, 2006; Kahana, 1996; WHO, 2015).

Another relevant aspect of healthy ageing is "ageing in place," which emphasizes the right of older people to live and be included in their community, since it is linked to security, connection, familiarity, identity, and autonomy (WHO, 2015). During the COVID-19 pandemic, most older adults were required to remain at home to mitigate related health risks. This context placed into question the efficacy of the ageing-in-place strategy (Pinazo-Hernandis et al., 2022; Streimikiene, 2025). For example, evidence revealed that the pandemic particularly disadvantaged older adults without access to, or skills in using, ICT, especially those with technophobia (Nimrod, 2021), thereby increasing social isolation in this age group (Roe et al., 2021; Seifert, 2021).

Supporting cognitive capacity, subjective well-being, and social participation in the community throughout the lifespan - and particularly in old age - therefore shows promise for enhancing healthy ageing. Previous research has demonstrated that information and communication technologies (ICT), including digital applications and devices, have the potential to support health care and cognitive training (Halmdienst et al., 2019; Morrison & McCutheon, 2019; Ryd et al., 2018), leisure and social relationships (Halmdienst et al., 2019; Spasova, 2023; Vulpe & Crăciun, 2020), social networks (Bilan et al., 2023; Chen & Schulz, 2016; Hasan & Linger, 2016; Righi et al., 2017; Vulpe & Crăciun, 2020), subjective well-being (Diaz-Lopez et al., 2016; Hur, 2016; Ryd et al., 2018; Saari et al., 2024), and learning opportunities (Díaz-López et al., 2016; Martinez et al., 2025; Mitzner et al., 2019; Morrison & McCutheon, 2019) for older adults.

It has been observed that using ICT for cognitive stimulation (general practices that help maintain and improve cognitive performance, such as staying active, engaging in learning processes, and participating in social activities) and cognitive training (exercises targeting specific cognitive abilities such as attention, memory, and processing speed) positively impacts older adults' cognitive performance. Some studies have reported a small but statistically significant effect size on overall cognitive functioning (Contreras-Somoza et al., 2021; Rosell, 2018) and decreased depressive symptomatology (Rosell, 2018) among older adults who engaged in computer-based cognitive stimulation activities. The use of virtual reality in cognitive interventions has been well accepted by older adults, with evidence of increased positive affect and reduced negative affect (Chan et al., 2020). Technological

interventions also foster cognitive engagement by involving participants in highly motivational and cognitively demanding activities, such as learning to use new digital technologies (Djabelkhir et al., 2017). Both types of interventions, cognitive stimulation and cognitive engagement, contribute to improvements in various aspects of cognitive performance and psychosocial functioning (Djabelkhir et al., 2017).

Despite these benefits, a substantial proportion of older adults do not use ICT in their daily lives. For instance, while Internet use in the United States is nearly universal among younger and middle-aged populations (90%), only 73% of people over 65 years report using it (Pew Research Center, 2019). In Costa Rica, in 2020, 74.71% of people aged 60 years and older had Internet access at home; however, only 11.84% had a desktop computer, 34.03% owned a laptop, 10.56% had a tablet, and 92.27% possessed a mobile phone (INEC, 2020). Among older adults, the digital divide has been the largest and most persistent between 2010 and 2017 (PROSIC, 2018).

For this population, the digital divide is associated with six basic factors: income, education, gender, age, geographic location, and disability (PROSIC, 2010). Research further suggests that older adults' difficulties in learning and using ICT are linked to limited prior experience, negative emotions associated with the learning process - particularly fear and shame - and insufficient individual support from family, friends, and instructors (Castro-Rojas, 2021; Castro-Rojas et al., 2016, 2018; Coto et al., 2017).

Involving older adults in the design and evaluation of interventions targeting ICT learning and use could be a strategy to promote more sensitive and contextualized interventions (Davis et al., 2021; Sumner et al., 2021). In a participatory approach the basic principle is that involving potential end-users during the process leads to outcomes better aligned with their needs, capabilities, and characteristics (Pelta Resano, 2022). In recent years, this approach with older adults has increased, highlighting opportunities and challenges in technological innovation (Duque et al., 2019).

To help overcome barriers related to geographic location and negative emotions associated with the learning process, the present study focuses on improving cognitive abilities and subjective well-being by adapting and implementing in a rural area with high longevity indicators (longer and healthier life expectancy compared to the rest of the country), a learning intervention previously evaluated in Costa Rica with urban older adults (Castro-Rojas, 2021). The study also evaluated the relevance of including, during the learning process, some strategies for coping with anxiety and stress when interacting with ICT: training grounded on mindfulness-based cognitive therapy (MBCT) (Crane, 2009); and group sessions for reflecting on digital inclusion of the older population.

Using a pretest and post-test design, the study describes and compares the improvements in cognitive abilities and subjective well-being in two groups of older adults. Both Group 1 (n = 11) and Group 2 (n = 12) participated in a 9-week blended learning experience using ICT devices and applications in daily life for stimulating autobiographical memory and social interaction. Additionally, Group 1 received training on coping strategies based on MBCT whereas Group 2 reflected on the digital inclusion of older people.

The study was implemented in Nicoya, Guanacaste, a community in the northeast of the country with a higher proportion of octogenarians, nonagenarians and centenarians compared to the rest of the country (Rosero-Bixby et al., 2013) and described as a mainly rural area based on population density, infrastructure and access to goods and services (INEC, 2016).

The results in each group are discussed, as well as the feasibility and limitations of this type of community intervention. This article presents the quantitative evaluation of the learning intervention. Additionally, a subsequent qualitative study, also part of the same project, explored what the intervention elements were positively evaluated by the participants and some suggestions for improvement. This complementary qualitative perspective provides valuable insights into the user experience and informs future iterations of the intervention.

MATERIALS AND METHODS

General design

Following a case study approach by focusing on a few instances of a particular phenomenon and with the end of providing and in-depth account of processes (Descombe, 2014) the study implemented a non-randomized group design and a pre-and post-test approach with two versions of the learning intervention. Participation was voluntary and given the sanitary restrictions by COVID-19, older people showed reservations to participate in group activities. As a result, the groups were intentionally conformed, and the participants were assigned to each group based on criteria of availability and convenience. In addition, considering time and resource limitations, when the first group was formed, the Learning Intervention 1 was implemented and when the number of participants for the second group was completed, the Learning Intervention 2 was executed. Consequently, these limitations led to differences between the groups that will be exposed in the results section.

Group 1 (n = 11) participated in Learning Intervention 1, which included strategies and practices for: learning and using ICT devices and applications; reminiscence activities to stimulate autobiographical memory and social interaction with peers; plus, strategies for coping with stress and anxiety based on MBCT. Group 2 (n = 12) participated in Learning Intervention 2, which included the same content as Learning Intervention 1 but instead of training on coping strategies they reflected on digital inclusion of the older population.

The primary hypothesis was that participants in both groups would improve their baseline indicators of cognitive abilities and subjective well-being after the learning intervention. The study also explored if there were different effects between both groups.

As proposed by the case study approach the study was implemented in a naturalistic setting and multiple sources of data were included (Descombe, 2014).

General description of the learning intervention

The 9-week learning intervention included learning activities for using basic features of a Samsung tablet, mobile data and wireless Internet connections (Wi-Fi hotspots at home or public venues). Using WhatsApp (WA) features (customize user profile; add new contacts; join a group; create and send pictures and audio; search and comment media files; reply to a specific post/message) and Zoom (join a meeting; use the toolbar on the screen: mute/unmute, start video/stop video, chat, leave and gallery view). It also included activities of a reminiscence protocol (Salazar-Villanea, 2010) for stimulating autobiographical

memory, which has been associated with creating empathy among groups and improvements in cognitive abilities and general well-being in older adults (Westerhof et al., 2010).

The participants shared, through text, audio and/or images on WA, personal stories about "vacation and holidays", "school time and/or training" and "games and friendship". The stories (reminiscences) followed a list of memory cues to help participants create more specific memories related to themselves. The participants commented and fed back the reminiscences of their companions both in the WA group and in the face-to-face sessions.

Additionally, the Group 1 training in coping strategies consisted of eight 2-hour workshops (one per week) facilitated by Zoom. Content included tools to identify cognitive, emotional, physiological, and behavioural manifestations related to anxiety and stress, and techniques to reduce their negative effects. Mindfulness techniques include cognitive components (full attention) and physiological (changes in physiological responses), emotional (attitude towards life), and philosophical (human beings and their reality) aspects (Crane, 2009; Kabat-Zinn, 1994). Such content can be adapted to any situation in daily life, but during the project, it was associated with older adults' ICT interactions, and COVID-19 coping strategies.

On the other hand, Group 2 reflected on digital inclusion which comprised eight 2-hour sessions (one per week) facilitated by Zoom that discussed: opportunities and barriers for learning about and using ICT; ICT-learning interests and needs; ICT-learning design for older people; skills and abilities required by ICT facilitators (teachers); myths and stereotypes about older adults; and social support for ICT learning. Figure 1 presents a schema of the learning intervention for both groups.

Figure 1. Schema of the learning intervention for both groups

Week #	Monday	Wednesday	Friday *
1	**Individual pretest - session**		
2	Face to face Session	Face to face Session	Synchronous session by Zoom
3	Asynchronous learning		Synchronous session by Zoom
4	Face to face Session	Face to face Session	Synchronous session by Zoom
5	Asynchronous learning		Synchronous session by Zoom
6	Face to face Session	Face to face Session	Synchronous session by Zoom
7	Asynchronous learning		Synchronous session by Zoom
8	Face to face Session	Face to face Session	Synchronous session by Zoom
9	**Individual post-test session**		

* Group 1: training on strategies for coping with anxiety and stress; Group 2: reflecting on digital inclusion for older adults.

The project provided each participant with one tablet (Samsung Galaxy A7 Lite, 8.7", 32 GB) and an Internet SIM card that they returned at the end of the learning intervention. Face-to-face sessions were conducted at the public library in the city centre of Nicoya and the project provided transportation subsidies to the participants.

The Universidad Nacional, Costa Rica ethical board, approved the study and the older adults gave their written consent before participating in the study.

Participants

The study recruited older adults from the databases of previous studies and a general call to the public library of Nicoya. Participants met the following inclusion criteria: older than 60 years; Mini-Mental State Examination (MMSE) score ≥ 24; able to read and write; little experience with ICT; no diagnosis of psychiatric, neurological, or neuropsychological disorders; and no present sensory and/or motor deficits affecting the use of a tablet.

Procedure

During Week 1 of the intervention, the inclusion criteria were verified, and each participant individually completed the pretest measures for cognitive performance and subjective well-being. In Week 2, participants received the tablet and SIM card and began the learning intervention described in Figure 1; the researchers facilitated all the learning activities. Each week the participants received printed learning material with the learning content. At Week 8, participants evaluated the intervention as a group, and individually completed an online evaluation form. At Week 9, each participant individually completed the post-test measures. All the activities took place in the public library of Nicoya.

Complementary Qualitative Data Collection (Participatory Workshop)

Four months after the completion of the learning intervention, a participatory design (PD) workshop was conducted with 20 older adults who had previously participated in the intervention. This qualitative component aimed to gather in-depth feedback and suggestions from the end-users' perspective. The workshop involved activities oriented towards reflecting on the participants' experience and gathering input for improving the three core learning activities (LA) (LA1: Learning about technology, LA2: Reminiscences, LA3: Synchronous online workshops). Participation was recorded through audio. The audio and transcripts were analyzed using a thematic analysis procedure. This involved reviewing the data to identify emergent themes and organizing them into categories and subcategories (Braun & Clarke, 2006). This qualitative component provides rich, participants centered data complementing the quantitative outcomes, addressing the need for deeper insights into participants´ experience, particularly valuable given the pilot nature and sample size of the quantitative study. For a comprehensive analysis of the qualitative findings, please refer to Castro-Rojas and Coto-Chotto (2025).

Data collection methods

Cognitive measures

- Screening/MMSE (Folstein et al., 1975) to assess orientation, immediate memory, attention, calculation, language, and constructive praxis.
- Stroop test (Golden, 1974) to evaluate cognitive flexibility and resistance to interference from external stimuli.

- Trail Making A and B tasks (Kortte et al., 2002) to measure cognitive flexibility and the ability to maintain a complex response and sustain attention.
- Wechsler Adult Intelligence Scale (WAIS) block design test (Wechsler, 1981) to measure visuospatial constructional ability.

Subjective well-being measures

- Short Form-8 (SF-8) Health Survey Questionnaire (Ware et al., 2001) to evaluate perceived health, with eight items asking participants to rate whether their health was "poor" (1) to "excellent" (5) and about their current physical health.
- Satisfaction with Life Scale (SWLS; Diener et al., 1985) to assess subjective well-being, concentrating on measuring global life satisfaction.
- Positive and Negative Affect Scale (PANAS; Watson et al., 1988) to measure emotional stability as an initial tool for assessing the emotional state.
- Center for Epidemiologic Studies Depression Scale (CES-D-10; Andresen et al., 1994) to evaluate depression in older adults.
- Perceived Stress Scale (Cohen et al., 1983) to measure perceived stress.
- Generalized Anxiety Disorder Scale (GAD-7; Spitzer et al., 2006) to evaluate experiencing several generalized anxiety symptoms.
- Functional Social Support Questionnaire (DUKE-UNC; Bellón et al., 1996) to measure the degree of perceived social support.

Health record measures

History of cardiovascular disease, diabetes, obesity, smoking, alcoholism, stroke or arteriosclerosis was recorded for each participant.

Sociodemographics

Gender (male, female), chronological age report, years in formal education and income were recorded.

Data analysis

The sample was characterized by descriptive analysis using means and standard deviations (SD) or percentages. Cognitive and subjective well-being outcomes were reported as means (SD) and ranges.

For each group, comparisons of outcomes between pre- and post-intervention assessments (within-comparison) or by group (between-comparison) were performed using paired and unpaired Student's *t*-tests or Wilcoxon-Mann-Whitney tests (for non-normal distributions) and one-way ANOVAS to seek cognitive performance differences by educational level in both groups. Given this study's small sample size, there was a high probability of finding non-significant differences when comparing the two groups (between-comparison). Therefore, to assess the magnitude and direction of intervention outcome, effect

size (ES) was computed in the form of Cohen's *d*. ES can be considered small ($d = 0.2$), medium ($d = 0.5$) or large ($d = 0.8$) (Cohen, 1988).

The significance level used for all statistical tests was set at 0.05. Data were processed using the statistical package SPSS v.25 (IBM, 2017).

RESULTS

Eleven participants were allocated to Group 1 and twelve to Group 2. Due to the characteristics of the recruitment process, Group 1 was formed mainly for housewives and Group 2 presented more retired workers. Table 1 presents the sociodemographic characteristics of the sample. There was no significant group difference in age, gender, MMSE score, or monthly income in the baseline assessment ($p > 0.05$) and only years of formal education showed significant differences (Group 1: $M = 9.64$; Group 2: $M = 12.82$; $t_{(21)} = 2.22$, $p = 0.037$). We ordered the education level into three categories: 1. Low level (primary), 2. medium level (high school), and 3. high level (technician or university studies) for comparison purposes.

Table 1. Participants´ characteristics

Sociodemographics	Group 1	Group 2
Male	0	2
Female	11	10
Average age (years)	74.45	73.42
SD	4	6.11
(Min-Max)	(68-81)	(60-81)
Educational level		
Low %	18.18	16.67
Medium %	54.55	25.00
High %	27.27	58.33
Average of years in formal education	9.64	12.82
Monthly income		
No income %	18.20	8.33
Less than $600 %	45.45	41.67
Between $600–$1600 %	36.36	50
Pension income %	54.55	83.33
***Average of p*eople living in the same household**	2.09	2.17
SD	1.30	1.64
(Min-Max)	(1-5)	(1-7)

None of the participants discontinued the intervention. Only one participant in Group 1 did not perform the post-test assessment, resulting in eleven subjects for the final analyses.

Cognitive outcomes

Group 2 showed better scores in the cognitive tests at the baseline. Table 2 presents a comparison of both groups at pre- and post-test measurement. The comparisons showed a trend of stability of cognitive indicators and screening measures, executive function, and visuospatial abilities in general. After the intervention, in Group 1, there was a significant improvement in performance on the Trail-Making-A Time task ($p = 0.011$) and Stroop Words task ($p = 0.002$). In Group 2, only the Trail-Making-B Time task indicated an improvement

(p = 0.05). There was a tendency for improvement in both groups after intervention despite not showing significant differences in other cognitive indicators. These results indicate improvement in executive functions such as processing speed, selective attention, and inhibition of irrelevant information, which are key abilities for performing activities of daily living.

Table 2. Comparisons within-groups of the cognitive functioning indicators in pre and post-test

Groups	Indicators	Mini-Mental		Trial Making A Time		Trial Making A Errors		Trial Making B Time		Trial Making B Errors		Cube		WAIS	Stroop Word		Stroop Color		Stroop Interference	
	Test time	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post		Pre	Post	Pre	Post	Pre	Post
01	Media	27.82	26.82	99.74	84.44	2.18	0	259.5	269.36	12.55	7.18	15.55	16.64		59.45	71.55	49.18	48.82	20.36	22.55
	SD	2.089	2.18	41.74	36.29	5.78	0	69.97	51.51	11.62	6.58	11.01	10.83		19.38	14.08	12.73	9.4	8.46	9.09
	t-test	-	-	$T_{(10)}$=3.127, p=.011		-	-	-	-	-	-	-	-		$t_{(10)}$=4,066, p=.002		-	-	-	-
02	Media	27.67	28.08	90.91	75.08	0.25	0.8	240.1	211.58	4.83	4.00	17.75	17.33		69.92	76.75	48.00	50.67	26.08	28.67
	SD	2.14	1.56	40.25	39.72	.45	0.3	76.85	51.51	6.5	5.68	7.46	6.69		17.5	15.46	10.81	6.67	5.12	7.25
	t-test	-	-	-	-	-	-	$t_{(11)}$=2.11, p=.05		-	-	-	-		-	-	-	-	-	-

Note: We only show significant *t-values* at p=0.05

Socio-emotional outcomes

Table 3 presents the outcomes from socio-emotional measures in both groups. Stability was found in pre- and post-intervention measures for most of the positive socio-emotional indicators, such as life satisfaction, social support, self-efficacy, and perceived health, which were scored at medium levels in all cases. Negative emotional variables evidenced a similar pattern: variables such as stress and depression were positioned at medium to low scores in both pre-and post-test measures without showing significant differences after the intervention but with a tendency to decrease in the post-test evaluation. Finally, significant differences indicating a decrease were found in the indicator of depression in both Group 1 (p = 0.63) and Group 2 (p = 0.013). The positive emotion indicator (PANAS-P) increased in Group 2 (p = 0.005). Most positive well-being indicators remained stable after the intervention in both groups, and some showed a tendency to improve.

Table 3. Comparisons within-groups of the socio-emotional indicators in pre and post-test

Groups	Indicators	LS		Stress		Anxiety		Depression		SE		PH		PANASP		PANASN		SS	
	Test time	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
01	Media	3.36	3.4	3.09	2.99	1.94	2.1	2.11	1.88	3.79	3.46	2.64	2.75	4.21	4.05	2,19	2,47	4,01	3,71
	SD	0.75	0.59	0.57	0.48	0.55	0.67	0.75	0.46	0.67	0.76	0.8	0.76	0.54	0.52	0,89	0,77	0,75	1,04
	t-test	-	-	-	-	-	-	$t_{(10)}$=2.09, p=.063		-	-	-	-	$t_{(10)}$=2.32, p=.042		$t_{(10)}$=-2.59, p=.027		-	-
02	Media	3.45	3.60	3.08	2.92	1.84	1.82	2.05	1.69	3.78	4.00	2.63	2.24	3.69	4.20	2.40	2.05	4.04	4.23
	SD	0.69	0.67	0.50	0.34	0.64	0.54	0.63	0.40	0.60	0.42	0.96	0.76	0.55	0.38	1.06	0.68	0.83	0.71
	t-test	-	-	-	-	-	-	$t_{(11)}$=2.94, p=.013		-	-	-	-	$t_{(11)}$=-3.49, p=.005		-	-	-	-

Note : LS: Life Satisfaction. SS= Social Support. SE= Self-efficacy, PH= Perceived Health. We only show significant *t*-values at p=0.05

In Group 1 there was a decrease in positive emotions (PANAS-P: p = 0.042) and a marginal increase in negative emotions (PANAS-N: p = 0.027), which can be related to lack of experience in learning and using ICT, the educational level of this group and to cognitive demands from the training in coping strategies, this will be discussed further in the discussion section.

Cognitive abilities: Between-group comparisons

It should be noted that there was a tendency for better performance in Group 2 than Group 1, both in the pre-and post-intervention cognitive measures. At the baseline assessment, the ES was different in most of the indicators and Group 2 showed better performance in Trail-Making-A Time (d = 0.21), Trail-Making-A Errors (d = 0.47), Trail-Making-B Time (d = 0.26), Trail-Making-B Errors (d = 0.81), WAIS Cube task (d = 0.23), Stroop Words task (d = 0.56) and Stroop Interference task (d = 0.81). Post-intervention comparison showed a significant difference in the Trail-Making-B Time task (p = 0.047, d = 0.88), with better performance in Group 2 than Group 1; a similar trend was observed in the other cognitive indicators, with small to medium ES in the MMSE (d = 0.66), Trail-Making-A Time (d = 0.24), Trail-Making-A Errors (d = 0.51), Stroop Words task (d = 0.35), Stroop Colour task (d = 0.22) and Stroop Interference task (d = 0.74). It should be noted that the cognitive indicators used are sensitive to formal educational differences such as those existing between the groups compared (see Table 4).

Table 4. Comparisons between-groups of cognitive functioning indicators in pre and post-test

Time	Indicators	Mini-Mental		Trial Making A Time		Trial Making A Errors		Trial Making B Time		Trial Making B Errors		Cube		WAIS		Stroop Word		Stroop Color		Stroop Interference	
	Groups	**01**	**02**	**01**	**02**	**01**	**02**	**01**	**02**	**01**	**02**	**01**	**02**	**01**	**02**	**01**	**02**	**01**	**02**	**01**	**02**
	Media	27.82	27.67	99.74	90.92	2.18	.25	259.4	240.2	12.55	4.83	15.55	17.75	59.45	69.92	49.18	48.00	20.36	26.08		
Pre-	**SD**	2.08	2.14	41.74	40.25	5.77	.45	69.9	76.8	11.62	6.59	11.01	7.46	19.38	17.50	12.73	10.81	8.46	5.12		
test	***t-test***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	Cohen's d	0.07		0.21		0.47		0.26		0.81		0.23		0.56		0.09		0.81			
Post-	**Media**	26.82	28.08	84.44	75.08	0.0	0.8	269.4	211.6	7.18	4.00	16.64	17.33	71.55	76.75	48.82	50.67	22.55	28.67		
test	**SD**	2.18	1.56	36.29	39.73	0.0	.28	51.54	75.99	6.58	5.68	10.83	6.69	14.08	15.46	9.40	6.67	9.09	7.25		
	t-test	-	-	-	-	-	-	$T_{(21)}$=2.11, p=.047		-	-	-	-	-	-	-	-	-	-		
	Cohen's d	0.66		0.24		--		0.88		0.51		0.07		0.35		0.22		0.74			

Note: We only show significant *t-values* at p=0.05

We ran a one-way variance analysis to test educational level differences between groups' cognitive performance at the pre and post-test. Education was ordered into three categories: 1. Low level (primary), 2. medium level (high school), and 3. high level (technician or university studies).

In groups 1 and 2, 8.7% of the sample had a low educational level, 26% in group 1 had a medium level, and in group 2, 13%. A high academic level in group 1 represented 13%, and in group 2, 30.4%.

The ANOVA found that the block design test significantly differed from the pre-test in both groups ($F_{(2,20)}$ = 9.76, p. 0.001, η^2= 0.49) by educational level. The difference was found between the medium level and high level by a post hoc analysis made with the Bonferroni correction ($t_{(20)}$ = 4.4, p< .001, IC 95=-3,19 to -0.85).

Also, we found a significant difference in the Trail Making B task by educational level in both groups from the pre-test ($F_{(2,20)}$ = 5.10, p. 0.016, η^2= 0.34). As before, by a post hoc analysis made with the Bonferroni correction, we found differences by educational level between low and high levels ($t_{(20)}$ =2.64, p=0.047, IC 95=0.23 to 2.90), and very similar by medium and high levels ($t_{(20)}$ = 2.64, p=0.047, IC 95=0.17 to 2.25).

Finally, we found a significant difference in the Trail Making B task by educational level in both groups from the post-test ($F_{(2,20)}$ = 8.87, p = 0.002, η^2= 0.47). A post hoc analysis

with the Bonferroni correction found differences by educational level by medium and high levels ($t_{(20)}$ =4.16, p=0.001, IC 95=0.76 to 3.06).

Socio-emotional variables: Between-group comparisons

Most of the socio-emotional variables showed no significant differences and the evidence indicated stability in both groups at the pre- and post-test assessments. However, in the pre-intervention measures there was a significant difference in positive emotion indicator PANAS-P, favouring Group 1 (p = 0.031, d = 0.95); and with a small ES in negative emotion indicator PANAS-N (d = 0.21), Group 1 also showed fewer negative emotions than Group 2. Nevertheless, the same indicators at the post-intervention assessment showed an inverted trend: Group 2 was observed with less negative emotions than Group 1 (medium ES, d = 0.57) and more positive emotions than Group 1 (small ES, d = 0.33). At the post-intervention assessment, Group 2 showed better scores in other socio-emotional variables, such as higher life satisfaction level (small ES, d = 0.31), low anxiety (medium ES, d = 0.46), less depression (medium ES, d =0.44), better perceived health (medium ES, d = 0.67) and higher scores in social support (large ES, d = 0.85) and self-efficacy beliefs (p = 0.046; large ES, d = 0.89; see Table 5).

Table 5. Comparisons between-groups of the socio-emotional indicators in pre and post-test

Time	Indicators	LS		Stress		Anxiety		Depression		SE		PH		PANASP		PANASN		SS	
	Groups	**01**	**02**	**01**	**02**	**01**	**02**	**01**	**02**	**01**	**02**	**01**	**02**	**01**	**02**	**01**	**02**	**01**	**02**
	Media	3.36	3.45	3.09	3.08	1.94	1.84	2.11	2.05	3.79	3.78	2.64	2.63	4.21	3.69	2.19	2.40	4.01	4.04
	SD	.75	.69	.57	.50	.55	.64	.75	.63	.75	.83	.80	.96	.54	.55	.89	1.06	.75	.83
Pre-test	***t-test***	-	-	-	-	-	-	-	-	-	-	-	-	$t_{(21)}$=2.30, p=.031		-	-	-	-
	Cohen's d	0.12		0.01		0.16		0.08		0.01		0.01		0.95		0.21		0.03	
	Media	3.40	3.60	2.99	2.92	2.10	1.82	1.88	1.69	3.46	4.00	2.75	2.24	4.05	4.20	2.47	2.05	3.71	4.23
	SD	.59	.67	.48	.34	.67	.54	.46	.40	.76	.42	.76	.76	.52	.38	.77	.68	.76	.42
Post-test	***t-test***	-	-	-	-	-	-	-	-	$t_{(21)}$=-2.1, p=.046		-	-	-	-	-	-	-	-
	Cohen's d	0.31		0.16		0.46		0.44		0.89		0.67		0.33		0.57		0.85	

Note: LS: Life Satisfaction. SS= Social Support. SE= Self-efficacy, PH= Perceived Health. We only showed significates t-values at p=0.05

These results suggest that Group 2 benefited the most from the intervention, which can be related to their better educational level and therefore more access to ICT devices and applications in their daily life.

Participants´ evaluation of the learning intervention

The general experience of the participants was significant, and attendance was almost 100% in all the sessions, which demonstrated enthusiasm and commitment to learning.

Regarding the content and activities carried out, in a customized questionnaire 80% of participants indicated that reminiscences (recovering and narrating personal memories) were the most significant activity for them, followed by using Zoom (76%) and recording and sharing audios in WA (76%). When asked about the learning that they can integrate into their daily lives, 80% mentioned calls and video calls in WA. It is interesting to note that 77% of Group 1 participants considered that what they learned in the training for coping with anxiety and stress was very useful for their daily lives.

The intervention also generated a change in attitudes towards ICT, with 84% indicating that they had incorporated some of the learning into their daily lives, 76% feeling more

comfortable interacting with ICT, 84% discovering that they are able to use technology and 100% becoming aware of aspects related to technology that they would like to continue learning.

Furthermore, all the participants showed a high degree of satisfaction with the facilitators, content, learning materials, and activities during the sessions.

Qualitative findings from the participatory workshop

Twenty (20) participants actively engaged in the workshop, with most understanding the tasks and offering valuable feedback and suggestions about the intervention. Their contributions complemented the satisfaction reported in the quantitative evaluation by providing concrete details on what worked well and what could be enhanced from their perspective. Participant feedback focused primarily on familiar aspects of the intervention, such as the location and format of sessions, teaching-learning strategies, learning materials, and the role of facilitators. Fewer suggestions were provided regarding novel or creative elements, or specific improvements to the ICT tools/functionalities themselves, possibly due to limited prior experience with technology.

The results are illustrated with verbatim transcriptions of the participants´ contributions.

Specific feedback included a preference for in-person sessions and more time for practicing the learned skills. They found the library facilities suitable. They also desired a greater number of sessions. The ease of resolving doubts and requesting help in person was a significant factor.

“I believe there could be more live classes initially, and over time, a gradual transition to virtual sessions.” (Participant 3, November 24, 2022)

Related to teaching-learning strategies suggestions pointed to the need for more in-depth explanations of ICT use. They also emphasized the importance of having time and opportunities for hands-on practice.

“More time for reflection is needed - allowing more space at the end of the class to synthesize newly acquired knowledge.” (Participant 2, November 24, 2022)

About learning materials, participants suggested that materials should be visually attractive and multimedia (combining printed, digital, audio, and video formats). They also highlighted the need for materials adapted for individuals with visual difficulties, such as larger text.

“To improve the learning materials, in addition to the printed booklet, it would be helpful to include a recording for review at home - perhaps an audio file for listening.” (Participant 2, November 24, 2022)

The support provided by the facilitators was highly appreciated, characterized by kindness and patience. Participants expressed satisfaction with the facilitators' performance and personal characteristics.

“All the support provided was excellent, and the way the content was delivered - with great care and sensitivity to our individual differences - was deeply appreciated.” (Participant 1, November 24, 2022)

Participants also highlighted the value of the reminiscence activities for social interaction and sharing experiences. The topics covered were also well-received, as was the ability to share audio or text reminiscences via WhatsApp. They also suggested more topics:

“Topics could be more closely related to older adults, for instance, addressing issues such as widowhood.” (Participant 4, November 24, 2022)

Related to the most important learnings, four months after the intervention concluded, the older adults continued to value the knowledge gained, particularly regarding ICT use in daily life. Therefore, 75% of participants considered the face to face sessions focused on learning about ICT the most relevant component of the intervention. Particularly, they enjoyed the in-class practice, the facilitators, and the support provided during sessions. This activity was also where they reported learning the most.

About using technological tools, 70% of participants were still using 8 out of the 10 technological tools and applications they learned about. Participants particularly valued the ability to use WhatsApp functionalities in their social interactions.

Participants expressed interest in continuing to learn more applications, especially using their mobile phones, which are the devices most owned and easily carried.

Among the online workshops, the "Reflections on digital inclusion” workshop (Group 2) was significantly more liked than the "Training on coping strategies" (Group 1). Participants in the digital inclusion workshop especially appreciated the facilitators' role and the technical support received during Zoom sessions.

As observed the participants focused on the how of learning (methodology, support, environment, materials) rather than the what (specific applications or content). This indicates that while the tools and general topics were relevant, the learning process is always subject to refinement. Overall, the qualitative data provided specific, actionable feedback from the participants, enriching the understanding of the intervention's impact and guiding future design iterations in a participant-centered manner. An in-depth discussion of the qualitative outcomes can be found in (Castro-Rojas & Coto Chotto, 2025).

DISCUSSION

The aim of this study was to evaluate the effectiveness of a learning intervention mediated by ICT on the cognitive abilities and subjective well-being of older adults residing in a rural area of Costa Rica with high longevity indicators such as longer life expectancy and lower risks of disease during the old age compared to the rest of the country (Rosero-Bixby et al., 2019).

The intervention was implemented during the last phase of COVID-19 pandemic which remarked the relevance of digital inclusion of older adults (Nimrod, 2021; Roe et al., 2021; Seifert, 2021). The results indicated that both modalities of the learning intervention were

highly feasible and acceptable for the participants, as indicated by the participants´ high assistance and no dropouts. The intervention was highly appreciated by participants because they perceived that it met their needs for cognitive stimulation, social interaction, and digital inclusion. The participants showed high motivation during all sessions and expressed a desire to continue learning about and using ICT. Developing the intervention in the community library supported the right of participants to "age in their place" (WHO, 2015).

For both modalities of the intervention, stability was observed in most of the indicators of cognitive abilities and subjective well-being at pre- and post-intervention assessment. However, there were significant improvements after the intervention in the Trail-Making-A Time task and Stroop Words task in Group 1 and in the Trail-Making-B Time task in Group 2, which supports the potential of this type of intervention to enhance cognitive performance during old age, particularly in abilities related to executive functioning (Djabelkhir et al., 2017; Halmdienst et al., 2019; Morrison & McCutheon, 2019; Ryd et al., 2018).

The between-group comparisons and ES analysis showed that Group 2 displayed better performance in cognitive abilities at both pre- and post-intervention assessments. As mentioned in the results section, all the cognitive indicators assessed were sensitive to formal educational differences, such as those existing between the groups. It has been noted that the contribution of education to cognitive reserve in old age is a criterion of optimal performance in cognitive function (Wilson et al., 2019). Differences on cognitive tests scores were found between lower and/or intermediate and high educational level, since group two had more participants with high levels of education, that could explain the better performance in group 2. These results indicated that the cognitive reserve and cognitive demand of the planned learning activities are key aspects to take into consideration when designing ICT interventions aimed at improving cognitive abilities in older adults. In future studies, an equivalent group design can help to clarify these results.

Both groups showed improvements in positive socio-emotional measures after the intervention and a reduction of negative socio-emotional indicators, as expected (Diaz-Lopez et al., 2016; Djabelkhir et al., 2017; Hur, 2016; Ryd et al., 2018). There was improvement in the depression indicator for both groups and an improvement in positive emotions for Group 2. The between-group comparisons and ES analysis showed larger effects for Group 2 than Group 1, this could be related to sociodemographic variables such as educational level, and occupation: Group 1 participants were primarily housewives and some of them worked in the industry services, whereas Group 2 were retired workers and some of them were educators and had qualified jobs which could be related to a more active social life. More research is needed to clarify these aspects.

Group 1 showed a decrease in positive emotions and a marginal increase in negative emotions; a possible explanation for this is lack of experience using Tablets, WA and Zoom applications, it is also possible that the training for coping with anxiety and stress may have been overly demanding for Group 1 because it was developed totally by Zoom and included the use of self-report instruments and at-home tasks that involved additional cognitive demands. It is important to note that the low educational level of this group could also have an influence on the way they face cognitive challenges.

Another important consideration is that the MBCT training techniques included meta-cognitive components, which could expose Group 1 to a self-assessment process of their emotional situation that increases their consciousness of daily life stressor events (Crane,

2009; Kabat-Zinn, 1994) and their emotional responses when using ICT and to COVID-19 environment. In Group 2 these effects did not exist.

The evidence showed that both versions of the learning intervention can support cognitive enhancement and subjective well-being because both groups showed stability of overall cognitive performance and improvements in cognitive abilities associated with executive functioning, as well as improvements in well-being indicators. The study results indicate that people with higher educational levels benefit the most from the intervention (Wilson et al., 2019), which poses a challenge for designing suitable interventions for people with low educational level and low incomes living in rural areas.

Regarding the content and activities focused on stress management when interacting with ICT, the improvements in both groups indicate that both modalities (training on coping strategies and reflecting on digital inclusion of the older population) can be beneficial for older ICT learners, as both are opportunities to elaborate thoughts and emotions emerging during the ICT learning process. Future studies must take into consideration the additional cognitive demand from training on stress coping strategies.

Both modalities of the learning intervention support the enhancement of cognitive abilities and subjective well-being, but further research is needed to distinguish specific effects related to ICT learning and use, reminiscence activities and training strategies for coping with anxiety and stress when interacting with ICT.

The quantitative findings on the intervention's feasibility and acceptability are significantly enriched by the qualitative data obtained from the participatory workshop. The workshop allowed participants to articulate why they valued certain aspects of the intervention, such as the library's familiar community environment, the kindness and patience of the facilitators, and the opportunities for social interaction, especially during reminiscence activities.

These qualitative insights underscore the importance of human and environmental factors, not just technological aspects, in the success of ICT learning interventions for older adults. The feedback gathered through the participatory workshop provides practical guidance for future iterations of the intervention, highlighting user preferences for blended modalities with a strong emphasis on in-person support and practice, diverse and accessible learning materials, and continuous assistance.

CONCLUSIONS

Both modalities of the intervention have the potential to improve cognitive abilities such as processing speed, selective attention and inhibition of irrelevant information, decrease depression indicators and increase positive indicators of subjective well-being in older adults without cognitive impairment. The study results highlight the need to continue studying the effectiveness of community interventions using ICT to facilitate cognitive activity and well-being. Furthermore, both intervention modalities (training in stress coping strategies and reflecting on digital inclusion of older people) were feasible and well accepted by the participants.

Based on the motivation and commitment of older people, community interventions using ICT aimed at facilitating cognitive activity and subjective well-being are an opportunity

to implement effective and low-cost interventions to promote healthy ageing and prevent decline during old age. Community interventions have the potential to reach older adults in their daily living environments. Using ICT devices and applications allows participants to perform activities and tasks at any time and place they wish, and they do not always require the presence of an instructor. Thus, these interventions are effective, flexible, and more affordable because they do not require so many human resources.

Replicating this type of intervention on a large scale can result in the inclusion of populations that would otherwise not receive any intervention and would be digitally excluded. Furthermore, there is a need for more studies with active control groups that allow comparisons with other types of interventions. Future research should therefore include larger and more diverse samples.

Beyond the quantitative outcomes, the qualitative study using participatory design provided critical insights into the user experience and practical suggestions for improving the intervention from the perspective of older adults. Key elements to consider for future iterations and similar interventions include ensuring sufficient hands-on practice time, providing continuous and empathetic support from facilitators, and offering diverse and accessible learning materials.

LIMITATIONS

The main limitations of the study were sample size and the non-randomized assignation of the participants to each intervention group, which reduced the probability to test the interventions effects. However, this was a pilot study, and it will be necessary to adjust the protocol of the intervention for future studies. Participants in this study were highly motivated to learn about and use ICT which limits the generalization of the research findings to similar learners. More studies are needed to evaluate the effectiveness of this approach for older people with low willingness to learn about and using ICT. Furthermore, the participatory design activities in the workshop were limited in scope (focusing primarily on improvement evaluation rather than generative design) and duration, potentially limiting the depth and novelty of the suggestions provided by participants. The sample for both components was predominantly female, limiting broader gender representation.

IMPLICATIONS FOR APPLICATION

Community-based interventions using ICT to promote cognitive activity and subjective well-being are suitable for older adults and public institutions in rural areas with high longevity indicators. Therefore, these types of interventions are an opportunity to implement effective and low-cost strategies to promote healthy ageing and prevent decline during old age. The study results indicated that people with a greater reserve benefit the most from the intervention, which poses a challenge for designing suitable interventions for people with low educational level and low income living in rural areas. Practitioners can collaborate in the design and implementation of these strategies aimed to meet older people needs and interests.

The findings, particularly from the qualitative participatory design component, offer practical implications for practitioners and researchers designing and implementing ICT learning interventions for older adults. It is crucial to tailor learning activities and materials to the specific needs and diverse abilities of older adults, ensuring clarity of instructions and ample opportunity for hands-on practice and personalized support. Community spaces like public libraries are suitable and comfortable environments for these interventions in Costa Rica. The insights gained from participants are valuable for creating interventions that are not only effective but also relevant, acceptable, and empowering for older adults

Conflicts of Interest

The authors report no conflicts of interest in this work.

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