

## Review



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# Cognitive Effects of Information and Communication Technology-Based Interventions in Older Individuals With Cognitive Impairments: A Systematic Review

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## ABSTRACT

Systematic reviews focusing on the impact of information and communication technology (ICT)-based intervention programs on cognitive functions in Korean older adults with cognitive impairment are lacking. This systematic review investigates the evidence regarding the effectiveness of ICT-based interventions in Korean older adults with mild cognitive impairment (MCI) or early-stage dementia. We conducted a systematic search on PubMed, Embase, Google Scholar, the Cochrane library, KISS, and KMBase for reports published before November 2023. Our review revealed the clinical efficacy of ICT-based interventions in patients with cognitive impairment. Among the 9 studies meeting the selection criteria, all found evidence of significant cognitive improvement, notably in global cognition (55.6%), memory (44.4%), and visuospatial (22.2%) domains, following ICT-based interventions. Good compliance of the participants and effectiveness in non-cognitive outcomes including depression, self-esteem, and functional abilities are also reported. However, it is crucial to note limitations in our review, such as variations in assessment tools, differing levels of cognitive functions, and small sample sizes in previous studies. Therefore, the presented findings should be interpreted with caution. In conclusion, ICT-based interventions are emerging as valuable options for improving cognitive function in older adults with MCI and early stage of dementia.

**Keywords:** Cognitive Intervention; Information and Communication Technology; Computerized Cognitive Training; Mild Cognitive Impairment; Dementia

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**Conflict of Interest**

The authors have no financial conflicts of interest.

**Author Contributions**

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**INTRODUCTION**

The World Health Organization estimates the global prevalence of dementia cases will increase from 55 million to 139 million by 2050, with a potential financial burden of US \$2.8 trillion by 2030.<sup>1</sup> Mild cognitive impairment (MCI) is a prodromal stage of dementia. Patients with MCI have a 10 times the risk of developing dementia than do cognitively normal individuals at the same age.<sup>2</sup> South Korea, which is undergoing rapid population aging, anticipates the number of individuals 65 years of age and older will rise from 8.53 million in 2021 to 19 million by 2050.<sup>3</sup> This demographic shift in South Korea suggests a growing challenge as the proportion of individuals with cognitive impairment such as MCI and dementia grows. The economic cost of treating these individuals was already approximately US \$6,957 per capita in 2019.<sup>4</sup>

Despite attempts to develop pharmaceutical treatments for patients with cognitive impairment, none have shown an ability to effectively restore cognitive or functional impairment. As a result, recent research has shifted to various non-pharmacological approaches, such as cognitive intervention or lifestyle changes, to slow down progression in patients with cognitive impairment.<sup>5,6</sup> A growing body of evidence suggests that cognitive intervention may help sustain cognitive performance and potentially postpone cognitive decline in individuals with MCI and dementia.<sup>7,8</sup>

Recently, there has been rapid advancement in information and communication technology (ICT), and prior research has demonstrated positive impacts of cognitive intervention using ICT on patients with MCI and dementia.<sup>9,13</sup> The coronavirus disease 2019 (COVID-19) pandemic is anticipated to further escalate the demand for cognitive-intervention programs that use ICT for older adults with cognitive impairment.

However, a comprehensive examination of the literature reveals a lack of systematic reviews focusing on the impact of ICT-based cognitive-intervention programs in older adults with cognitive impairment in South Korea. This literature review is designed to assess prior research into the efficacy of cognitive intervention programs utilizing ICT for older adults experiencing cognitive impairment. The primary goal of this study is to present clinical evidence for each program, particularly among ICT-based cognitive intervention programs available in South Korea.

**METHODS****Search strategy**

We searched for and reviewed the contents and results of ICT-based cognitive intervention studies involving older Korean individuals with cognitive impairment. The review was conducted following the PRISMA checklist for reporting items for systematic reviews. The research question in this study was “Is ICT-based cognitive intervention effective for cognitive function of Korean older adults with cognitive impairment?” Selection criteria were set accordingly to the PICOS framework. The participants (P) in this study were Korean older adults with MCI or early stage of dementia, the intervention (I) was cognitive intervention using ICT, the comparator (C) was a control group, the outcome (O) was cognitive function, and the study type (S) was randomized controlled trials.

Because the research question focused on the cognitive effects of ICT-based interventions, only studies using cognitive function tests as a primary outcome were eligible. We considered studies published before November 2023. Studies published in either English or Korean were accepted. We did not exclude trials based on sample size, outcome variables, or duration of the interventions. Exclusion criteria were as follows: study participants only with normal cognition; enrollment of participants without any cognitive tests; interventions using robots or virtual reality programs; outcomes without any cognitive function test; and studies involving non-randomized trials, single-arm designs, or observational methods.

### Data collection

We searched for papers published in several databases. MEDLINE (PubMed), Embase, Google Scholar, and the Cochrane Library, which correspond to the core databases, were searched. The Korean databases KISS and KMBase were also included. After reviewing abstracts obtained using MeSH keywords in MEDLINE, alternative words were added to create a concept map of the search terms and improve the sensitivity of search terms. A search query for each database was constructed using a combination of [mild cognitive impairment, dementia, non-demented, cognitive impairment, cognitive decline] AND [information and communication technologies, digital, computerized, ICT, tablet, smartphone] AND [intervention, therapy, rehabilitation, training] AND [cognitive benefit, efficacy, effectiveness, cognitive outcome] search terms, and a region filter was added to include search terms in the title and abstract to improve the search specificity. In the process of reviewing the full texts, if there were any related documents that were not included in the search results, the references were manually searched and confirmed. The selection process was independently conducted by 3 reviewers who had experience with systematic literature reviews. The quality of the studies was evaluated independently by 3 researchers, and in cases of disagreement, mutual agreement was reached through a research meeting.

### Narrative synthesis

The selected studies are summarized in a general table and discussed in a narrative synthesis that summarized their characteristics (Table 1).

## RESULTS

### Search results

A total of 35 studies were identified using different databases: PubMed (n=6), Embase (n=0), Google Scholar (n=4), KISS and KMBase (n=19), and other sources (2 by citation search and 4 by manual search). We excluded 4 duplicated studies and screened the titles and abstracts of the remaining 31 non-duplicated studies. We excluded 22 studies that did not meet our designed inclusion criteria: primary outcomes other than cognitive tests (n=2), interventions involving robot or virtual reality-based programs (n=6), varied study designs, including non-randomized controlled trial (RCT) (n=5), and participants unrelated to neurodegenerative disease (n=9). Following the full-text review, 9 studies for 8 programs were included and selected in this systematic review for quality evaluation (Fig. 1).

### Study characteristics

*Ubiquitous Spaced Retrieval-based Memory Advancement and Rehabilitation Training (USMART)*

The USMART program, initially designed for MCI, involved transforming a face-to-face, spaced

Table 1. Characteristics, Study Design, and Outcome Measurements of RCT Studies about ICT-based cognitive training program

Study	Program	Setting	Device	No. of population	Mean age (yr)	Education (yr)	Cognitive levels	Experimental group	Control group	Training Dose per Session (min) × Frequency (weeks) × Duration (weeks)	Compliance	Primary outcome measurements	Secondary outcome measurements	Results
1	USMART	Community and hospital	Tablet	43 (23, 20)	74.0 (73.7, 74.5)	13.2 (13.5, 12.7)	MCI	USMART	Usual care	30×2×2	Dropout rate: 16.0%	CERAD-K-N (WLMT, WLRT, WLRT scores), K-MMSE, FAB, DST	SMCQ, GDS	The USMART group had larger improvements in WLRT score than the control group.
2	CoTras-G	Long-term care hospital	Tablet PC	32 (16, 16)	77.6		MCI and mild dementia	CoTras-G	Usual care	40×1×8	Dropout rate: 11.1%	K-MMSE, SGDS, ELS, BI		CoTras-G could improve cognitive function, depression, life satisfaction and activity of daily living.
3	Braindoctor	Hospital	Computer	20 (10, 10)	(69.4, 68.0)	(7.4, 12.6)	MCI and mild dementia	Braindoctor	Usual care	60×2×10	Dropout rate: 0%	SNSB		The Braindoctor program had beneficial effect on general cognitive function.
4	SUPERBRAIN	Community and hospital	Tablet	152 (51, 51, 50)	(71.6, 70.9, 70.1)	9.8 (10.1, 10.3)	Non-demented	FMI intervention and HMI program	Usual care	50×2×24	Adherence rate: FMI group 94.5%, HMI group 96.8%	RBANS	MMSE, CDR, Prospective Memory Test, PRMQ, SGDS, Bayer ADL, QoL-AD, Pittsburgh Sleep Quality Index, SPPB, TUG test, NQ-E, BP, body fat mass, SDI, plasma cortisol, serum BDNF	Both FMI and HBI groups showed better RBANS total scale index score than the control group.
	SUPERBRAIN	Hospital	Tablet	49 (16, 16, 17)	(74.8, 76.1, 75.8)	9.7 (11.0, 8.7)	Amyloid positive MCI and mild AD with dementia supplements), group B (only nutritional supplements)	Group A (multidomain intervention with nutritional supplements), group B (only nutritional supplements)	Usual care	50×2×8	Adherence rate: Group A 96.1–100.0%, Group B 83.7%	RBANS	MMSE, CDR, K-IADL, SGDS, ZBI, SPPB, grip power, 30-s sit-to-stand test, body composition, NO-E, plasma cortisol, serum BDNF, gut microbiome	SUPERBRAIN - based multidomain intervention with nutritional supplements improves cognition and gut microbiota.

(continued to the next page)

**Table 1.** (Continued) Characteristics, Study Design, and Outcome Measurements of RCT Studies about ICT-based cognitive training program

Study	Program	Setting	Device	No. of population	Mean age (yr)	Education (yr)	Cognitive levels	Experimental group	Control group	Training Dose per Session (min) × Frequency (weeks) × Duration (weeks)	Compliance	Primary outcome measurements	Secondary outcome measurements	Results
5	CoCoTA	Long-term care hospital	Computer	53 (26, 27)	60.4 (65.4, 55.6)		MCI	CoCoTA	Usual care	20-40 × 3-10	Dropout rate: Intervention group 21.2%, Control group 22.9%	MMSE-KC, SGDS, Self-Esteem Inventory, K-IADL		The CoCoTA program could improve cognitive function and self-esteem and lower depression.
6	Bettercog	Hospital	Computer	20 (10, 10)	74.3 (74.5, 74.0)	6.3 (7.7, 4.9)	MCI and mild dementia	Bettercog	ComCog	30×4×3	Dropout rate: Intervention group 10.0%, Control group 20.0%	SNSB-II, K-MMSE, CDR, K-BMI		No statistically significant difference in the K-MMSE, CDR, SNSB-II, K-MBI scores between the two treatment groups.
7	Inbrain	Community	Mobile phone	299 (136, 163)	(70.8, 70.5)	(14.2, 14.2)	Non-demented	Inbrain	Educational program	30×5×52	Dropout rate: Intervention group 30.3%, Control group 15.1%	Inbrain Cognitive Screening Test (Total score and composite score for each cognitive domain)	MMQ, PRMQ, SGDS, GAI, PSS, WHOQOL, and self-reported amount of physical, cognitive, and social activities	The Inbrain may improve global cognition in non-demented older individuals.
8	Happytable	Community	Multitouch screen over a rectangular table	32 (16, 16)	74.5 (73.9, 75.0)	9.9 (10.8, 9.1)	Non-demented	Happytable	Traditional paper-and-pencil-based intervention	40×3×4	Dropout rate: 0%	DST, VLT, RCFT, CWST, COWAT, Go/No-go, TMT, K-MMSE		The Happytable group showed better improvement in memory function than the control group.

MCI: Mild cognitive impairment, CERAD-K-N: Korean version of the Consortium to Establish a Registry for Alzheimer's Disease Neuropsychological Assessment Battery, WLMT: Word List Memory Test, WLRT: Word List Recall Test, WLRT: Word List Recognition Test, K-MMSE: Korean version of Mini Mental Status Examination, FAB: Frontal Assessment Battery, DST: Digit Span Test, SMCQ: Subjective Memory Complaint Questionnaire, GDS: Geriatric Depression Scale, WAIS: Wechsler Adult Intelligence Scale, RAVLT: Rey Auditory Verbal Learning Test, RCFT: Rey Osterrieth Complex Figure Test, TMT-B: Trail Making Test-Part B, CWST: Color-Word Stroop Test, SF-36: Short-Form Health Survey, SGDS: Short Form of Geriatric Depression Scale, ELS: Elderly Life Satisfaction, BI: Barthel Index, fNIRS: functional near infrared spectroscopy, MoCA-K: Korean version of Montreal Cognitive Assessment, K-IADL: the Korean instrumental activities of daily living, SNSB: Seoul Neuropsychological Screening Battery, FMI: facility-based multidomain intervention, HMI: home-based multidomain intervention, RBANS: Repeatable Battery for the Assessment of Neuropsychological Status, CDR: Clinical Dementia Rating, PRMQ: Prospective and Retrospective Memory Questionnaire, ADL: activities of daily living, QoL-AD: Quality of Life in Alzheimer's Disease, SPPB: Short Physical Performance Battery, TUG test: Timed Up and Go test, NQ-E: Nutrition Questionnaire-Elderly, BP: Blood Pressure, SDI: Social Disconnection Index, ZBI: Zarit Burden Interview, MMSE-KC: MMSE in the Korean version of CERAD-K (The consortium to establish a registry for Alzheimer's disease assessment packet), K-MBI: Korean version of the modified Barthel Index, Inbrain-CST: Inbrain Cognitive Screening Test, MMQ: Multifactorial Memory Questionnaire, GAI: Geriatric Anxiety Inventory, PSS: Perceived Stress Scale, WHOQOL: World Health Organization Quality of Life assessment questionnaire, VLT: verbal learning test.

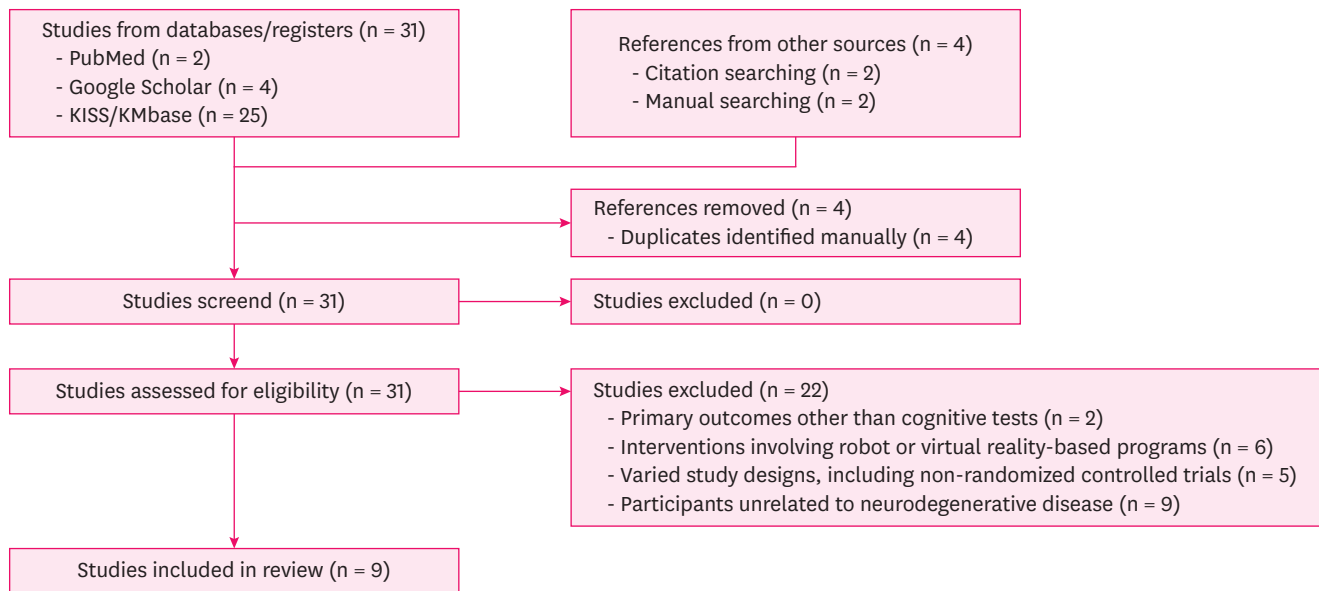


Fig. 1. Flowchart of study selection.

retrieval-based memory training program into a self-administered application on an iPad tablet. The program entailed 30-minute sessions, twice a week, spanning a 4-week intervention period.<sup>14</sup> Successful recall of a specified set of words within 12 minutes in 2 consecutive sessions prompted an automatic sequential increase in the number of words to be memorized in the subsequent session, ranging from 1 to 5 words. All USMART procedures were guided by automatic verbal messages from the application. An open-label, single-blind, randomized, controlled, crossover study involving MCI patients revealed that 4-week use of USMART led to more significant improvements in word list recall test scores (effect size=0.49,  $p=0.031$ ) compared with a usual-care group. No adverse events related to USMART were reported.<sup>15</sup>

#### The CoTras-G

The CoTras-G program (Netblue Co., Ltd., Daegu, Korea) is a cognitive-rehabilitation training program designed specifically to treat patients with MCI and mild dementia in group settings, targeting specific training areas.<sup>16</sup> This program offers both cooperative and competitive modes for training and can be implemented on the examiner's server computer and the examinee's tablet, allowing for one-to-many treatments. It can adjust the difficulty levels for each group, and storage of records in a database enables real-time statistical analysis by therapists. The training sessions can be conducted wirelessly in group settings, and the touchscreen interface is designed to be user-friendly for older adults. The content of CoTras-G encompasses 9 areas, including pattern matching, rapid button pressing, spatial memory, rotation, remembering and erasing, sequence memory, reacting to sounds, word creation, and calculation. Each area is divided into 3 difficulty levels, each featuring 20 questions. Users can customize difficulty levels and set time limits for answering questions, ranging from slow to very fast. Participants receive immediate feedback by touching the image or number they believe is the correct answer. After completing all questions in a specific area, the program provides the number of correct answers and accuracy, offering praise and encouragement before advancing to the next section.

An 8-week randomized clinical trial involving individuals demonstrated significant improvements in cognitive function, depression, life satisfaction, and activities of daily

living (ADL). These improvements were measured using the Korean Mini-Mental State Examination (K-MMSE), Short Form of Geriatric Depression Scale Korean Version (SGDS-K), Elderly Life Satisfaction, and Barthel Index, respectively.

#### *Braindoctor*

The Braindoctor program is a computerized cognitive-intervention tool that includes attention, visuospatial, memory, executive function, language function, calculation, and auditory domains that can be adjusted based on the participant's cognitive functions.<sup>17</sup> In a randomized controlled trial of 20 participants (14 with MCI, 6 with Alzheimer's disease [AD] dementia), the program was run 20 times over 10 weeks in the intervention group, with significant improvements in attention, calculation, memory, and frontal function reported in the intervention group compared with controls.

#### *SoUth Korean study to PrEvent cognitive impaiRment and protect BRAIN health through lifestyle intervention in at-risk elderly people (SUPERBRAIN)*

The SUPERBRAIN tool is a multidomain intervention program suitable for older Koreans using tablet. In a previous paper in 2021, the feasibility and efficacy of the program were investigated in 152 participants.<sup>18</sup> In the study, participants were randomly assigned to 3 groups: 51 to a facility-based multidomain intervention, 51 to a home-based multidomain intervention (ICT-based intervention using tablet), and 50 to a control group. Over 24 weeks, the intervention groups received 5 intervention components: monitoring and management of metabolic and vascular risk factors, cognitive training and social activity, physical exercise, nutritional guidance, and motivational enhancement. The cognitive-training sessions were performed twice a week and physical exercise sessions were performed 3 times a week. The ICT-based intervention group exhibited good adherence rates and cognitive effects using Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) scores.<sup>18</sup> In a recent paper in 2023, 49 participants with amyloid-positive MCI and mild AD dementia were enrolled and underwent ICT-based SUPERBRAIN training for 8 weeks; the intervention group (n=15) showed cognitive improvements using RBANS compared with a control group (n=16).<sup>19</sup>

#### *Computerized Cognitive Training Apparatus (CoCoTA)*

The CoCoTA is a computer-based program designed to train seven domains (memory, psychomotor speed, attention, language, calculation, visuospatial function, and executive ability).<sup>20</sup> This program can adjust difficulty levels according to the participants' cognition and allow assessment of cognitive function improvement based on accumulated training outcomes. In this study, the program was performed 3 times a week for 10 weeks, with sessions lasting 20–40 minutes each, to adults with MCI in long-term care facilities. The final analysis comprised 26 participants in the intervention group after excluding one discharged, one deceased, and five attending fewer than 20 out of 30 sessions. The control group comprised 27 participants, excluding one deceased, five lost to follow-up, and 2 discharged. The intervention group showed significant improvements in MMSE ( $p=0.002$ ), SGDS ( $p=0.036$ ), and Self-Esteem Inventory ( $p=0.008$ ) scores compared to the control group. These findings suggest a positive impact of the program on cognitive function, depression, and self-esteem.

#### *Bettercog*

The Bettercog program (M3 Solution, Daegu, Korea), which trains multiple cognitive domains such as memory, attention, orientation, calculation, executive function, language, comprehension, and visuospatial function, consists of easy, intermediate, and difficult levels

for each domain. The program utilizes words, photos, images, pictures, animations, and game elements.<sup>21</sup> To evaluate the therapeutic efficacy of Bettercog, a randomized, single-blind comparison pilot study of 20 older patients with cognitive decline was conducted by comparing it with ComCog,<sup>22,23</sup> which was the first clinically licensed device in South Korea. The control group used the ComCog program and the experimental group using Bettercog. Members of each group underwent 12 sessions of computerized cognitive rehabilitation training for 3 weeks.

At the initial and final assessments, no notable statistical differences were observed in the K-MMSE, Clinical Dementia Rating (CDR), Seoul Neuropsychological Screening Battery second edition (SNSB-II) scores, and the Korean version of the Modified Barthel Index (K-MBI) scores between the ComCog and Bettercog groups. Both groups showed improvements in K-MMSE, CDR, and SNSB-II scores after treatment, but only the Bettercog program achieved statistically significant improvements in K-MMSE scores ( $p=0.005$ ) and the memory domain of the SNSB-II ( $p=0.026$ ) compared with pre-treatment. The K-MBI scores improved significantly after treatment in both groups. These findings suggest Bettercog is more effective in cognitive training compared with ComCog, with significant post-treatment improvements observed in certain domains solely for Bettercog.

#### *Inbrain-Trainer*

Inbrain-Trainer is a cognitive-training smartphone application that uses 10 training tasks over 6 cognitive domains.<sup>24</sup> A randomized, single-masked, and parallel group study recruited 387 community-dwelling non-demented older adults and followed 136 individuals in an intervention group and 163 in a control group after 12 months. Members of the intervention group underwent a 30-min program at home with regular feedback from the administrator, 5 times per week for 12 months. The participants received education on lifestyle management and were provided with lifestyle monitoring via smartphones and feedback. The primary outcome was the change in the scores of Inbrain Cognitive Screening Test.

The intervention group demonstrated superior performance compared with the control group in the total score ( $p=0.001$ ), as well as the sub-scores for language ( $p<0.001$ ) and memory ( $p<0.001$ ) domains. These results imply that cognitive training using a mobile application can enhance global cognitive function among older adults without dementia living in communities.

#### *HAPPYTABLE*

HAPPYTABLE (Spring Soft Co. Ltd., Seoul, Korea) is an interactive multitouch game-based cognitive-intervention program that uses a multitouch screen on a rectangular table, and 4 participants can play together.<sup>25</sup> This program consists of 12 games covering major cognitive domains, including attention, visuospatial skills, memory, language, and executive function. In a single-blind, randomized study, community-dwelling older adults were divided into an intervention group and a control group. All participants engaged in 10 intervention sessions for 40 min per day, 3 times a week for 4 weeks. The intervention group played 12 games, while the control group engaged in traditional paper-and-pencil-based cognitive intervention. Analysis of covariance revealed that the intervention group achieved significantly superior results on memory function in the verbal learning test (VLT), delayed task ( $p=0.015$ ), and VLT recognition task ( $p=0.035$ ) compared with the control group. This multitouch game-based cognitive intervention may improve cognitive performance among older adults living in the community compared with traditional cognitive intervention using paper-and-pencil tasks.

### Study characteristics

#### *Interventions*

The cognitive trainings involved multiple cognitive tasks stimulating multidomain cognitive function in all studies (**Table 1**). Training doses ranged from 30 to 60 minutes per session and 1–5 sessions per week. Study durations and detailed programs of the cognitive interventions varied widely. The majority of the studies (n=7) focused on cognitive interventions, while 2 studies<sup>18,19</sup> included multi-domain interventions (cognitive training, lifestyle modification, and physical exercise).

#### *Study technologies and design*

The selected studies used the following technologies: traditional keyboard computers (n=3), tablets (n=4), smartphones (n=1), and touchscreen computers (n=1). All but 4 studies compared intervention and control (usual care) groups; the other 2 studies adopted an active comparer (other cognitive-training methods).

#### *Study population*

The mean age of the participants was 60–70 years old (range, 60.4–77.6). Most studies (7 of 9, 77.8%) enrolled relatively small samples (<50). Most studies (7 out of 9) included a mixed population (MCI and early-stage of dementia or MCI and normal cognition), while two out of 9 studies included only MCI participants.

#### *Outcomes*

Although all studies used cognitive function tests as a primary outcome, the specific tests varied. MMSE was the most commonly used cognitive outcome (7 out of 9). Most studies (7 out of 9) used multiple cognitive function tests as outcome variables to assess memory, executive, visuospatial, attention, and language functions as well as global cognition.

#### *Cognitive effects of the interventions*

All nine studies demonstrated a significant improvement in cognition was reported after ICT-based intervention. Global cognition improvement was observed in 5 studies (55.6%).<sup>16,18–20,24</sup> Regarding each cognitive function domain, improvements in the memory domain were also reported in 4 studies (44.4%).<sup>14,17,24,25</sup> Improvements in visuospatial domain was also documented in 2 studies (22.2%).<sup>18,19</sup>

## DISCUSSION

We conducted a systematic review of RCT studies to assess the impact of ICT-based cognitive-intervention programs on older adults with cognitive decline. We selected 9 RCT studies published in academic journals until November 2023, and compiled the effects of cognitive-based interventions. In our systematic review, we examined 9 studies of 8 cognitive interventions utilizing ICT devices including computers, tablets, mobile phones, and gaming devices in older adults with cognitive decline. The findings revealed that ICT-based interventions had positive effects on cognitive improvements in these individuals.

Our first major finding was the clinical efficacy of ICT-based interventions in patients with cognitive impairment. Among the 9 studies, 8 (88.9%) showed cognitive improvement in the ICT-based interventions compared with a control group receiving usual care or traditional paper-and-pencil-based cognitive interventions. One study compared a new ICT-based

program against an ICT-based program that had already been proven effective in the control group, showing no difference in efficacy, ultimately indicating the positive effects of the ICT-based program.<sup>21</sup> Five of the 9 studies reported improvements in global cognition and the memory domain. These findings align with previous meta-analyses highlighting the efficacy of computerized cognitive training in enhancing cognition among older adults.<sup>26,27</sup>

Neuroplasticity is regarded as a mechanism that enhances cognition through learning and cognitive training.<sup>28-30</sup> Computerized training could impact neuroplasticity, enhancing cognitive abilities in various patient groups.<sup>31,32</sup> Although the precise mechanism for cognitive enhancement in older adults with cognitive decline remain elusive, the potential for improvement through neuroplasticity is considerable. Further investigations, such as using functional magnetic resonance imaging, may clarify this mechanism. ICT-based program may therefore promote cognitive improvement by inducing neuroplasticity in older adults.

Within our review, 4 studies involving MCI and early-stage dementia patients found evidence of improvements in global cognition, attention, memory, or visuospatial function. However, subgroup analyses in 2 studies focusing exclusively on dementia patients showed no significant changes pre- and post-treatment.<sup>17,19</sup> ICT-based interventions are known to enhance cognition at the MCI level.<sup>33-35</sup> However, meta-analyses of computerized cognitive training revealed a lack of substantial evidence supporting its efficacy in individuals with dementia,<sup>33,36</sup> which is consistent with our findings. In cases in which neurodegeneration has advanced to the dementia stage, the effectiveness of ICT-based interventions could be constrained. Conversely, some studies have reported positive effects of ICT-based interventions in patients with mild dementia,<sup>22</sup> and the overall efficacy of treatments for patients with dementia is controversial. The two studies within our review that conducted subgroup analyses targeting dementia patients<sup>17,19</sup> had small sample sizes, potentially contributing to the lack of significant findings. The scarcity of studies targeting dementia patients may contribute to the observed absence of significant effects, necessitating further investigation.

The second major finding of our review was the generally good compliance observed in ICT-based intervention studies, with dropout rates ranging from 0% to 30.3%. In a single study,<sup>24</sup> the dropout rate in the experimental group undergoing ICT training was 30.3%, higher than in other studies (which ranged from 0% to the early 20% range). This particular study had an intervention period of 52 weeks, the longest among the included research. Excluding this study, the intervention group tended to have a higher adherence rate compared with the control group. In 2 studies, both the intervention and control groups had a dropout rate of 0%, with 1 study being community-based<sup>25</sup> and 1 being hospital-based.<sup>17</sup> In a hospital setting, events such as patient discharge or mortality may reduce adherence rates compared with studies conducted in the community.<sup>20</sup>

Our final major finding was that ICT-based interventions also benefitted secondary outcomes, including depression, self-esteem, and functional abilities. In particular, improvement in depression was observed in 2 studies,<sup>16,20</sup> which is consistent with prior studies.<sup>37</sup> Previous meta-analyses also reported moderate effect sizes in psychosocial functioning (depression, quality of life, and neuropsychiatric symptoms).<sup>33,38</sup> By applying the appropriate level of difficulty and providing immediate feedback to participants, which should increase motivation and confidence, it may be possible to reduce depression and improve intervention outcomes.<sup>20</sup> Improvements in ADL was also observed in one study,<sup>16</sup>

which is supported by previous studies.<sup>22,39</sup> ICT-based interventions may therefore have positive effects not only on cognition but also on mood and functional ability in older adults experiencing cognitive decline.

ICT-based interventions offer several advantages. First, they include difficulty settings that can be adjusted for each participant. Most traditional cognitive-intervention programs have been conducted in group settings within facilities. However, ICT-based interventions enable the adjustment of difficulty levels to suit individual capabilities. Second, they can address environmental factors such as social isolation. Many older adults, particularly those vulnerable to infection (i.e., in situations like those of the COVID-19 pandemic), experience limited social interactions, leading to increased time at home alone, which can hasten cognitive decline. ICT-based interventions can offer effective and easily accessible cognitive training for such isolated individuals. Third, a supervisor can easily monitor and assess a participant's performance and compliance compared with traditional programs that use paper and pencil.

Despite its comprehensive analysis of South Korean RCT studies on ICT-based cognitive interventions, our study faced limitations. First, the use of different assessment tools across studies made it difficult to standardize and integrate the outcomes and assess the intervention effects and validity. Second, participants in each study exhibited varying levels of cognitive function. A future meta-analysis study with a larger sample size could allow for comparisons according to cognitive level. Third, some individuals received concurrent drug therapy, complicating the isolation of the effects of the interventions from drug treatment. Last, our evaluation of publication bias was hindered by our focus on literature related to ICT-based interventions used in South Korea. To achieve generalizability, more RCT studies with traditional cognitive-training programs as control groups need to be conducted in the future.

In conclusion, our systematic review of 9 studies found that ICT-based cognitive-intervention programs can have positive effects on cognitive improvement. Our findings can offer valuable guidance for healthcare providers in creating and applying personalized cognitive-intervention programs.

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