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Does cognition-specific computer training have better clinical outcomes than non-specific computer training? A single-blind, randomized controlled trial

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Abstract

Objective: The purpose of this study was to investigate differences between non-specific computer training (NCT) and cognition-specific computer training (CCT).

Design: Randomized controlled experimental study.

Setting: Local community welfare center.

Subjects: A total of 78 subjects with mild cognitive impairment (MCI) were randomly assigned to the NCT ($n = 39$) or CCT group ($n = 39$).

Intervention: The NCT group underwent NCT using Nintendo Wii for improving functional performance, while the CCT group underwent CCT using CoTras for improving function of the cognitive domain specifically. Subjects in both groups received 30-minute intervention three times a week for 10 weeks.

Main measures: To identify effects on cognitive function, the Wechsler Adult Intelligence Scale (WAIS) digit span subtests, Rey Auditory Verbal Learning Test (RAVLT), Trail Making Test–Part B (TMT-B), Rey–Osterrieth Complex Figure Test, and Modified Taylor Complex Figure (MTCF) were used. Health-related quality of life (HRQoL) was assessed using the Short-Form 36-item questionnaire.

Results: After 10 weeks, the WAIS subtests (digit span forward: 0.48 ± 0.08 vs. 0.12 ± 0.04; digit span backward: 0.46 ± 0.09 vs. 0.11 ± 0.04) and HRQoL (vitality: 9.05 ± 1.17 vs. 2.69 ± 1.67; role-emotional: 8.31 ± 1.20 vs. 4.15 ± 0.71; mental health: 11.62 ± 1.63 vs. 6.95 ± 1.75; bodily pain: 4.21 ± 2.17 vs. 0.10 ± 0.38) were significantly higher in the NCT group ($P < 0.05$).

Conclusion: NCT was superior to CCT for improving cognitive function and HRQoL of elderly adults with MCI.

Keywords

Non-specific computer training, cognition-specific computer training, cognitive function, quality of life, mild cognitive impairment

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Introduction

Since the early 1980s, with the development of computers, cognition-specific computer training (CCT) after mild cognitive impairment (MCI) has been conducted.[1–5] CCT allows patients to use a computer as a treatment tool and provides simultaneous feedback to individual responses through an input device such as a touch screen or joystick.[6]

In previous studies, CCT has been proven to be effective in preventing cognitive decline and in improving cognitive function of elderly adults with MCI.[7–12] However, most of these previous studies either did not include a treatment control group[7,8] or utilized a wait-list control group.[9–12] In addition, there is no evidence that the effects of CCT transfer to untrained tasks.[13–15]

Therefore, non-specific computer training (NCT) focused on functional aspects has been developed to prevent effects from being confined to a specific cognitive area.[16] NCT is an approach that uses an interactive simulation system created by computer hardware and software with three-dimensional environment that mimic reality and enable users to be engaged in activities regardless of their physical disabilities.[16,17]

It has been reported that the effects of NCT can be similar to those of CCT. In addition, when conducting NCT, elderly adults use physical movement to perform functional tasks. As physical movement helps to improve the cognitive function of elderly adults, previous NCT studies found improvements in cognitive as well as physical function.[18–20]

However, there remains controversy concerning the different effects of non-specific and CCT. Accordingly, there is an urgent need to verify if there is any difference in effects of the two different forms of computer training.

The purpose of this study was to investigate differences between non-specific and CCT group after a 10-week intervention for elderly people with MCI. We hypothesized that the NCT group would improve more in cognitive function and quality of life as compared with the CCT group after a 10-week intervention for elderly adults with MCI.

Subjects and methods

This study was conducted from October to December 2015, and recruitment took place from October 5 to 16. This was a single-blind study, and subjects were allocated randomly to the non-specific or CCT group using a random number generated by computer software. The assignment was stored in number-sealed envelopes and opened by one occupational therapist who was not involved in subject recruitment. All assessors were blinded to group allocation. This study was conducted for 10 weeks, and subjects were assessed before and after the intervention. This study was registered at the Thai Clinical Trials Registry ID: TCTR20160916001 after approval by the local research ethics committee. All subjects provided informed consent before study inclusion according to the Declaration of Helsinki (2004).

Elderly people over 60 years old with amnestic MCI were recruited from a local community welfare center in Korea. They were screened by a blinded assessor. The inclusion criteria were derived from a previous CCT study[21] and were as follows: (1) subjective memory complaint, (2) objective memory impairment defined by score on the Placing Test $<$ 13,[22] (3) intact general cognitive function as determined by score on the Korean version of the Mini-Mental State Examination $\geq$ 24,[23] and (4) intact activities of daily living as determined by score on the Seoul instrumental activities of daily living score $\geq$ 8.[24] Exclusion criteria were as follows: (1) neurological, psychiatric, or medical disorders; (2) moderate or severe depressive symptom as determined by score on the Korean version of the Geriatric Depression Scale $>$ 19;[25] (3) presence of auditory, visual, motor, or language impairments that would hinder use of a computer; and (4) participation in cognitive training within three months.

Sample size estimation was conducted using G*Power 3.1 (Informer Technologies, Dusseldorf, Germany).[26] According to a previous study,[27] the effect size (ES) was set at 0.90, the α error at a probability of 0.05, and the power at 0.95. A minimum of 34 subjects was required in each group.

All sessions were conducted by one occupational therapist with six years of clinical experience. All subjects performed a total of 30 sessions, three days a week for 10 weeks. The two interventions were similar in that they were computerized and performed on a computer screen with the subject seated. The difficulty levels of training were adjusted during the sessions depending on each subject's performance.

To conduct the NCT, the Nintendo Wii (Nintendo, Japan) was used. It introduced a new style of virtual reality using a wireless controller that interacts with the player through an avatar and a motion detection system. The controller uses embedded acceleration sensors responsive to changes in acceleration, direction, and speed that enable subjects to interact with the games. A 2-point infrared light sensor, mounted on top of a television, captures and reproduces on the screen the movement from the controller as performed by subjects. In this study, three sports games (table tennis, sword play, and archery) that affect cognitive function from Wii Sports Resorts were used in accordance with a previous study.[27] In each session, the subjects played each game for 10 minutes. Detailed descriptions are presented at http://wiisportsresort.com/

The CoTras program (Netblue, Korea) made for Korean was used for the CCT. CoTras consists of various training programs including attention, memory, and visual spatial abilities. This program was designed for patients with cognitive impairment in order to improve cognitive function. The CoTras panel with large buttons makes the training easy for subjects who are unfamiliar with computers.[28] In this study, attention (sustained and selective attention), memory (working memory), and visual spatial ability (visual discrimination and visual constancy) were trained for 10 minutes with each of the three trainings. None of the subjects showed adverse effects in using the computer during the sessions.

The assessments were performed before and after the intervention. Two occupational therapists with more than three years of experience conducted all the assessments in a fixed order. Neuropsychological assessments were performed to assess attention, memory, executive function, and visual spatial abilities.

Attention was measured using the Wechsler Adult Intelligence Scale (WAIS) digit span subtest according to a previous study.[29] It consists of two separate tasks (digit span forward and digit span backward), which require subjects to listen to a string of digits and repeat back the numbers in the same or reverse order.[30]

The Rey Auditory Verbal Learning Test (RAVLT) and Rey–Osterrieth Complex Figure Test were used to measure memory. The RAVLT is word list memory test in which the test assessor read aloud a list of 15 nouns for five consecutive trials and each trial is followed by a free recall test.[31] It has several different word lists. In order to reduce practice effects, a different list of nouns was used at each assessment.

The Rey–Osterrieth Complex Figure Test involves the subject copying a complex figure and then drawing it from memory.[31] Visual spatial ability was measured using the Wechsler Adult Intelligence Scale-Revised Block Design Test. It requires that colored blocks be arranged so as to duplicate a maximum of 10 target patterns presented in order of ascending difficulty. The subjects were required to arrange a set of nine blocks to duplicate a presented pattern, within 120 seconds. Scores can range from 0 to 48, with higher scores reflecting better visual spatial ability.[32]

Executive function was measured using the Trail Making Test–Part B (TMT-B) and the Stroop Color-Word Test. The TMT-B consists of 25 circles distributed over a sheet of paper. The circles include both numbers (1–13) and letters (A-L). The subjects were asked to connect the circles in ascending order with the added task of alternating between numbers and letters as quickly as possible.[33] The Stroop Color-Word Test consists of three subtasks. The first subtask shows color words (blue, green, red, and yellow) in random order printed in black ink. The second subtask shows solid color patches in each of these four colors. The third subtask includes color words printed in an incongruous ink color (e.g. the word blue printed in green ink). The subjects were asked to read the words, name the color, and finally, name the ink color of the words as quickly and accurately as possible.[34]

To measure health-related quality of life, the Short-Form Health Survey (SF-36) was used. It consists of 36 items and 8 subscales: (1) physical functioning, (2) role-physical, (3) bodily pain, (4) general health, (5) vitality, (6) social functioning, (7) role-emotional, and (8) mental health.[35] The score of each subscale ranges from 0 to 100, and higher scores indicate better health.

All data analyses were conducted using SPSS version 22.0 (SPSS Inc., Chicago, USA). Means and standard deviations for subject characteristics of the two groups were calculated. To compare subject characteristics between the two groups, independent-sample *t*-tests and chi-square tests were used. The Shapiro–Wilk test was used to determine the normal distribution of all outcome measurements.

In the main analysis, we examined the gap at baseline. After 10-week intervention, we checked the difference between groups. A 2×2 mixed model repeated-measures analysis of covariance with time (pre- and post-intervention) as the within-group variable and training (cognition-specific and non-specific) as the between-subject variable. The ES of each intervention group was calculated using partial η^2. Partial $\eta^2 \geq 0.14$ was considered a large effect, between ≥ 0.06 and < 0.14 was considered a moderate effect, and between ≥ 0.01 and < 0.06 was considered a small effect.[36] Statistical significance was accepted at $P < 0.05$.

Results

A total of 89 elderly people with cognitive impairment were selected from 186 elderly people in a local community welfare center.[37] Among them, 78 were selected finally according to the inclusion and exclusion criteria (Figure 1). The subjects were randomly allocated to groups of 39.

There were no significant differences between groups in terms of gender, age, years of education, or score on the Korea version of Mini-Mental State Examination at baseline (Table 1). When comparing the differences in outcome measures before and after the intervention within each group, cognitive function (attention, memory, and visual spatial ability) showed a significant increase in both groups ($P < 0.05$), as did the mental components of health-related quality of life ($P < 0.05$), except for social functioning ($P > 0.05$). In the physical components of health-related quality of life, bodily pain improved significantly increased in the NCT group (see Tables 2 and 3).

There were significant differences in outcome measures, with greater improvement in the NCT group for attention ($P < 0.05$; $\eta^2 = 0.835$–0.876), vitality ($P < 0.05$; $\eta^2 = 0.833$), role-emotional ($P < 0.05$; $\eta^2 = 0.821$), mental health ($P < 0.05$; $\eta^2 = 0.662$), and bodily pain ($P < 0.05$; $\eta^2 = 0.641$; Tables 2 and 3). The NCT group achieved clinical improvement in cognitive function and health-related quality of life compared with the CCT group. There was no significant difference between groups in the incidence of adverse effects or in the number of subjects who stopped performing computer training.

Discussion

After a 10-week intervention, significant differences in attention and self-efficacy were observed between the NCT group and the CCT group. These results supported the hypothesis that NCT has positive effects on improving cognitive function and health-related quality of life, which is consistent with the results of previous studies.[27]

Cognitive function can be improved by enhancing the ability to learn new tasks.[16] In this study, the NCT group continued adapting to new tasks, which has positive effects on attention. Several studies have indicated that video games might improve attention compared with training that is specific to cognitive function.[27,38] NCT can facilitate the training in a fun manner through an avatar and virtual reality environment. Thus, NCT might motivate subjects to participate more efficiently as compared to CCT. Furthermore, it has been reported that higher motivation is associated with better intervention outcomes, which may decrease issues with intervention compliance.[39] Those who received NCT had no experience playing Wii before this study and showed interest in it.

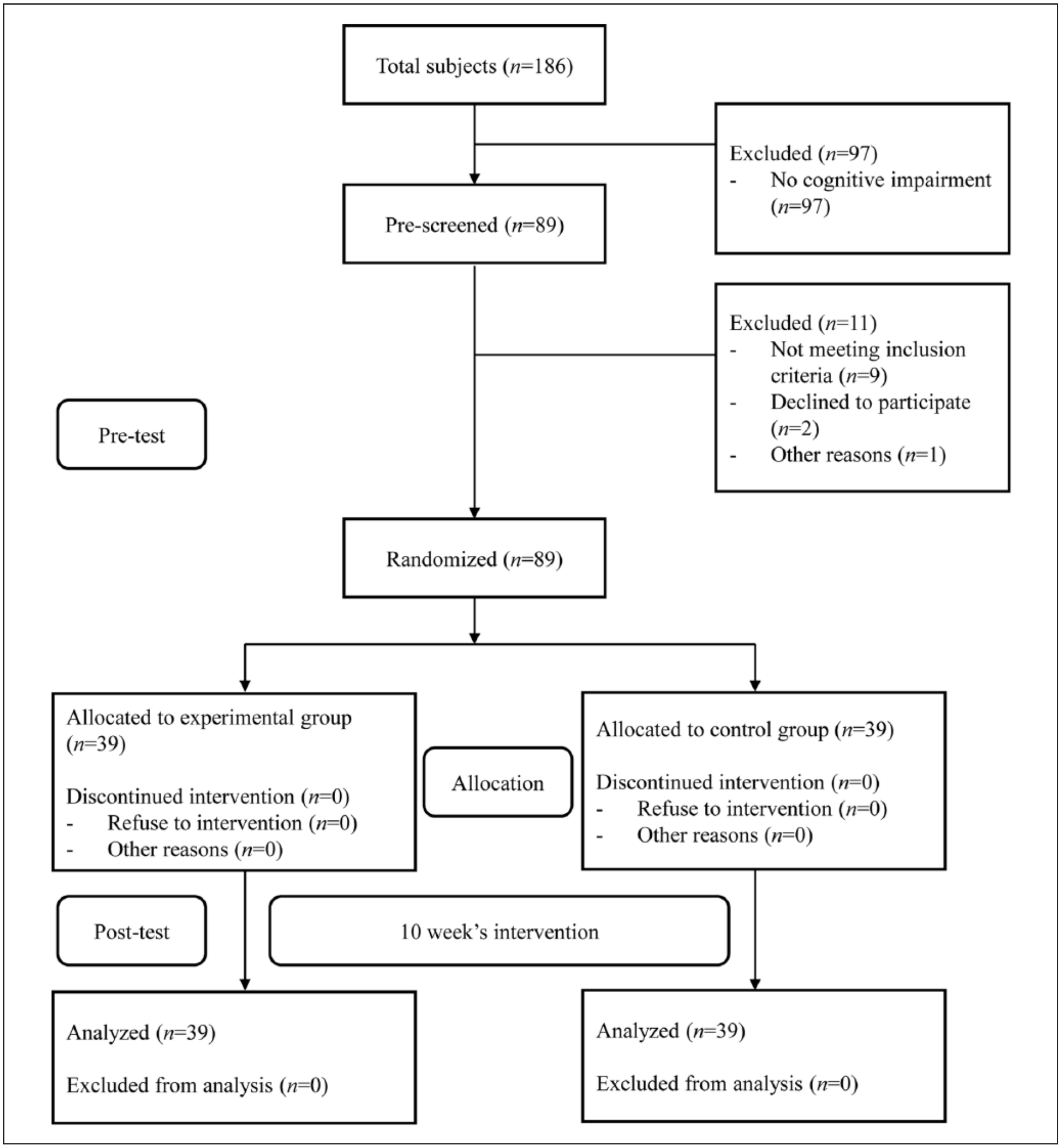

Figure 1. Flow diagram of subjects in the study.

In addition, the NCT group received game-based cognitive training with additional physical exercise. Several studies have suggested that physical exercise has positive effects on cognitive function among elderly people with dementia as well as healthy elderly people.[18–20] A number of studies on aging, cognition, and physical exercise have suggested that adequate physical exercise results in increased ability of the heart to deliver oxygen to working muscles.[18] These improvements are related

Table 1. General characteristics of subjects.

	NCT group ($n=39$)	CCT group ($n=39$)	χ^2/t	P
Gender				
Male	20	22	0.206	0.821
Female	19	17		
Age (years)	66.95 ± 4.10	67.64 ± 4.55	−0.706	0.483
Years of education	8.54 ± 4.25	8.74 ± 4.51	−0.207	0.837
MMSE-K (score)	26.41 ± 1.94	26.67 ± 1.68	−0.624	0.534

MMSE-K: Korean version of mini-mental state examination; CCT: cognition-specific computer training; NCT: non-specific computer training.
Values are expressed as mean ± SD.

to changes in physiological mechanism such as cerebral blood flow and brain-induced neurotrophic factors that have been shown to be associated with cognitive function.[40,41] Therefore, physical exercises have had an additional positive effect on cognitive function in the NCT group.

The finding of this study indicated that NCT was superior to CCT in some respects. Green and Bavelier[16] reported cognition-specific training is task-specific, and its effects are scarcely transferred to other tasks. In previous studies, elderly adults who received cognitive training that was focused on specific cognitive function (planning, problem solving, and reasoning) showed significant improvements in the specifically trained tasks but not in other cognitive functions.[22,42] In this study, there was no improvement of executive function, which was not trained in either group, which is consistent with previous studies.[22,42] In conclusion, this study suggested that CCT may be more appropriate for cognitive training in patients with a specific cognitive impairment, while NCT is more appropriate for elderly adults with multiple cognitive impairments such as MCI.

Regarding health-related quality of life, the NCT group showed more improvement in vitality, role-emotional, and mental health compared with the CCT group. The NCT group was trained with a three-dimensional avatar of the subject and soft music and received auditory and visual feedback. The characteristics of NCT might have positive effects on subjects' mental health. Sudenski et al.[43] indicated that elderly people who were trained with virtual reality game showed gains in mental health compared with elderly people who were not. In another study, it was reported that NCT promotes mental health among elderly adults with depression.[44] However, in this study, there was no significant difference in social functioning between the groups, as both training groups only received training individually, without opportunity for social interaction. Thus, it is necessary to develop a NCT system to supplement social health.

In terms of physical components, there were no significant differences between groups except for bodily pain. This is likely because most subjects were already healthy before participating in the intervention. Hence, a ceiling effect may have been at play, as most questions were related to basic activities of daily living. Furthermore, the training contents could have limited an improvement in physical components. Sartor-Glittenberg et al.[45] showed that lower extremity function is the primary factor influencing physical components. However, in this study, neither NCT nor CCT focused on lower extremity function.

Meanwhile, the NCT group showed more improvement in bodily pain than did the cognition-specific group. A previous study suggested that NCT could accelerate relaxation and reduce pain via auditory and visual feedback for patients with arthritis,[46] which is consistent with the results of this study.

Compared with CCT, NCT has some advantages in terms of motivation through virtual reality environmental stimulation. As a result, NCT appears to be superior to CCT in improving cognitive function and health-related quality of life

Table 2. Changes in cognitive function.

Variables	NCT group ($n = 39$)			CCT group ($n = 39$)			Between-group difference (95% CI)	η^2
	Pre	Post	Change value	Pre	Post	Change value		
Attention								
Digit span forward	7.21 ± 0.16	7.61 ± 0.19*	0.40 ± 0.08	7.16 ± 0.17	7.29 ± 0.18*	0.12 ± 0.04	0.28 (0.25 to 0.31)*	0.835
Digit span backward	3.32 ± 0.19	3.78 ± 0.23*	0.46 ± 0.09	3.29 ± 0.22	3.39 ± 0.23*	0.11 ± 0.04	0.36 (0.33 to 0.39)*	0.876
Memory								
RAVLT	97.15 ± 7.14	106.46 ± 8.20*	9.31 ± 2.54	97.77 ± 11.29	107.03 ± 8.34*	9.26 ± 4.38	−0.07 (−1.48 to 1.35)	0.000
RCFT	95.08 ± 5.05	101.00 ± 5.63*	5.92 ± 1.86	96.08 ± 5.62	101.92 ± 4.74*	5.84 ± 3.34	−0.08 (−1.25 to 1.10)	0.000
Visual spatial ability								
WAIS-BDT	24.87 ± 2.59	27.03 ± 2.60*	2.15 ± 0.99	24.95 ± 2.41	26.92 ± 2.76*	1.97 ± 0.99	0.18 (−0.27 to 0.63)	0.008
Executive function								
TMT-B	129.67 ± 7.08	129.38 ± 7.02	1.31 ± 0.98	128.36 ± 8.88	128.21 ± 8.71	1.38 ± 1.21	−0.05 (−0.55 to 0.45)	0.001
SCWT	26.90 ± 2.56	26.77 ± 3.15	1.15 ± 0.84	27.00 ± 2.31	26.97 ± 2.49	0.90 ± 0.72	0.18 (−0.10 to 0.61)	0.002

CCT: cognition-specific computer training; NCT: non-specific computer training; CI: confidence interval; RAVLT: Rey Auditory Verbal Learning Test; RCFT: Rey–Osterrieth Complex Figure Test; WAIS-BDT: Wechsler Adult Intelligence Scale-Block Design Test; TMT-B: Trail Making Test–Part B; SCWT: Stroop Color-Word Test.
Values are expressed as mean ± SD.
*Significant group × time interaction ($P < 0.05$).

Table 3. Changes in health-related quality of life.

Variables	NCT group (n = 39)			CCT group (n = 39)			Between-group difference (95% CI)	η^2
	Pre	Post	Change values	Pre	Post	Change values		
Mental component								
Vitality	63.56 ± 4.72	72.62 ± 4.78*	9.05 ± 1.17	56.64 ± 3.52	62.33 ± 3.66*	2.69 ± 1.67	6.50 (5.78 to 7.23)*	0.833
Social functioning	79.13 ± 5.23	79.18 ± 5.25	0.05 ± 0.22	75.62 ± 3.60	75.69 ± 3.59	0.08 ± 0.27	−0.03 (−0.15 to 0.09)	0.003
Role-emotional	67.49 ± 5.13	75.79 ± 5.15*	8.31 ± 1.20	65.64 ± 3.75	69.79 ± 3.83*	4.15 ± 0.71	4.18 (3.72 to 4.63)*	0.821
Mental health	76.95 ± 5.22	88.56 ± 5.97*	11.62 ± 1.63	75.74 ± 3.71	82.69 ± 3.73*	6.95 ± 1.75	4.63 (3.85 to 5.40)*	0.662
Physical component								
Physical functioning	75.41 ± 4.15	75.49 ± 4.15	0.08 ± 0.27	71.69 ± 3.50	71.74 ± 3.48	0.05 ± 0.22	0.04 (−0.08 to 0.17)	0.003
Role physical	72.36 ± 4.18	72.41 ± 4.16	0.05 ± 0.32	68.62 ± 3.48	68.67 ± 3.37	0.05 ± 0.22	0.03 (−0.11 to 0.17)	0.000
Bodily pain	68.41 ± 4.66	72.67 ± 5.05*	4.21 ± 2.17	64.64 ± 3.52	64.74 ± 3.65	0.10 ± 0.38	4.12 (3.34 to 4.90)*	0.641
General health	66.33 ± 5.03	66.83 ± 5.01	0.33 ± 0.74	62.21 ± 3.95	62.26 ± 3.92	0.15 ± 0.37	0.21 (−0.08 to 0.50)	0.000

CCT: cognition-specific computer training; NCT: non-specific computer training; CI: confidence interval.
Values are expressed as mean ± SD.
*Significant group × time interaction ($P < 0.05$).

among elderly adults with MCI. NCT is an entertaining alternative to CCT. Moreover, NCT can be performed easily at home, helping to improve or maintain cognitive functions and quality of life among elderly adults with MCI who cannot go the medical facility.[16,17]

This study, however, has several limitations. First, the long-term effects of the NCT and CCT were not confirmed. Second, the sample size in this study was relatively small. Therefore, in the future, studies with a larger sample size and a follow-up assessment are needed to clarify the robustness of the present findings.

Clinical Messages

- Non-specific computer training (NCT) produced more significant improvements in cognitive function and health-related quality of life than did cognition-specific computer training (CCT) in elderly adults with MCI.
- NCT appears to be an entertaining alternative to CCT.

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