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PERSPECTIVE

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Cognitive and physical benefits of a game-like dual-task exercise among the oldest nursing home residents in Japan

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Abstract

Introduction: Dual-task (DT) exercise can act as a substitute, which can help improve both physical and cognitive functions. Thus, this study investigated the effects of a game-like cognitive DT exercise called "Synapsology" (SYNAP) among the oldest residents of a nursing home.

Methods: Participants (aged 85–97 years) were assigned to the intervention group (n = 12) and the control group (n = 12). The intervention group underwent 60-minute sessions, twice a week for 24 weeks.

Results: A comparison of the Mini-Mental State Examination scores and six physical function tests, before and after the intervention, shows that the SYNAP had a positive impact on the cognitive and physical functions among the intervention group.

Discussion: These findings suggest that SYNAP may help maintain or improve cognitive and physical functions among older adults compared to no interventions. Therefore, SYNAP would act as a beneficial tool amidst a "superaging" society like Japan.

KEYWORDS
brain activity, cognitive function, game-like dual-task exercise, Japanese traditional games, physical function

1 | HEAD AND TAIL OF SUPER-AGING SOCIETY: JAPAN

According to the World Health Organization (WHO),[1] the population of Japan has the longest life span, averaging 84.3 years. Furthermore, Japan has already become a "superaging" society. This increased average life expectancy has been enabled by medical advancements. In addition, the national health insurance and long-term care insurance system facilitate this phenomenon in Japan.

In long-lived societies, as the birthrate declines and the population ages, the population pyramid changes into an inverted triangle. Individuals over 70 and 80 years account for 21.5% and 8.9% of the total population, respectively. According to the Japanese Ministry of Health, Labour, and Welfare,[2] the incidence of dementia increases exponentially after the age of 65, and it is predicted that by 2025, one in two people (55%) aged 85 years or older will suffer from dementia. Considering these situations, the Nursing Care Insurance Act system was implemented in 2000, to address various problems related to older adults that are faced by society. Approximately 50% of the financial resources are secured by collecting insurance premiums from workers aged 40 and older, while the other half is covered by the government. Older adults with dementia need long-term care (namely, Long-Term Care Insurance System), which imposes a substantial personal and societal burden.[3] Indeed, Japan has faced considerable financial burden and difficulties related to providing care for them. Thus, there will be an increase in the phenomenon of "aged care," in which older adults care for those older than them. Therefore, one of the major goals of the Japanese government is to extend a "healthy lifespan"—

that is, to maintain Japan's older adult population's health and well-being. Subsequently, public awareness regarding the importance of healthy lifestyles has increased. Moreover, the "Sports Promotion Lottery Law" was enacted in 1998 to promote healthy lifestyles. Consequently, numerous public sports facilities and sport activity societies for older adults have emerged throughout Japan. However, although there are such nationwide infrastructures in place for older adults, no intervention that can help maintain or enhance their cognitive and physical functions has been presented. Because no practical, scientifically validated program has been proposed to delay or prevent mild cognitive impairment (MCI) and Alzheimer's disease (AD), there is a strong demand for an effective intervention to help older adults in Japan.

RESEARCH IN CONTEXT

1. **Systematic review**: We searched PubMed using the terms "most elderly," "oldest," "dual task," "dual-task," "cognitive function," and "physical function" from January 1, 2000.
2. **Interpretation**: This study is the first to evaluate a game-like dual-task (DT) intervention for the most elderly residents of a nursing home. Findings: By performing a cognitive dual-task (DT), the cognitive function (MMSE) and the six items of physical function were improved in the experimental group receiving the intervention compared to no intervention. This indicates that this unique DT may help to improve cognitive and physical function abilities in the most elderly population.
3. **Future directions**: Future research on the underlying mechanisms would help evaluate the interactive influence of SNAYP and cognitive function in the human brain by fMRI/FDG-PET. In addition, a method of quantitatively measuring amyloid beta (Aβ) in serum samples by MALDI-TOFMS is needed to gather powerful evidence for understanding the cognitive function changes.

2 | REASONS TO SUBSTITUTE MEDICATION THERAPY WITH DUAL-TASK EXERCISES AMONG OLDER ADULTS

Because we, as human beings, hope to have normal cognitive and physical functions until our death, scientists involved in AD research are trying to achieve this through science and technology that is currently available. For example, although the breakthrough medical treatment antibody aducanumab reduces amyloid bet (Aβ) plaques[4] in the brain, the day when humankind overcomes AD is still far away. There are very few scientifically possible measures to meet such needs thus far. However, the difficult questions about how to continue to maintain cognitive function in an aging society and how to prevent the onset of AD must be answered.

Various diseases cause dementia; however, it is difficult for the oldest population to take special precautions other than antidementia medication therapy due to its high costs and ambiguous effects. Although antidementia medications can be helpful for patients with AD, these medications have various side effects, especially in older adults.[5–6] In Japan, apart from medication, there are no specific programs to help improve cognitive function in the oldest population; thus, there is a need for effective interventions. Furthermore, financial cost is a barrier for the older adult population to engage in physical activities.[7] Therefore, the ideal treatment must include low-cost physical activities,[8] and supplements,[9] in place of medication therapy. Of these, according to the WHO's recommendation, physical activity (e.g., aerobic, resistance training, and multicomponent physical activities) may be the best solution for this problem.[10] It is beneficial for both the physical and mental health of most of the older adults, especially those with cognitive impairments, such as MCI and AD.[11–17] However, many of the studies regarding this have not quantitatively assessed how physical activity reduces MCI and AD. Therefore, it is unclear what kind of physical activity is beneficial and how such activities must be conducted to achieve these beneficial effects. Recently, dual-task (DT) training/exercises have attracted extensive attention in the field of gerontology. Dual-task exercise refers to when specific cognitive and motor tasks are performed simultaneously to improve the selected cognitive or physical functions.[18–20] Evidence consistently shows that both physical and cognitive training have the potential to maintain cognitive functioning in aging individuals and that successively combining them amplifies the effect. Dual-task and physical exercise, to our knowledge, cannot treat patients with AD. However, if DT is more effective in improving cognitive and physical functions among older adults, compared to medication therapy, it may help prevent or delay AD onset. Therefore, combining therapies is expected to help address the problems faced by the most elderly. To the best of our knowledge, existing studies have not explored which DT exercise is more beneficial for older adults. Moreover, the mechanisms underlying cognitive and physical functions are multitudinous and interact in complex ways. Despite the several answered scientific questions related to DT's effects on cognitive and physical functions, our current understanding points to specific solutions and answers therein. Therefore, we aim to maintain and prevent the deterioration of older adults' cognitive functions through gaining an in-depth understanding of cognitive training and developing the DT intervention accordingly. Additionally, if the purported benefits of DT are accurate, accelerating the spread of DT will be beneficial for older adults.

3 | CONSOLIDATED RESULTS AND STUDY DESIGN

3.1 | Synapsology program (details in supporting information and Video 1)

To clarify the beneficial effects of physical activity, which was recommended by the WHO, and to overcome the weaknesses of simple

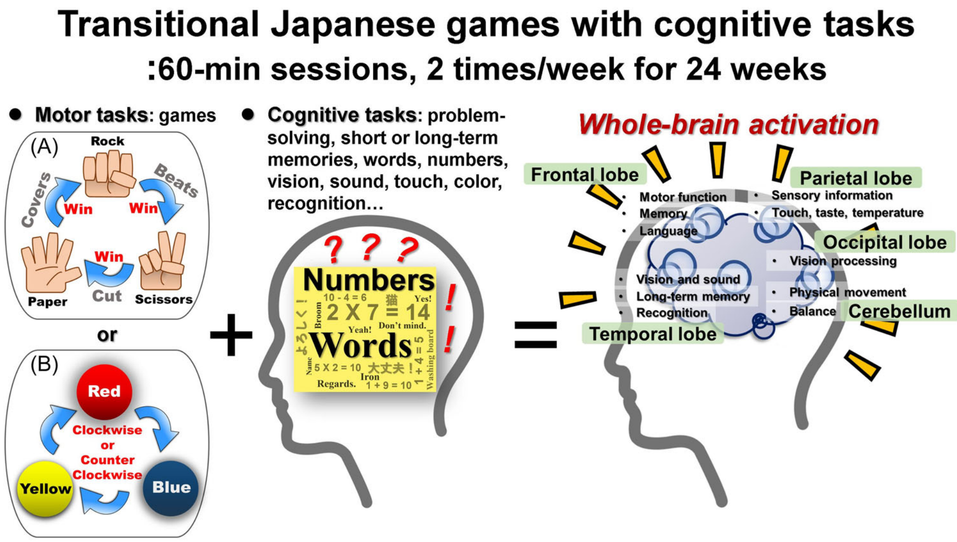

FIGURE 1 Design and its brain activation of "Synapsology" (SYNAP; games combined with number-counting, calculation, memory, problem-solving, visual color recognition, enumerating words, etc.). A, First session: rock, paper, scissors (RPS) game, (B) second and third sessions: pass the colored balls game. The program consisted of 60-minute sessions twice a week for 24 weeks. The sessions were conducted in groups of five to seven participants with one instructor to help them maintain their concentration. The SYNAP group (SG) began with a 10-minute warm-up of breathing and flexibility exercises for the upper and lower body, followed by a 45-minute SYNAP task. The program ended with 5 minutes of breathing and stretching exercises to cool down (see details in supporting information)

and conventional DT, we conducted a unique DT to maximize the cognitive and physical functions of the brain. Considering the relationship between DT exercise and cognitive function, a unique DT exercise method, "Synapsology" (SYNAP), may help improve cognitive and physical functions of the most elderly. SYNAP, which was developed in 2011,[21] is a game-like DT exercise program that is safe and effective for older adults with cognitive impairments.[22]

The SYNAP, which includes both physical and cognitive games, uses a multidisciplinary approach to stimulate brain activity and thereby improve cognitive and physical functions (Figure 1). The DT program is helpful and ideal because it is simple and enjoyable, similar to a game. For example, playing the rock-paper-scissors or colored ball games while performing a simple calculation or short-/long-term memory word task activates the functions of the frontal (responsible for motor function, problem-solving, short-term memory, and language), temporal (responsible for visual and sound processing, long-term memory, and problem recognition), and occipital (responsible vision processing) lobes. The SYNAP activates the brain's cognitive functioning and the entire brain to control the body, compared to other interventions that use a more conventional and simpler DT.[18–20] In addition, the SYNAP was designed to include traditional Japanese games so that older adults understand it better and are more motivated to continuously participate in it. Indeed, our previous study showed that the motor ability and cognitive function of older adults aged 65 years and older (mean age of 70.6 years), who participated in the SYNAP intervention (60-minute sessions, twice a week, for 8 weeks) improved significantly or remained stable.[22] Therefore, it is worth extending the benefits of SYNAP to a difficult target population, such as the oldest adults.

The SYNAP does not require any special tools or facilities; therefore, it is cost-efficient. It can be applied anywhere in the world (see supporting information). For example, in the United States, it can be modified to include culturally relevant childhood games (e.g., Duck, Duck, Goose) along with long-term memory tasks (e.g., childhood nickname); this is expected to simultaneously activate all the parts/functions of the brain. Consequently, the cognitive and physical functions of older adults will be positively impacted. The key here is to incorporate simplicity and fun into the tasks so that it can be continued on a regular basis.

3.2 | Synapsology program trials among the oldest nursing home residents

3.2.1 | Designing a SYNAP trial

Participants were residents of a nursing home facility in Machida City, Tokyo, Japan. Initially, patients with dementia were excluded; thus, only those without cognitive impairment were included. The 24 participants were randomly assigned to the SYNAP group (SG; n = 12) and the control group (CG; n = 12; Table S1 in supporting information), after which they completed the 24-week trial (Figure S1 in supporting information).

In general, in Japanese nursing homes, the most elderly are predominantly patients with dementia. This is due to the burden, related to long-term care, on the family. In addition, it is difficult to obtain the consent of the facility's medical personnel and their families who are concerned about the effects of this physical-intervention study. These are significant obstacles for many researchers who understand the mechanism of the brain and aim to maintain cognitive function and prevent AD. However, all participants provided written informed consent for their participation in the study.

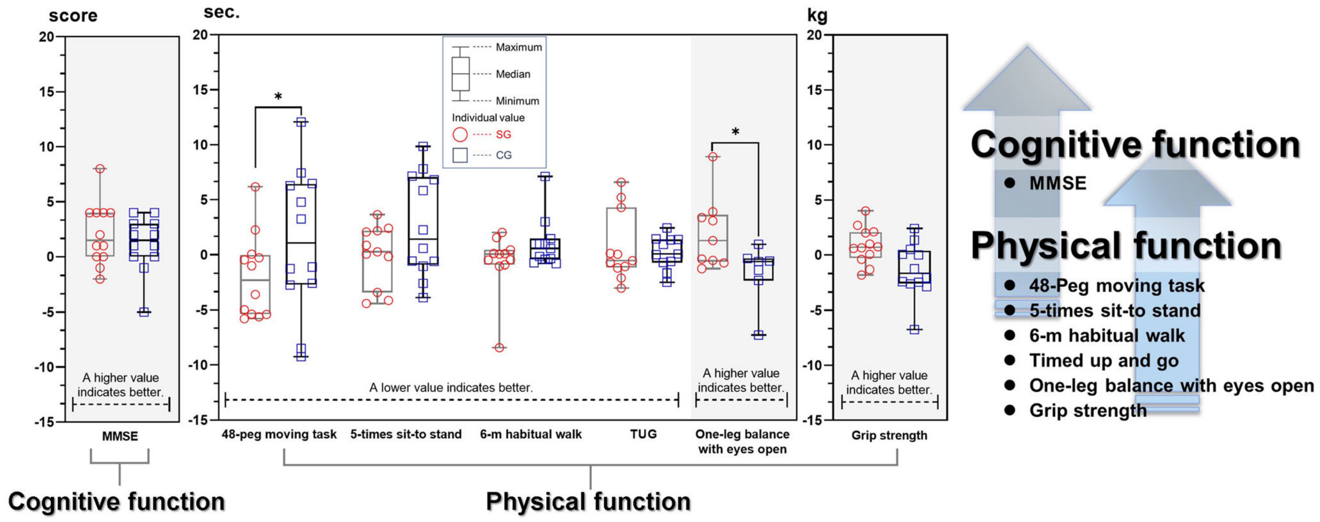

FIGURE 2 Individual tested items of cognitive and physical functions in the oldest nursing home residents. Empty red circles (SG) and blue squares (CG) represent the participants' change from baseline. CG, control group; MMSE, Mini-Mental State Examination; SG, SYNAP group; SYNAP, Synapsology; TUG, timed up and go. **P* < .05

The mean ages of the participants in the SG and CG (Table S1) were 89.9 years (range: 86–97) and 90.3 years (range: 85–96), respectively. The SYNAP consisted of 60-minute sessions, twice a week, for 24 weeks. The CG did not receive the intervention; however, they performed regular activities of daily living during the study period. The participants in the SG expressed that they would like to continue with the intervention (participation rate = 100%) because it was fun and similar to a game.

There were no significant differences in baseline characteristics such as age, height, body weight, and body mass index between those in the SG and CG (Table S1). The participants had the typical body and health conditions observed in Japanese adults of this age group. Despite the participants being the most elderly, they were healthy for their age because the nursing home was a premier facility that provided good medical care and health management. Unfortunately, we were unable to compare the relationship between the effect of SYNAP and the participants' educational background because we could not obtain information regarding it from their families.

3.3 | Evaluating a SYNAP trial

3.3.1 | Cognitive function

The Mini-Mental State Examination (MMSE; score range: 0–30) was used to assess the cognitive function of the participants. Those who received a score less than 21 were diagnosed with dementia.[23] Using the MMSE questionnaire, the researchers conducted one-on-one interviews of the participants.

Based on the results pertaining to cognitive functions (Figure 2, Table S2 in supporting information) in Japanese cross-sectional studies using MMSE scores (range: 1–30), adults with a mean age of 82.3±6.6 years show scores of 23.8±2.0, which is considered MCI.[24] From the baseline of this study, the CG group had a similar result (24.2: MCI) to that of a previous study; however, the SG group had a slightly higher score (25.9: MCI) for their age. Cho et al.[25] reported that lower limb aerobic-based exercise (40 minutes, three times per week for 6 months) was effective in improving physical function and mental health among Japanese older adults (86.2±1.5 years). Our trial showed that the MMSE score improved from 25.9±3.3–28.3±1.6 (normal cognition) compared to findings from Cho et al.[25] (24.13–25.13: MCI). This result pertaining to cognitive function may be influenced by the areas of the brain that were activated by the DT program. In other words, it is possible that cognitive function improved after SYNAP intervention. Therefore, we infer that it may be beneficial for older adults to regularly engage in DT activities.

3.3.2 | Physical function evaluation

In general, it is well known that cognitive function is closely associated with physical function. To evaluate the effectiveness of SYNAP, we measured six items of physical function,[26] which included a cognitive function, the 48-peg moving task,[27] 5-times sit-to-stand,[28] a 6-meter habitual walk,[29] timed up and go (TUG),[30] a one-leg balance with eyes open,[31] and a grip strength[32,33] in the pre- and post-trial. Among the participants, one or two persons did not participate the 5-times sit-to-stand, the 6-meter habitual walk, and TUG as they were wheelchair users. In addition, participants in both groups who used a cane, push-cart, or wheelchair were unable to participate in the physical activities.

Participants in the SG, after the 24-week intervention, showed positive outcomes in all the items, compared to those in the CG (Figure 2, Table S2). The results indicate that the SYNAP intervention improved overall physical function. Among the items, the outcomes pertaining to the 48-peg moving and one-leg balance with eyes open tasks were significantly different between the groups. The SG, compared to the CG, demonstrated significant improvement in these items. Additionally, the CG's response time in the 48-peg moving task was much slower than that at baseline. In other words, if a DT exercise such as SYNAP is not performed and the cognitive function of the brain is not stimulated, physical function/reaction appears to slow down. The TUG task's results provide more information regarding mobility because it measures cognitive capacity during simultaneous motor tasks.[34] The TUG activity is strongly associated with cognitive capacity, and the effective performance of the TUG depends on a person's cognitive function. Thus, the TUG test is a convenient method for evaluating cognitive function in older adults. Our results showed that the main effect of TUG was significantly different between the SG and CG ($P < .003$). Hiyamizu et al.[35] also demonstrated a significant improvement in TUG ($P < .002$) through a DT intervention program consisting of strength/balance training while performing cognitive tasks. This provides further evidence to support the notion that an effective DT program improves cognitive function and may also improve physical function. Therefore, DT may lead to cognitive and physical improvements in participants. Indeed, cognitive function improved after the SYNAP intervention, especially task-switching and response speed. Additionally, mild exercise incorporated into DT improves executive function in older adults. A study by Grothe et al.[36] demonstrated that this is due to mediation by the exercise-induced arousal system and cortical activation in task-related prefrontal subregions. From the spatial profiles obtained through functional near-infrared spectroscopy (fNIRS), strong signals were visible in the forebrain and lateral brain during exercise. In other words, it can be said that cognitive function is closely related to motor function. Therefore, SYNAP, which incorporates mild physical activity, may be appropriate for strengthening the physical functioning of the oldest population.

4 | CONCLUSION

To the best of our knowledge, this study is the first to examine the effects of this unique cognitive-motor DT program for the oldest population. The 24-week game-like DT program—SYNAP—maintained or improved the cognitive and physical functioning of the most elderly with normal cognitive functions, compared to those who did not receive the intervention. Therefore, it is assumed to have beneficial effects by efficiently activating the role of each region of the brain. That is, this effectiveness may be because the frontal, temporal, and occipital lobes are activated while playing games that involve movement.

Therefore, the SYNAP can be an effective DT program for older adults to help improve and maintain their cognitive and physical functions. Additionally, it may help improve quality of life, when used as a social exercise in retirement homes and municipal sports facilities in Japan. Because this DT intervention is expected to be a useful tool for maintaining and improving the cognitive and physical functions of older adults, we aim to help address the problems faced by older adults worldwide through further large-scale verification in Japan.

Therefore, these findings suggest that SYNAP will be a useful addition to the social and recreational activities of older adults, especially in a "superaging" society such as Japan.

However, because this is a small-sized intervention study, it is necessary to quantitatively examine the effect of this DT intervention further. In recent years, the accumulation of Aβ in the brain has been found to be the reason for the onset of AD. Thus, we are now trying to address this problem by simultaneously monitoring Aβ and the mechanisms underlying physical functions in the elderly, using enzyme-linked immunosorbent assay and matrix-assisted laser desorption/ionization–time of flight mass spectrometry. Furthermore, we plan to use fNIRS to investigate the change in the "signal transduction pathway" that occurs simultaneously in all the regions of the brain in response to cognitive tasks and movements through real-time monitoring. This will elucidate whether the biological effects of DT are mediated by or lead to clinical or behavioral changes in the near future.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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