Review of the Application of Artificial Intelligence (AI) Exercise Training in Improving Cognitive Function in the Elderly Population

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Abstract:

With the increasing cognitive dysfunction of the elderly and the incidence rate of dementia caused by aging, in recent years, many countries have studied and applied artificial intelligence (AI) to reduce the pressure on caregivers and improve the quality of life of dementia patients. This study comprehensively summarizes the impact of AI cognitive training on the mental symptoms of dementia patients from 2010 to 2024 through literature review. The results show that AI training has been used in multiple fields, breaking through many limitations of traditional action recognition technology. Through virtual cyberspace, real-time interaction of multiple senses can be achieved, allowing people to feel reality in the virtual network and accurately capture participants' actions; Through AI games, elderly people can improve their physical and cognitive functions, reduce depression and anxiety, meet the psychological and social needs of dementia patients, enhance their independence and dignity in life, and make objective assessments of cognitive function, which may help prevent dementia.

Today, population aging is unstoppable and has become a highly anticipated social phenomenon worldwide. The degree of population aging in China is at an upper middle level in the world. By the end of 2023, the elderly population aged 60 and above in China has exceeded 290 million, accounting for 21.1% of the total population [1]. Related studies have shown that increasing age is associated with lower performance measured by various cognitive functions. Starting from the age of twenty, brain function will gradually deteriorate, and this situation will last a lifetime [2]. Starting from the age of twenty, brain function will gradually deteriorate, and this situation will last a lifetime [3]. Due to changes in neuroanatomy, healthy individuals may also experience specific cognitive decline during aging, such as processing speed, executive function, and episodic memory [4]. Therefore, with the

increasing aging trend in China, cognitive decline has gradually become one of the major diseases threatening the healthy aging of the elderly. In China's 14th Five Year Plan for Healthy Aging, it is explicitly stated that over 78% of elderly people in China suffer from at least one chronic disease such as cognitive decline and sensory dysfunction caused by old age.

In the face of such severe aging and elderly health issues, the Healthy China 2030 Development Strategy explicitly states: "Properly addressing the social problems caused by population aging is related to the overall development of the country and the well-being of the people". What methods or strategies should be applied to prevent and improve cognitive decline in the elderly, as well as neurological diseases such as dementia that they may face in old age, is an urgent issue that needs to be addressed. Previous studies have shown that exercise training is a healthy and effective way to improve physical fitness, cognitive function, and prevent diseases in older adults [5]. With the continuous development of science and technology, AI has been able to be used in many fields. Especially in the context of the overall popularity of the Internet, the research on the impact of AI sports training on the health function of the elderly is increasing. Therefore, in-depth research on the impact of AI exercise training on the cognitive abilities of the elderly is of great significance. It may not only provide new ideas and solutions for solving the problem of cognitive decline in the elderly in China, but also facilitate the development of more efficient strategies for improving the cognitive function of the elderly in China. At the same time, it also has certain reference value for the formulation of relevant policies in other countries.

1 The relationship between cognitive decline in the elderly and AI exercise training

1.1 The impact of aging on cognition

Cognition involves complex information processing, planning, and inference [6]. During aging, specific cognitive functions such as inference, memory, and processing speed may weaken [7]. Although some of these functions decline throughout the entire lifespan, some cognitive functions only decline in later years, while others remain relatively intact. This phenomenon generally occurs around the age of 70 [8,9]. Research from magnetic resonance imaging has found that a decrease in gray matter and hippocampal volume in the brain is associated with impaired episodic memory [10]. Processing speed and working memory decrease linearly throughout the entire life cycle [9], and middle-aged people (50-60 years old) have longer reaction times to text processing tasks than younger people (25-35 years old) [11], indicating that cognitive decline is likely to begin in the middle age. This decline in cognitive decline may also pose a significant threat to society, as older people face a higher risk of car accidents due to decreased processing speed, executive function, and visual processing ability [12]。 Compared to younger adults, older people tend to remember positive memories and are less likely to recall negative information, with language abilities particularly declining after the age of 60 [13]. However, studies have also shown that as age increases, language proficiency and general knowledge do not deteriorate, but may instead show a trend of improvement [7], which may be attributed to the compensatory mechanism of the brain.

In summary, age-related cognitive decline (ARCD) may have a negative impact on the daily lives of participants, and over time, it may greatly limit the range of activities that people could have engaged in in the past [14]. It is worth noting that the speed and degree of decline in knowledge and ability vary from person to person. Just as there is heterogeneity in the onset and progression of diseases, there is also heterogeneity in everyone's lifestyle, which ultimately affects the degree of ARCD development and susceptibility (individual sensitivity to cognitive decline) [14]. Due to different life experiences and even varying levels of physical activity throughout one's life, there may be inherent differences in individual plasticity [15]. Additionally, the interaction between genes and environment throughout an individual's life cycle, some people may be more susceptible to cognitive decline. In addition, education level also has an impact. Studies have shown that people with higher education are less likely to experience cognitive impairments such as memory loss and language proficiency [16]. As age changes, some areas of cognitive function continue to decline throughout the life cycle, some can be maintained in old age, and some may show significant decline after aging, such as memory and information processing speed. This is exactly what we aim to prevent and improve in our research. As exercise has long been proven to be beneficial for cognitive function in older adults, it is worth exploring in depth how to train and design exercise.

1.2 AI Sports Training Equipment and Application Methods

1.2.1 AI sports training equipment

1）Wearable AI devices. Wearable intelligent sports products refer to digital products that can be presented in the form of accessories or clothing. They use modern information networks and various sensor technologies to record various physiological data to monitor the overall physical state of the human body [17]. The design mode of wearable AI devices comes from the development of the Internet. The hardware core consists of various physiological information sensors and wearable technologies, while the software core technology is wireless network transmission and statistical data processing. This technology integrates sensors, multimedia, and wireless communication technologies, enabling sensing, feedback, and interactive experiences of basic human movements. It can collect physiological parameters of the human body throughout the entire physical training process and provide feasible services and suggestions to exercise participants through a big data analysis system. For example: MySwing Professional is a golf training aid that can accurately capture players' movements and club trajectories based on full body motion analysis. The device includes 17 wireless full body sensor nodes and connected wearable extension bands, built-in wireless antennas, and pre installed MySwing software for real-time playback and cloud storage. Due to the players wearing multiple micro sensors, the positioning system can accurately capture their movements. At the same time, there is a sensor near the club handle that can be used to record the spatial motion data of the club and provide analysis results.

2）Analysis of Visual Object Tracking System. Real time tracking of athletes' movements and positions, as well as targeted training plans, are crucial for sports training [18], which can help athletes analyze their performance in sports training more intuitively. Therefore, visual object tracking systems have become an important research

direction in the field of AI in recent years. The main purpose of developing this system is to enable smooth communication between calculators and humans, and to understand human speech, gestures, and other actions that go beyond what the human brain can accomplish. This system uses cameras and calculators to capture, track, and measure targets, and achieves automatic motion recognition through AI algorithm, breaking through many limitations of traditional motion recognition technology. The visual object tracking system uses an image detection module to detect the motion trajectory of the target. This module is mainly composed of cameras capable of capturing target images. In order to accurately obtain the position, posture, and other information of the target, it is necessary to install corresponding cameras around the target according to a specific expansion structure to obtain real-time image information of the target. In this section, expansion is essential because expansion between different regions plays a key role in obtaining various visual relationships [19]. The placement of cameras can generally adopt a surround structure to ensure the acquisition of motion information of targets in various directions, thereby providing accurate input information for the system. Then, the image is transmitted to the target recognition section. In this section, images can be recognized through an image recognition module that includes a calculator processing system. Computers can run complex artificial intelligence algorithms to recognize the state of targets. Afterwards, the computer can process the image to analyze the motion state of the target. This part of image recognition is very important in the system because it can transform complex motion into data analysis. Finally, the analysis results will be presented visually to people in the form of images or data. Therefore, visual object tracking systems can achieve motion analysis of targets.

3) Analysis of Virtual Reality Technology. Virtual reality (VR) is an emerging technology that combines computer graphics, sensing technology, artificial intelligence technology, and other fields [20]. It integrates multimedia, artificial intelligence, human-computer interface technology, dynamic device networks, and other information technologies to simulate the real world by constructing a virtual world [20]. VR technology is a calculator simulation system that simulates a virtual network space, allowing users to immerse themselves in a virtual environment with three-dimensional information. In this virtual environment, users can achieve real-time interaction of multiple senses, which is quite realistic. In the 3D dynamic scene created by the calculator simulation system, interactive devices such as head mounted displays, data gloves, and intelligent language can be used to enhance the visual, auditory, tactile, and sensory experience feedback for users. This technology has the characteristics of interactivity, immersion, and authenticity, which can enable people to feel reality in virtual networks. The VR simulation system includes multiple senses, with interactivity and immersion. At the same time, sports training requires the joint participation of athletes' multiple senses such as vision, hearing, and touch. Therefore, with the continuous development of VR technology, simulations built on VR have been widely applied in sports training. VR has become one of the most important and effective educational and training tools, providing athletes with effective and new training methods to help them improve their skills. In addition, for some team sports training projects, VR can solve the problem of insufficient teammates and better meet their training needs.

Therefore, VR has become increasingly popular among people who want to have a better training experience in recent years.

1.2.2 AI cognitive training methods

1）Aerobic/resistance training. At the beginning of each training session, warm up for 5 minutes on the machine chosen by the participants (elliptical machine, treadmill, or horizontal bike), followed by muscle strengthening for different lower body muscle groups (quadriceps, hamstring, hip extensor flexors, ankle plantar flexors, etc.). Muscle strengthening exercises are conducted through elastic bands, with the aim of gradually increasing elastic resistance throughout the entire training process. Sitting- standing exercises are also required, which requires participants to practice as much as possible within a given time. The training course will last for approximately 30 minutes of cardiovascular training, and participants will be arranged to walk on a treadmill while maintaining a moderate to high pace using the Borg Rate of Perceived Exertion Scale [21]. The intensity and duration gradually increase from one training session to the next. When needed, the slope of the treadmill will increase to enhance its strength. Then comes a 5-minute cooling period. Certified kinematic experts supervise training and continuously monitor the condition of participants during the process. For example, effort level, fatigue level, etc., in order to adjust the exercise intensity accordingly.

2）Stretching/body shaping exercises. The subjects participated in a stretching course supervised by a sports expert. These exercises are used to improve flexibility, but do not enhance cardiorespiratory capacity. The course begins with a 5-minute warm-up on the machine they have chosen. Next is a 50 minute stretching exercise, targeting the entire body from head to toe, one joint at a time. Practice in a sitting position as much as possible. The course ends with a 5-minute relaxation on a yoga mat [22]. Cognitive training is conducted in a room equipped with a computer and supervised by a nurse specializing in neuropsychology. The participants underwent visual dual task training, designed to perform the same tasks as the pre-test and post test, but with different visual discrimination tasks. These two visual recognition tasks include number recognition task and shape recognition task. The structure of the task is similar to the pre-test, but it involves more experiments. There are a total of 72 pure single experiments, 240 single mixed experiments, and 864 double mixed experiments. More importantly, during the dual mixing block period, the training task provides continuous performance feedback. Feedback is provided through a histogram that changes colors (green, yellow, red) to inform participants of their reaction speed. The color is determined based on the average reaction time of the last three trials of the double mixed block, and compared with the median reaction time of the pure single block. The goal is to keep the histogram bar in the green area and avoid it turning red. In addition to real-time feedback, global feedback is also provided at the end of the session, informing participants of their average reaction time and accuracy to date. Both types of feedback are used to enhance the motivation of participants[23].

3）Computer courses. Using computer software independently developed by research institutions or teams for specific cognitive training such as memory, concentration, reaction time, or recently commercialized cognitive

training software packages, to understand how the brain adapts to new and challenging situations. In some cases, these training protocols are designed to train specific cognitive processes, that is, specific intellectual functions [23]. From the above mentioned methods and prescriptions for cognitive and exercise training, it can be found that under relatively traditional training methods, the condition of trainees is monitored by relevant personnel, and it is not possible to obtain the current objective state of everyone in a timely manner. When adjusting exercise intensity, such as treadmills, it is also adjusted based on the subjects' own feelings or unified standards, which makes it difficult to achieve real-time and personalized changes and designs. In contrast, referring to the previous introduction of AI, AI as an assistant can not only monitor comprehensive physiological values at any time, but also provide data and analysis of various movements. While improving efficiency, it is also more likely to balance safety [24,25]. In addition, some devices equipped with AI can create virtual environments. If this technology is extended and developed more widely, it may increase the richness and fun of home sports. Such convenience may also help promote sports and make them more popular among people of all ages [26].

2 The impact of AI exercise training on cognitive function in the elderly

2.1 The improvement effect of AI cognitive training on mental disorders

Dementia patients often experience Behavior and Physiology Syndrome for Dementia (BPSD), such as anxiety, delusions, depression, wandering, etc. These symptoms can affect the patient's emotions and daily routine, and even lead to aggressive behavior, resulting in heavy caregiving pressure for family caregivers. In recent years, many studies have confirmed that the effectiveness of using drugs to control BPSD symptoms is limited [27]. Non pharmacological therapy is as effective as drug therapy for BPSD and has fewer side effects. Therefore, for BPSD in patients with mild, moderate, or severe dementia, non pharmacological therapy should be prioritized[28]. There are many non pharmacological therapy methods, such as nostalgia therapy, validation therapy, music therapy, etc. Cognitive training and rehabilitation is also a type of non pharmacological therapy that focuses on groups and combines various functions in daily life. Through individual or group activity design, dementia patients continuously practice and apply various cognitive abilities, such as concentration, calculation, memory, logical reasoning, etc., to maintain existing cognitive functions and delay degeneration [29].

In recent years, many studies have found that cognitive training for dementia patients can reduce their symptoms of BPSD such as depression and agitation. Kim et al. (2015) divided 85 healthy elderly people into three groups (control group, traditional training group, robot training group) and conducted 12 weeks of cognitive training. The results showed that the cerebral cortex of the elderly who received cognitive training was thinner than that of those who did not receive cognitive training, and the abnormal strength of the trained individuals was thinner than that of those who did not receive cognitive training, indicating that cognitive training intervention helps promote elderly learning[29]。 Yuan et al. (2021) found after 12 weeks of cognitive training for patients with moderate dementia that individualized cognitive training can improve cognitive function and reduce clinical symptoms of

dementia (depression, anxiety, etc.), with higher cognitive function leading to better self-control in dementia patients [30]. Recent studies have shown that training games may help alleviate cognitive decline in dementia patients and aid in physical recovery [31,32]. However, these positive benefits can only be achieved if older players can continue to play games with high enthusiasm until clinical effects are seen. If a training game is too complex and boring for elderly people, although it is helpful for health, it still cannot bring any targeted benefits to elderly participants [33]. A study has designed a digital healthcare application aimed at improving the physical and cognitive functions of elderly people through memory, judgment, and endurance training, reducing depression and preventing dementia. The study has designed a training game called Farming, in which a PC and Kinect camera are linked to process real-time motion data received from individual users. Farming integrates AI processing into the user feedback system, responsible for difficulty level adjustment and relative rating system, to encourage users to continue playing games happily. After three months of empirical research, elderly participants showed high acceptance and feasibility of this training game, and demonstrated continuously improving training scores and average success rates[34].

2.2 The impact of AI cognitive training on social interaction in elderly dementia patients

Due to the decline in brain function and the impact of BPSD, dementia patients are unable to fully express their meaning, have difficulty living independently, and are unable to go out on their own, resulting in social disorders. Social disorders can make dementia patients feel lonely, emotionally depressed, and anxious, which in turn affects their quality of life. A study on dementia patients found [35] that cognitive activity intervention can improve patients' cognitive function. Patients who participate in group cognitive training also have improved creativity and imitation ability in language narration, as well as improved quality of life, social and emotional loneliness, depression, and delusions, especially with a strong decrease in social and emotional loneliness; The praise and affirmation from the leader in group activities also make the elderly with dementia more confident, alleviate their emotions, and improve their quality of life. Moradinasab et al. (2023) found that after cognitive training [36], the phenomenon of elderly people with dementia wandering and defecating everywhere decreased, and patients also became more involved in activities within the institution, or more often sat in the activity room to talk to other residents, and smiled more frequently on their faces.

AI Humanoid robot （AIHR）is a robot designed to interact with humans (such as the elderly) using AI. As a means of promoting interaction and social participation among the elderly, it has developed into various forms such as humanoid and doll like robots. AIHR has been found to effectively increase the frequency of independent communication by encouraging older adults to initiate conversations [37]. Due to the development of various technologies, AIHR has evolved to not only explain and express speech, gestures, eye contact, and emotional expression, but also non-verbal communication methods, and its ability to communicate with the elderly is constantly developing. AIHR has been proven to effectively enhance interaction with individuals aged 65 and above [38], improve quality of life [39], alleviate depression and anxiety, and enhance the quality of life of dementia

patients [40]. In a meta-analysis conducted through AIHR, it was confirmed that the improvement effect of AI cognitive training on the brain function of dementia depends on intervention methods, AIHR methods, and individual characteristics of the elderly [41-43]. Its main applications include expanding interactive robots in social settings, addressing the shortage of caregivers, and extending the use of AIHR into digital social prescription programs.

2.3 AI is used for cognitive function testing

Early detection of mild cognitive impairment (MCI) is crucial for effective treatment and prevention of dementia. Therefore, screening tests for cognitive function are crucial. At present, the Mini Mental State Examination (MMSE) is commonly used to screen for cognitive impairment [44]. However, it is impractical to screen a large number of subjects in a short period of time, as it is essentially subjective and conducted on a one-by-one basis between the inspector and the subjects. To address this issue, based on research results on the impact of systemic metabolic disorders, including lifestyle related diseases and anemia, on cognitive function [45,46], researchers have developed a deep neural network model (DNN) that can use basic blood test data without dementia specific biomarkers to evaluate cognitive function; The assessed cognitive function is expressed using the MMSE score [47]. Studies have shown that exercise diet therapy can effectively improve cognitive function and prevent the occurrence of dementia [48]. In a study, the usefulness of the DNN model in monitoring the impact of exercise diet therapy on cognitive function in older adults was evaluated by using blood test data before and after exercise diet therapy to assess cognitive function using the DNN model. Unlike MMSE, DNN testing objectively evaluates cognitive function. This is a convenient and non-invasive test that uses blood test data instead of dementia specific biomarkers such as beta amyloid. In addition, this test may help with personalized care for preventing dementia, as blood test data reflects systemic metabolic abnormalities that may affect cognitive function. This study suggests that cognitive function testing of DNN may help objectively evaluate the impact of exercise diet therapy on cognitive function in older adults, and the combination of DNN testing and exercise diet interventions may also help prevent the onset of dementia [49].

3 Conclusion

1) In the field of sports, AI can digitize and refine human movements, and even create virtual environments to provide tremendous assistance for intelligent scientific training;

2) AI cognitive training can enhance the cognitive function of dementia patients, thereby improving their quality of life. With the assistance of AI assisted devices, it can better meet the psychological and social needs of dementia patients, and enhance their independence and dignity in life;

3) AI can serve as a feedback system to provide timely responses in games that effectively train physical and cognitive functions, as well as an interactive robot to enhance interaction and socialization among the elderly. It can also serve as an objective and relatively inexpensive tool for testing cognitive functions.

Disclosure

Author's contribution
This article is designed and written by Tingran Zhang and Jiong Luo. Mufan Zhang is responsible for literature collection and organization. Meanwhile, Jiong Luo is the project manager and has approved the author and corresponding author of this study.

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