

Utilization of Spatial Communication for Executive Function in Autism Convergence and Integration of Animal-Assisted and Exercise Rehabilitation

Myung-Mi Kim ^{a,*}

^a Department of Liberal Studies, Major in Rehabilitation Sports Welfare, National KunSan University, Jeollabuk-do, Republic of Korea
Corresponding author: *101538@ksnu.ac.kr

Abstract—This study aims to enhance executive function in individuals with ASD and reduce comorbidities through a converged approach to animal-assisted and exercise rehabilitation using spatial communication. It addresses spatial and environmental constraints, individual preferences, and the shortage of trained leaders. The study proposes developing integrated educational simulators and programs for rehabilitation exercises. Expected outcomes include improved communication, self-esteem, self-expression, and social skills. While limited to a literature review, future studies will develop AI and metaverse-based simulators for systematic data collection, providing foundational material for ASD rehabilitation. For individuals with ADS (Alcohol Dependence Syndrome), this approach enables emotional expression through spatial communication during animal-assisted activities, facilitating interaction with surroundings and companion dogs. It enhances exercise rehabilitation effectiveness, allowing safe emotional expression, increased self-esteem, improved self-expression, and social adaptability. This method can prevent ADS-related issues and improve social perceptions, addressing limitations in societal awareness. The convergence of animal-assisted activities and exercise rehabilitation with spatial communication offers a comprehensive approach to addressing executive function challenges in ASD and ADS, promising improved outcomes and social integration.

Keywords— ADS; ADHD; executive function; comorbidity; spatial communication; animal-assisted; exercise rehabilitation.

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I. INTRODUCTION

Recently, the incidence of Autism Spectrum Disorders (ASD) has been rapidly increasing worldwide, with the age of diagnosis gradually decreasing [1]. ASD is a complex neurodevelopmental disorder that manifests with diverse behavioral and cognitive symptoms from an early age [2]. It presents atypical characteristics in both the quantitative and qualitative aspects of social relationships and interactions [3]. Due to the distinct characteristics in social interaction, communication, and behavior of autistic children, the educational community has recently seen a heightened need for support measures in inclusive education settings [4], [5]. Children with ASD also exhibit impairments in processing and integrating sensory stimuli [6], leading to sensory regulation issues such as hyper- or hypo-responsiveness to specific stimuli [7].

This sensory processing immaturity is linked to autonomic nervous system responses, causing difficulties in arousal

regulation, resulting in behavioral control issues or maladaptive behaviors related to functional performance, such as impulsivity, disorganization, hyperactivity, and emotional instability [8]. Children with developmental disorders often exhibit maladaptive behaviors in classroom settings, such as task avoidance or social withdrawal, which directly impact their academic and play-based engagement [9]. The absence of exercise facilities is crucial for promoting physical health among individuals with disabilities, and their physical fitness levels are lower compared to the general population [10], [11]. Inaccessible exercise facilities worsen health disparities for individuals with disabilities, who face systemic barriers (economic inequity, stigma, poor policy enforcement) leading to lower physical fitness. These inequities compound risks for secondary health conditions. Solutions demand inclusive design, community advocacy, and policy reform to bridge gaps. Consequently, individuals with disabilities, adolescents, and children find it more challenging to learn sports skills for health promotion than the general population learning exercise methods and techniques

[12]. With the increasing population of individuals with autism, various efforts are being made to treat ASD, with a growing specificity in understanding the genetic risk factors [13]. Therefore, this study aims to propose a converged and integrated approach to animal-assisted and exercise rehabilitation utilizing spatial communication to enhance the executive function of individuals with ASD and reduce comorbidity rates, as shown in Fig. 1.

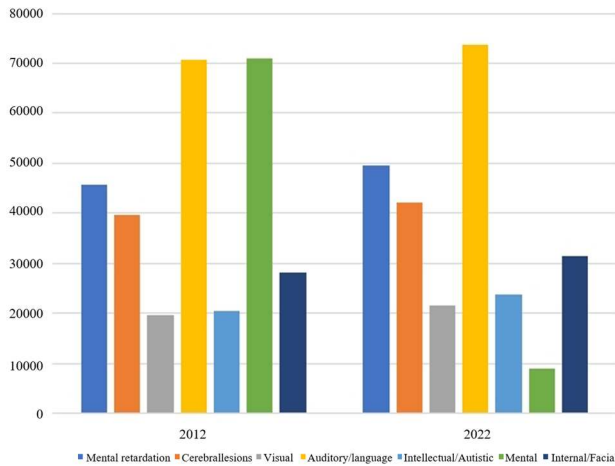


Fig. 1 Trends in Intellectual Disability Population(2012-2022)

II. MATERIALS AND METHOD

A. Comorbidity and Executive Function in ASD and ADHD

Children with ASD experience difficulties in behavioral control and maladaptation in functional performance. Previous studies on comorbidity in children with ASD report that about 70% have at least one comorbid condition, and 41% have two or more comorbid conditions [14]. Among these, the executive function includes the following: setting specific and achievable goals, establishing step-by-step plans to achieve them, prioritizing essential tasks, and making a list of things to do by period so that they can be visually checked.

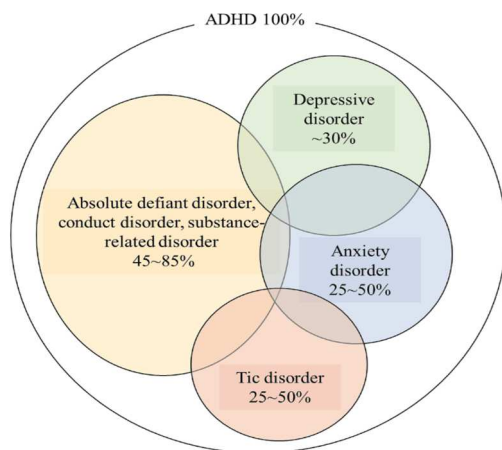


Fig. 2 Comorbidity Rate of ADHD

To improve attention, we should create an organized environment, not do two tasks simultaneously, enhance attention through meditation, and choose clear solutions for problem-solving skills to reach our goals effectively. The executive function involves deciding what to focus on, while the attention function focuses on it. Executive function refers

to the mental control processes that enable physical, cognitive, and emotional self-control, crucial for maintaining and achieving goal-directed behavior [15]. The comorbidity rate of ADHD in children with ASD is reported to be between 54% and 78%, with ADHD symptoms exacerbating executive function and hindering social and language development, as shown in Fig. 2 [16].

Initial studies on executive function began with research on individuals with frontal lobe damage due to accidents and later expanded to include students with ADHD. As brain research progressed, it was discovered that early childhood is the critical period for brain development. This led to a focus on infants and young children in studies on executive function. However, executive function continues to develop significantly during elementary school (9-12 years old) and into adolescence, with development continuing into the 30s [17].

The executive function consists of various subdomains. For example, it includes planning ability, which involves anticipating situations and making plans; cognitive flexibility, which entails thinking of multiple alternatives and adapting to tasks or situations flexibly; behavioral inhibition, which consists in ignoring unnecessary stimuli and restraining actions to achieve goal-directed behavior; and attentional control, which is the ability to regulate and shift attention according to the demands of the situation and tasks. Damage to executive function results in deficits in creativity, spontaneity, thought, planning, organization, memory, language, attention, spatial and temporal abilities, and self-regulation [18].

Conversely, a well-developed executive function enables flexible regulation of mental representations for goal-directed behavior, including planning, impulse inhibition, attention focus, and working memory regulation, facilitating effective and discerning social behavior [19]. Children with ASD and ADHD face difficulties in developing executive function, which is also found in other developmental and neurological disorders such as learning disabilities, tic disorders, obsessive-compulsive disorder, and conduct disorders [20].

B. Positive Functions of Converged And Integrated Animal-Assisted And Exercise Rehabilitation

The term 'rehabilitation' originates from the Latin word 'habilitare', meaning 'to make fit', with the prefix 're-' added. In the context of human subjects, it refers to restoring functions and abilities by reducing or eliminating physical disabilities to reintegrate individuals into society. This concept was first used at the National Rehabilitation Conference in San Francisco in 1943. Subsequently, in 1976, the Second World Health Assembly resolution defined rehabilitation as the 'third medicine,' expanding its meaning beyond mere treatment and training to encompass comprehensive service activities to enable persons with disabilities to live as social beings [21]. In South Korea's special physical education, it has been reported that youth are learning basic exercises and motor skills with incorrect postures, requiring specific tools and spaces for motor skill development [22]. Moreover, studies have shown that compared to non-disabled individuals, people with disabilities experience a more significant decline in health-related fitness factors as they age, with differences in flexibility, strength, muscular endurance, and muscle morphology becoming

apparent after the age of 20 [23]. Fig. 3 is an example of AI Metaverse convergence.

In Korea, rehabilitation exercise and physical education are based on Article 15 of the "Act on Guarantee of Right to Health and Access to Medical Services for Persons with Disabilities" (hereinafter referred to as the Disability Health Rights Act), enacted in December 2017. Article 15, Paragraph 1 stipulates, "The Minister of Health and Welfare may provide rehabilitation exercise programs prescribed by doctors to persons with disabilities or those expected to become disabled within a certain period due to injury or illness that is difficult to recover from fully." Paragraph 3 of Article 15 states, "The Minister of Health and Welfare shall strive to improve the physical, mental, and social abilities of persons with disabilities or those expected to become disabled within a certain period due to injury or illness that is difficult to recover from fully."



Fig. 3 AI Metaverse convergence rehabilitation exercise using colipat

To ensure continuous and systematic rehabilitation exercises after hospital treatment and community reintegration, it is crucial to establish effective connections between hospitals and communities. This is particularly important in rural areas lacking rehabilitation hospitals. An integrated service combining medical care and rehabilitation exercises should be provided, allowing for comprehensive management of exercise data. Through smart healthcare content, the effectiveness of self-exercise can be enhanced without constraints of weather, time, or place. Furthermore, a treatment model should be established to provide consistent and appropriate rehabilitation therapy [24], [25].

The obesity rate among individuals with intellectual disabilities is approximately 1.7 times higher than that of the general population [26]. This leads to a vicious cycle of decreased physical activity, muscle atrophy, reduced basal metabolic rate, and a disinclination towards physical activities in individuals with intellectual disabilities. In response, virtual reality exercise, which stimulates interest and provides a high sense of presence, has shown significant positive effects. A 12-week experimental study using a game bike in virtual reality with nine individuals with level 3 intellectual disabilities resulted in considerable weight reduction, improved muscular endurance, a tendency towards enhanced mental health, reduced depression, and improved social adaptation levels among participants. Table 1 summarizes this study along with other research on the application of XR technology in exercise and training in the special education field in Korea.

TABLE I
RESEARCH ON THE USE OF XR TECHNOLOGY FOR AUTISM SPECTRUM DISORDER

Research	Object	Tool	Effective
Lee et al. [26]	intellectual disability 3 Grade 9 adults	VRGame Bike (Kartrider, Nexon, Korea)	Significant effects on weight loss, muscle endurance, depressive symptoms, and social maladjustment levels
Yoo et al. [27]	intellectual disability Five children	Nintendo Wii	Positive changes in knee joint muscle function, task processing speed, attention, and exercise immersion
Kang et al. [28]	intellectual disability Five children	Nintendo Wii	Positive changes in hand coordination, coordination of general movements, and ability to perform movements
Beun et al. [29]	Intellectual disability 18 children	Nintendo Wii	Improvement of physical abilities such as cardiopulmonary endurance, strength, agility, and flexibility

Individuals with Autism Spectrum Disorder (ASD) experience significant difficulties in social interaction and communication, often struggling with conversations or expressing themselves to others. Additionally, individuals with ASD may sometimes express their intentions through self-harm or aggression [30]. A characteristic and strength of individuals with ASD is their superior ability to process visual stimuli [31]. Consequently, international researchers have shown great interest in AR technology-based studies that maximize this visual advantage for individuals with ASD [31]. However, in Korea, research utilizing XR technology for individuals with ASD is still relatively limited compared to studies focused on intellectual disabilities. The related studies in this field are summarized in Table 2.

TABLE II
RESEARCH ON THE USE OF XR TECHNOLOGY FOR AUTISM SPECTRUM DISORDER

Research	Object	Tool	Effective
C-W. Ha [32]	Ten students with autism spectrum disorder	Xbox 360	Significant effects on basic physical strength and concentration
Kim et al. [33]	Three children with autism spectrum disorder	Nintendo Wii	Significant effects on verb vocabulary acquisition, positive changes in attention

Although we have previously examined research on the intellectually disabled and autistic, there is a lack of comprehensive exercise methods for rehabilitation exercise. In 2003, the Delta Society in the United States defined animal-assisted therapy as goal-oriented animal intervention activities that use specially conditioned animals to improve

participants' issues. Animal-assisted interventions describe intentionally integrating or including animals for therapeutic purposes or environmental improvement. The term "therapy" is not limited to traditional medical aspects but also encompasses broader meanings of recovery and improvement, such as health enhancement, emotional stability, or improvement in quality of life [34]. Individuals with intellectual disabilities often exhibit low concentration levels and are less likely to show interest or engagement [35]. Their cognitive abilities are also lower, resulting in relatively limited movements compared to the general population, and they require multiple repetitions to internalize specific activities. Considering these characteristics of intellectual disabilities, exercise and training through XR technology provide these individuals with an appropriate environment and context. XR technology allows for repeated training and exercise programs tailored to the characteristics of intellectual disabilities and frequent opportunities for a sense of achievement. Moreover, using XR technology can create an illusion for individuals with intellectual disabilities that they are experiencing the real world within virtual reality, allowing them to feel the effects of exercise, enjoyment, and other emotional aspects as if they were confirmed [36]. Animal-assisted therapy for children can be particularly beneficial for children with autism spectrum disorder (ASD) as it effectively promotes physical, emotional, and social development, and interactions with animals can lead to a variety of positive changes.

The empathy and emotional understanding learned through children caring for animals significantly contribute to their physical and emotional development. Furthermore, interaction with animals helps stabilize children's emotions, and activities such as walking and playing with them contribute to alleviating depression and reducing loneliness and feelings of isolation. Additionally, owning pets has several positive effects, including increased activity levels, reduced stress indices, and decreased social isolation [37]. Exercise rehabilitation using animal-assisted therapy offers many physical, emotional, and social benefits. It can be carried out safely and effectively through professional guidance and customized programs, as it allows natural participation in exercise and improves emotional stability and social skills through animal interaction.

Various rehabilitation exercise programs that involve different exercise skills and movements are being implemented for children with autism, and their positive effects have been reported [38]. Exercise rehabilitation programs for children with autism spectrum disorder (ASD) require a personalized approach that is tailored to the individual child's abilities and needs. These programs can include a variety of exercises and activities, including aerobic exercise, strength training, flexibility training, and sensory integration activities to promote physical, emotional, and social development. The purpose of physical education is not merely to perform exercises but to contribute maximally to human growth and adaptation through exercise education programs [39].

Therefore, a rehabilitation exercise plan to improve the executive function of ASD and reduce comorbidity rates should first address spatial constraints, individual characteristics (animal preference), environmental constraints

(weather, fine dust), and the lack of trained intellectual disability leaders and activity assistants through a converged and integrated approach to animal-assisted and exercise rehabilitation. Subsequently, it proposes the development of converged and integrated animal-assisted and exercise rehabilitation educational simulators and programs using spatial communication for application in rehabilitation exercises.

III. RESULTS AND DISCUSSION

Metaverse is a compound word of 'meta,' meaning virtual or transcendent, and 'universe,' referring to the real world. It describes a three-dimensional virtual world where economic, social, and cultural activities are similar to the real world. Metaverse is a concept that has evolved beyond virtual reality (VR), allowing users to engage in social and cultural activities akin to real life through avatars rather than merely enjoying games or virtual reality experiences [40]. The metaverse is ushering in a new era. Initially created by gaming and entertainment companies as a platform for play and communication, it is now being widely utilized across various domains, including politics, society, culture, and economy. Businesses are also using the metaverse as a space for conducting work. Economy Chosun presented a new future where the metaverse era extends beyond gaming and social activities to the automotive and aviation industries [41].

Moreover, metaverse healthcare is expanding its scope, assisting with dementia diagnosis through brain wave and gaze analysis, virtual space dementia prevention training programs, and rehabilitation therapy. While Mnet broadcasting uses digital humans to alleviate longing for loved ones, metaverse healthcare helps increase real-time spent with loved ones and aids in restoring youth for seniors [42]. Analyzing international research, the use of virtual reality and metaverse-related technologies for rehabilitating disabled individuals and elderly patients is more diverse than domestic research, with various exercise rehabilitation programs being utilized. While domestic research tends to use simple games in exercise rehabilitation programs, international research employs virtual reality or metaverse-related technologies specialized for appropriate forms of exercise rehabilitation. Therefore, it is analyzed that effectively utilizing the metaverse and various metaverse games for exercise rehabilitation of elderly patients and disabled individuals could help activate the body and mind and aid in brain enhancement, physical ability improvement, and anti-aging.

In the future, these metaverse technologies are expected to assist in increasing physical activity for individuals with intellectual disabilities, with exceptionally high applicability in rehabilitation exercises for ADS (Alcohol Dependence Syndrome). For individuals with intellectual disabilities, the decrease in physical activity begins in their 20s, suggesting the need for various efforts to recognize the importance of physical activity and fitness and to promote these aspects. The limited opportunities for participation in physical activities and low activity levels can be associated with exercise deficiency [43]. Furthermore, as adults, individuals with disabilities are more likely to develop various adult diseases, endocrine disorders, and changes in muscle morphology, leading to insufficient muscle movement and an increased

probability of chronic degenerative arthritis and musculoskeletal diseases [44].

Physical disabilities require multifaceted support more than other types of disabilities, as they not only involve difficulties due to physical limitations in posture, movement, and mobility but also often accompany cognitive impairments resulting from neurological disorders. Furthermore, delivering rehabilitation exercises and physical education emphasizes restoring residual functions in individuals with disabilities by providing planned physical activities to improve physical, social, and emotional abilities. However, there are differing interpretations regarding whether 'rehabilitation exercise and physical education' should be viewed separately as 'rehabilitation exercise and rehabilitation physical education' or as 'rehabilitation exercise' and 'physical education.' In response, the Ministry of Health and Welfare's Rehabilitation Exercise and Physical Education Council has decided to institutionalize rehabilitation exercise and physical education without distinguishing between the two [45].

When examining animal-assisted activities, it is evident that animals' characteristics are particularly useful in therapeutic situations. Animals promote sociality and contribute to creating a comfortable atmosphere. It has been shown that children with experiences of emotional or physical abuse who participate in animal-assisted activity programs exhibit increased emotional openness towards the therapeutic process [46]. These results indicate that group counseling involving animal-assisted activities positively affects children's emotional development, social interaction skills, self-esteem, and sociality, as shown in Fig. 4 [47].

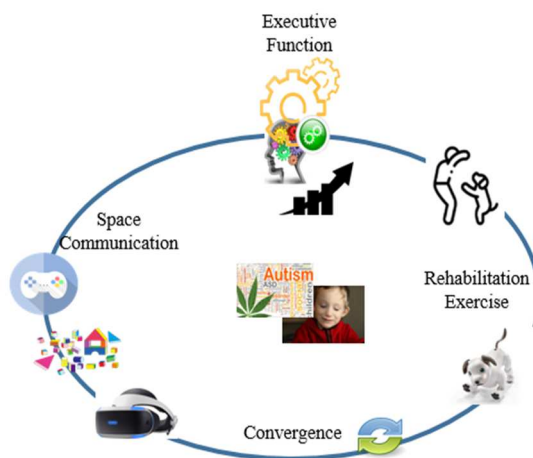


Fig. 4 Research Model

In the case of exercise rehabilitation, a 20-week Water Exercise Swimming Program (WESP) conducted with 16 boys with autism spectrum disorder (ASD) showed positive results regarding social deficits behavior. Studies on individuals with ASD using functional magnetic resonance imaging (fMRI) revealed a metabolic decrease in the frontal cortex, particularly in the anterior cingulate cortex (ACC), a critical region involved in executive function [48].

For people with Autism Spectrum Disorder (ASD), exercise rehabilitation can be beneficial in many ways, as shown in Fig. 5. Exercise rehabilitation can bring about positive changes in many areas, including physical health, behavior, emotions, and social interaction. Exercise improves

muscle strength and flexibility, balance, and physical ability, and it releases energy through exercise, improving behavior and emotional state. In addition, through exercise, one can learn cooperation and communication skills, interact with others, and learn self-confidence and a sense of accomplishment. Thus, exercise activities can improve the physical abilities of individuals with ASD and promote social interaction. Group exercises or team sports help them learn social skills such as cooperation, leadership, and rule compliance. Additionally, for individuals with disabilities, it is possible to provide various exercise experiences by using imagination or to help them perform challenging movements in a virtual environment [49], [50].

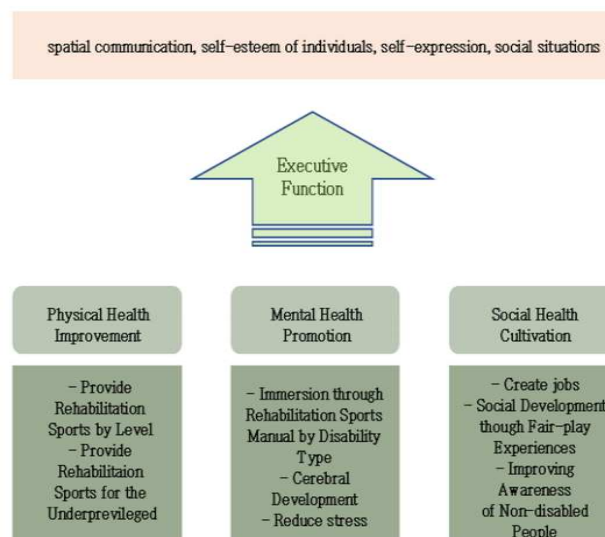


Fig. 5 Expected Effects of Utilizing Spatial Communication in Converged and Integrated Animal Assisted and Exercise Rehabilitation

Therefore, the expected effects of converged and integrated animal-assisted and exercise rehabilitation are to address spatial constraints, individual characteristics (animal preference), environmental constraints (weather, fine dust), and the lack of trained intellectual disability leaders and activity assistants. By developing educational rehabilitation exercise simulators and programs using AI and the metaverse for individuals with intellectual disabilities, systematic and scientific data can be collected, directly benefiting the rehabilitation exercises of individuals with ASD.

IV. CONCLUSION

This study proposes a converged and integrated approach to animal-assisted and exercise rehabilitation utilizing spatial communication for the executive function of individuals with ASD. Animal-assisted activities provide intimacy and stability, aiding in forming social relationships, while exercise activities can improve physical correction and fitness abilities and promote social interaction in individuals with ASD. This approach helps improve social skills and self-development in individuals with ASD and offers the advantage of tailoring personalized rehabilitation exercise programs based on individual characteristics.

Therefore, the expected effects of the converged and integrated approach to animal-assisted and exercise rehabilitation utilizing spatial communication for the

executive function of individuals with ASD. First, it provides opportunities for individuals with ASD to express and communicate their emotions, offering love and support to companion animals, which helps them safely express their feelings. Second, it enhances the self-esteem of individuals with ASD, enabling them to love and accept themselves more. Third, it teaches and practices methods of self-expression, which helps improve the ability to express oneself in social situations. Fourth, it strengthens social abilities such as cooperation, sharing, participation, and compliance, allowing individuals to practice and learn social interactions.

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