Trends in Korean Medical Device Development for ADHD and ASD: Scoping Review

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Abstract

Background: Attention deficit hyperactivity disorder (ADHD) and autism spectrum disorder (ASD) are some of the most prevalent mental disorders among school-aged youth in Korea and as such, may play a role in the increasing pressures on teachers and school-based special education programming. The lack of support for special education, tensions between teachers, students, and parents, and the lack of backup for teacher absences are common complaints among Korean educators. New innovations in technology to screen and treat ADHD and ASD may offer some relief to students, parents, and teachers through earlier and efficient diagnosis, access to treatment options, and ultimately, better-managed care and expectations.

Objective: This scoping review provides a review of medical device use and development in Korea for the diagnosis and management of ADHD and ASD and highlights research gaps.

Methods: A scoping review was conducted based on the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) checklist.

Results: The trends in Korean medical device development were categorized into 2 major groups: “digital therapeutics” and “traditional therapy.” Digital therapeutics have 5 subgroups: “virtual reality (VR) & artificial intelligence (AI),” “machine-learning & robot,” “gaming & visual contents,” “eye-feedback & movement intervention,” and “EEG & neurofeedback.” Traditional therapy has 3 subgroups: “cognitive behavioral therapy & working memory,” “diagnosis & rating scale,” and “musical, literary therapy & MBSR.”

Conclusions: Future development of medical devices for ADHD and ASD is predicted to heavily rely on digital technologies, such as those that sense people’s behaviors, eye movement, and brainwaves.

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Scoping Review

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TRENDS IN KOREAN MEDICAL DEVICE DEVELOPMENT FOR ADHD AND ASD: SCOPING REVIEW

ABSTRACT

Background: Attention deficit hyperactivity disorder (ADHD) and autism spectrum disorder (ASD) are some of the most prevalent mental disorders among school-aged youth in Korea and as such, may play a role in the increasing pressures on teachers and school-based special education programming. The lack of support for special education, tensions between teachers, students, and parents, and the lack of backup for teacher absences are common complaints among Korean educators. New innovations in technology to screen and treat ADHD and ASD may offer some relief to students, parents, and teachers through earlier and efficient diagnosis, access to treatment options, and ultimately, better-managed care and expectations.

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subgroups: “cognitive behavioral therapy & working memory,” “diagnosis & rating scale,” and “musical, literary therapy & MBSR.”

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Keywords: ADHD, ASD, medical device, digital therapeutics

INTRODUCTION

Attention deficit hyperactivity disorder (ADHD) and autism spectrum disorder (ASD) are some of the most prevalent mental disorders among school-aged youth in Korea. Insufficient support for those with ADHD or ASD affects their delayed improvement, and this circumstance may play a role in the increasing pressures on teachers and school-based special education programming. As teachers are the second most important people who impact children’s early diagnosis and intervention,[1] they are under increasing pressure in Korea from parents and sub-standard special education resources leading them to protest.[2] The protests were prompted by a news of a teacher who resorted to suicide over excessive complaints from demanding parents while also trying to manage students.[3] Sadly, this tragedy was followed by several more incidents of teacher suicides.[4] The lack of support for special education, tensions between teachers, students, and parents, and the lack of backup for teacher absences are common complaints among Korean educators.[4] New innovations in technology to screen and treat ADHD and ASD may offer some relief to students, parents, and teachers through earlier and efficient diagnosis, access to treatment options, and ultimately, better-managed care and expectations.

ADHD is recognized by an ongoing pattern of inattention and/or hyperactivity-impulsivity that interferes with development or functioning.[5] ASD is defined as a developmental and neurological disorder that affects how people communicate with others, interact, behave, and learn.[6] The number

of patients with ADHD in Korea has consistently increased, and the total number has risen by 250% in 2022.[7] Among this entire population, people aged 0-19 accounted for the majority of cases, ranging from 57-85% from 2018-2022.[8] The prevalence of ASD in 2021 was 12.8%, which translated to roughly 32,000 individuals.[9] The rate has increased by 4.3% since 2010.[9] According to the database of registered people with developmental disabilities in June 2021, the Ministry of Health and Welfare of South Korea announced that 56.7% of the population with ASD were young individuals aged 0-19.[10]

To set up improved special education systems for young people with ADHD or ASD, experts claim innovational medical devices for ADHD and ASD are crucial to treating them in a timely and proper manner.[11,12] While diverse types of medical devices exist, including devices for assessment, screening, and training, few studies have examined the use of these medical devices in Korea or trends in the development of new devices for ADHD and ASD in Korea. This study provides a review of the literature focused on gaps in the research related to medical device use and development in Korea for the diagnosis and management of ADHD and ASD.

METHODS

Overview

A scoping review was conducted to examine the trends in Korean medical device development focusing on medical equipment for ADHD and ASD. The paper was drafted based on the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) checklist.

Eligibility Criteria

Journal articles and dissertations were included if they discussed diverse types of medical devices for ADHD and ASD, were peer-reviewed, and were published in 2013 or later. Government R&D

project reports were also included if they discussed relevant topics and were published in 2013 or later. Only Korean or English papers were included. The expected outcome from the included sources was updated information on Korean medical equipment for ADHD and ASD and an emphasis on examining the trends in Korean medical equipment for ADHD and ASD. Interview articles were also included as non-peer-reviewed resources.

Resources were excluded if they did not correspond to the research objective or did not discuss at least one topic about medical devices for ADHD and ASD in the title or abstract. Journal articles were excluded if they were not peer-reviewed, published before 2013, or written other than Korean or English.

Information Sources and Search Strategy

Searches were conducted using the National Assembly Library and PubMed. Data and studies from 2013 to 2024 were retrieved and reviewed. Key search terms included: “ADHD,” “ASD,” “early,” “diagnosis,” “treatment,” “screening,” “medical device,” “intervention,” and “training.” The list of references from the National Assembly Library and PubMed were cross-checked to identify duplicates.

RESULTS

Selection of Sources of Evidence

The systematic search identified 2,629 records through the National Assembly Library and 575 records through PubMed (Figure 1). Of the total 3,204 records, one duplicate record was found, and 2,939 records (91.7%) were removed after titles and abstracts were screened. The reasons for exclusion were unrelated topics (2,884/2,939, 98.1%), publication date before 2013 (12/2,939, 0.4%), and other languages (43/2,939, 1.5%). Of the remaining 264 full-text articles, 197 were excluded for unrelated to medical devices (76/197, 38.5%), irrelevant problems (112/197, 56.8%),

and non-Korea focus (11/197, 5.5%). Thus, 65 records were included in this paper. Figure 1 depicts a flow diagram describing the selection of sources of evidence.

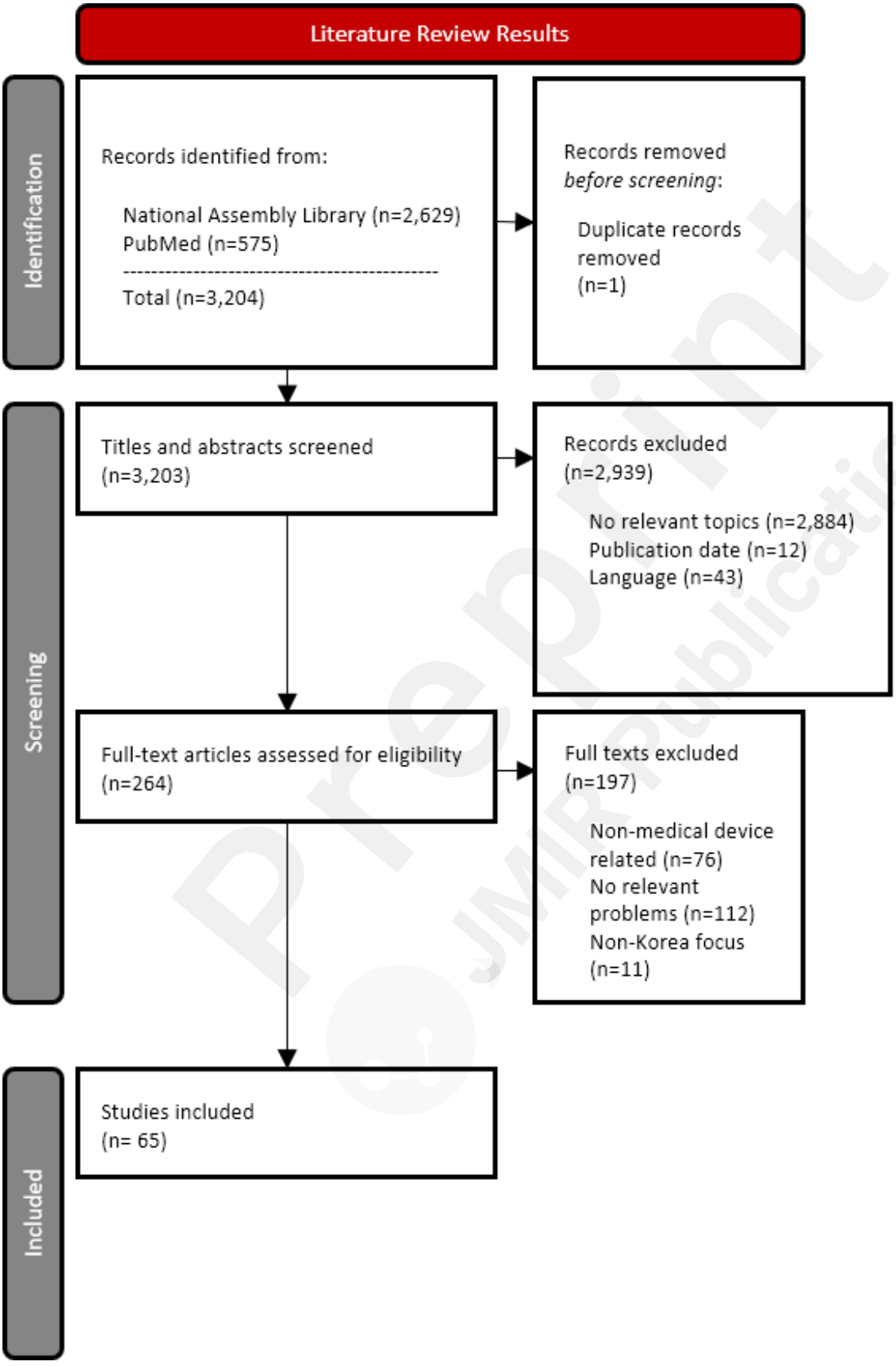

Figure 1. Flow diagram describing the selection of sources of evidence

Synthesis of Results

Overview

After a review of the articles, nine categories were developed post-hoc to describe trends in Korean medical device development (Figure 2). The 9 groups included “digital therapeutics,” “virtual reality (VR) & artificial intelligence (AI),” “machine-learning & robot,” “gaming & visual contents,” “eye-feedback & movement intervention,” “EEG & neurofeedback,” “cognitive behavioral therapy & working memory,” “diagnosis & rating scale,” and “musical, literary therapy & MBSR.” These 9 groups were recategorized into two big groups: “digital therapeutics” and “traditional therapy.”

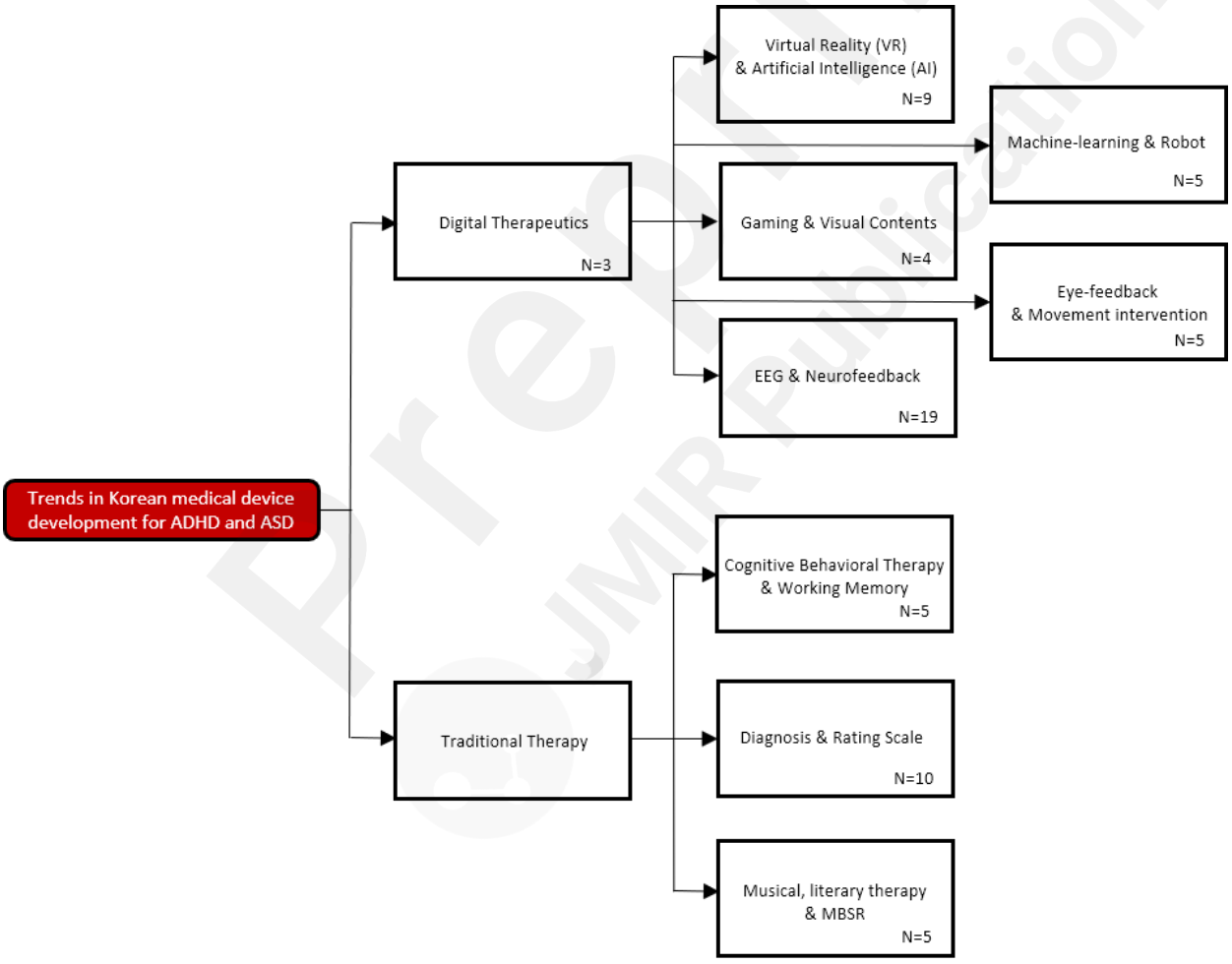

Figure 2. 9 Groups of the trends in Korean medical device development for ADHD and ASD

Digital Therapeutics

Digital therapeutics is a broad category that refers to high-quality software, which is digital

technologies including artificial intelligence (AI), virtual reality (VR), augmented reality (AR), applications, and wearable devices, that provides evidence-based therapeutic interventions to patients to prevent, manage, or treat medical disorders or diseases.[13] Digital therapeutics is one of the promising methods of interventions, treatments, and diagnosis for ADHD and ASD in Korea. Two dissertations[14,15] and one research report[13] described digital therapeutics. Several specific types of digital therapeutics, such as AI, machine learning, and VR, will be further discussed in detail in other groups below.

The digital healthcare market is consistently growing in Korea, especially since the COVID-19 pandemic has facilitated online treatments and health communication. The Korean government has suggested diverse policies to promote the digital healthcare industry. In April of 2022, 10 digital therapies have been approved by the Ministry of Food and Drug Safety of the Republic of Korea (MFDS) to conduct clinical trials.[13] However, none of them have been approved as a medical device.[13] Although the Korean digital therapeutics industry is in a beginning stage of development, the digital therapeutics market is highly promising in Korea given policy support and attention from the Korean government.

For instance, digital therapeutics is applied to treatments and education for students with ADHD.[14,15] Digital therapeutics is emphasized as a new treatment approach for children and adolescents with ADHD. A significant improvement was found in groups using digital therapeutics compared to control groups.[15] Educational materials about digital therapeutics were also highlighted for elementary school teachers educating students with ADHD. The use of Korean medical devices for ADHD and ASD reflects the attention to educating teachers about the importance and functions of digital therapeutics, as well as its direct application to those with ADHD or ASD.

Virtual Reality (VR) & Artificial Intelligence (AI)

VR and AI are categorized into digital therapeutics. Both technologies are promising tools that recent studies have highlighted their potential.[16,17] VR and AI were mentioned in 9 articles. Two government

R&D project reports,[18,19] 4 peer-reviewed articles,[17,20-22] 2 dissertations,[16,23] and 1 interview [24] described medical devices for ADHD and ASD using VR and/or AI.

Although the fundamental treatment method for ADHD is medication, behavioral problems are treated by cognitive behavioral therapy.[24] However, traditional cognitive behavioral therapy has limited accessibility in clinical settings due to additional time to visit hospitals, healthcare personnel, and relevant resources.[24] In this circumstance, VR technology has a big advantage in solving these limitations by enabling real-time simulations and virtual training.[24] VR-based diagnosis of ADHD is also considered as accurate and objective results given that the model is based on virtual reality settings, while the traditional diagnosis relies on verbal interviews.[23] Furthermore, virtual social interactions allow repetitive practice for anger recognition, anger regulation, and social problem-solving.[21] This VR-based training helps control their aggressive and impulsive behaviors.[21] Some recent studies also indicated that VR-based interventions for ADHD can prevent potential crime, especially for young people with ADHD.[21,22] An AI-automated diagnosis system for diagnostic classification and automated detection based on the bio-signals of ADHD was introduced for the prediction, suppression, and prevention of adolescent recidivism.[22]

To enhance the efficiency of treatment and diagnosis of ADHD and ASD, VR technologies are often integrated with AI to predict, analyze, and define different types of data from patients and users.[16-17] For example, a device using a gradient-boosted decision tree algorithm was evaluated to test the accuracy of its AI-based software, when healthcare providers diagnose ASD in children aged 18-72 months.[17] The study found that an increased number of children with ASD were able to be diagnosed in a primary care setting, potentially promoting early intervention and treatment.[17]

Following the trends of the combined technologies with VR and AI, research and government R&D projects have studied possible medical device models for people with ADHD or ASD.[18-20,23] The Korea Electronics Technology Institute conducted a project to develop VR/AR platform technology based on bio-signal for the mental health of kids/silver generation.[19] Seven types of VR, 6 types of

AR mental health content, a mental-care cloud platform, wireless transfer technology for 4k video streaming, and systems to measure and analyze bio-signals were developed throughout the project.[19] These VR/AR technologies can be broadly applied to mental health VR/AR platform services at mental health clinics in Korea.[19] This application also positively impacts the Korean online content industry beyond the Korean medical device industry.

Medical VR/AI technologies were interweaved with IT and life care content markets.[20] Regarding ADHD treatments, contents and systems utilizing immersive and vivid exposure in virtual settings have been actively tried.[20] The system virtually provides the actual circumstances where people with ADHD can be trained through sensory, cognitive, and linguistic simulations.[20] With a similar purpose, the Office of Research Affairs at Yonsei University conducted a project to develop mobile VR neuropsychological batteries and an AI-based database of early diagnosis and promotion systems using digital phenotypic modeling.[18] The developed device was based on a multilayer platform integrating emotions, social ability, and neurological information.[18] Both devices target vulnerable populations with limited access to traditional treatments of ADHD.

The overall trends of Korean medical devices for ADHD and ASD concentrate on improving the current conditions of the medical device application and its usage.[18,23] While most of the traditional approaches require personnel, physical resources, and travel time, VR/AI-based medical devices minimize the requirements.

Machine-learning & Robot

Machine-learning and robot-based medical devices for ADHD and ASD are also included in the category of digital therapeutics. They were found in 5 articles. Two dissertations [25,26] and three journal articles [27-29] addressed its trends.

The importance of early diagnosis is highlighted in many studies about ADHD and ASD.[28,30] To facilitate early diagnosis and ADHD screening, machine-learning and robot-based technologies are utilized as a promising tool. A machine-learning predictive model is one of the solutions to increase

the accuracy of ADHD prediction.[28] As a longitudinal predictive model, several types of machine-learning analysis were applied to predict the future and classify findings, such as supervised learning, LASSO, random forest, gradient boosting, and neural network model.[28] This model identified that children who showed specific risk indicators during infancy and early childhood are likely to be diagnosed as being at risk for ADHD when entering elementary schools.[28] In addition, several robot-based ADHD screening devices have been tested, such as a contactless sensing system, a deep-learning-based classifier, a storyboard content for children, and an automated childhood ADHD classifier.[25,26,29] The contactless sensing system, for instance, quantitatively measures the movements of children with ADHD.[26] These devices automatically detect and analyze behavioral reactions, or/and identify results based on collected data.[25,26,29]

Furthermore, machine-learning and robot-based devices are also applied to interventions. Remote-robot-based interventions are effective in enhancing the level of concentration and encouraging positive learning attitudes among children with severe ADHD symptoms.[27] They recognize a robot as a peer, a good behavioral model, and a learning helper.[27]

The overall observations and findings imply that robot-based models are relatively more attractive in younger ages. Machine-learning systems also have a higher effectiveness and accuracy of screening.

Gaming & Visual Contents

Many types of gaming can be a part of digital therapeutics depending on their medium. Given that a gaming approach has less rejection than others,[31] its utilization is actively discussed in the recent medical device development for ADHD and ASD. Gaming was mentioned in 4 articles. One dissertation,[31] one interview,[32] one journal article,[33] and one research report [34] found their trends in Korean medical device development for ADHD and ASD.

Gaming is applied to various fields today, not just as an entertainment tool.[34] The research found that gaming helps people relieve negative emotions and improves symptoms.[34] The development of gaming items was motivated by one of the limitations that psychiatrists' diagnosis relies on

subjective individual decisions.[32] A gaming device, 'AttnKare,' is a complex equipment that uses a VR test and measures eye movements and patience.[32] The AI in the device analyzes the collected information and makes individual diagnoses.[32]

The cognitive rehabilitation field recently uses computer technology, focusing on basic cognitive function, memory, problem-solving ability, and perception of space-time.[31] This new digital model is personalized to different individuals.[31] Serious game in this field, defined as education-purposed games with entertaining functions,[34] is a promising method that can result in easier and faster positive outcomes both in education and treatment.[31] For example, when comparing responses from two groups using a communication-functional board game or a traditional board game, those who used a communication-functional board game showed a better score in self-control, self-esteem, family function, and peer relationship.[33]

Eye-feedback & Movement Intervention

Eye feedback and movement technologies are often found in ADHD screening devices. Since eye movements are linked to brain areas with neuropsychological functions, such as response inhibition, selective attention, and working memory, their impairments lead to the primary traits of ADHD.[30] Eye feedback and movement intervention also have a complex relationship with the categories above, such as VR/AI, gaming, and machine learning. The information about this category was found in 5 articles. Two dissertations [35,36] and 3 journal articles [30,37,38] described medical devices using eye-feedback and movement intervention.

Using a screening model for ADHD with eye-tracking features and machine learning, 33 eye-tracking features were identified to distinguish children with ADHD from typically developing children.[30] Eye-tracking characteristics have the potential to serve as a reliable marker for compromised neurobiological function in individuals undergoing ADHD screening.[30] The Focus Reaction Time Tests were identified as a valid tool for diagnosing children with ADHD.[37] Given that visual materials tend to be eye-catching and vision accounts for 80% of human recognition,[36] visual

content can also play an important role in developing interventions for ADHD using eye movements. For example, eye-feedback training improves sluggish cognitive tempo, one of the symptoms of ADHD that shows a lack of energy, slowness in behavior or thinking, and drowsiness.[35] A motion-training system with real-time visual feedback also facilitated motion control in children with ASD.[38]

EEG & Neurofeedback

This category discusses electroencephalography (EEG) and neurofeedback. Both concepts are relevant to digital technologies including gaming and machine learning.[39] EEG, a recording of the brain's electrical activity, technology measures brainwaves. Neurofeedback is used to modify brainwaves by providing stimulus in neurofeedback training, which is considered a promising physiological approach for the diagnosis and interventions of neurological disorders, such as ASD and ADHD.[40-49] This topic was mentioned in 19 articles. Two research reports,[49-50] 10 journal articles,[40-43,45,51-55] and 7 dissertations [39,44,46-48,56,57] discussed EEG-based medical devices.

Wearable wireless systems and sensing systems are new potential solutions for diagnosing ASD and ADHD by collecting physiological indicators.[40,53,54] EEG can detect the abnormalities of the neural system related to ASD and ADHD.[40,53,54] The research found that ADHD can be diagnosed by sounds derived from brainwaves, using 1) ADHD diagnosing algorithms developed by EEG brainwaves with several mathematical methods, eyes-open, and resting-state brainwaves, and 2) a sonification algorithm to convert brainwaves to musical sounds.[56]

Convolutional neural network (CNN) is another emerging idea to automatically extract EEG features for medical diagnosis.[39,41] CNN is a neural network modeled after the functioning of the visual cortex, for processing data that contain spatial information.[39] Recent research explores deep-learning-based devices using CNN to effectively classify EEG signals.[41] A deep learning approach using fMRI (Functional Magnetic Resonance Imaging) was also another recent discussion.[39] While previous trials cover the entire brain areas to identify ADHD, the recent study suggests examining specific brain portions related to the classification of ADHD using the deep learning system by demonstrating a

higher level of accuracy.[39]

Neurofeedback is another key topic in interventions for ADHD and ASD. Neurofeedback training is a form of self-regulation therapy for brainwaves, utilizing the concept of operant conditioning.[44] During brainwave measurement, patients receive visual or auditory feedback on cortical activity to normalize brain function by inhibiting or reinforcing specific frequency ranges of brainwaves.[44] Neurofeedback enables them to receive real-time feedback on their brainwave states and engage in training to regulate brainwaves as desired.[44] Many studies claim that neurofeedback training positively impacts children with ADHD.[44-48]

Neurofeedback training positively impacted children with ASD by improving their attention and abnormal brainwaves.[44] Furthermore, neurofeedback training can be applied to those with ADHD.[45-46] Recent research has reported that 30% of people with ADHD with executive function deficits and inhibitory deficits cannot be treated both by medication and cognitive behavioral therapy.[45,52] Neurofeedback training is suggested as one of the promising alternative solutions of medication to improve executive functions, inhibition, and working memory.[45,46,52] Moreover, delayed language development and communication ability among children with ADHD can be improved by neurofeedback training.[47,48] In fact, parents having children with ADHD have reported positive outcomes after using neurofeedback training.[52] These trends imply that neurofeedback models can be more effective when they are integrated with different digital items, such as VR, gaming, and AI.[48]

As an example of complex medical devices for interventions of ADHD, research suggested a robotic intervention education using neurofeedback.[42] In this program, students with ADHD were encouraged to craft a robot and control its movements using brainwave signals.[42] This program aimed to enhance the level of concentration as well as treatment of ADHD with a children-level storyline.[43] The satisfaction was evaluated positively, while a general operation process had a few comments on further development.[43] In addition, CNN is also used to diagnose ADHD in young children aged under 16, who are too immature to perform self-diagnosis or use medical equipment.[51]

Gaming content is utilized to increase the objectivity and accuracy of ADHD diagnosis, and collected EEG data is classified based on the CNN model.[51]

With a similar context of education using neurofeedback, the Korea Institute of Curriculum and Evaluation (KICE) conducted a 2-years project to design and implement brain-based training for children with ADHD.[49,50] Neuroeducation was applied to the project to explore neuroeducational research tools, including EEG, positron emission tomography, and fMRI.[50] fMRI was especially highlighted to indirectly measure brain activity status by quantifying cerebral blood volume, cerebral blood flow, and blood oxygen saturation.[50] The training program, named KICE Working memory Enhancement Program (K-WEP), involves altering brain function through interaction with the environment which leads to improved cognitive functions.[49,50] The K-WEP showed positive outcomes among children with ADHD in a clinical trial by enhancing cognitive abilities and demotivating behavioral problems.[49]

Traditional Therapy

Traditional therapy mostly does not use medical devices. The three categories below examined the trends in traditional treatments and diagnosis for ADHD and ASD.

Cognitive Behavioral Therapy & Working Memory

Cognitive behavioral therapy (CBT) and working memory fundamentally aim to improve cognitive ability as well as attention deficits and impulsive behaviors.[58-60] CBT focuses on a behavioral intervention [59] while working memory refers to a cognitive function that involves temporarily holding or manipulating information for a short period.[58,61] They were found in 5 journal articles.[58-62]

CBT can be a more effective intervention for adults with ADHD than children with ADHD because adults relatively have a higher cognitive ability and reflective thinking.[59] CBT demotivated people to think about ADHD and think negatively, while knowledge of ADHD was increased.[59] CBT can also be developed as a self-monitoring cognitive training program to help children with ADHD regulate

and monitor their thoughts and behaviors during task execution.[60] This approach focuses on individual behavioral problems as well as individual thinking processes, which can be applied to diverse treatments and research on ADHD.[62]

A working memory training program is another method to reduce impulsive behaviors and hyperactivities.[58] Given that delivery forms of information and cognitive ability are correlated with one another, previous research findings indicated that delivery forms of information influence outcomes of working memory training programs.[61] This statement implies that a better performance is presented when performing a preferred delivery form of information,[61] meaning that understanding a target population's preference for communication matters in working memory training.

Diagnosis & Rating Scales

While many studies discuss the recent trends in medical devices for ADHD and ASD mostly focusing on digital technologies, traditional methodologies of diagnosis and rating scales are still discussed to update the standards and guidelines. Diagnosis and rating scales were examined in 11 articles. One news release,[63] 7 Journal articles,[1,63-69] and 2 dissertations [70,71] addressed the current trends in diagnosis and rating scales of ADHD and ASD.

ADHD diagnosis should be systematically approached through diagnostic algorithms to make safe and accurate decisions.[69] Multiple factors including age, gender, and individual perceptions of ADHD, need to be considered, and the diagnostic decision needs to be based on the Diagnostic and Statistical Manual of Mental Disorders, 5th edition (DSM-5).[69] The International Classification of Diseases, 10th Revision (ICD-10) is also discussed.[65,69] Although a few differences are presented between DSM-5 and ICD-10, both models focus on attention deficits, hyperactivities, academic and social difficulties, and impulsive behaviors.[69] ADHD diagnosis usually refers to the DSM-5, while public health statistics and materials are based on ICD-10.[65] ICD-10 has more strict standards of ADHD diagnosis than DSM-5 by recognizing all three categories: attention deficits, hyperactivity, and impulsion.[65]

In addition to DSM-5 and ICD-10, the Children Behavior Check List (CBCL) is a self-report assessment scale developed to evaluate various emotional and behavioral problems of children and adolescents through reports from parents or close adults in their environment.[70] In Korea, the US version, CBCL 4-18 in 1991, was standardized and first introduced as the K-CBCL, and K-CBCL 6-18 is the recent version for parents.[68,70]

ADHD screening and evaluation were performed in in-person interviews at hospitals, mental health centers, and school counseling offices.[66] Two interview tools are utilized: Diagnostic Interview Schedule for Children-IV (DISC-IV) and Kiddie-Schedule for Affective Disorders and Schizophrenia-Present and Lifetime Version (K-SADS-PL-K).[66] While DISC-IV is a structured interview tool that can be administered by general people, K-SADS-PL-K is a semi-structured tool that should be administered by trained evaluators.[66] With K-SADS-PL-K, recent research tried the Advanced Test of Attention (ATA), consisting of visual tests and auditory tests that present target and non-target stimuli at regular intervals, designing that subjects are instructed to respond only to the target stimuli.[71] However, the accuracy distinguishing a group with ADHD and another group without ADHD was not high, which suggests limitations in using ATA as a diagnostic tool for confirmation.[71]

Given that ADHD symptoms tend to be presented at an early age, parents' and teachers' knowledge and perception of ADHD greatly impact their children's diagnosis and intervention.[1] Interestingly, the ratings of parents and teachers about symptoms of children with ADHD had no significant correlations, and parents' ratings and DISC were not matched.[1] On the other hand, the rating of teachers was consistent and showed a high correlation with DISC.[1] These findings imply that DISC and the rating of teachers are more reliable and consistent than the rating of parents.[1]

In case childhood ADHD may persist into adulthood, the Korean Adult ADHD Rating Scale (K-AARS) was developed for monitoring and screening treatment of adults with ADHD.[64] Inattention was recorded as the most general symptom of ADHD in adulthood.[64] K-AARS is expected to

effectively rate difficulty in emotional control and disorganization, such as inattention, hyperactivity, and impulsivity.[64] This rating scale was also suggested to extend its range of usage to adolescents, embrace gender differences, and identify screening and rating scales respectively.[67] In this light, traditional rating scales are consistently developed. For example, one of the recent rating scales is a tactile stimulation distribution device to quantify exercise and mindfulness-based stress reduction (MBSR).[70] The details of MBSR and other traditional therapies are discussed in the last category below.

Musical, Literary Therapy & MBSR

MBSR, musical, and literary therapy described below were developed to increase the effectiveness of screening and intervention for children with ADHD. They were addressed in 5 articles. One journal article [72] and 4 dissertations [73-76] discussed how they were recently shaped.

The tactile stimulation distribution device was motivated by mindfulness, MBSR, and CBT and scientifically demonstrated a level of concentration of subjects.[72] The quantified data of stimulation was compared to the cognitive outcomes of subjects.[72] The correlative data was referred to as concentration, and the opposed data was considered as a distraction.[72] This logic was also supported by left- and right-brain activities.[72] In fact, a MBSR-based program showed a significant improvement in reducing inattention, stress, and anxiety in college students with ADHD.[72]

Another approach to intervention for children with ADHD is literary therapy based on social skills training (SST).[72] The program was designed to train them to improve a social relationship between peers and adults and engage in group activities at home and school.[72] Using photo cards and photo books to inspire their imagination and creativity, the general symptoms of ADHD decreased with a significant improvement in emotional and mental stability.[72]

Musical therapy is also used for screening and intervention of ADHD. Screening ADHD using musical therapy aims to strategize a plan of treatment by understanding individual conditions and the goals of treatments.[73] This screening is essential to comprehend how musical reactions can be

utilized to improve symptoms when music attracts clients' changes.[73] While musical therapy screening is designed for a broad understanding of individuals, interventions using musical therapy have a specific purpose to target specific symptoms. A rhythm-based musical intervention was developed to enhance timing control of children with ADHD.[74] The protocol contributed to controlling motor timing and perceived timing using a metronome, guiding a proper speed of response to suggested stimuli in the environment.[74] Carl Orff's pedagogics, focusing on improvisatory performance with observation, imitation, exploration, and music literacy, is another type of intervention using musical therapy.[75] This program required small group activities, which encouraged social interaction with different individuals.[75] Furthermore, improvisatory work improved inattention, and imitating musical expression demotivated hyperactivities.[75] These findings indicate that musical therapy is a highly effective method both for screening and intervention in children with ADHD.

DISCUSSION

Principal Results

This study conducted a review of the literature to reduce gaps in the research related to medical device use and development in Korea for the diagnosis and management of ADHD and ASD. The trends in Korean medical device development for ADHD and ASD are categorized into 2 major groups with 8 subgroups in total. Digital therapeutics utilizing AI, machine learning, and EEG technologies account for the biggest portions of development in Korea, rather than traditional therapies. Given that both ADHD and ASD are neurological disorders, emerging medical device technologies especially focus on EEG and neurofeedback. Different types of digital models are combined or applied to understand brain activities and brainwaves.

In this vein, future development of medical devices for ADHD and ASD is predicted to heavily rely on digital technologies. As digital medical devices are emerging trends in Korea, they can also be

integrated with traditional therapies. For example, the rhythm-based musical intervention can be applied to a gaming device for ADHD which can also detect particular brainwaves and provide real-time neurofeedback. Recent research has reported that traditional therapies including musical features and MBSR have succeeded in screening and intervention for ADHD and ASD. Understanding their strengths and integration with digital medical devices will double the effectiveness of screening and intervention outcomes.

However, this growing transformation is faster than people's perception of their development. To follow the trends and learn digital literacy for new digital medical devices, training programs about up-to-date digital devices for ADHD and ASD are recommended, especially for parents and teachers to relieve tension in school. The active application of digital devices in school settings is also expected to enable early diagnosis and treatment for students with ADHD or ASD. Since parents and teachers are primary and secondly important people for children with ADHD or ASD,[1] education for them is essential to implement new medical devices into routine care in the real world.

In addition to the application of digital devices, traditional therapies are utilized for children with ADHD or ASD in school settings. While digital therapeutics is a promising tool today, traditional therapies have still demonstrated their efficacy in screening and interventions. The research presented real-world case studies of the applications that showed positive outcomes and high reliability.[72-75] Extending this idea, future research could discuss the potential efficacy of integrating digital therapeutics and traditional therapies for the diagnosis and interventions of ADHD and ASD. Furthermore, potential ethical dilemmas associated with the use of medical devices for these conditions are another important topic to study. Understanding negative effects and limitations of different types of devices in clinical settings will also guide the direction of future development of medical devices for ADHD and ASD.

Limitations

The first limitation of this study is that many articles had small sizes of populations to conclude their findings, which makes it hard to generalize the outcomes. To define the accurate trends in Korean medical device development for ADHD and ASD, additional studies conducted with larger populations should be examined. In addition, a lower number of articles specifically discussed medical devices for ASD while a majority of the selected articles focused on ADHD. Further research on medical devices for ASD should be studied to understand the need for medical devices for ASD. These studies expect to promote early diagnosis and interventions, which lead to reduced prevalence rates for both ADHD and ASD. Moreover, given a number of emerging medical device areas, a majority of the selected articles were dissertations. Peer-reviewed journal articles are required in the future to examine in-depth trends in specific medical devices for ADHD and ASD.

Conclusions

In conclusion, this study aims to provide significant insight to understand the recent trends in Korean medical device development focusing on medical devices for ADHD and ASD. Emerging digital medical devices and those integrated with traditional therapies are some of the important solutions to reducing the prevalence rates of ADHD and ASD in Korea by promoting early diagnosis and intervention. Furthermore, their application will relieve pressures on teachers and school-based special education programming by providing direct supporting resources to students with ADHD or ASD. Educating parents and teachers about the trends in relevant medical devices also matters in further responses to their children.

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Conflicts of Interest

None declared.

REFERENCES

1. Lee Y., Bae S, Hong S, et al. ADHD □□ □□□□□ □□ □□ □□ □□□. □□·□□□□□□. A Study on Agreement between Parent's and Teacher's Ratings According to ADHD Screening. 2014;30(4):387-400. http://dspace.kci.go.kr/handle/kci/762145?show=full.
2. Kim K. □□□,□□□ □□□."..□□□ □□ 2 □ □□□□ '□□□□' □□ □□□ □□. Korea Teachers and Education Workers Union, don't participate today either".. Teachers hold a large-scale rally at 2 PM to 'improve teaching rights' at Gwanghwamun Document. *Pennmike.* July 29, 2023. https://www.pennmike.com/news/articleView.html?idxno=67022.
3. Kim D. "00 □□ □□.." □□□ □□ □□, '□□ □□□'□ □□□ □□ □□□ □□ □□□. She was born in 2000..." Seoi Elementary School teacher commits suicide, new faculty member loses life due to 'truthful parents.' *Newssocdak.* July 19, 2023. https://www.newssocdak.com/news/articleView.html?idxno=10534.
4. Choi J. "□□ □□ □□□"…□□ 1 □□ □□□□ □□ □□□□. "I can't hurt"…Special education in schools with only one teacher in mind. *Yonhap News.* July 31, 2023. https://www.yna.co.kr/view/AKR20230731104000061.
5. Attention-Deficit/Hyperactivity Disorder. National Institute of Mental Health (NIMH). https://www.nimh.nih.gov/health/topics/attention-deficit-hyperactivity-disorder-adhd#:~:text=Attention%2Ddeficit%2Fhyperactivity%20disorder%20(,interferes%20with%20functioning%20or%20development.
6. Autism spectrum Disorder. National Institute of Mental Health (NIMH). https://www.nimh.nih.gov/health/topics/autism-spectrum-disorders-asd.
7. HIRA Bigdata Open portal. □□□ ADHD □□□□. ADHD treatment status by region. Published July 31, 2023. https://opendata.hira.or.kr/op/opb/selectRfrmList.do?sno=0&rfrmTpCd=&searchCnd=&searchWrd=%EC%A7%84%EB%A3%8C%ED%98%84%ED%99%A9&pageIndex=1.
8. National Health Insurance Service. ADHD □□□□ □(F900). Number of patients treated for ADHD (F900). https://www.data.go.kr/data/15123392/fileData.do
9. □□□□□ □□□□□□□. Ministry of Health and Welfare of South Korea Division of Services for Persons with Disabilities. *2021* □ □□□□□ □□□□ □□□□. *Announcement of the results of the 2021 Survey on the Developmental Disabilities.* Ministry of Health and Welfare of South Korea; 2022: 5. Available at: https://www.mohw.go.kr/board.es?mid=a10503000000&bid=0027&tag=&act=view&list_no=372831&cg_code=#:~:text=%2D%20%EC%9D%B4%20%EC%A4%91%20%EC%A7%80%EC%A0%81%EC%9E%A5%EC%95%A0%EC%9D%B8%EC%9D%80,%EB%A7%8C%20%EB%AA%85(12.8%25)%EC%9D%B4%EB%8B%A4.&text=(%EC%9E%A5%EC%95%A0%EB%B0%9C%EA%B2%AC)%20%EB%B0%9C%EB%8B%AC%EC%9E%A5%EC

%95%A0%EC%9D%B8%EC%9D%98,%EC%9E%A5%EC%95%A0%EB%8A%94%207.9%EC%84%B8%EB%A1%9C%20%EB%82%98%ED%83%80%EB%82%AC%EB%8B%A4. Accessed September 6, 2022.

10. □□□□□ □□□□□□□. Ministry of Health and Welfare of South Korea Division of Services for Persons with Disabilities. *2021 □ □□□□□ □□□□ □□ □□. Main indicators of the 2021 survey on the status of people with developmental disabilities.* Ministry of Health and Welfare of South Korea; 2022: 12. Available at: https://www.mohw.go.kr/board.es?mid=a10503000000&bid=0027&tag=&act=view&list_no=372831&cg_code=#:~:text=%2D%20%EC%9D%B4%20%EC%A4%91%20%EC%A7%80%EC%A0%81%EC%9E%A5%EC%95%A0%EC%9D%B8%EC%9D%80,%EB%A7%8C%20%EB%AA%85(12.8%25)%EC%9D%B4%EB%8B%A4.&text=(%EC%9E%A5%EC%95%A0%EB%B0%9C%EA%B2%AC)%20%EB%B0%9C%EB%8B%AC%EC%9E%A5%EC%95%A0%EC%9D%B8%EC%9D%98,%EC%9E%A5%EC%95%A0%EB%8A%94%207.9%EC%84%B8%EB%A1%9C%20%EB%82%98%ED%83%80%EB%82%AC%EB%8B%A4.

11. Lee S, Lee S, J, Yoon S. □□ □□□ □□□ □□□□ □ □□ □□□ □□ □□ □□ □□ □□: □□□ □□□ □□□ □□□□. A Study of Support System for Facilitating Early Diagnosis and Intervention for Young Children with Autism Spectrum Disorders: Based on the Experiences and the Perceptions of Parents. *Journal of the Korean Association for Persons With Autism*. 2013;13(1):167-199. http://kmbase.medric.or.kr/KMID/08949201301300101 67.
12. Skutle A, Bu ETH, Jellestad FK, et al. Early developmental, temperamental and educational problems in ‘substance use disorder’ patients with and without ADHD. Does ADHD make a difference? *Addictive Behaviors Reports*. 2015;2:13-18. doi:10.1016/j.abrep.2015.03.001
13. Son J, Yang S, Jung I. □□□ □□□ □□□ □□. *Current status and outlook for digital therapeutics*. Korea Insurance Research Institute; 2023:94. Available at: https://dl.nanet.go.kr/search/searchInnerDetail.do?controlNo=MONO12023000037043
14. Choi E. *ADHD □ □□□ □□□ □□□ □□ □□□ □□□ □□ □□ □□. Study of Textbooks on the Principles of Digital Therapeutics to Respond to ADHD and Digital Drama*. [Doctoral dissertation]. Jeju, ROK: Jeju National University; 2022.
15. Lee D. □□□□□□□□ □□ □□□□□ □□□□□□*(ADHD)* □□ □□*:* □□□ □□□□ □ □□□□. *The Efficacy of Digital Therapeutics for the Treatment of Attention Deficit Hyperactivity: A Systematic Review and Meta-analysis.* [Master’s thesis]. Seoul, ROK: Chung-Ang University; 2022.
16. Son H. *Towards Standardizing Attention-Deficit/Hyperactivity Disorder Diagnosis- A Virtual Reality, Artificial Intelligence Application*. [Master’s thesis]. Seoul, ROK: Sungkyunkwan University; 2022.
17. Megerian JT, Dey S, Melmed RD, et al. Evaluation of an artificial intelligence-based medical device for diagnosis of autism spectrum disorder. *Npj Digital Medicine*. 2022;5(1). doi:10.1038/s41746-022-00598-6
18. Yonsei University Office of Research Affairs. □□□ *VR* □□□□□□□ □□ □ □□□□□□ □□□ □□□□□□ □□□□ □□□ □□□□ □□□□ *AI* □□ □□□□/□□ □□□ □□ *. Development of mobile VR neurocognitive battery and establishment of database, implementation of AI-based early diagnosis/prevention system for cognitive control vulnerable groups utilizing digital representation modeling*. Ministry of Science and ICT; 2019:52. Available at: https://dl.nanet.go.kr/search/searchInnerDetail.do?controlNo=MONO12022000027327
19. Korea Electronics Technology Institute. □□/□□ □□□ □□□□□ □□ □□□□ □□□ □□□ *VR/AR* □□□ □□. *VR/AR platform technology based on bio-signal for mental health of kids/silver generation.* Korea Creative Content Agency; 2020:238. Available at: https://dl.nanet.go.kr/search/searchInnerDetail.do?controlNo=MONO12022000016473

20. Park JW, Jin CS, Jeong WJ, et al. Design and implementation of VR-Based Life Care contents for Attention Deficit Hyperactivity Disorder (ADHD). *The Journal of Korean Institute of Next Generation Computing*. 2019;15(5):84-91. https://www.kci.go.kr/kciportal/ci/sereArticleSearch/ciSereArtiView.kci?sereArticleSearchBean.artiId=ART002520634.
21. Ryu CH. Implications of VR-Based Psychotherapeutic Effects for ADHD and CD among Adolescents. *Korean Association of Addiction Crime*. 2022;12(1):25-55. doi:10.26606/kaac.2022.12.1.2
22. Ryu CH, Hwang YS. Artificial intelligence analysis of bio-signals for automated detection and automated diagnosis of ADHD and CD. *Asian Forum for Corrections*. 2021;15(3):87-118. doi:10.46626/affc.2021.15.3.4
23. Yoo SH. *Virtual reality based digital therapeutics system for diagnosing attention-deficit hyperactivity disorder*. [Master's thesis]. Seoul, ROK: Sungkyunkwan University; 2020.
24. Kim JJ. □□□□ □□ □□□□, □□□ □□ □□□ □. To strive for the universalization of virtual reality therapy programs. *Smart Device Trend Magazine*. November 30, 2019; 37(1): 42-45.
25. Yeom J. *Supervised classification of childhood ADHD using robot-assisted tests*. [Master's thesis]. Seoul, ROK: Sungkyunkwan University; 2018.
26. Lee DW. *Development of a contactless sensing system and a classifier using deep learning for robot-based ADHD screening*. [Doctoral dissertation]. Gwangju, ROK: Gwangju Institute of Science and Technology; 2022.
27. Kim S, Kim J, Lee H, et al. Exploring the Applicability of Tele-presence Robot Intervention for at-Risk Children with ADHD. *Journal of Special Education & Rehabilitation Science*. 2016;55(3):415-434. doi:10.15870/jsers.2016.09.55.3.415
28. Lee D, Jang HI, Kim HJ, et al. Development of a Machine-Learning Predictive Model for First-Grade Children at Risk for ADHD. *Korean J of Childcare & Education.* 2021;17(5):83-103. https://doi:10.14698/jkcce.2021.17.05.083
29. Shin YW, Lee HS, Kim SB, et al. Exploring the Performance Difference on the Active Based Task with a Robot for ADHD Screening. *Journal of Emotional & Behavioral Disorders*. 2018;34(1):113-133. doi:10.33770/jebd.34.1.7
30. Yoo JH, Chen K, Lim JS, et al. Development of an innovative approach using portable eye tracking to assist ADHD screening: a machine learning study. *Frontiers in Psychiatry*. 2024;15. doi:10.3389/fpsyt.2024.1337595
31. Park W. *To improve the concentration of ADHD children study on functional games.* [Master's thesis]. Daegu, ROK: Daegu University; 2019.
32. Jung T. ADHD, □□□□ □□□□ □□□ □ □□. ADHD can be treated like playing a game in daily life. *NOW.* February 28, 2022; 376(3): 44-45.
33. Lee YJ, Lim J. A Study on the Effect of Communication Functional Board Game on Self-control, Self-esteem, Family Function and Peer Relationship of ADHD Children Dong-Eui Lee. *Dong-eui University Local Research Institute*. 2018;35(1):99-134. https://www.kci.go.kr/kciportal/ci/sereArticleSearch/ciSereArtiView.kci?sereArticleSearchBean.artiId=ART002414997.
34. Sungkyunkwan University Cooperation Center. *A study on the therapeutic applications of digital games.* Korea Creative Content Agency; 2020:291. Available at: https://dl.nanet.go.kr/search/searchInnerDetail.do?controlNo=MONO12021000024297
35. Kim G. *The characteristic of attentional networks in sluggish cognitive tempo: the effect of eye-feedback training on orienting attention in individuals with SCT*. [Doctoral dissertation]. Seoul, ROK: Chung-Ang University; 2019.
36. Kim E. *Development of movement intervention visualization contents to improve behavior of ASD and ADHD*. [Master's thesis]. Incheon, ROK: Inha University; 2018.

37. Yoo J, Kim G. A Preliminary Study on the Development of the Focus Reaction Time Tests. *Journal of Developmental Disabilities.* 2015;43(3):59-74. https://www.kci.go.kr/kciportal/ci/sereArticleSearch/ciSereArtiView.kci?sereArticleSearchBean.artiId=ART002040902

38. Sandbank M, Cascio CJ. Using a motion-tracking device to facilitate motion control in children with ASD for neuroimaging. *Developmental Neurorehabilitation*. 2018;22(6):365-375. doi:10.1080/17518423.2018.1502831
39. Kim T. *Deep learning approach on the improvement of diagnosing ADHD with fMRI*. [Master's thesis]. Seoul, ROK: Hanyang University; 2022.

40. Alhassan S, Soudani A, AlMusallam M. Energy-Efficient EEG-Based scheme for autism spectrum disorder detection using wearable sensors. *Sensors*. 2023;23(4):2228. doi:10.3390/s23042228
41. Kim MG. Machine learning-based EEG classification for assisting the diagnosis of ADHD in children. *Journal of Korea multimedia society.* 2021;24(10):1336-1345. https://dl.nanet.go.kr/search/searchInnerDetail.do?controlNo=KINX2021257379

42. Nam HW. Effect of Neurofeedback based Robotic Invention Education on Attention Ability of ADHD Children. *Asia-pacific Journal of Multimedia Services Convergent with Art, Humanities, and Sociology*. 2016;6(6):273-283. doi:10.14257/ajmahs.2016.06.33
43. Nam HW, Mun YH. Development of Neurofeedback based Robotic Invention education Program for ADHD children. *Asia-pacific Journal of Multimedia Services Convergent with Art, Humanities, and Sociology*. 2015;5(6):429-438. doi:10.14257/ajmahs.2015.12.18
44. Lee Y. *The effects of the neurofeedback training on the attention in adolescents with autism spectrum disorders*. [Master's thesis]. Seoul, ROK: Hanyang University; 2013.

45. Yoon SM, Kwack YS. The treatment effect of neurofeedback training on executive Function in Attention-Deficit Hyperactivity Disorder. *Journal of the Korean academy of child and adolescent psychiatry*. 2015;26(1):45-51. doi:10.5765/jkacap.2015.26.1.45
46. Kim MA. *The effects of neurofeedback training and executive function improvement programs on attention and brain function quotient of elementary school children.* [Master's thesis]. Daegu, ROK: Daegu National University of Education; 2017.
47. Lee HR. *Effects of neurofeedback brain wave training on the attention concentration and language development of children delayed in language development.* [Master's thesis]. Daegu, ROK: Daegu University; 2020.
48. Lee MR. *The effect of EEG training through neurofeedback on attention and pragmatic language ability in children with ADHD prone language delay.* [Master's thesis]. Daegu, ROK: Daegu University; 2022.
49. Hong S, Lee M, Jin G. *ADHD □□□ □□ □□□ □□ □□□□ □□□ □□. Validation of the effectiveness of brain-based training programs for ADHD students.* Korea Institute of Curriculum and Evaluation; 2014:154. Available at: https://dl.nanet.go.kr/search/searchInnerDetail.do?controlNo=MONO1201543162
50. Hong S, Lee M, Jin G. *ADHD □□□ □□□ □□ □ □□□ □□ □□□□ □□. Development of brain imaging diagnosis and brain-based training programs for ADHD students.* Korea Institute of Curriculum and Evaluation; 2013:235. Available at: https://dl.nanet.go.kr/search/searchInnerDetail.do?controlNo=KINX2015112913
51. Kim DH, Park SM, Kim DH. The classification scheme of ADHD for children based on the CNN model. *Korea Electronics and Telecommunications Society.* 2022;17(5):809-814. doi:10.13067/JKIECS.2022.17.5.809

52. Kim JI, Yoon S, Oh HK, et al. Clinical Significance for Neurofeedback Training of Children

with Attention-Deficit/Hyperactivity Disorder. *Journal of Korean Neuropsychiatric Association*. 2015;54(1):62. doi:10.4306/jknpa.2015.54.1.62

53. Siddharth, Patel AN, Jung TP, Sejnowski TJ. A wearable Multi-Modal Bio-Sensing system towards Real-World applications. *IEEE Transactions on Bio-medical Engineering/IEEE Transactions on Biomedical Engineering*. 2019;66(4):1137-1147. doi:10.1109/tbme.2018.2868759
54. Bhattacharyya NK, Singh S, Banerjee A, et al. Integration of electroencephalogram (EEG) and motion tracking sensors for objective measure of attention-deficit hyperactivity disorder (MAHD) in pre-schoolers. *Review of Scientific Instruments Online/Review of Scientific Instruments*. 2022;93(5). doi:10.1063/5.0088044
55. Ryu CH. A study on the clinical usefulness of EEG and QEEG measurements for the diagnostic criteria of ADHD. *Korean association of addiction crime review*. 2021;11(3):23-45. doi:10.26606/kaac.2021.11.3.2
56. Kang GM. *Brain music as a potential tool for diagnosing attention-deficit/hyperactivity disorder (ADHD)*. [Master's thesis]. Daejeon, ROK: Korea Advanced Institute of Science & Technology; 2013.
57. Ryu MH. *Effects of neurofeedback training on EEG, continuous performance task, and ADHD symptoms in ADHD-prone college students*. [Master's thesis]. Jeonju, ROK: Jeonbuk National University; 2015.
58. Jang YI, Park HY. Development and Application of the Working Memory Improvement Program for Children with ADHD in the First Grade Elementary School. *Journal of learner-centered curriculum and instruction*. 2020;20(14):879-904. doi:10.22251/jlcci.2020.20.14.879
59. An JS, Kim JM, Jung HN. Cognitive Behavioral Therapy for College Students with ADHD Tendencies. *(The)Korean journal of health psychology*. 2016;21(4):699-718. doi:10.17315/kjhp.2016.21.4.002
60. Lee KH. The Effects of Self-monitoring Cognitive Functions Training Program on the Attention-Concentration Ability and the Hyperactivity of the Children with ADHD Tendency. *The Korean Society of Emotional and Behavioral Disorders*. 2019;35(4):59-75. doi:10.33770/jebd.35.4.4
61. Hong SJ, Lee MJ, Jung E, et al. Development of working Memory training program for ADHD children and effectiveness verification. *The journal of curriculum and evaluation*. 2015;18(3):209-232. doi:10.29221/jce.2015.18.3.209
62. Park W, Park SJ, Hwang S. Effects of Cognitive Behavioral Therapy on Attention Deficit Hyperactivity Disorder among School-aged Children in Korea: A Meta-Analysis. *Journal of Korean Academy of Nursing*. 2015;45(2):169. doi:10.4040/jkan.2015.45.2.169
63. National Research Foundation of Korea. □□□ □□□ □□ □□ □□□ □□□ □□ □□□□ □□ [□□□□] : □□ ADHD, □□□, □□ □□ □□ □ □□ □□. Success in quantifying the level of attention and concentration through meditation and exercise [electronic data]: Expected to be used in diagnostic tests for ADHD, depression, and dementia in children. *BioIn*. November 28, 2016; https://dl.nanet.go.kr/search/searchInnerDetail.do?controlNo=NONB1201704643
64. Kang T, Kim JW, Bahn GH, et al. Development of Korean Adult ADHD rating Scale. *Journal of the Korean Academy of Child and Adolescent Psychiatry*. 2015;26(4):295-310. doi:10.5765/jkacap.2015.26.4.295
65. Lee SH. A Review on the Diagnosis of ADHD for Special Education. *The Korean Society of Emotional and Behavioral Disorders.*2017;33(4):283-311. doi:10.33770/JEBD.33.4.14
66. Lee S, Choi JW, Kim KM, et al. The Guideline of Diagnosis and Treatment of Attention-Deficit Hyperactivity Disorder: developed by ADHD Translational Research Center *Journal*

of the Korean academy of child and adolescent psychiatry. 2016;27(4):236-266. doi:10.5765/jkacap.2016.27.4.236

67. Lee SH. Current Status and Future Improvement of the Korean ADHD Rating Scale-Ⅳ(K-ARS-Ⅳ). *The Korean Society of Emotional and Behavioral Disorders*. 2015;31(4):227-259. uci: G704-000501.2015.31.4.004
68. Lee SJ, Shin MS, Kim BY, et al. Clinical utility of the Korean version of CBCL6-18 in the diagnosis of Attention-Deficit Hyperactivity Disorder. *Korean Journal of Clinical Psychology*. 2015;34(4):829-850. doi:10.15842/kjcp.2015.34.4.001
69. Lee SH. A Review of Diagnosis and Evaluation Procedure for the Child & Adolescent with Attention Deficit Hyperactivity Disorder. *The Korean Society of Emotional and Behavioral Disorders*. 2020;36(3):1-24. doi:10.33770/JEBD.36.3.1
70. Kim SA. *(The)clinical utility of K-CBCL 6-18 in diagnosing ADHD: focused on children with psychological disorder in child welfare institution*. [Master's thesis]. Seoul, ROK: Sookmyung Women's University; 2016.
71. Park JH. *Clinical application of advanced test of attention as a diagnostic tool in children with attention-deficit/hyperactivity disorder*. [Doctoral dissertation]. Ulsan, ROK: University of Ulsan; 2015.
72. Kim BR. *Effects of mindfulness-based stress reduction (MBSR) program on attention, perceived stress, and anxiety on attention-deficit/hyperactivity disorder (ADHD) prone university students*. [Master's thesis]. Jeonju, ROK: Jeonbuk National University; 2016.
73. Son MG. *A study on development of diagnostic assessment tools of music therapy in children with attention deficit hyperactivity disorder*. [Doctoral dissertation]. Busan, ROK: Dong A University; 2022.
74. Cho MR. *Development of rhythm-based music intervention protocols through timing control in children with ADHD.* [Doctoral dissertation]. Busan, ROK: Kosin University; 2023.
75. Choi YJ. *Development of a Music Program for Improvement of the Mental Concentration and Human Relationship Using Carl Orff's Pedagogics: Centered About the ADHD Students*. [Master's thesis]. Daejeon, ROK: Chungnam National University; 2019.
76. Kim SB. The Effects of Literary Therapy Program based on SST by Using Picture Cards on ADHD of Adolescents for EBD. *Journal of Special Education & Rehabilitation Science*. 2016;55(2):1. doi:10.15870/jsers.2016.06.55.2.1