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K-WISC-V Processing Speed Index Analysis to Verify the Effectiveness of ADHD Symptom Improvement Using Pediatric Digital Content

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Abstract: The most common treatment approach for children diagnosed with attention deficit hyperactivity disorder (ADHD) involves drug therapy; however, persuading parents and motivating children in the early stages of treatment is challenging. Consequently, there is a growing interest among parents of children with ADHD in non-drug therapies. Moreover, recent advancements in information and communication technology have increased the accessibility of digital treatments for ADHD and non-drug therapy content. However, some challenges persist in confirming specific and objective effects. In this retrospective study, we developed game-type digital therapy content for children aged 6–16 years and monitored improvements in ADHD symptoms using the K-WISC-V subtest processing speed index. The analysis revealed that the rate of change in the sum of converted scores on the 14th day was 0.64% lower in the experimental group compared with the control group; however, on the 28th day, the rate of change increased by 6.93%. This suggests that the supplementary use of Neuroworld DTx therapy proved effective for visual enhancement. Furthermore, improvements were observed in visual discrimination, short-term memory, and motor cooperation abilities. Consequently, game-based digital content is an effective adjunctive therapy for children dealing with ADHD.

Keywords: pediatric; ADHD; digital therapy devices; therapeutic supplements

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1. Introduction

Attention deficit hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by inattention and impulsivity, leading to diminished daily functioning. Although the pathogenesis of the disorder is not fully understood, biological factors and genetic influences have been implicated [1,2]. Moreover, although controversial, the parenting process and the child's habits are suggested to minimally influence ADHD development [3]. However, according to existing neurology research, genetic factors are the most important pathological factors, with environmental factors accounting for only 20% of cases [4]. The psychological burden of ADHD on patients is substantial, and the associated anxiety about adapting to daily life is often transferred to their caregivers. Children, in particular, require significant time to collaborate with their guardians. Therefore, ADHD is a collection of abnormalities in concentration and behavior due to decreased brain function, including frontal lobe function, due to various causes [5]. Key issues associated with ADHD in children and adolescents are defiance, aggression, and difficulty maintaining peer relationships [6]. Additionally, approximately 20–30% of children with ADHD symptoms have learning disabilities, leading to serious difficulties during their growing years [7]. Moreover, according to existing research, ADHD symptoms persist from childhood to adulthood in 60% of cases [8]. ADHD in adulthood may be associated with difficulties in forming interpersonal relationships, including social deficits and cognitive impairment, and ADHD is

associated with depressive symptoms [2]. The prevalence of ADHD in school-age children is approximately 5% [9], with a prevalence of 3–7% in American children [10]. In another study, conducted by the National Institute of Special Education in Korea, the incidence rate was 5.7%, indicating differences in prevalence rates between studies. However, considering this prevalence rate, two to three children in a class containing children can be classified as having ADHD [11]. Given the gravity of ADHD owing to its incidence, early detection and treatment are considered crucial [12]. However, not all patients exhibiting aggressive behavior or poor concentration who seek psychiatric evaluation receive an ADHD diagnosis. Accurate diagnosis requires careful consideration of factors such as intentional defiance, influence from home or environment, and lack of parental attention [13].

No direct ADHD tests or brain tests for ADHD diagnosis have been established [14]. Currently, ADHD diagnosis is based on the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) diagnostic criteria and intelligence tests, including behavioral observation in children, the clinical global impression scale, the ADHD rating scale, and the Korean-Wechsler intelligence scale for children (K-WISC-V), which employ questionnaires and rely on expert opinions [15].

The DSM-5 diagnostic criteria and the differential diagnosis consider the mental condition of the child, general health condition, neurological condition, and environmental factors [16]. Among them is the K-WISC-V, a personal intelligence test created in 1939. It is one of the most widely used intelligence tests administered to children and adolescents aged 6–16 years and 11 months [17]. The WISC can evaluate a child's overall intellectual ability through a full-scale intelligence quotient (FSIQ) test and can comprehensively measure cognitive ability [18]. Objective evaluations, such as the evaluation of symptoms using questionnaires and psychological status, can help with the diagnosis.

Presently, established treatments for ADHD are based on medication use. Methylphenidate is considered the first-line drug. Drug treatment has demonstrated effectiveness, with reported improvements in 80% of children and various positive effects, including the restoration of peer relationships and social skills, owing to reduced ADHD symptoms [19]. However, drug treatment can cause side effects, such as abdominal pain, headache, and sleep disorders [20]. Due to associated risks, parents of children with ADHD are increasingly interested in non-drug treatments. Non-drug approaches for ADHD vary depending on symptoms and the condition of the child. According to research on ADHD, non-drug treatments include play and behavioral therapy, neurofeedback, and digital treatments [21]. For example, play and behavior therapy showed improvements in how children expressed their feelings and intentions to peers and how siblings played together, and it also showed positive effects on the children's interactions with others [22]. Neurofeedback improves the attention and cognitive abilities of children with ADHD through interactions with computers [23]. These non-pharmacological treatments emphasize building rapport between parents and children, underscoring their vital role in ADHD management.

In this study, we present game-type content that adapts the existing play and behavioral therapy to a computerized format, aiming to supplement medication effects and enhance the child's concentration.

With the development of information technology and communication, digital therapeutics (DTx) using mobile games have been introduced. DTx is defined as evidence-based therapeutic interventions driven by high-quality software programs for the prevention, management, and treatment of chronic diseases and is mainly designed to run on electronic devices, commonly known as digital therapeutic devices [24]. DTx has the advantage of complementing the burdensome face-to-face and continuous treatment of mental illness, enabling real-time monitoring through at-home treatment regardless of space and time [25]. Particularly, this treatment form addresses the side effects and limitations associated with existing pharmacological interventions for ADHD, which are based on stimulants. Accordingly, this study targeted children with ADHD aged 6–13 years using game-type digital content and applied Neuroworld DTx (ver. 2.1.0), an AI-based attention and working memory improvement training program, employing the K-WISC-V evaluation tool. We

investigated the core symptoms of ADHD and the effects and changes in attention improvement. In addition, we verified whether DTx could serve as a supportive therapy alongside drug treatment for pediatric patients with ADHD.

2. Materials and Methods

2.1. Research Participants

This randomized clinical trial was conducted between 19 December 2022 and 30 March 2023. The minimum number of participants required was 34, with a dropout rate of 10%, to prove the superior effect of DTx in the experimental group compared with the control group. Four children opted to withdraw from the study because they did not want to participate. Therefore, we eventually analyzed the results of 30 children, and 30 clinical investigators were randomly assigned to the control and experimental groups. Sample sizes were calculated using G*power (ver. 3.1.2) and analyzed using the two-sample *t*-test, but the Wilcoxon rank-sum test was used if the data were not normally distributed.

The inclusion criteria for selecting the participants were as follows: (1) those who provided voluntary written consent from their legal guardian and themselves to participate in the clinical trial; (2) children aged 6–13 years diagnosed with ADHD according to the DSM-5 criteria; and (3) those taking medication for ADHD. However, participants who met criteria 1–3 were excluded if they met any of the following conditions: having disorders or diseases other than ADHD (i.e., post-traumatic stress, psychosis, severe obsessive-compulsive disorder, severe depression, and conduct disorder), having conditions that affect the use of clinical trial products (deformities of the hands or arms, prosthetic hands, and so on), having a confirmed or suspected history of drug abuse or during dependence within the preceding 6 months, color blindness, and being considered ineligible for the clinical trial by the investigator. As shown in Table 1, the participants comprised 13 boys (81.3%) and 3 girls (18.7%) in the experimental group and 12 boys (85.7%) and 2 girls (14.3%) in the control group. The average age was 9.27 ± 1.62 years and 8.93 ± 1.91 years for the experimental and control groups, respectively.

Table 1. Demographic and baseline characteristics of the participants.

		Experimental Group (N = 16) N (%) or M ± SD	Control Group (N = 14) N (%) or M ± SD	*p*-Value
Sex	Male	13 (81.3)	12 (85.7)	0.67 *
	Female	3 (18.7)	2 (14.3)	
Age		9.27 ± 1.62	8.93 ± 1.91	0.61 **

* Chi-square test, ** *t*-test.

The clinical trial plan was approved by the Institutional Ethics Review Committee of Keimyung University Dongsan Hospital (IRB File No. 2022-12-020), and written informed consent was obtained from all patients. The overall research plan is illustrated in Figure 1. Participants were allowed to make decisions after a mental health specialist explained the clinical trial. In addition, after obtaining written consent to participate in the clinical trial and sequentially assigning a screening number, participants who met all the selection and exclusion criteria were randomly assigned to the experimental or control group at baseline.

2.2. Study Procedures

In the experimental group, Neuroworld DTx, software comprising a cognitive training application, was used along with the medication. Neuroworld DTx was developed by Woorisoft Co., Ltd. (Daegu, Republic of Korea) and is described in Figure 2. Each member of the experimental group was assigned a tablet PC with the installed application. The exposure comprised at-home participation in the experimental group, conducted five times a week over 4 weeks, with each session lasting 25 min.

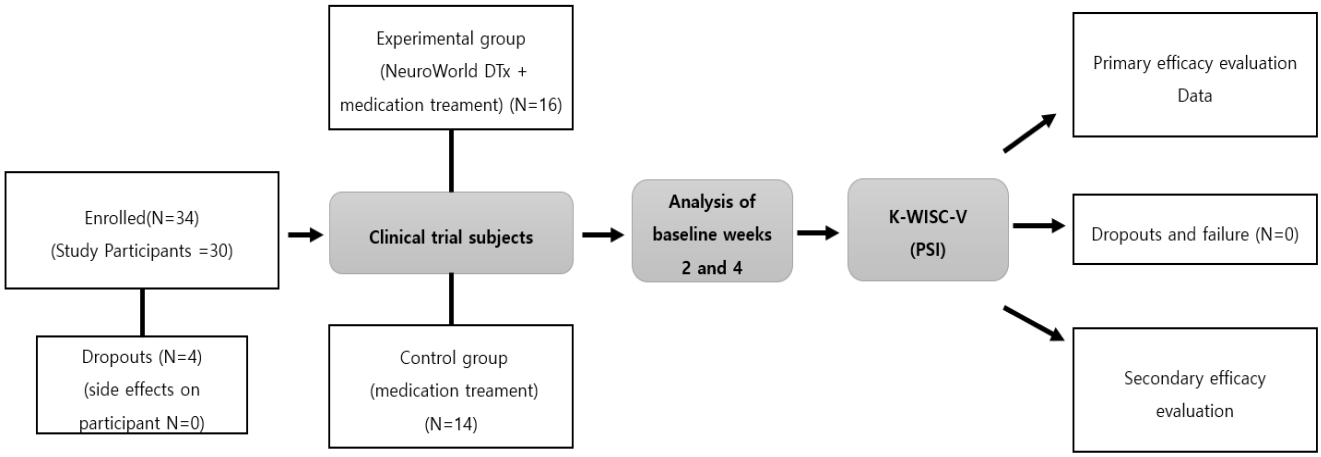

Figure 1. Study composition flowchart.

Figure 2. Program configuration screen. (**a**) Login screen, (**b**) child information input screen, (**c**) main screen. 로그인: login, 회원가입: join the membership, 비밀번호 찾기: find password, 사용자 정보: user information, 나이: age, 전체: entire, 출생년도: Year of birth, 성별: gender, 남: male, 여: female, 확인: confirm, 취소: cancel, 위 사용자 정보가 맞으면 '확인' 을 눌러주세요: If the above user information is correct, click 'Confirm'.

Considering the young age of the participating children (6–13 years), program use was limited to 30 min to prevent addiction and dizziness from excessive use. The attention and working memory of the children for digital therapy were monitored until the fourth week of the study using the processing speed item of the K-WISC-V to evaluate the effectiveness of the research.

2.3. Neuroworld DTx

The program consists of a total of five items. One working memory item, which measures the ability to remember and process a series of stimuli in order, and four attention items, such as the ability to respond to the desired visual stimuli and continuous attention maintenance training and the ability to ignore the surrounding disturbance stimuli and respond to the necessary stimuli (Figure 3).

Existing game-type contents predominantly consist of selection or question-and-answer formats and often serve as static tools. However, these static tools pose challenges for maintaining the motivation of children with ADHD, as the game may devolve into a one-sided question-and-answer activity centered on the assistant. To address this, our content was designed by adjusting the difficulty level while retaining the game format or introducing variety by changing characters at a consistent level of difficulty. The traditional approach of advancing through stages with a scoring goal reduces the effectiveness of training. Our focus is to develop coping skills by immersing children in repetitive situations. Neuroworld comprises five games with familiar content for children and is advantageous because it does not seem to narrowly train the child to concentrate on the activity but inspires the child's interest through their direct participation. With the game, in addition to choosing characters, the child is exposed to increasing difficulty levels due to the inclusion

of a quantitative pattern that automatically adjusts the difficulty level based on the child's performance in previous games as soon as the username is entered.

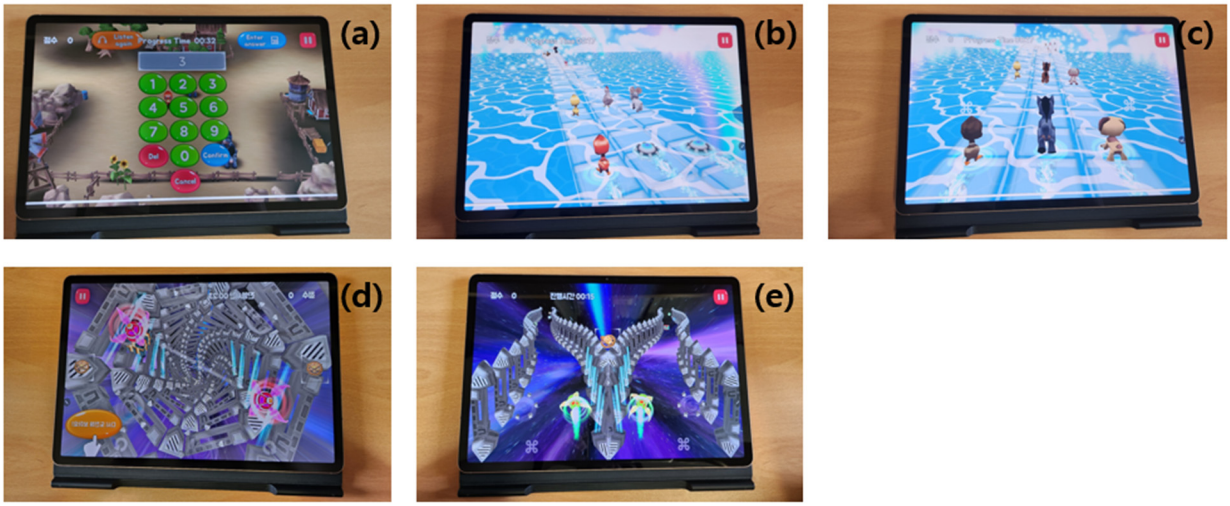

Figure 3. Composition of an artificial intelligence-based attention and working memory training program. (**a**) Working memory, (**b**) Attention 1, (**c**) Attention 2, (**d**) Attention 3, (**e**) Attention 4. 점수: Score, 진행시간: Time.

2.4. Hypothesis and Statistical Analysis

This study examined whether digital treatments could treat ADHD. We hypothesized that there would be a difference in the K-WISC-V scores of the control and test groups.

Based on the above hypothesis, the following detailed hypotheses were also established.

H1: There will be group differences in K-WISC-V scores after 4 weeks from the start of the test. H2: There will be between-group differences in K-WISC-V scores. H3: There will be between-group differences in K-WISC-V scores according to time points. H4: There will be between-group differences in K-WISC-V scores compared to the baseline.

The collected data were analyzed using the SPSS Win 23.0 program for Windows (SPSS Inc., Chicago, IL, USA), and a two-sided test was performed ($p < 0.05$ was considered significant) [26]. Efficacy evaluation was performed using the full analysis set (FAS) and per-protocol set (PPS) analysis. However, in principle, the final decision regarding clinical trial results was based on the PPS analysis results. Descriptive statistics are presented for each group for all effectiveness evaluation variables, and an analysis of variance (ANOVA) was performed to evaluate the quantitative scores between the experimental and control groups. Comparisons between the experimental and control groups were performed using a two-sample *t*-test. If normality was not satisfied, Wilcoxon's rank-sum test was used [27].

2.5. Ethical Considerations

Before data collection and the intervention, approval was obtained from the Institutional Ethics Review Committee of Keimyung University Dongsan Hospital. A research description and consent form specifying the purpose of the research, research content and procedures, confidentiality of data, disposal after completion of the study, and cancellation at any time during participation were provided to the participants and legal guardians. Signed informed consent forms were obtained for participation in the study. The use of personal information for research activities was in accordance with the Personal Information Protection Act. In addition, it was explained verbally and in writing that participation could be discontinued at any time during the program. The data collection and intervention were started after written consent was received.

The safety of the personal (name, sex, series) and sensitive (scale items) information of the participants was assessed based on whether all data were coded and stored on an external hard drive separate from the computer. Participation in the study was believed

to not pose fatal physical risks or damage to the participants. However, given the specific characteristics of the participants, if unexpected risks were noted or the child expressed difficulties or refused to participate, the program could be stopped immediately. Moreover, participants were afforded the option to take a break at any point during the study

2.6. Measures

K-WISC-V-Processing Speed Index (K-WISC-V-PSI)

The K-WISC-V was developed for children and adolescents aged 6–16 years [28]. This test consists of 10 basic subtests and six additional subtests. The full index within the basic subtest comprised five primary and five ancillary indices and was calculated by focusing on the basic subtest [29]. The basic index scale consists of the verbal comprehension index (VCI), visual-spatial index (VSI), fluid reasoning index (FRI), working memory index (WMI), and processing speed index (PSI) [30]. The ancillary index consists of a quantitative reasoning index (QRI), auditory working memory index (AWMI), nonverbal index (NVI), general ability index (GAI), and cognitive proficiency index (CPI) [31]. According to the qualitative classification of indicator scores presented by Wechsler (2014c), a score of 130 or higher is very good, 120–129 is excellent, 110–119 is above average, and 90–109 is average. A score of 80–89 is classified as below average, 70–79 low, and 69 or less very low [32].

In the K-WISC-V, the overall cognitive ability of children can be confirmed using an FSIQ. The range of intelligence that can be measured through the test is $40 \leq \text{FSIQ} \leq 160$, which is expanded compared with K-WISC-IV [33]. Compared with the K-WISC-IV edition, the K-WISC-V provides the overall IQ (FSIQ), five basic indicator scores (VCI, VSI, FRI, WMI, and PSI), and five additional indicator scores (QRI, AWMI, NVI, GAI, and CPI). In the K-WISC-V, a child's overall cognitive ability is confirmed through an FSIQ. The range of intelligence that can be measured through the test is $40 \leq \text{FSIQ} \leq 160$, which is expanded compared with the K-WISC-IV [33]. The K-WISC-V provides the overall IQ (FSIQ), five basic index scores (VCI, VSI, FRI, WMI, and PSI), and five additional index scores (QRI, AWMI, NVI, GAI, and CPI). Structural changes were observed compared with the WISC-IV version.

In the Korean standardization process, the overall average internal consistency coefficients for FSIQ and the four indicators for the entire standardization group were appropriate, ranging from 0.81 (PSI) to 0.94 (FSIQ), and test and retest stability coefficients were also appropriate, ranging from 0.82 (PRI) to 0.92 (FSIQ) [34].

In this study, the criteria for participant selection were evaluated using the FSIQ, and the primary effectiveness evaluation was confirmed using the PSI variable. The PSI measures the speed and accuracy of decision-making and decision-making processes. Since scanning, visual discrimination, visual short-term memory, and concentration are involved in performing the PSI subtests, this study examined rapid decision-making ability, recognition ability, attention, and overall cognitive processing speed as PSI scores increased. The PSI was used for the K-WISC-V.

3. Results

Effectiveness Evaluation Results

In this clinical trial, the PSI (symbol writing and isomorphism finding) subtest of the K-WISC-V was conducted to evaluate general cognitive ability. The higher the score, the better the visual scanning, discrimination, short-term memory, and visual-motor collaboration. Table 2, Figure 4 summarizes the scores of the experimental and control groups in the K-WISC-V processing speed test. There were no significant differences between the experimental and control groups in the repeated-measures analysis of variance and baseline-corrected covariate analysis. Significant changes were confirmed on day 28 compared with baseline in the experimental group's symbol search ($p < 0.001$), scaled score ($p = 0.001$), and indicator score ($p = 0.001$).

Table 2. Korean-Wechsler Intelligence Scale for Children (K-WISC-V).

	Control Group					Experimental Group					*p*-Value
	N	Mean	SD	Median	IQR	N	Mean	SD	Median	IQR	
Coding											
Baseline	14	7.71	3.31	8.50	10	16	10.19	3.71	9.50	13	0.066 [a]
2 weeks	14	8.00	3.11	8.50	11	16	10.44	3.72	9.50	13	0.064 [a]
4 weeks	14	8.43	3.57	9.00	13	16	11.00	3.48	11.00	14	0.056 [a]
p-value	0.520 [c]		0.086 [d]			0.181 [d]					0.052 [b]
Symbol Search											
Baseline	14	8.93	3.87	8.50	14	16	10.44	3.01	10.50	10	0.240 [a]
2 weeks	14	9.86	4.24	10.50	11	16	11.63	3.46	12.00	13	0.219 [a]
4 weeks	14	10.79	4.32	12.00	12	16	14.00	3.86	14.50	13	0.040 [a]
p-value	0.075 [c]		0.016 [d]			0.000 [d]					0.108 [b]
Scaled score											
Baseline	14	16.64	6.80	17.50	23	16	20.63	6.41	20.00	23	0.110 [a]
2 weeks	14	17.86	6.87	18.50	21	16	21.94	6.63	22.50	26	0.109 [a]
4 weeks	14	19.21	7.42	21.50	25	16	25.00	6.74	26.00	26	0.033 [a]
p-value	0.146 [c]		0.009 [d]			0.001 [d]					0.064 [b]
Indicator Score											
Baseline	14	91.07	18.10	93.50	61	16	101.75	17.08	100.00	61	0.108 [a]
2 weeks	14	94.29	18.30	96.00	56	16	105.75	18.12	106.50	71	0.096 [a]
4 weeks	14	97.93	19.67	104.00	66	16	113.56	18.23	116.00	71	0.032 [a]
p-value	0.140 [c]		0.009 [d]			0.001 [d]					0.060 [b]

[a] Student's *t*-test, [b] repeated measures analysis of variance, [c] covariate analysis corrected for baseline, [d] baseline vs. 4-week paired-sample *t*-test.

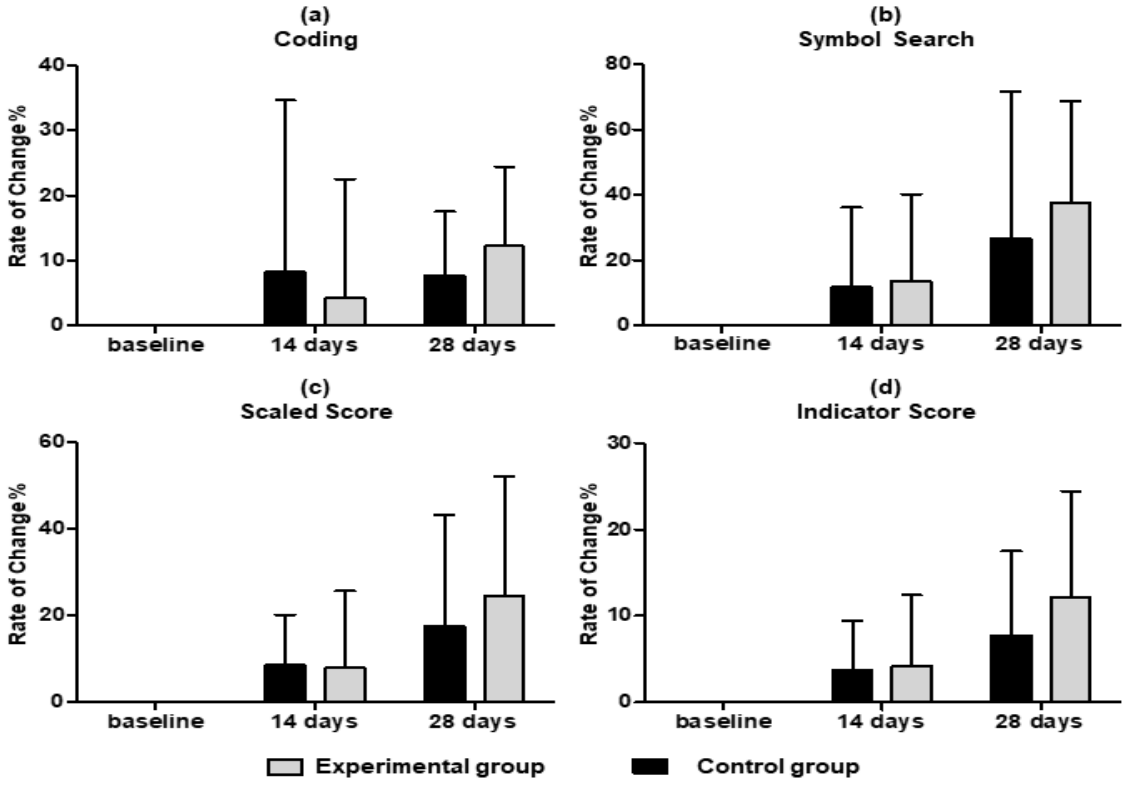

Figure 4. K-WISC-V, Korean-Wechsler Intelligence Scale for Children.

4. Discussion

This study aimed to assess the efficacy of game-based digital content, a form of ADHD medication-assisted therapy, in enhancing attention in children with ADHD using the K-WISC-V (PSI). PSI gauges the ability of an individual to process information and respond appropriately within a limited time. Concerning the four hypotheses, for H1, no significant difference was found in the symbol writing categories in the control and experimental groups, but a significant difference was found in homotype search, conversion score sum, and indicator score. Regarding H2, significant between-group differences were found in the K-WISC-V score. Although the *p*-value for the symbol writing item was 0.056, showing non-significance, the *p*-value was lower than those at baseline and week 2, showing a possibility for experimentation. No significant difference in homotype search was found between baseline and week 2, but a significant difference was noted at week 4. The sums of the converted and index scores showed significant differences in the 4th week, and H3 and H4 were rejected. Therefore, the study results indicate that the experimental group showed higher K-WISC-V scores after 4 weeks of the experimentation, demonstrating improvement in decision-making ability and overall cognitive processing speed compared to the control group. These results provide evidence that PSI is a significant predictive indicator of diminishing ADHD symptoms in children. We also observed that the developed game-type digital content could improve the children's concentration and cognitive function.

Randomized controlled trials have been conducted on children with ADHD aged between 5 and 12 years using game-type digital therapy, such as virtual reality (VR) [35,36]. The children who participated in this study exhibited diminished ADHD-related hyperactivity and impulsiveness and high compliance at the end of treatment [37]. In various digital therapy studies involving mobile and tablet PCs and VR, the therapy through games was advantageous owing to its ability to apply real-time monitoring and at-home treatment. In particular, the therapy can be considered a temporal and spatial adjuvant therapy to compensate for the inconvenience of visiting hospitals for pharmacological treatment [38].

This study has limitations due to its relatively short research period. The value of this study can potentially be increased if the improvement in attention and cognitive function according to the child's growth period is confirmed through large-scale, long-term research. In addition, because ADHD is accompanied by other mental illnesses such as conduct disorder and tic disorder, there is a limitation in that there was no analysis of ADHD comorbidities for the children who participated in this study. Therefore, in the future, we plan to access more quantitative data by analyzing participants' medical records for full evaluation [39].

The reliability of the program is very important because the computer-based ADHD digital therapy aids in training and learning through the content displayed on the screen. Therefore, the program is a valuable tool for evaluating diagnostic values such as brain nerve response and visual quantitative expression. Future clinical trials that directly show visual and quantitative factors are required. Additionally, in future research, we intend to analyze the comorbidities of participating children and verify the effectiveness of this therapy in treating mental disorders apart from ADHD [40].

In general, improving the situation by applying a game format is primarily about motivating the subject, and its effectiveness is more pronounced in younger individuals [41]. While the motivation of the game can be initially increased, maintaining, continuing, or enhancing motivation for the desired purpose presents another challenge that cannot be solely addressed by the game itself. In the case of children with ADHD, the need for continuous repetition of the same learning to remember and recognize situations underscores the importance of maintaining the game format, which is achieved by changing characters while keeping the content difficulty consistent.

Although there has not yet been a single successful case of using games to treat children with ADHD, it has sufficient potential as an adjunctive treatment, as shown in this study. This study yielded significant results, suggesting its potential as future training content for children with ADHD. Therefore, future research should focus on establishing

the effectiveness of digital therapeutics, aiming not just for adjuvant treatment but a drug-replacement option with no side effects. Achieving this necessitates a standardized definition of the role and function of the content, along with demonstrating effectiveness based on varying levels of game proficiency, requiring clinical data from numerous subjects.

ADHD digital therapy in the form of mobile games was associated with reduced resistance to treatment and high accessibility for children [42]. Through this study, we expect that digital therapeutics can create natural motivation in children with ADHD [43]. The strategy employed in this study, aiming to enhance cognitive function through repetitive training with game-based digital therapy, may lead to improvements in attention and working memory in children.

5. Conclusions

This retrospective study on Neuroworld DTx, a software program featuring a cognitive training application, aimed to evaluate its potential for improving attention, working memory, and cognitive function in children with ADHD. The coding and symbol search (PSI) subtest of the K-WISC-V was used to assess general cognitive abilities. On day 14, the rate of change in the scaled converted scores was 0.64% lower in the experimental group than in the control group. However, on the 28th day, the change rate increased by 6.93%. Considering the findings of this study, the combination of Neuroworld DTx treatment demonstrated improvements in visual scanning, visual discrimination, visual short-term memory, and visual-motor collaboration ability. These results suggest that mobile game-based content can serve as a new non-drug adjunct to ADHD treatment.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Ethics Review Committee of Keimyung University Dongsan Hospital (IRB File No. 2022-12-020 and 10 January 2023).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original contributions presented in the study are included in the article, further inquiries can be directed to the author.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Faraone, S.V.; Larsson, H. Genetics of attention deficit hyperactivity disorder. *Mol. Psychiatry* **2019**, *24*, 562–575. [CrossRef] [PubMed]
2. Sahmurova, A.; Arikan, S.; Gursesli, M.C.; Duradoni, M. ADHD symptoms as a stressor leading to depressive symptoms among university students: The mediating role of perceived stress between ADHD and depression. *Int. J. Environ. Res. Public Health* **2022**, *19*, 11091. [CrossRef] [PubMed]
3. Asherson, P.; Agnew-Blais, J. Annual Research Review: Does late-onset attention-deficit/hyperactivity disorder exist? *J. Child. Psychol. Psychiatry* **2019**, *60*, 333–352. [CrossRef] [PubMed]
4. Kian, N.; Samieefar, N.; Rezaei, N. Prenatal risk factors and genetic causes of ADHD in children. *World J. Pediatr.* **2022**, *18*, 308–319. [CrossRef] [PubMed]
5. Moradi, N.; Rajabi, S.; Mansouri Nejad, A. The effect of neurofeedback training combined with computer cognitive games on the time perception, attention, and working memory in children with ADHD. *Appl. Neuropsychol. Child.* **2024**, *13*, 24–36. [CrossRef]
6. Milledge, S.V.; Cortese, S.; Thompson, M.; McEwan, F.; Rolt, M.; Meyer, B.; Sonuga-Barke, E.; Eisenbarth, H. Peer relationships and prosocial behaviour differences across disruptive behaviours. *Eur. Child. Adolesc. Psychiatry* **2019**, *28*, 781–793. [CrossRef] [PubMed]
7. Patil, A.U.; Madathil, D.; Fan, Y.T.; Tzeng, O.J.L.; Huang, C.M.; Huang, H.W. Neurofeedback for the education of children with ADHD and specific learning disorders: A review. *Brain Sci.* **2022**, *12*, 1238. [CrossRef] [PubMed]
8. Mamiya, P.C.; Arnett, A.B.; Stein, M.A. Precision medicine care in ADHD: The case for neural excitation and inhibition. *Brain Sci.* **2021**, *11*, 91. [CrossRef] [PubMed]

9. Mechler, K.; Banaschewski, T.; Hohmann, S.; Häge, A. Evidence-based pharmacological treatment options for ADHD in children and adolescents. *Pharmacol. Ther.* **2022**, *230*, 107940. [CrossRef] [PubMed]
10. Vuori, M.; Koski-Pirilä, A.; Martikainen, J.E.; Saastamoinen, L. Gender- and age-stratified analyses of ADHD medication use in children and adolescents in Finland using population-based longitudinal data, 2008–2018. *Scand. J. Public Health* **2020**, *48*, 303–307. [CrossRef]
11. Jacob, L.; Haro, J.M.; Koyanagi, A. Attention deficit hyperactivity disorder symptoms and disordered eating in the English general population. *Int. J. Eat. Disord.* **2018**, *51*, 942–952. [CrossRef] [PubMed]
12. Pasco, G. The value of early intervention for children with autism. *Paediatr. Child. Health* **2018**, *28*, 364–367. [CrossRef]
13. Ogundele, M.O. Behavioural and emotional disorders in childhood: A brief overview for paediatricians. *World J. Clin. Pediatr.* **2018**, *7*, 9–26. [CrossRef] [PubMed]
14. Langer, N.; Benjamin, C.; Becker, B.L.C.; Gaab, N. Comorbidity of reading disabilities and ADHD: Structural and functional brain characteristics. *Hum. Brain Mapp.* **2019**, *40*, 2677–2698. [CrossRef] [PubMed]
15. Jang, H.I.; Kang, S.; Park, J. The impact of an intensive phoneme and grapheme intervention with explicit instruction in word recognition and generalization on first-grade students with reading difficulties. *J. Spec. Educ.* **2023**, *39*, 93–113. [CrossRef]
16. Kim, S.H.; Choi, H.S.; Koo, C.M.; Joo, B.R.; Park, B.J.; Lee, H.K.; Lee, J.S.; Kim, H.D.; Kang, H.C. Effects of Cannabidiol on Adaptive Behavior and Quality of Life in Pediatric Patients With Treatment-Resistant Epilepsy. *J. Clin. Neurol.* **2023**, *19*, 214. [CrossRef] [PubMed]
17. Kadiyala, P.K. Mnemonics for diagnostic criteria of DSM V mental disorders: A scoping review. *Gen. Psychiatry* **2020**, *33*, e100109, Erratum in *Gen. Psychiatry* **2020**, *33*, corr1, e100109. [CrossRef] [PubMed]
18. Twomey, C.; O'Connell, H.; Lillis, M.; Tarpey, S.L.; O'Reilly, G. Utility of an abbreviated version of the Stanford-Binet intelligence scales (5th ed.) in estimating 'full scale' IQ for young children with autism spectrum disorder. *Autism Res.* **2018**, *11*, 503–508. [CrossRef] [PubMed]
19. Willis, D.; Siceloff, E.R.; Morse, M.; Neger, E.; Flory, K. Stand-alone social skills training for youth with ADHD: A systematic review. *Clin. Child. Fam. Psychol. Rev.* **2019**, *22*, 348–366. [CrossRef]
20. Stueber, A.; Cuttler, C. Self-reported effects of cannabis on ADHD symptoms, ADHD medication side effects, and ADHD-related executive dysfunction. *J. Atten. Disord.* **2022**, *26*, 942–955. [CrossRef]
21. Fotoglou, A.; Moraiti, I.; Diamantis, A.; Stergios, V.; Gavriilidou, Z.; Drigas, A. Nutritious diet, physical activity and mobiles. The game changers of ADHD. *Biochemmed* **2022**, *3*, 87–106. [CrossRef]
22. Feizollahi, J.; Sadeghi, M.; Rezaei, F. The effect of cognitive behavioral play therapy and its integration with parental management training on symptoms of ADHD in 7–11 year old children: A quasi-experimental study. *JRUMS* **2020**, *19*, 155–172. [CrossRef]
23. Hajmohammadi, Z.; Hajializadeh, K.; Arteshdar, R. Effectiveness of neurofeedback therapy with cognitive-behavioral (play therapy) in improving attention and cognitive function in children with learning disorder in primary school. *IJLM* **2023**, *5*, 31–42.
24. Maple, A.; Palko, L.; Cañadas, E.; Jina, A. STARS Adjunct trial: Evidence for the effectiveness of a digital therapeutic as adjunct to treatment with medication in pediatric ADHD. *CNS Spectr.* **2023**, *28*, 215–216. [CrossRef]
25. Thomopoulos, S.C.A.; Kanellos, T.; Doulgerakis, A.; Georgiou, E.; Bessa, M. REEFocus: A VR/AR mixed reality digital game system for non-medication treatment of ADHD and remote monitoring with data privacy and security by design: The FocusLocus approach. In *Smart Biomedical and Physiological Sensor Technology*; SPIE: Baltimore, MD, USA, 2019; Volume 11020, pp. 166–180. [CrossRef]
26. Yu, X.; Sun, S.; Shi, Y.; Wang, H.; Zhao, R.; Sheng, J. SARS-CoV-2 viral load in sputum correlates with risk of COVID-19 progression. *Crit. Care* **2020**, *24*, 170. [CrossRef] [PubMed]
27. Kitani, M.; Murakami, H. The limiting distribution of combining the t and Wilcoxon rank sum tests. *Statistics* **2020**, *54*, 871–884. [CrossRef]
28. Lee, K.S.; Jung, S.J.; Park, H.S. Models of the psychological assessment applicable to the adoption process. *J. Korean Soc. Matern. Child. Health* **2022**, *71*, 93–132.
29. Park, Y.A.; Kim, Y.; Kwak, K. Optimism as a mediator of the relationship between adolescents' stress and intelligence: Using the K-WISC-V. *Korean Assoc. Hum. Dev.* **2023**, *30*, 29–42. [CrossRef]
30. Audras-Torrent, L.; Miniarikova, E.; Couty, F.; Dellapiazza, F.; Berard, M.; Michelon, C.; Picot, M.C.; Baghdadli, A. WISC-V profiles and their correlates in children with autism spectrum disorder without intellectual developmental disorder: Report from the ELENA cohort. *Autism Res.* **2021**, *14*, 997–1006. [CrossRef]
31. Puttaswamy, A.; Barone, A.; Viezel, K.D.; Willis, J.O.; Dumont, R. Wechsler Intelligence Scale for Children–fifth edition ancillary and complementary index critical values and base rates for the normative sample. *J. Psychoeduc. Assess.* **2020**, *38*, 539–550. [CrossRef]
32. Watkins, M.W.; Dombrowski, S.C.; Canivez, G.L. Reliability and factorial validity of the Canadian Wechsler Intelligence Scale for Children–fifth edition. *Int. J. Sch. Educ. Psychol.* **2018**, *6*, 252–265. [CrossRef]
33. Li, G.; Rossbach, K.; Jiang, W.; Du, Y. Resting-state brain activity in Chinese boys with low functioning autism spectrum disorder. *Ann. Gen. Psychiatry* **2018**, *17*, 47. [CrossRef]
34. Kim, H.; Song, D.H. Comparison of the K-WISC-IV profiles of boys with autism spectrum disorder and attention-deficit/hyperactivity disorder. *Res. Dev. Disabil.* **2020**, *97*, 103539. [CrossRef] [PubMed]

35. Alqithami, S.; Alzahrani, M.; Alzahrani, A.; Mustafa, A. AR-Therapist: Design and simulation of an AR-Game environment as a CBT for patients with ADHD. *Healthcare* **2019**, *7*, 146. [CrossRef]
36. Parsons, T.D.; Bowerly, T.; Buckwalter, J.G.; Rizzo, A.A. A controlled clinical comparison of attention performance in children with ADHD in a virtual reality classroom compared to standard neuropsychological methods. *Child. Neuropsychol.* **2007**, *13*, 363–381. [CrossRef]
37. Yerys, B.E.; Bertollo, J.R.; Kenworthy, L.; Dawson, G.; Marco, E.J.; Schultz, R.T.; Sikich, L. Brief report: Pilot study of a novel interactive digital treatment to improve cognitive control in children with autism spectrum disorder and co-occurring ADHD symptoms. *J. Autism Dev. Disord.* **2019**, *49*, 1727–1737. [CrossRef] [PubMed]
38. Davis, N.O.; Bower, J.; Kollins, S.H. Proof-of-concept study of an at-home, engaging, digital intervention for pediatric ADHD. *PLoS ONE* **2018**, *13*, e0189749. [CrossRef] [PubMed]
39. Elwin, M.; Elvin, T.; Larsson, J.O. Symptoms and level of functioning related to comorbidity in children and adolescents with ADHD: A cross-sectional registry study. *Child. Adolesc. Psychiatry Ment. Health* **2020**, *14*, 30. [CrossRef] [PubMed]
40. Verrotti, A.; Moavero, R.; Panzarino, G.; Di Paolantonio, C.; Rizzo, R.; Curatolo, P. The challenge of pharmacotherapy in children and adolescents with epilepsy-ADHD comorbidity. *Clin. Drug Investig.* **2018**, *38*, 1–8. [CrossRef]
41. Martucci, A.; Gursesli, M.C.; Duradoni, M.; Guazzini, A. Overviewing gaming motivation and its associated psychological and sociodemographic variables: A PRISMA systematic review. *Hum. Behav. Emerg. Technol.* **2023**, *2023*, 5640258. [CrossRef]
42. He, F.; Qi, Y.; Zhou, Y.; Cao, A.; Yue, X.; Fang, S.; Zheng, Y. Meta-analysis of the efficacy of digital therapies in children with attention-deficit hyperactivity disorder. *Front. Psychiatry* **2023**, *14*, 1054831. [CrossRef]
43. Lutz, J.; Offidani, E.; Taraboanta, L.; Lakhan, S.E.; Campellone, T.R. Appropriate controls for digital therapeutic clinical trials: A narrative review of control conditions in clinical trials of digital therapeutics (DTx) deploying psychosocial, cognitive, or behavioral content. *Front. Digit. Health* **2022**, *4*, 823977. [CrossRef]