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The Effects of Interactive Metronome (IM) Training on Impulsivity, Attention, Emotional, and Behavioral Regulation in Children with Attention-Deficit/Hyperactivity Disorder (ADHD): A Single-Case Study

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Abstract

Purpose: This study aimed to examine the effects of Interactive Metronome (IM) training on impulsivity, attention, emotional, and behavioral regulation in a child with Attention-Deficit/Hyperactivity Disorder (ADHD). **Research Design, Data, and Methodology:** A single-case study was conducted with a 9-year-old child diagnosed with ADHD. The study followed an ABA' design, consisting of three phases: baseline, intervention, and follow-up. The intervention included a total of 12 IM training sessions. To assess pre- and post-intervention changes, the Abbreviated Conners Rating Scale (ACRS), Interactive Metronome's Long Form Assessment (LFA), and Short Form Assessment (SFA) were used. **Results:** The results indicated positive changes in impulsivity and emotional regulation. The child's ACRS total score decreased from 26 to 16, demonstrating an improvement in behavioral symptoms. Additionally, significant improvements were observed in attention-related indicators, including SFA scores and synchronization rate (SRO), with sustained effects over time. **Conclusion:** These findings suggest that IM training can effectively enhance self-regulation, emotional control, and attention in children with ADHD, highlighting its clinical and home-based applicability. However, given the limitations of a single-case study, further research involving larger samples and long-term follow-ups is necessary.

Keywords : Interactive Metronome (IM), ADHD, Impulsivity, Attention, Emotional Regulation, Single-Case Study

JEL Classification Code : I10, I12, I18

1. Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is a common neurodevelopmental disorder in childhood, characterized by behavioral traits such as inattention, hyperactivity, and impulsivity (American Psychiatric Association, 2013). ADHD is recognized as a major mental health issue affecting approximately 5% of children worldwide (Polanczyk et al., 2015).

In South Korea, according to the Health Insurance Review and Assessment Service (2023), the number of children diagnosed with ADHD has increased from approximately 57,000 in 2018 to over 90,000 in 2022, highlighting the need for continuous attention and intervention. The primary age group for ADHD diagnosis is concentrated between 6 and 12 years, significantly impacting school performance and social adaptation. Children with ADHD often struggle to maintain focus in class or complete tasks persistently, leading to lower academic achievement, reduced learning motivation, and decreased self-efficacy (Frick & Lahey, 1991).

In addition to cognitive difficulties, they may experience conflicts with teachers and peers due to excessive physical movement or impulsive speech, potentially resulting in social isolation through repeated negative interactions (DuPaul & Stoner, 2014). Furthermore, deficits in emotional regulation may manifest as emotional outbursts or mood swings, contributing to negative self-concept and lower social competence (Hoza, 2007).

ADHD is not merely a behavioral issue but is closely linked to neurobiological abnormalities, particularly in the prefrontal cortex. The prefrontal cortex governs executive functions such as attention control, planning, and response inhibition. Children with ADHD exhibit deficits in these executive functions (Barkley, 1997).

Additionally, from a motivational perspective, they tend to have difficulty delaying gratification and respond more readily to immediate stimuli, which is associated with impaired self-regulation (Sonuga-Barke, 2002). These characteristics contribute to persistent inattentive and impulsive behaviors not only in academic settings but also in daily life interactions at home and with peers (Barkley, 2015).

Various interventions have been explored to mitigate these challenges, among which Interactive Metronome (IM) training has gained attention as an alternative intervention (Shaffer et al., 2001). IM training involves synchronizing bodily movements with a rhythmic auditory stimulus, aiming to enhance timing skills, working memory, and sensorimotor coordination (Chang et al., 2014).

This process is believed to strengthen neural connectivity between the prefrontal cortex and basal ganglia, potentially improving impulse control and attention (Lieberman, 2011). Studies have reported that IM training enhances attention, reduces impulsivity, and facilitates learning and emotional-behavioral regulation in children with ADHD (Shaffer et al., 2001; Taub et al., 2007; Leisman & Melillo, 2010).

In South Korea, prior research has indicated improvements in timing ability, attention, and motor functions through IM training (Kim et al., 2015), while other studies have suggested its superior effectiveness over traditional cognitive enhancement therapy in improving attention and impulse control in children with ADHD traits (Jung, 2010).

More recent studies have reinforced these findings. Taub, McGrew, and Keith (2020) conducted a meta-analysis confirming the effectiveness of IM training on academic achievement, particularly in reading.

Pereira and Roebuck (2021) reviewed recent IM-based interventions and found consistent evidence supporting improvements in timing, attention, and behavioral control. In a Korean study, Park, Lee, and Kim (2022) demonstrated that rhythm-based movement interventions significantly enhanced attention and working memory in children with ADHD, validating the practical utility of IM training in school-based contexts. Furthermore, Kim and Jeong (2023) provided neurocognitive evidence—through event-related potentials (ERP)that IM training positively affects brain activation and behavioral responses in children with ADHD symptoms.

However, most existing research has focused on attention and motor function improvement, with limited studies analyzing the comprehensive effects of IM training on emotional and behavioral regulation.

To address this gap, this study aims to empirically investigate the effects of IM training on impulsivity, attention, emotional regulation, and behavioral control in children with ADHD using a single-subject design. By examining the intervention's efficacy, this study seeks to provide a more effective and integrated approach for ADHD intervention.

2. Research Method

2.1. Research Participants

This study was conducted on a 9-year-old child diagnosed with ADHD who was receiving occupational therapy at a behavioral development center in Mokpo, Jeollanam-do. The participant was selected based on the following criteria.

1. A child diagnosed with ADHD by a pediatric psychiatrist.
2. A child with no prior experience with Interactive Metronome (IM) training.
3. A child who was not taking any medication related to ADHD.
4. A child whose legal guardian fully understood the purpose and procedure of the study and provided written informed consent. Additionally, the child was given age-appropriate verbal and visual explanations and voluntarily assented to participate.

In accordance with ethical research guidelines for minors, the study ensured the protection of the participant by providing a detailed explanation of the research process to both the child and their guardian.

The guardian signed a written consent form, and the child provided verbal assent after the explanation. The research was conducted with approval from the institutional review board (IRB), and all procedures adhered to ethical standards for research involving human participants, particularly minors.

2.2. Research Design

This study employed a three-phase ABA' single-subject research design, consisting of a one-week baseline phase (A), a four-week intervention phase (B), and a one-week follow-up phase (A'), conducted one month after the intervention. A total of 18 sessions were conducted: three sessions during the baseline phase, 12 sessions during the intervention phase (three sessions per week for four weeks), and three sessions during the follow-up phase.

Each session lasted approximately 40–50 minutes and followed a structured format using standard Interactive Metronome (IM) protocols.

The ABA' design was selected due to its effectiveness in identifying functional relationships between independent and dependent variables in single-subject studies. It allows for observation of changes following the intervention and assessment of maintenance over time.

The intervention program was developed based on prior research demonstrating the effectiveness of IM training in improving attention, motor planning, and timing in children with ADHD (Shaffer et al., 2001; Cosper et al., 2009).

Grounded in neurocognitive theory, the IM protocol targets temporal processing and motor timing, which are closely associated with executive functioning. According to Barkley's (1997) model of executive function deficits in ADHD, improving timing mechanisms may enhance attention regulation and behavioral self-control.

To evaluate the intervention's effects, the Short Form Assessment (SFA) of IM was administered during every session. Additionally, the Long Form Assessment (LFA) of IM and the Abbreviated Conners' Parent Rating Scale-Revised (ACRS) were conducted at three time points: pre-intervention (baseline), post-intervention, and follow-up. These tools were used to monitor changes in attentional performance, emotional regulation, and behavioral control throughout the study (see Figure 1).

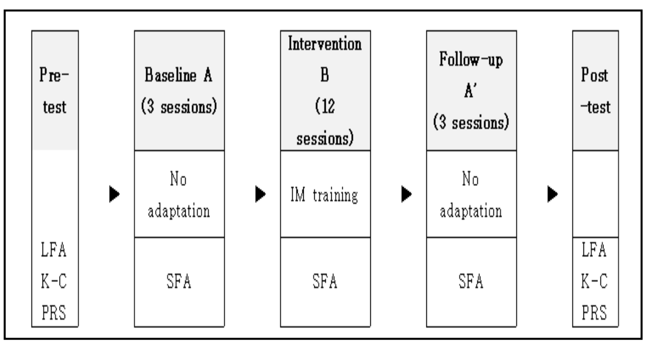

Figure 1: Research Flow Chart

2.3. Research Instruments

2.3.1. Interactive Metronome (IM)

The Interactive Metronome (IM) system consists of hardware and software components, including hand and foot triggers, a headset, and an auditory metronome cue. The IM provides two types of assessment tools: the Long Form Assessment (LFA) and the Short Form Assessment (SFA).

The LFA was used for initial evaluation and follow-up assessment, while the SFA was administered repeatedly during the baseline and intervention phases to track progress over time. The LFA comprises 13 standardized motor tasks plus one additional task, totaling 14 exercises that require the participant to perform rhythmic tapping using hands and feet in response to metronome beats. The objective is to synchronize bodily movements precisely with auditory cues.

Performance is measured in milliseconds (ms), representing the average time deviation from the metronome beat. Lower task average scores indicate better synchronization and improved motor timing. In addition, the Synchronization Rate Output (SRO) is calculated to reflect the percentage of responses occurring within a ±15 ms window from the target beat, with higher percentages denoting greater accuracy. Real-time visual and auditory feedback enables participants to adjust their timing and improve coordination during training.

2.3.2. Abbreviated Conners Parent Rating Scale-Revised (ACRS)

The Abbreviated Conners Parent Rating Scale-Revised (ACRS) is a widely used instrument for evaluating ADHD-related behaviors from the parent's perspective. Originally developed by Conners (1970) as a 93-item scale, it was later shortened to 10 items by Goyette, Conners, and Ulrich (1978). The Korean version was translated and standardized by Oh Kyung-Ja and Lee Hye-Ryun (1998).

The ACRS consists of 10 items rated on a 4-point Likert scale ranging from 0 (not at all) to 3 (very much). The total score ranges from 0 to 30, with higher scores indicating greater severity of ADHD symptoms.

A total score of 16 or above is considered to exceed the diagnostic threshold for behavioral concerns. The Korean adaptation of the scale has shown strong internal consistency, with a Cronbach's alpha of .82, indicating reliable measurement of ADHD symptomatology in clinical and educational settings.

2.4. Data Analysis

This study employed a single-subject ABA' experimental design. To analyze the participant's performance across the intervention phases, the following methods were used. Short Form Assessment (SFA) results were analyzed using visual inspection techniques, including trend, level, and variability analysis across sessions.

Long Form Assessment (LFA) and Abbreviated Conners' Parent Rating Scale–Revised (ACRS) scores were presented in tabular format to compare pre-intervention, post-intervention, and follow-up results.

Graphical representations were used to illustrate progress and detect patterns of change over time, providing both qualitative and quantitative insights.

3. Analysis Results

3.1. Changes in IM Scores of the Participant

3.1.1 Long Form Assessment (LFA)

To evaluate changes in impulsivity and timing accuracy, the LFA was administered at three time points: baseline, post-intervention, and follow-up. The participant's average task score at baseline was 224.31 ms, categorized as "severe deficiency." Following the 4-week IM training, the score significantly improved to 59.31 ms, which falls within the "average" range for the child's age group (55–79 ms). At the 1-month follow-up, the score was further maintained at 58.29 ms, indicating consistent retention of improvement.

This change represents a two-level improvement (from severe to average) in timing accuracy, suggesting that the participant gained better control over impulsive motor responses.

Additionally, task-by-task analysis revealed a reduction in average error across all LFA items, further supporting the effectiveness of the intervention (see Table 1).

Table 1: Changes in LFA Task Average Scores at Each Phase

Task	Baseline A	Intervention B	Follow-up A'
1. Both hand	215	34	29
2. Right hand	418	56	47
3. Left hand	251	48	34
4. Both toes	269	40	34
5. Right toes	292	42	21
6. Left toes	252	169	121
7. Both heels	234	33	30
8. Right heels	274	88	50
9. Left heel	157	81	66
10. Right hand/ left toe	336	52	45
11. Left hand/ right toe	267	63	54
12. Balance right foot/ tap left toe	203	56	45
13. Balance left foot/ tap right toe	216	227	200
14. task 1 + guide sound	110	42	40
Total	244.31	59.31	58.29

3.1.2 Short Form Assessment (SFA

To assess changes in the participant's attention, the SFA of IM was conducted during the baseline, intervention, and follow-up phases. The average task score for Task 1 was 241.67ms at baseline, which decreased to 109.62ms during the intervention phase and further to 59.00ms post-intervention. The reaction time error gradually decreased throughout the intervention, with a significant reduction below 70ms in sessions 8 (61ms), 11 (39ms), 12 (45ms), 13 (46ms), 14 (51ms), 15 (63ms), and 16 (66ms). This trend indicates an improvement in attention in the latter half of the training. For Task 2, the average task score was 217.33ms at baseline, which decreased to 105.15ms during the intervention and further to 56.50ms post-intervention. Throughout the intervention, reaction time errors were consistently below 70ms in sessions 8 (42ms), 9 (54ms), 11 (35ms), 13 (40ms), 14 (41ms), 15 (61ms), and 16 (60ms), with particularly precise performance below 40ms in sessions 11, 13, and 14.

The significant reduction in reaction time errors throughout the intervention and the maintenance of post-intervention scores at 59.00ms (Task 1) and 56.50ms (Task 2) confirm the sustained effects of the training (Figure 2).

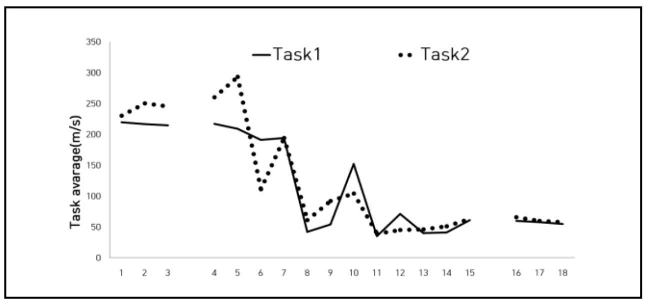

Figure 2: Changes in Motor Task Ratings of Task 1 and Task 2 During the Intervention Period

The participant's average synchronization rate (SRO) score for Task 1 was 2.00 at baseline, increasing to 14.54 during the intervention phase and 29.50 post-intervention. During the baseline period, the accuracy score remained consistently low at below 10. However, from session 8 onwards, scores showed a sharp increase, maintaining high accuracy levels above 25 from session 13 onward. Notably, in sessions 15 and 16, the participant achieved a perfect score of 30 consecutively, indicating highly precise response execution. Even after the intervention, the participant maintained high accuracy levels, scoring 28 in session 17 and 31 in session 18, demonstrating the lasting effects of the training. For Task 2, the average SRO score was 1.00 at baseline, increasing to 16.08 during the intervention and 27.50 post-intervention. Like Task 1, the initial scores were very low but showed a sharp increase from session 8, maintaining a stable high accuracy between 24 and 28 from session 13 onward. The post-intervention scores remained stable, confirming the persistence of the training effects in Task 2 as well. The accuracy scores for both Task 1 and Task 2 were initially low during the baseline and early intervention phases. However, from the mid-intervention phase onward, the scores gradually improved, and after completing the training, the improvements were stably maintained (Figure 3). These results indicate that IM training effectively enhances attention and sustains its positive effects over time.

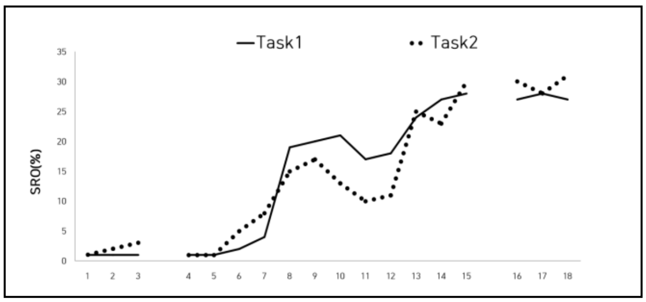

Figure 3: Changes in Accuracy Scores (SRO) of Task 1 and Task 2 During the Intervention Period

3.1.3 Abbreviated Conners Parent Rating Scale-Revised (ACRS)

To assess changes in the participant's social skills and behavioral patterns, the ACRS was administered before and after the intervention. The pre-intervention total score was 26, exceeding the diagnostic threshold of 16, indicating severe behavioral issues. In the post-intervention assessment, the total score decreased to 16, aligning with the diagnostic threshold, suggesting a significant reduction in behavioral problems. The total score reduction of 10 points indicates a positive effect of the intervention on the child's behavioral improvements. Improvements were observed in hyperactivity and impulsivity-related items (items 1, 2, and 3), with a decrease of 1 point in each category, indicating enhanced impulse control and social interactions. Attention-related items (items 4 and 6) also showed a reduction of 1 point each, suggesting an improvement in task persistence and concentration. Emotional regulation items (items 7, 8, 9, and 10) showed a general decrease, with item 8 ("frequently cries") decreasing by 2 points, highlighting a notable stabilization in emotional responses (Figure 4).

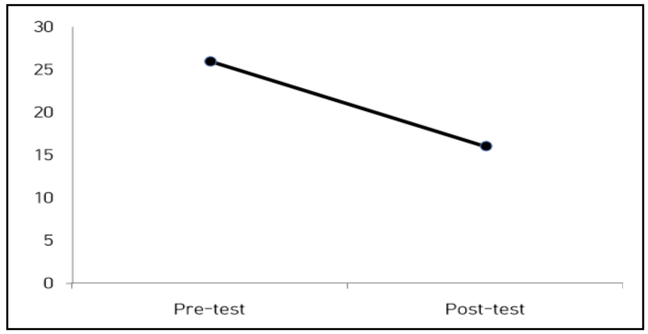

Figure 3: Changes in ACRS Scores Before and After Intervention

4. Discussion

This study aimed to examine the effects of Interactive Metronome (IM) training on impulsivity, attention, emotional regulation, and behavioral control in a child diagnosed with Attention Deficit Hyperactivity Disorder (ADHD), using an ABA' single-subject design. The findings revealed positive changes across multiple domains, supporting the effectiveness of IM training not only as a tool for improving attention and impulsivity, but also as an intervention that promotes emotional stability and behavioral self-regulation.

To assess behavioral and emotional outcomes, the Abbreviated Conners Parent Rating Scale-Revised (ACRS) was administered before and after the intervention. The total ACRS score decreased from 26 to 16, reaching the diagnostic threshold and indicating a meaningful reduction in behavioral symptoms. Items related to emotional instability—such as mood swings, frequent crying, and emotional outbursts—showed a 1–2 point decrease, suggesting improvements in emotional regulation and stimulus response control.

These findings are consistent with previous studies. Cosper et al. (2009) reported that IM training enhances reaction speed and sustained attention in children with ADHD, promoting functional improvement in academic and daily life. Koomar et al. (2001) also emphasized the neurobiological basis of IM training, linking it to prefrontal cortex activation and executive function enhancement. In this study, these neurocognitive mechanisms appear to have contributed to the observed behavioral changes.

Regarding attention, the participant initially showed relatively high average task scores during the baseline phase. However, the scores gradually decreased during the intervention, indicating improved timing accuracy and sustained attention. Importantly, the improvement was maintained during the follow-up phase, suggesting the durability of IM training effects. IM training involves synchronizing rhythmic motor responses with auditory cues, enhancing timing, inhibition, and sensorimotor coordination (Chang et al., 2014). Through repeated stimulation of working memory and executive functions, IM training appears to support both behavioral and cognitive regulation in children with ADHD.

Moreover, parental reports indicated tangible improvements in the child's behavior at home, reinforcing the potential applicability of IM training beyond clinical settings and into daily life environments. This aligns with current discussions on the need for home-based, non-pharmacological interventions for ADHD.

Despite these promising findings, this study has several limitations. First, as a single-subject design, the generalizability of the results is limited. Second, the use of parent-reported assessments introduces the possibility of subjective bias. Third, the study focused on short-term outcomes, and the long-term sustainability of effects remains unverified. To address these limitations, future studies should incorporate larger and more diverse samples, use multi-informant assessments (e.g., teacher reports, behavioral observations, neuropsychological testing), and conduct long-term follow-up evaluations. Additionally, applying more rigorous methodological elements such as inter-rater reliability and control group comparisons would enhance the robustness of future findings.

Lastly, from a practical and policy perspective, this study suggests that IM training may serve as a cost-effective, accessible intervention for children with ADHD, particularly in community or home-based settings. Its integration into therapeutic programs at schools or developmental centers could provide non-invasive support for children who struggle with attention and emotional self-regulation.

6. Conclusion

This study investigated the effects of Interactive Metronome (IM) training on impulsivity, attention, emotional regulation, and behavioral control in a child with ADHD using a single-subject ABA' design. The results demonstrated meaningful improvements in behavioral and emotional functioning, with a 10-point reduction in ACRS scores and enhanced timing accuracy in SFA and LFA ssessments. These findings provide preliminary evidence for the utility of IM training in improving executive functioning and self-regulation.

Notably, this study expands the scope of IM-related research by exploring its effects beyond attention and motor skills, addressing less-studied areas such as emotional regulation and behavioral control. The neurocognitive basis of IM, which targets prefrontal cortex activity, offers a promising framework for developing holistic interventions for children with ADHD.

While the generalizability of the findings is limited due to the single-subject design, the study contributes valuable exploratory insights. Future research should involve larger-scale, controlled studies with longitudinal tracking to validate and expand upon these results. The incorporation of objective evaluation tools and multi-modal data sources will further improve the accuracy and applicability of findings.

Overall, IM training shows potential as a neuropsychological intervention that can be applied in both clinical and home settings, contributing not only to symptom reduction but also to the overall quality of life for children with ADHD.

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