EFFECT OF ACTION OBSERVATION THERAPY ON SOCIAL AND MOTOR SKILL IMPAIRMENT IN SCHOOL-GOING CHILDREN: A SINGLE-BLINDED RANDOMISED CONTROLLED TRIAL

by

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Under the Guidance of

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DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation/thesis entitled **"Effect of Action Observation Therapy on Social and Motor Skill Impairment in School-Going Children: A Single-blinded Randomised Controlled Trial"** is a bonafide and genuine research work carried out by me under the guidance of Dr. Deepak Kumar Pradhan (PT), Associate Professor and Dr. Partha Ranjan Das (PT), Sr. Assistant Professor, Abhinav Bindra Sports Medicine and Research Institute, Bhubaneswar, Odisha and there are no conflict of interest associated with this dissertation work.

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LIST OF ABBREVIATIONS USED

Abbreviation	Full Form
AOMI	Action Observation with Motor Imagery
AON	Action Observation Network
AOT	Action Observation Therapy
APA	American Psychiatric Association
ASD	Autism Spectrum Disorder
CG	Control Group
DCD	Developmental Coordination Disorder
DCDQ	Developmental Coordination Disorder Questionnaire
DSM-5	Diagnostic and Statistical Manual of Mental Disorders, 5th Edition
EG	Experimental Group
EFS	Executive Function Scale
fMRI	Functional Magnetic Resonance Imaging
ICF	International Classification of Functioning, Disability and Health
IFG	Inferior Frontal Gyrus
IPL	Inferior Parietal Lobule
MIS	Motor Imitation Scale
MIP	Motor Intervention Program

Abbreviation	Full Form
MNS	Mirror Neuron System
MP	Motor Practice
NDD	Neurodevelopmental Disorders
OL	Observational Learning
PAM-AOT	Pathological ameliorative model-Action Observation Therapy
RCT	Randomized Controlled Trial
SCD	Social Communication Disorder
SCQ	Social Communication Questionnaire
SCS	Social Competence Scale
STS	Superior Temporal Sulcus
TDM-AOT	Typically Developing Model-Action Observation Therapy

ABSTRACT

Background: School-going children (6–12 years) experience rapid motor and social development, closely linked through the MNS. Dysfunction of the MNS, described by the "broken mirror hypothesis," contributes to motor and social deficits commonly observed in DCD and SCD, affecting academics, peer relations, and well-being. AOT activates the MNS through observing and imitating goal-directed actions. However, its effectiveness in children with co-occurring motor and social impairments remains underexplored.

Objective: To evaluate the effectiveness of AOT compared to a standard Motor Intervention Program (MIP) in social and motor skills among school-going children.

Methods: Screening was conducted in two phases: Phase 1 involved parent-reported questionnaires, namely the SCQ for assessing social skills and the DCDQ for evaluating motor skills. In Phase 2, clinical confirmation was done using DSM-5 criteria for SCD (F80.89) and DCD (F82). 24 eligible participants were randomly allocated into two groups in a single-blinded manner to reduce allocation bias. The EG received AOT for 40 minutes daily, 6 days/week, for 4 weeks, which involved structured observation and imitation of goal-directed actions to enhance motor and social skills. The CG underwent a MIP of equal duration and frequency without the observational learning component (social, motor & preacademic skills). Both groups were assessed through pre-test and post-test evaluations to measure improvements in motor and social skills.

Results: Paired-samples t-tests showed significant pre–post improvements in the EG across the SCS ($p<0.001$, $d=-2.94$), MIS ($p<0.001$, $d=-3.79$), Apraxia Test (p<0.001, d=-6.62), and EFS (p<0.001, d=-1.59). The CG also improved significantly but with smaller effect sizes (SCS: p<0.001, d=-2.54; MIS: p<0.001, d=-2.82; Apraxia Test: p<0.001, d=-2.90; EFS: p<0.001, d=-1.73). Independent-samples t-tests on mean difference scores revealed greater EG gains in MIS (p<0.001, d=-2.15), Apraxia Test (p<0.001, d=-2.02), and EFS (p=0.009, d=-1.16), while CG showed superior improvement in SCS (p=0.006, d=1.24).

Interpretation & Conclusion: Overall, AOT yielded stronger effects on motor skills, whereas MIP contributed more to social skills improvement, with all findings supported by large effect sizes, underscoring clinical significance.

Keywords: “Apraxia”, “Imitation”, “Neurodevelopmental”, “Perceptuomotor”, “Social Cognition”

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INTRODUCTION

School-going children, typically between the ages of 6 to 12 years, experience rapid growth and development across multiple domains, including social cognition, emotional competencies, and motor skills [1]. This period is crucial for acquiring fundamental abilities that influence academic achievement, social integration, and overall well-being. During these years, children refine their motor coordination and develop advanced social skills that facilitate peer interactions and emotional regulation. Motor skills, classified into gross (e.g., reaching) and fine (e.g., manual dexterity, grasping), have a significant role in cognition and executive functions, which are essential for problem-solving, attention control, and learning [2]. School environments provide opportunities for structured learning and peer interactions, fostering both academic and social development [3]. However, children with motor and social impairments often face difficulties in educational and extracurricular performance [4]. These impairments manifest in NDD such as DCD and SCD, affecting a child's ability to engage effectively with their surroundings [5]. Addressing these challenges is essential to ensure holistic development.

The development of social competence in young children is a crucial aspect of their development and is closely linked to the development of motor skills. The activity-deficit hypothesis states that children with impaired motor skills avoid motor-demanding activities, creating a negative feedback loop that limits skill development. Poor motor ability has been associated with increased peer victimization, as children who exhibit clumsiness are more likely to experience social isolation and peer rejection. This often leads to withdrawal and the development of poor social skills [6]. According to the Single Domain Hypothesis, motor skills and social cognition form a unified system, with progress in one domain influencing the other. Both rely on shared neural mechanisms, especially the MNS, which enables internal simulation of others' actions for understanding, termed the "mirroring mechanism". According to this view, "action cognition" is the brain's ability to perceive and internally represent actions serves as the developmental core from which higher-level social skills develop. [7] Impairments in motor skills could lead to difficulties in social cognition, indicating that these domains are not independent but rather integrated within a single cognitive framework.

Impairment in the ability to acquire motor skills in children, in isolation of any detectable neurological condition, has been extensively reported in the developmental literature since the last century. Throughout this period, several terms have been used to describe this syndrome: Developmental Dyspraxia, clumsiness, Minimal Brain Damage, physically awkward, and perceptuo-motor dysfunction. In 1994, following a consensus meeting of the world's leading clinicians and researchers, it was decided that the term Developmental Coordination Disorder (DCD) should be applied [8][9]. "DCD, also known as dyspraxia, is a neurodevelopmental disorder characterized by poor motor coordination and difficulty with motor planning in an otherwise healthy child with a normal gross neurological examination" (Black et al., 2014; APA,2013) [10]. By interfering with socialisation and academic achievement, this disorder may have a detrimental effect on the child's motor learning and overall life. Additionally, Zwicker et al. (2012) stated that DCD can lead to executive function deficits, i.e., difficulty executing coordinated motor actions accurately (dyspraxia, difficulties in imitation), which results in modest delays in fine and gross motor skills, preventing effective learning in early childhood education. "The global prevalence of DCD among school-going children is approximately 5-6%" (Li et al.,2024; APA,2013) [11]. In India, studies suggest a prevalence rate is 0.8% among children aged 6-12 years, though underdiagnosis remains a concern due to limited awareness and diagnostic facilities [12]. DCD is associated with executive function deficits, hindering children's ability to plan and execute motor actions accurately [13]. These impairments can result in challenges related to socialization, self-esteem, and academic performance [56]. Although the exact cause is unknown, poor coordination is thought to arise from an impaired ability to predict and control movements, a deficit described by the Internal Modelling Deficit (IMD) Hypothesis.[13] Children with DCD frequently struggle to participate in and perform other motor-based tasks that are integral to childhood experiences. These challenges can lead to peer rejection, social isolation, and a decline in confidence in social settings [15]. DCD has an impact on cognitive ability, executive processes, and mental health, in addition to motor abnormalities [16]. Interventions aimed at improving motor coordination can significantly enhance the quality of life for children with DCD, enabling better academic and social performance [17]. For detailed Diagnostic Criteria 315.39 (F80.89), refer to annexure-4.

Persistent challenges with verbal and nonverbal communication used for social goals, such as issues with pragmatic language, social reciprocity, and interpreting social cues, are hallmarks of social communication disorder (SCD). In contrast to ASD, SCD does not involve restricted and repetitive behaviours [18][19]. Children with SCD struggle with making eye contact, engaging in appropriate peer interactions, and perceiving social and emotional experiences effectively. Its primary symptoms include difficulties using communication for social objectives, a reduced capacity to adapt communication to the situation or the listener's demands, trouble adhering to conversational and storytelling norms, and trouble comprehending nonverbal cues.[20] The global prevalence of SCD is estimated between 6.1% and 10.5% [36]. In India, there is limited epidemiological data, but estimates suggest that the prevalence rate is 4.29% among school-aged children [21]. The impact of SCD is profound, often leading to peer rejection, academic underachievement, and difficulties in forming meaningful relationships. SCD is also associated with impaired motor development, further exacerbating social integration issues [22]. Murphy et al. (2014) described that Children with SCD frequently experience difficulties in classroom interactions, group recreations, discussions, and game-based learning. Their struggles with understanding social cues can lead to misinterpretations and difficulties in forming friendships. Early intervention strategies focusing on social skills training, speech therapy, and structured social activities can help children with SCD navigate these challenges more effectively [14]. For detailed Diagnostic Criteria 315.39 (F80.89) refer to annexure-4.

Imitation, social cognition, language, empathy, theory of mind, and motor learning are all fundamentally influenced by the MNS [23][24]. Mirror neurons, first found in the premotor cortex of macaque by Giacomo Rizzolatti and colleagues, fire both when an individual observes & performs an action [25]. This system enables perceptual-motor coupling, allowing children to learn new motor and social behaviours through observation and imitation, called the "direct matching hypothesis" [26]. The MNS is primarily located in the premotor cortex (area F5 in monkeys, equivalent to Brodmann area 44 in humans), the IPL, and other related areas such as the STS [27]. These regions are involved in action recognition, motor planning, and social cognition [28]. "Two primary networks have mirror properties: one is the parietofrontal mirror system formed by parietal lobe & premotor cortex, along with the caudal part of IFG focuses on recognition of voluntary behavior; another is the limbic mirror system formed by the insula and the anterior mesial frontal cortex for recognition of affective behavior" (Rajmohan et al., 2007). "The human brain's mirror neuron 'core' system, located in the IPL and IFG, is complemented by an 'extended' system—including the insula, middle temporal gyrus, and somatosensory cortex—that interfaces with the core to process information essential for action mirroring and simulation" (Pineda et al., 2008). The MNS integrates sensory input with motor execution, facilitating learning through imitation and enhancing understanding of others' intentions and emotions [29]. Mirror neurones are identified by the fact that they activate both when a goal-directed action is performed (such as grasping an object) and when a comparable goal-directed action is observed. Mirror neurons support the Perceptual-motor coupling and internal models that enable monitoring and control of executed actions.[30]

The "broken mirror hypothesis" refers to MNS dysfunction. According to this theory, the malfunction of these mirroring regions, necessary for social cognition and imitation, is linked to these processes. Imitation is regarded to be basic to social development and necessary for understanding people and for communicating. Williams et al. (2001) speculate that deficiencies in the AON/MNS might be a factor in social impairments and imitation. [31][32] Ham, H. E. (2010) detangled imitation and dyspraxia & proposed that gesture performance is supported by several interacting processing stages. These include:

- Input lexicon (recognizing gestures)
- Action semantics (understanding meaning)
- Output lexicon (producing gestures)
- Visuomotor conversion (translating visual input into motor action)

Based on neurophysiological information, AOT is a neurorehabilitation method whereby the same neural substrate, known as the MNS, is activated by observation of a goal-directed movement as is the actual execution of the observed action to improve motor and social abilities in children with DCD and SCD [33]. AOT consists of watching purposeful, goal-oriented movements, then imitating and performing those same actions [34][35]. Neurophysiological studies suggest that AOT activates the same neural circuits responsible for motor execution, strengthening perceptual-motor integration and facilitating skill acquisition [36].

The physiology of AOT is rooted in the principle that the MNS facilitates motor learning by linking perception and action[37]. Observing an action activates mirror neurons in the premotor cortex and IPL, which are responsible for action planning and execution [28]. Additionally, the superior temporal sulcus processes biological motion and provides crucial visual input for action recognition. Through repeated exposure and imitation, AOT strengthens neural connections and enhances synaptic plasticity, making it an effective intervention for children with motor and social impairments [38].

Imitation plays dual roles in both learning and communication, serving as a critical mechanism for development. Nadel J. (2015) stated that these functions are supported by perception–action coupling through two pathways:

1. direct motor route for immediate imitation and
2. indirect route involving inhibitory & prefrontal processes for delayed imitation.

Beyond skill acquisition, imitation fosters social coordination, role negotiation, and anticipation of others' intentions, linking the mirror neuron system with the mentalizing system. Ultimately, imitation integrates bottom-up and top-down processes, making it a powerful developmental booster even in children with neurodevelopmental impairments.

AOT generally involves patients observing goal-directed actions through video [39] or real-life demonstrations [40]. Depending on the approach, patients may then perform the observed action to facilitate motor relearning [41][42]. AOT can be used alone or combined with imitation and execution, where typically 1–2 actions are practiced per session. These actions are broken into 3–4 smaller tasks and presented from different perspectives (first-person or third-person) to enhance understanding and engagement [41][43].

AOT consists of two phases: the observation phase, where the patient carefully observes the action, and the execution phase, where they attempt to replicate it. Sessions last 30–60 minutes, including task explanation, 9–12 minutes of observation, and 6–8 minutes of execution. Each motor act is observed for about 3 minutes and executed for 2 minutes. Evidence is lacking on whether extending sessions to 1 hour improves outcomes over the standard 30 minutes.[43]

AOT actions are classified as transitive (object-related) or intransitive (without objects), with first-person perspectives eliciting stronger MNS activation than third-person views [32]. Action selection should prioritize simple, meaningful, and ecologically relevant tasks tailored to the patient's abilities. Studies most often reported video duration (85.71%) and viewing perspective (62.85%), while movement speed (7.14%) and sound (8.57%) were rarely mentioned. Control videos typically featured static landscapes or geometric patterns [44].

MNS activation during action observation was compared between children with ASD and their typically developing children in a meta-analysis by Chan et al. (2020) using ES-SDM. The left supplementary motor area and right IFG were overactive in children with ASD, with non-emotional stimuli activating left parietal/motor areas and emotional stimuli engaging the right frontal region. Age analysis revealed bilateral inferior frontal hyperactivation in adolescents, right-sided activation in adults, and meta-regression showed age-related increases in right cerebellum crus I and decreases in left inferior temporal gyrus activity[38].

Errante et al. (2024) compared PAM-AOT with TDM-AOT in 26 children with unilateral cerebral palsy. Children who observed peers with similar motor impairments showed greater improvement in bimanual activities, though both groups improved equally in unimanual tasks. fMRI revealed increased ventral premotor cortex activity in the PAM-AOT group, suggesting that observing impaired models better engages motor networks and enhances rehabilitation outcomes.[55]

Kinematic analysis done by Simon-Martinez et al. (2020) in 36 children with unilateral cerebral palsy undergoing 9 days of mCIMT, with the experimental group receiving an additional 15 hours of AOT. Both groups practiced unimanual tasks, but only the EG observed goal-directed actions. Kinematic analysis showed modest overall improvements, but the AOT group had better movement timing during reaching tasks. This suggests that combining AOT with mCIMT refines specific aspects of motor control, particularly movement timing.

Scott et al. (2023) evaluated a home-based, parent-led AOMI program for children with DCD (ages 7–12). Both groups improved in daily living tasks, but AOMI produced greater gains in shoelace tying and cup stacking, with faster performance and better technique retained at follow-up. Notably, 89% of children who could not tie shoelaces at baseline learned the skill with AOMI, compared to 44% in the control group. These results show AOMI is especially effective for teaching complex or novel motor skills in children with DCD.

Buchignani et al. (2019) conducted a systematic review and meta-analysis of 22 studies (19 in meta-analysis, 626 participants) on AOT for brain injuries. Results showed significant benefits for the upper limb in both body function ($g = 0.44$) and activity ($g = 0.47$), and for the lower limb in activity only ($g = 0.56$). These findings indicate AOT effectively improves motor function and activity, especially for upper limb rehabilitation. However, variability in study design and limited pediatric data highlight the need for larger, high-quality trials to refine AOT protocols.

In humans, non-invasive studies have confirmed the existence of a matching mechanism between action observation and execution in specific regions of the frontal and parietal lobes. This MNS forms the neurological foundation of AOT, supporting its use in motor rehabilitation.

Previous literature has predominantly concentrated on motor skill deficits, with limited attention to social functioning. In contrast, the present study addresses the dual domain of impairments, examining both motor and social skill deficits concurrently. This integrated approach acknowledges the interrelated nature of these domains and their collective importance for holistic developmental outcomes in children.

Need for the study

- Increasing Prevalence of Neurodevelopmental Disorders (NDD): Recent interventions often focus on either motor or social skills, but few address both simultaneously. This creates a gap in holistic interventions that can target multiple domains of development. Incorporating motor activities into social skills training could enhance both areas of development, particularly for children with developmental disorders characterized by social and motor skill impairments.

- Perceptual-motor coupling: It refers to the interconnected relationship between perception and action, in which sensory information guides motor responses and vice versa. AOT presents a novel approach by integrating visual learning and physical execution, which can simultaneously enhance both motor and social learning, making the intervention more engaging and comprehensive.
- Potential for Early Intervention: Early interventions that simultaneously target motor and social skills could prevent long-term developmental delays and enhance children's overall academic and social outcomes.

AIM & OBJECTIVE OF THE STUDY

AIM OF THE STUDY

To check the effect of Action Observation Therapy on social and motor skill impairment in school-going children.

OBJECTIVES OF THE STUDY

To assess the efficacy of Action Observation Therapy on social and motor skill impairment in school-going children using Social Competence Scale, Motor imitation test, Apraxia test, Executive functioning scale.

HYPOTHESIS OF THE STUDY

Null Hypothesis: There will be no significant effects of Action Observation Therapy on social And Motor Skill Impairment In school-going children.

Alternate Hypothesis: Action Observation Therapy will have significant effects on social And Motor Skill Impairment In school-going children.

REVIEW OF LITERATURE

- Section 1: Population (Relation of MNS with social and motor skill impairment)
- Section 2: Intervention (Action Observation Therapy)
- Section 3: Outcome (Social and Motor Skill)
- Section 4: Comparison (Motor Intervention Program)

SECTION 1: POPULATION (RELATION OF MNS WITH SOCIAL AND MOTOR SKILL IMPAIRMENT)

1. Reynolds, Jess E., et al. (2015) conducted a comprehensive systematic review on existing literature on imitation, motor imagery, and neuroimaging to investigate evidence of impaired MNS functioning in both children and adults with DCD. Total of 31 articles are included. The review highlights consistent evidence that both children and adults with DCD struggle with imitating actions. These individuals also show inconsistencies in performing complex motor imagery tasks when compared to typically developing peers. The authors point to emerging evidence suggesting that these difficulties may stem from underlying impairments in the MNS, a neural system thought to play a key role in understanding and imitating others' actions. Notably, the review highlights that children with DCD frequently struggle to imitating both familiar, learned gestures and unfamiliar, non-representational movements, suggesting possible impairments in MNS function. Understanding MNS deficits may clarify DCD mechanisms and help refine interventions such as AOT, motor imagery & CO-OP approaches.

2. Jessica M Lust et al. (2019) using neurophysiological evidence of action observation paradigm, stated that activation of mirror neuron regions is altered in DCD. Children with DCD struggle with motor skill learning, possibly due to impaired MNS function. This study used EEG to assess MNS activity in 15 children with DCD and 15 typically developing peers during two tasks: imitation (OL) and movement detection (MP). EEG measures focused on mu rhythm suppression and fronto-parietal coherence. The result revealed that children with DCD exhibited markedly lower levels of mu suppression and coherence modulation, especially while performing imitation tasks. These findings suggest impaired neural processes underlying observational motor learning in DCD, supporting the theory that disrupted MNS function may contribute to their motor difficulties.

3. Schmidt, Stephanie NL, et al. (2021) stated that the human MNS is the common neural basis for social cognition. This study involved 75 adults aged between 18 and 36 years, including both male and female participants. While engaging in tasks related to these three domains, participants' brain activity was recorded using a combination of EEG and fMRI, allowing for a detailed analysis of both the timing and location of neural responses. The findings revealed that several brain areas were consistently activated across the different tasks, suggesting that the MNS plays a central role in supporting diverse social-cognitive abilities. This supports the theory of embodied simulation, which proposes that we understand others' actions, emotions, and intentions by internally simulating them through shared neural mechanisms. The study provides compelling evidence that the MNS is not just limited to action observation but is deeply involved in broader social understanding.

4. Melody M Y Chan et al. (2020) conducted a meta-analysis of neuroimaging study. This meta-analysis employed ES-SDM to examine differences in MNS activation between children with ASD and typically developing peers during biological motion observation with and without social-emotional components . The results indicated that children with ASD showed increased activation in the right IFG and left supplementary motor area. Stimuli without emotional content triggered left parietal and motor hyperactivation, while emotional stimuli led to right frontal hyperactivation. Age-based analysis revealed bilateral inferior frontal hyperactivation in adolescents and right-sided activation in adults with ASD. Meta-regression analysis revealed that with increasing age, there was increased activation in the right cerebellum crus I and reduced activation in left inferior temporal gyrus. These findings suggest MNS dysfunction in ASD is influenced by age and stimulus type.

5. Marco Sperduti et al. (2015) conducted a fMRI study to examined how the MNS and Mentalizing System connect during online social interaction involving reciprocal hand gesture imitation. Using psychophysiological interaction analysis, results showed increased functional connectivity between the two systems during imitation (both being imitated and imitating) compared to passive observation. Findings suggest that the MNS supports action simulation and execution, while the Mentalizing System helps anticipate others' intentions, highlighting their complementary roles in regulating social interaction and role-switching.

6. Lorcan Kenny et al. (2016) investigated the relationship between social and motor cognition in primary school-age children, utilizing a cognitive approach that assesses specific domains such as theory of mind, motor skill, action understanding, and imitation. The findings indicate that these domains, particularly theory of mind, operate relatively independently, challenging the 'single domain hypothesis' and supporting models where social and motor skills develop as separate yet potentially interactive systems. While action understanding and imitation are closely linked and somewhat related to motor control, social cognition, as measured by theory of mind tasks, appears independent of these motor-related skills. The study also highlights that environmental factors may play a role in linking motor and social development, evidenced by prior longitudinal research suggesting that early motor skills can predict later social abilities. The results suggest modular development of social and motor cognition in children, with implications for understanding developmental trajectories and informing interventions. The research underscores the importance of examining these domains both independently and in interaction, as they appear to follow different developmental pathways, at least during the primary school years.

7. **Alicia Wilson et al. (2012)** conducted a study on the mediating role of social skills in the relationship between motor ability and internalizing symptoms in pre-primary children. Using structural equation modeling on a sample of 234 boys and 241 girls typically developing children aged 4 to 6, the results supported the hypothesis that social skills fully mediate this relationship, with lower motor ability associated with poorer social skills, which in turn relate to greater internalizing symptoms such as anxiety and depression. The findings suggest that deficits in motor skills can indirectly contribute to emotional difficulties through their impact on social competence, emphasizing the importance of focusing on social skill development in children with motor impairments to potentially prevent subsequent psychosocial problems. Overall, the research underscores the interconnectedness of motor development, social functioning, and emotional well-being in early childhood.

SECTION 2: INTERVENTION (ACTION OBSERVATION THERAPY)

8. Bianca Buchignani et al. (2019) conducted a systematic review and meta-analysis aimed to evaluate the efficacy of AOT for rehabilitation in both adults and children with brain damages. Researchers systematically searched seven databases until September 16, 2018, for RCTs on AOT interventions lasting at least one week for upper or lower limbs. Two reviewers independently selected and extracted data, assessing study quality using the Oxford EBM criteria and PEDro scale. Using R software, Hedge's g was calculated, and meta-analyses were performed by ICF domains (body function and activity) for both limb types.Out of 210 identified records, 22 studies were selected for review and 19 included in a meta-analysis with 626 participants. The results revealed statistically significant effect sizes for the upper limb in both the body function domain (0.44; 95% CI: 0.24–0.64; $p < 0.001$) and the activity domain (0.47; 95% CI: 0.30–0.64; $p < 0.001$). For the lower limb, a significant effect size was observed for the activity domain alone (0.56; 95% CI: 0.28–0.84; $p < 0.001$). Overall, the findings suggest that AOT is a promising and innovative rehabilitation approach for enhancing motor function and activity, particularly in individuals with upper limb impairments. However, the studies included varied in design and quality, highlighting the need for more rigorous, large-scale trials, especially in pediatric populations, to better define the most effective AOT protocols.

9. Emily Kilroy et al. (2019) conducted a review of functional and structural neurobiology of the AON in ASD and DCD in key functions such as social interaction, imitation, and motor planning—areas that are often impaired in individuals with DCD. The AON is a crucial brain network involved in understanding and imitating others' actions, and its dysfunction may help explain the challenges in motor planning and imitation commonly seen in people with DCD. The findings suggest a positive link between motor planning abilities and activity in the IFG, a core region of the AON, highlighting how closely motor skills are tied to brain function in this network. The AON is also influenced by other interconnected networks, including the sensorimotor, fronto-parietal, cerebellar, and reward systems, which together may shape its performance. While children with ASD may also show motor and imitation difficulties, the variability in these symptoms suggests there is no single neurobiological cause behind them. It implies that the more general motor abnormalities observed in DCD may be indicative of deficiencies in the AON.

10. Antonino Errante et al.(2024) conducted a study to compare the impact of two variation on AOT i.e., PAM-AOT and TDM-AOT on improving upper limb function in children with unilateral cerebral palsy. The study involved a sample of 26 children. The EG observed videos of individuals with similar motor impairments for three weeks, while the CG viewed videos of typically functioning models. After the intervention, children in the EG showed greater improvement in bimanual hand activities compared to the CG. However, both groups made similar progress in tasks involving only one hand. Brain scans (fMRI) conducted after the treatment revealed increased activity in the ventral premotor cortex of the EG, suggesting that observing peers with similar challenges may more effectively engage motor-related brain areas and enhance rehabilitation outcomes.

11. Scott, M. W. et al (2023) conducted a study to investigate the effectiveness of a parent-led, home-based AOMI on learning of ADL in children with DCD. The study involved children aged 7 to 12, including 23 with a confirmed diagnosis of DCD and 5 with suspected cases. Over four weeks, the EG received both a structured MIP and the AOMI intervention, while outcomes were measured using the Movement Imagery Questionnaire for Children (MIQ-C) and the manual dexterity subtest of the

Movement Assessment Battery for Children (MABC-2). By the end of the intervention, children in the AOMI group completed tasks more quickly than those in the CG. These findings suggest that AOMI can be a valuable tool for teaching complex motor tasks to children with DCD, particularly those skills they have not yet mastered. The study also highlights the potential of involving parents in delivering effective, accessible home-based therapy.

12. Simon-Martinez C. et al. (2020) conducted a randomized controlled trial on effects of combining mCIMT and AOT on upper limb kinematics in children with unilateral cerebral palsy(uCP). 36 children aged 6 to 12 with uCP participated in a 9-day mCIMT program, during which they wore splints for six hours each day. The EG received an additional 15 hours of AOT, which involved watching videos of goal-directed unimanual tasks followed by performing the same tasks. In contrast, the CG also performed the tasks but viewed placebo videos that did not include any biological motion. Researchers assessed changes in motor control and movement patterns by analyzing kinematic factors such as movement duration, peak velocity, time to reach peak velocity, and the straightness of the movement path during 3 unimanual tasks. While overall changes in upper limb movement patterns were modest, the combination of AOT with mCIMT was particularly effective in improving movement timing during reaching tasks, suggesting a targeted benefit of AOT in refining specific aspects of motor performance in children with uCP.

13. Maria Chiara Bazzini et al., (2022) conducted a study on the proactive synergy between action observation and execution in the acquisition of new motor skills. Motor learning involves lasting changes in motor behavior through repeated interaction with the environment and can occur via physical practice or covert strategies like action observation. This study compared MP, OL, and AOT—a method alternating observation and execution—by training 54 participants to tie nautical knots. Results showed AOT led to the greatest performance improvement (42%), surpassing MP (25%) and OL (10%). The findings suggest that combining observation with execution enhances learning more than either strategy alone, with applications in rehabilitation, sports, music, and fine motor skill training.

SECTION 3: OUTCOME (SOCIAL AND MOTOR SKILLS)

14. Dadgar, Hooshang, et al. (2017) conducted a study to check the relationship between motor, imitation, and early social communication skills in children with autism. This study involved 20 children aged 3 to 5 years who were all diagnosed with ASD based on DSM-5 criteria. To evaluate their development, researchers used 3 key assessment tools: the SCS to measure social communication skills, the MIS to assess imitation ability, and the Test of Gross Motor Development (TGMD-2) to evaluate motor function. Each assessment was video-recorded for accurate scoring and analysis. The researchers used the Pearson correlation coefficient to examine the relationships among the different skill domains. The results revealed a strong and significant relationship between early social communication and both motor and imitation abilities. Notably, the total scores on the TGMD and the MIS were highly correlated ($r = .776$, $p < 0.001$), highlighting the close link between motor skills and imitation in young children with ASD. These findings suggest that motor and imitation abilities may play a key role in the development of early social communication.

15. Uljarević M. et al (2023) conducted a study on Development, validation and preliminary psychometric testing of 52-item EFS intended for children aged 2 to 17. The findings indicated that the scale performed well in terms of reliability. Subscale scores met or exceeded the acceptable threshold for reliability (0.70), while the full scale showed excellent reliability with a score of 0.90. To assess validity, the EFS was compared with the established 24-item BRIEF-sf (Behaviour Rating Inventory of Executive Function – short form). The strong correlation between the two tools (r = 0.85) demonstrated high convergent validity, suggesting that the EFS is a reliable and valid tool for measuring executive functioning in children

16. Chang, S.H. et al. (2016) compared the motor praxis and performance in children with varying levels of DCD. The apraxia test is a relatively underexplored method for detecting functional indicators of childhood dyspraxia. Children between the ages of 6 and 8 were gathered for this study in the following ways: There are 35 children without apparent motor coordination issues, 17 children with DCD, and 18 children at risk for DCD. Motor skills were assessed using the Movement Assessment Battery for Children (MABC-2), while limb praxis was evaluated through apraxia test, gesture representation tasks, and object-use knowledge questions. Results showed that children at risk for DCD struggled with most gesture tasks, while those with DCD scored lower on the apraxia test. Only a weak correlation was found between MABC-2 scores and apraxia test results.

SECTION 4: COMPARISON (MOTOR INTERVENTION PROGRAM)

17. Gülsüm Hatipoğlu Özcan et al. (2024) conducted a study to assess the effects of

MIP on academic skills, motor skills and social skills in children with ASD. This study involved 34 children aged 3 to 6 years, divided evenly into an EG and a CG, with 17 participants in each. The EG took part in a structured MIP over a period of 12 weeks, with 40-minute sessions conducted twice a week. Results showed that the EG demonstrated significantly greater improvement in all subtests of the Peabody Motor Development Scale-2 (PMDS-2) and Pre-Academic Skills Evaluation Form (PASAF) total scores compared to the CG. Additionally, the EG showed a meaningful reduction in social interaction difficulties and stereotypical behaviors on the Turkish version of the Gilliam Autism Rating Scale-2 (GARS-2 TV). Improvements were also seen in social skills areas such as cooperation, self-control, and reduced externalizing behaviours on the Social Skills Rating System – Preschool Teacher Form (SSRS-PTF). Overall, the motor intervention had a positive impact on motor, social, and pre-academic skills in young children.

SN.	AUTHOR(YEAR)	AIM	METHODOLOGY	FINDINGS	INSIGHTS
SECTION 1: POPULATION (RELATION OF MNS WITH SOCIAL AND MOTOR SKILL IMPAIRMENT)					
1	Reynolds, Jess E., et al. (2015)	To investigate the evidence of abnormal functioning of the MNS in children and adults with DCD, through examination of imitation, motor imagery, and neuroimaging literature	Six databases were searched; 31 eligible studies (27 cross-sectional, 1 longitudinal) were narratively reviewed due to heterogeneous outcomes.	Children/adults with DCD show deficits in imitating meaningful gestures, & Reduced activation and connectivity in key MNS regions	MNS dysfunction in DCD, both behaviourally and neurologically. Understanding MNS deficits may clarify DCD mechanisms and help refine interventions such as AOT, motor imagery & CO-OP approaches.
2	Jessica M Lust et al. (2019)	To test the hypothesis that MNS function is disrupted in DCD by examining neurophysiological activation during action observation and imitation.	Thirty children (15 with DCD, 15 controls) completed imitation and detection tasks while EEG recorded mu suppression and fronto-parietal coherence as indices of MNS activation. Data were analyzed using linear mixed-effects models	DCD showed significantly reduced mu suppression and weaker modulation of fronto-parietal coherence during OL compared with controls. Behaviorally, they made more errors in imitation tasks.	Impaired MNS activation in DCD, suggesting deficits in coupling observed actions to internal motor representations. These findings support MNS-based interventions such as action observation and motor imagery training for motor learning in DCD.
3	Schmidt, Stephanie NL, et al. (2021)	investigated whether the MNS provides a shared neural substrate for core social-cognitive processes—imitation, empathy, and ToM—as proposed by embodied simulation theory.	75 healthy children underwent fMRI while performing imitation, empathy, and ToM tasks using standardized facial expression stimuli. Data were analyzed through task contrasts, conjunction analyses, and shared voxel (sVx) counts to assess overlapping neural activation across and within participants.	All tasks activated overlapping MNS and face-processing regions (IFG, IPL, pSTS, fusiform, amygdala), with distinct patterns for specific demands.	The findings provide strong evidence that the MNS underlies multiple facets of social cognition through embodied simulation. While not proving mirror neurons directly, the results highlight a common mirroring mechanism for interpersonal understanding and suggest the MNS as central to the "social brain."
4	Melody M Y Chan et al. (2020)	To investigate differences in MNS activation between ASD & typically developing individuals	The methodology involved using effect size signed differential mapping (ES-SDM) to synthesize available fMRI data.	individuals with ASD showed hyperactivation in the right IFG and left supplementary motor area.	This abnormal activation pattern in the brain regions with mirror neurons supports the idea that impaired imitation in ASD is associated with

		during action observation, with or without social-emotional components.			"broken" frontoparietal mirror neurons during social component.
5	Marco Sperduti et al. (2015)	to explore the synergy between the Mirror Neuron System (MNS) and the Mentalizing System during live social exchanges	used fMRI to record brain activity during reciprocal hand gesture imitation, and then used psychophysiological interaction to investigate functional connectivity.	Greater connection between the MNS(IFG & IPL) and the Mentalizing System (MPF & ACC) during both imitating and being imitated.	complementary role for the 2 networks: the MNS simulates and prepares for actions, while the Mentalizing System anticipates the other's intentions to co-regulate reciprocal actions.
6	Lorcan Kenny et al. (2016)	To investigate the relationship between social and motor cognition in primary school-age children, utilizing a cognitive approach	Using tasks measuring ToM, action understanding, imitation, and motor skills, the methodology involved testing 101 children and analyzing correlations between these domains.	The findings showed that ToM is independent of motor and imitation skills, while action understanding and imitation are closely linked.	The strong link between imitation and action understanding, but weak connection to ToM, supports the idea that social and motor skills may originate from a single, unified cognitive system during development.
7	Alicia Wilson et al. (2012)	To examine if social skills mediate the relationship between motor ability and internalizing symptoms in pre-primary children.	A cross-sectional research design was employed to assess the mediation model using data from 234 boys and 241 girls aged 4 to 6 years.	Lower motor ability was linked to poorer social skills, which then related to higher internalizing symptoms.	The insight emphasizes the importance of enhancing social skills in children with motor difficulties to prevent emotional problems.
SECTION 2: INTERVENTION (ACTION OBSERVATION THERAPY)					
8	Bianca Buchignani et al. (2019)	To systematically review and analyse the effects of AOT on adults and children with brain damage.	7 electronic databases were searched for RCTs on adults and children with brain damage. 2 independent reviewers analyzed data to calculate pool effect sizes across different ICF domains for upper and lower limbs.	AOT shows promising results in improving the activity domain for upper and lower limbs, and also the body function domain for the upper limb.	AOT improves motor skills, which are a foundational component of many social interactions; it may support the improvement of multiple domains of development.
9	Emily Kilroy et al. (2019)	To review the current neuroimaging literature on the AON in both ASD and DCD to understand	exploring neuroimaging findings from fMRI and diffusion-weighted imaging studies	Some studies on ASD show that the AON has reduced activity, while others show it is intact. In DCD, studies consistently	While AON dysfunction may be linked to motor and social impairments in ASD and DCD, the relationship is complex and

		the underlying neural mechanisms for motor impairments.		show decreased AON activation..	influenced by the heterogeneity of the populations and other brain networks
10	Antonino Errante et al.(2024)	To compare the effectiveness of AOT based on a PAM-AOT *versus* TDM-AOT in improving upper limb ability in children with uCP.	This evaluator-blinded RCT compared PAM-AOT with TDM-AOT in 26 children with UCP. A 3-week program, was assessed via motor measures at 4 time points, with fMRI in 16 participants, analyzed using Generalized Estimating Equations.	Both groups improved significantly in bimanual and unimanual function, with EG showing greater gains & increased ventral premotor cortex activation. PAM-AOT proved effective for enhancing upper limb ability	seven bimanual actions for AOT.
11	Scott, M. W. et al (2023)	to investigate the effectiveness of a home-based, parent-led AOMI intervention for helping children with DCD learn ADLs	28 children with confirmed or suspected DCD were split into an AOMI group and CG, and a parent-led intervention was conducted for 4 weeks, with task completion times and movement techniques recorded at pre-, post-, and retention tests	AOMI group showed significantly faster task completion times and improved movement techniques. 89% of participants in the AOMI group learned the skill, compared to only 44% in the CG.	home-based, parent-led AOMI interventions can be an effective way to help children with DCD learn complex ADLs, especially new motor skills that are not yet part of their motor repertoire
12	Simon-Martinez C. et al. (2020)	to investigate the effect of AOT combined with mCIMT on upper limb movement in children with UCP.	9-day mCIMT camp for 36 children with UCP. EG received 15 hours of AOT, while the CG watched videos without human movement. Kinematic and clinical changes were measured before and after the intervention, and at a 6-month follow-up	Adding AOT to mCIMT affected overall upper limb movement patterns; & movement duration during reaching. Both groups showed improved peak velocity and trajectory straightness	AOT is effective for upper-limb movement patterns & duration
13	Maria Chiara Bazzini et al., (2022)	to compare the efficacy of **AOT** against MP and OL in the acquisition of new, complex motor skills	enrolling 54 subjects to learn to tie nautical knots. They were divided into three groups: AOT (regularly alternating observation & execution), MP& OL	The AOT group had a performance improvement (42%) over both the OL and MP groups. The AOT group also experienced a 25-30% average decrease in time-to-completion	Regular alternation of action observation and execution is effective for motor skill learning than either MP or OL alone. This suggests a synergistic relationship between the two processes.

SECTION 3: OUTCOME (SOCIAL AND MOTOR SKILLS)					
14	Dadgar, Hooshang, et al. (2017)	to investigate relationship between motor skills, imitation ability, & social communication in children with ASD	20 children with ASD using the Test of Gross Motor Development, the Motor Imitation Scale (MIS), and Social Communication Scales (SCS).	strong correlation between motor and imitation skills, and a significant correlation between both motor and imitation skills.	these areas could be beneficial targets for early intervention programs in children. MIS & SCS are reliable tools for assessing motor & social skills.
15	Uljarević M. et al (2023)	to develop and validate tool for comprehensively assessing executive functioning called the EFS	two independent data collections with both an exploratory sample (n=2004) and a confirmatory sample (n=954) of children aged 2-17, including those with neurodevelopmental and neuropsychiatric conditions	EFS had excellent reliability and internal consistency, and its six-factor model (including working memory, response inhibition, and emotion regulation) fit the data well.	EFS has the potential to be widely adopted for examining executive function in children.
16	Chang, S.H. et al. (2016)	to compare motor praxis and motor performance in children with varying levels of DCD	70 children aged 6-8 and classified into 3 groups: DCD, at-risk of DCD, and typically developing. Motor performance was measured using the MABC-2, while praxis was assessed through apraxia test.	children with DCD had lower scores on the apraxia test, while children at risk of DCD had lower scores on gesture production. A weak relationship was found between the MABC-2 and the praxis tests.	A better understanding of developmental dyspraxia and its effect on motor coordination suggests that specific praxis tests may be clinically useful for children.
SECTION 4: COMPARISON (MOTOR INTERVENTION PROGRAM)					
17	Gülsüm Hatipoğlu Özcan et al. (2024)	to examine the effect of a MIP on motor, academic, and social skills in children with ASD	12-week program for 34 children aged 3-10, with an EG participating in a MIP for 40 minutes, two days a week.	EG had statistically significant improvements in motor skills, pre-academic skills, and social skills, along with a decrease in the autistic index	Effective intervention for children to improve motor, academic, and social skills .

METHODOLOGY & PROCEDURE

- **STUDY DESIGN:** Randomized Controlled Trial
- **STUDY POPULATION:** School-going children with social and motor skill impairments
- **SAMPLE SIZE:** 24
- **SAMPLING TECHNIQUE:** purposive sampling
- **STUDY SETTING:** multicentred primary schools of Sonepur district
- **STUDY DURATION:** 1 year
    - Ethical clearance: 4 months
    - Sample selection, data collection: 4 months
    - Statistical analysis, results analysis, discussion: 4 months
- **MATERIALS USED:**

  Play-dough, rolling pin, Mold, pan, paintbrush, glass, glue, cardboard, box, ball, chocolate, baguette, chocolate cream, nuts, jar, plate, beads, thread/wire, scissors, school bag, stamp

  Spoon, rattle, car, teacup, toy, hairbrush/comb, blocks, beads, string, eraser, toy hammer, screwdriver, and candle
- **INCLUSION CRITERIA:**
    - aged 6-12 years
    - Screening through DSM-5 criteria and parent-reported questionnaires

1. Social Communication Questionnaire (SCQ): Cut-off >=15

2. Developmental Coordination Disorder Questionnaire (DCDQ)

Cut-off:

Ages 5 years to 7 years 11 months: 15- 46

Ages 8 years to 9 years 11 months: 15- 55

Ages 10 years to 15 years: 15- 57

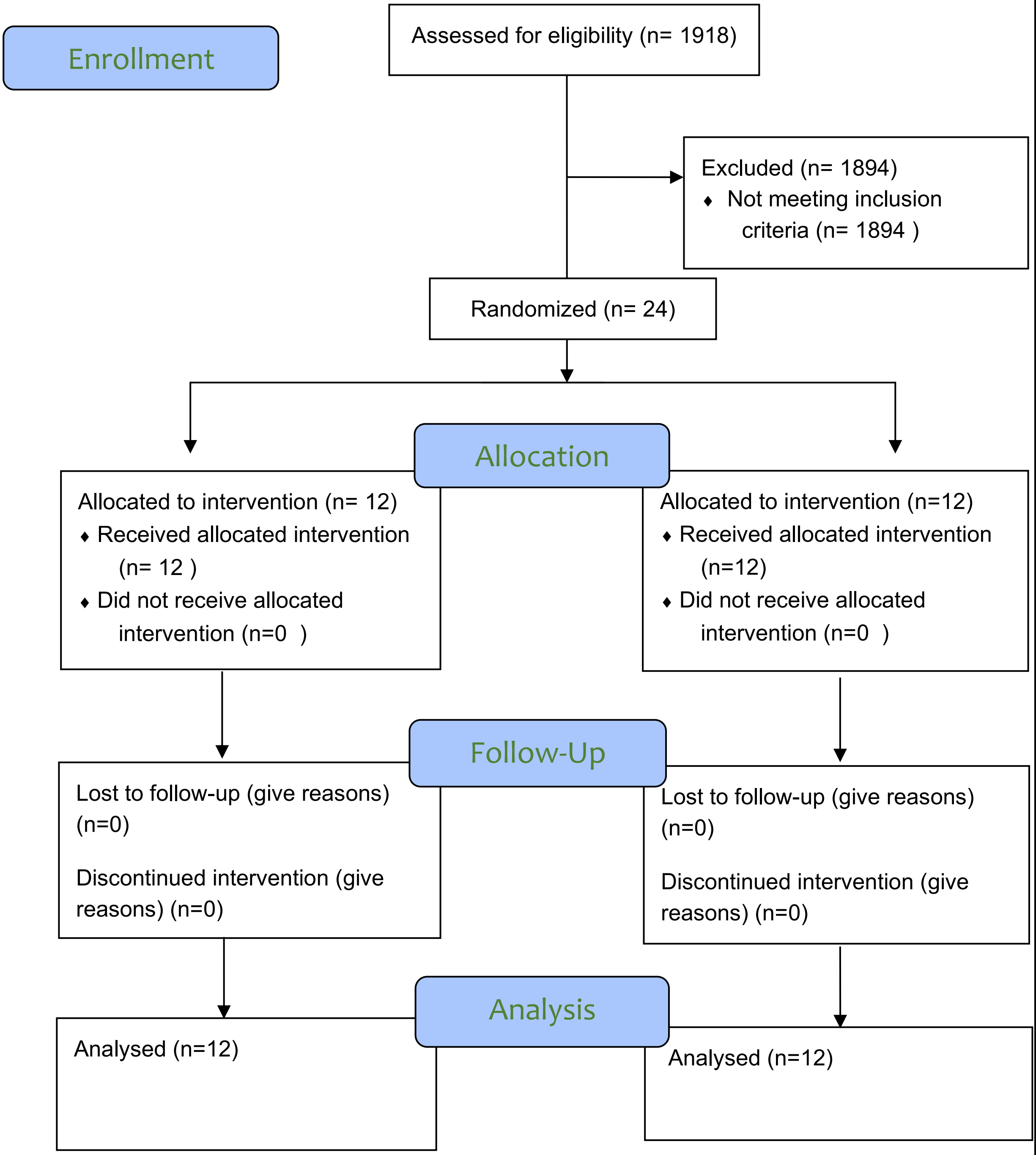
- **EXCLUSION CRITERIA:**

    - Severe intellectual disabilities or physical impairments that prevent participation.
    - Visual or auditory impairments.
    - Co-occurring medical condition known to further impair motor function e.g. CP, MD

- **OUTCOME MEASURES**

    - Social Competence Scale (SCS)
    - Motor Imitation Scale (MIS)
    - Apraxia test
    - Executive functioning scale (EFS

- **CONSORT 2010 Flow Diagram**



➢ PROCEDURE

Ethical clearance was obtained from the Institutional Ethics Committee (IEC) to ensure all protocols comply with ethical standards (ABSMARI/IEC/2025/144). Following this, the screening of subjects was carried out in two phases.

In **Phase 1**, screening was conducted using parent-reported questionnaires, i.e., **SCQ** to assess the social skill impairment and the **DCDQ** to evaluate motor skill impairment in children. **Phase 2** involved a clinical diagnostic approach using the **DSM-5** criteria, i.e., **SCD (F80.89)** for provisional diagnosis of social skill impairment and **DCD (F82)** for provisional diagnosis of motor skill impairment. Based on the diagnostic criteria and predefined selection criteria, eligible children were selected for the intervention. The selected participants were then briefed in detail about the study objectives and procedures, and written informed consent was obtained from their parents. Subsequently, each participant's demographic data was recorded.

A total 24 samples were selected by using purposive sampling based on inclusion and exclusion criteria. Next, the participants were randomly allocated into two groups in a single-blinded manner, i.e., Group allocation by the teacher was blinded about the nature of the intervention to minimize bias. Both groups underwent a pre-test evaluation to establish baseline measurements for comparison.

- **Group 1** is designated as the EG and received **AOT** (40 minutes of structured activity per day, for 6 days a week, over a period of 4 weeks). The therapy focused on enhancing motor and social skills through the observation and imitation of goal-directed actions, i.e., OL & MP
- **Group 2** is the CG and participated in a standard **MIP** (for 40 minutes per day, 6 days

a week, for 4 weeks). This program focuses on social, motor, and preacademic skills without the OL component present in Group 1.

After the completion of the 4-week intervention period, both groups were subjected to a post-test evaluation to measure improvements in the targeted domains.

- **PROTOCOL**

- **Experimental group (EG): Action Observation Therapy** [55]

The children performed 2 tasks from the table given in annexure-5 each day:

Each session consists of 2 tasks. A single task will be divided into 3 motor components. Each component of 15 minutes (observation through videoclips 3 minutes, and execution 2 minutes). .10 minutes of rest period will be given between the 2 tasks.

- **Control Group (CG): Motor Intervention Program** [54]

4 phases

(i)Immersive/warm-up movements (5 min) e.g., walking, running & jumping

(ii)Functional exercises (5 min): for improving joint mobility and flexibility

(iii)Tasks for both individuals and groups (20 minutes) that concentrate on three developmental domains (motor, social, and pre-academic skills)

(iv) group activities (10 min): games to reinforce targeted developmental skills and increase social interaction.

TASK PERFORMED BY THE CHILDREN OF EG

FIGURE 1.1: Flattening the Play-Doh with a rolling pin

FIGURE 1.2: Spreading glue in a square on cardboard to paste picture card

TASK 1.3: Unscrew the ball into 2 halves to take the candy out

FIGURE 1.4: Spreading chocolate cream on a slice of bread

FIGURE 1.5: Threading the beads on wire to make a bracelet

FIGURE 1.6: Cutting a paper circle on the marked line

TASK 1.7: Removing a glue cap to stick a small ball

TASK PERFORMED BY THE CHILDREN OF CG

FIGURE 1.8: phase 1 of MIP-Immersive/warm-up movements

FIGURE 1.9: phase 2 of MIP-Functional exercises (toe touch, squatting, lunges)

FIGURE 1.10: phase 3 of MIP- social games (ball pass, carrom)

FIGURE 1.11: phase 3 of MIP-motor activities (glue ball on cardboard, cutting circle)

FIGURE 1.12: Phase 3: preacademic tasks (colour match, identifying geometrical shapes)

FIGURE 1.12: phase 4 MIP- group activities

- **OUTCOME MEASURES:**

1. **Social Competence Scale – T**

"It is a 25-item, five-point Likert scale: Not at all (0), A little (1), Moderately well (2), Well (3), and Very well (4). This scale has 3 subscales: **Prosocial/Communication Skills** (Items 9,13, 19, 20, 22, 23, 24, and 25), **Emotional Regulation Skills** (Items 2, 3, 6, 7, 8, 11, 12, 14, 16, and 18), and **Academic Skills** (Items 1, 4, 5, 10, 15, 17, and 21). Along with the individual subscale scores, a combined score is generated for the Prosocial/Communication and Emotional Regulation items, and an overall total score across all 25 items is also provided. score ranges from 0-100" (Thompson et al., 2019) [49]. The lower the score higher the impairment. The Prosocial/Communication Skills and Emotional Regulation Skills subscales both have a reliability coefficient of 0.96, while the Academic Skills Subscale shows a slightly lower but still strong value of 0.95. The combined score for Prosocial Communication and Emotional Regulation subscales is 0.98. The overall Social Competence Scale Total also yields a reliability of 0.98, indicating excellent consistency in measuring social competence.[45][46]

2. **Motor Imitation Scale**

"This scale includes 16 tasks demonstrated by an adult within a structured interaction. 8 tasks involve imitation of object action, and the other 8 tasks focus on imitation of body movements. The object actions are further divided into meaningful vs. non-meaningful actions. Each item is scored based on the child's motoric response: 2 (Pass): complete imitation, 1 (Emerge): partial imitation or unsuccessful attempt, 0 (Fail): no imitation. The child's best of 3 trial for each item is recorded. Total score range 0-32. Lower is the score higher is the impairment. The Cronbach's alpha was 0.90 (good internal consistency). Cohen's Kappa was 0.93" (Stone et al., 1997) [46][47]

3. **Apraxia Test**

"It consists of 2 subtests: demonstration of object use and imitation of gestures. In total, 9 objects are presented (3 verbal commands, 3 verbal and visual commands, 3 actual object use), and 6 gestures are imitated. The performance is scored on a 0, 2, 3, & 6 scale ranging from 0-90. The lower the score higher the impairment.[48] A cut-off value of 86 is recommended. A score higher than 86 means no presence of apraxia. Intra-rater reliability was substantial with a Cohen's Kappa (dichotomous scores) of 0.69 and good with an ICC (continuous score) of 0.88. Interrater reliability was substantial with a Cohen's Kappa of 0.69 and an ICC of 0.73." (Caroline M. van Heugten and Chantal Geusgens; Wilson et al., 2017) [49]

4. **Executive Functioning Scale (EFS)**

It is a 52-item scale to measure executive function in NDD. The informant rates behaviour, skill, or ability of the child in the past week on a 5-point Likert scale (0=Never, 1 = Rarely, 2 = Sometimes, 3 = Often, 4 = Very Often). EFS subscale content: Sequencing / Working Memory (items 1-7, 42-46), Risk Avoidance (items 8-12, 21, 38), Response Inhibition (items 29-33, 38-41), Emotion Regulation (items 14-20, 22-24), Set Shifting items (34, 36-37, 44, 47-52), Processing Speed items (25-28). Score ranges from 0-208. Higher scores indicate better executive functioning. "Excellent model reliability and internal consistency for the general factor ($\omega = 0.98$; $\alpha = 0.97$) as well as for the specific factors ($\omega = 0.89$–0.96; $\alpha = 0.84$–0.94). Excellent Conditional reliability (≥ 0.90) for the overall EFS and better reliability (≥ 0.70) for the subscales. The EFS also displayed strong convergent validity with the 24-item BRIEF-sf ($r = .85$)" (Uljarević et al., 2023) [50].

STATISTICAL ANALYSIS

Data was analysed using SPSS 22.0 (SPSS Inc., Chicago, IL), and the level of significance was set at $p<0.05$.

Finding normality: Normality was taken out using the Shapiro-Wilk test

Descriptive statistics: The data were presented using mean and standard deviation.

Inferential statistics: Paired t-test/dependent t-test was used to find out the statistical difference within groups (pre- and post-intervention). An unpaired t-test/independent t-test was used to measure between groups (EG &CG) difference of the variables.

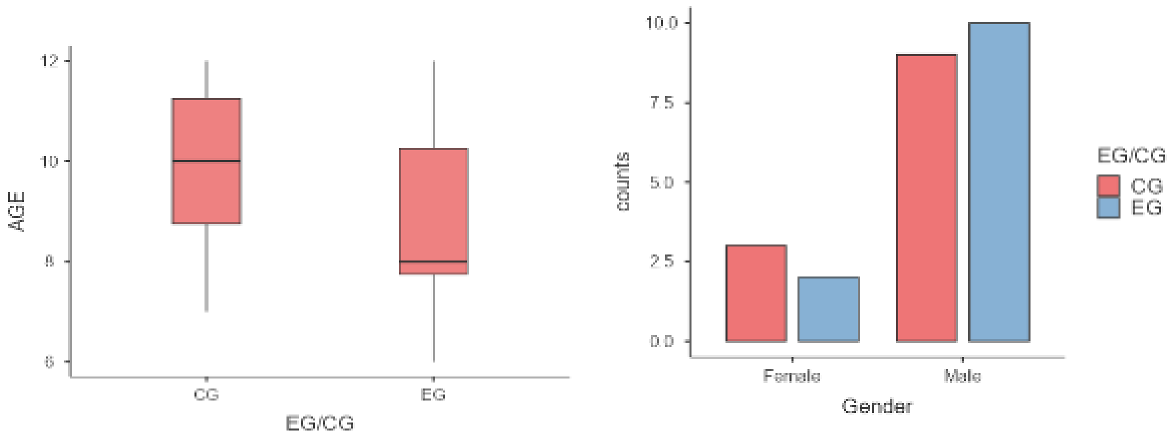
RESULTS

In the present study, 24 children with social and motor skill impairments were recruited. All participants completed the study protocol, and the data were analyzed. The analyses were conducted at a significance level of 0.05 (95% confidence level).

BASELINE DATA

Demographic details

The EG consisted of 12 children (10 male & 2 female) with social and motor skill impairments, with mean age (8.83 ± 1.99) years. The CG consisted of 12 children (9 male & 3 female) with social and motor skill impairments, with mean age (10.00 ± 1.70) years.



Graph 1.1: Demographic details

FINDING THE NORMALITY

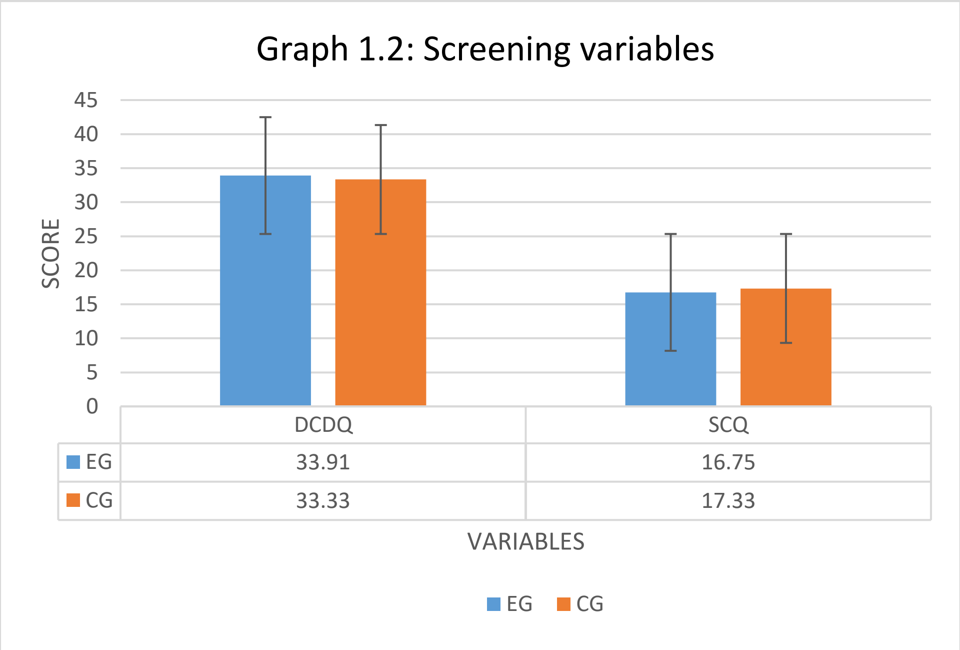
The mean age between the two groups showed a p-value of 0.41, which was statistically significant (P > 0.05), indicating normal distribution of the data.

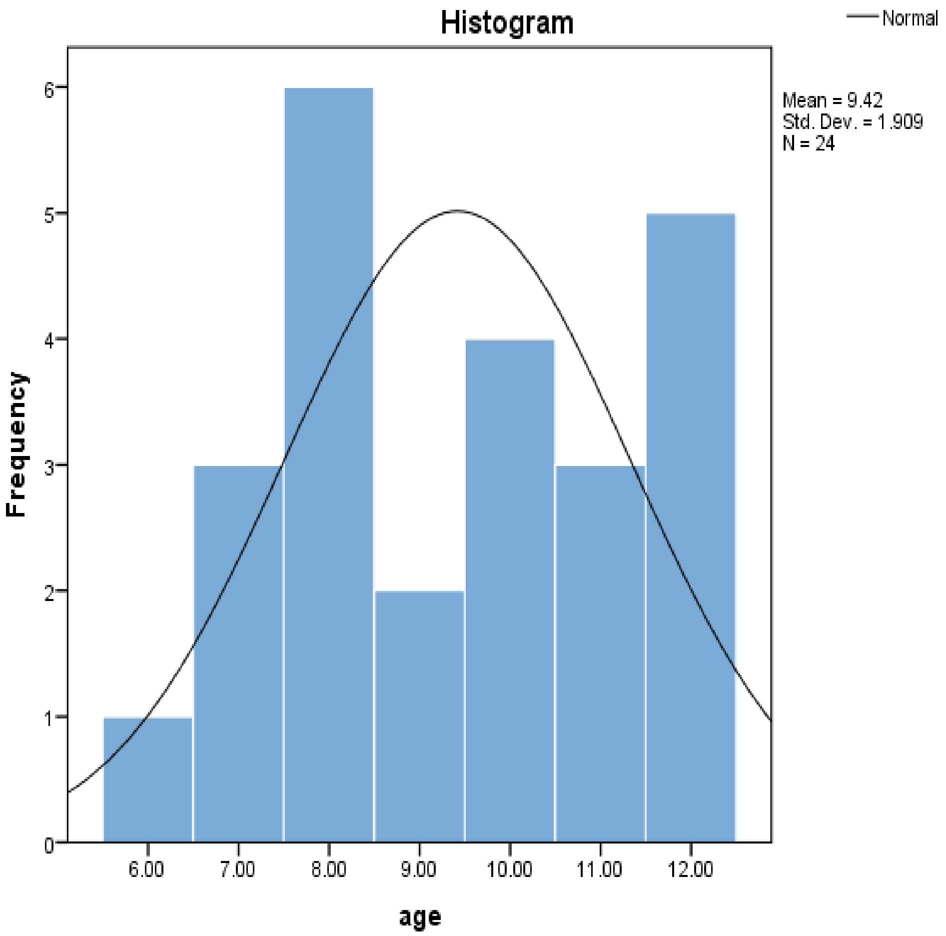
DCDQ score: p-value of 0.148, which was statistically significant (P > 0.05), indicating normal distribution of the data.

SCQ score: p-value of 0.51, which was statistically significant (P > 0.05), indicating normal distribution of the data.

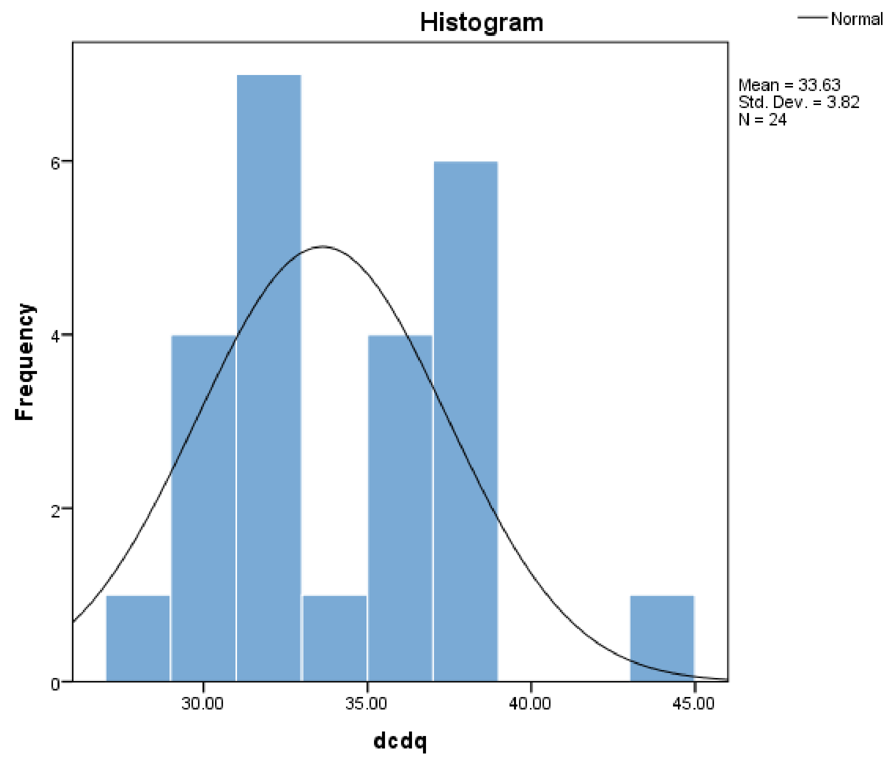
Table 1.1: BASELINE DATA

VARIABLES		Mean ± SD	P-value
Age (in years)		9.42±1.90	0.41
DCDQ SCORE		33.62±3.82	0.148
SCQ SCORE		17.04±1.39	0.51
Pre-intervention score	**SCS**	41.75±9.96	0.226
	MIS	16.54±3.76	0.581
	APRAXIA TEST	44.50±7.51	0.246
	EFS	62.70±7.99	0.427

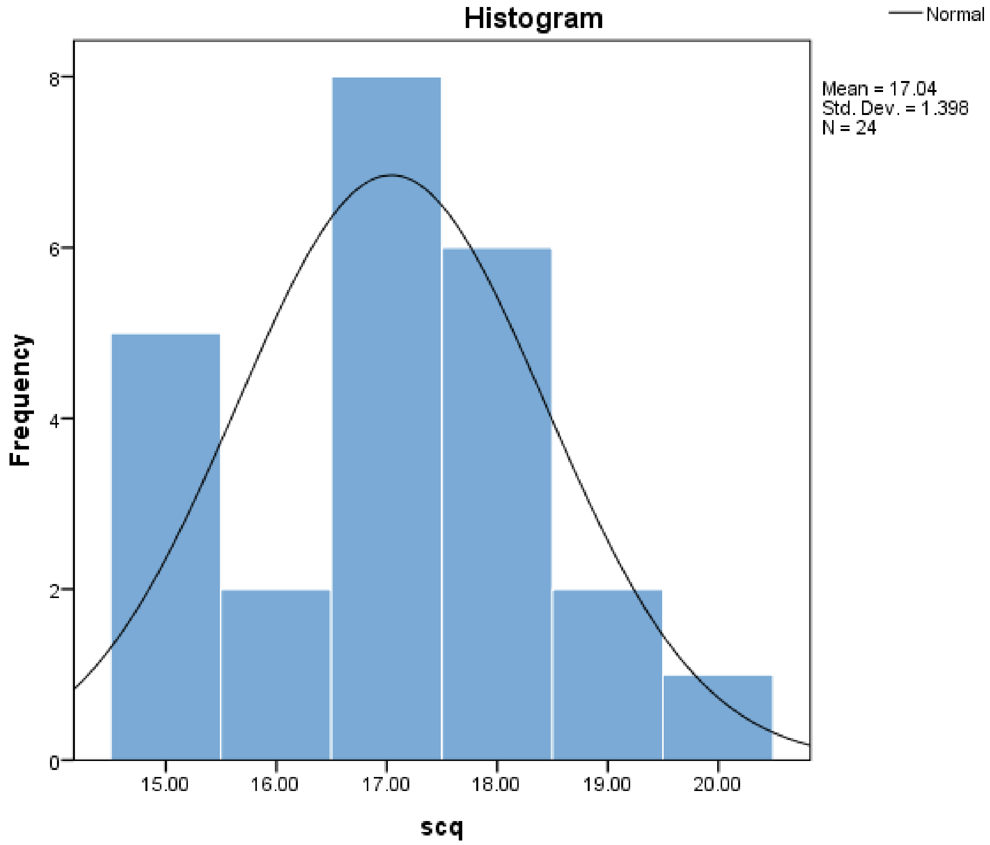




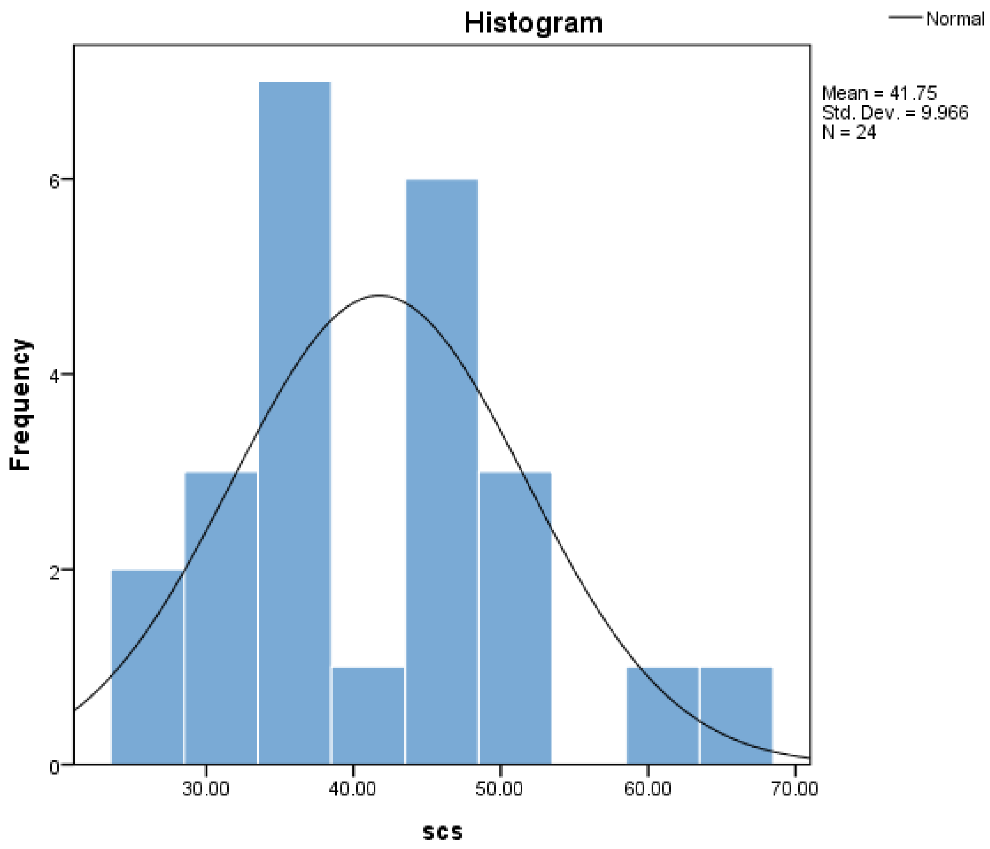
GRAPH 1.3: Normal distribution curve of age showing mean 9.42 (SD=1.90) & p-value of 0.41, which was statistically significant (P > 0.05), indicating normal distribution of the data



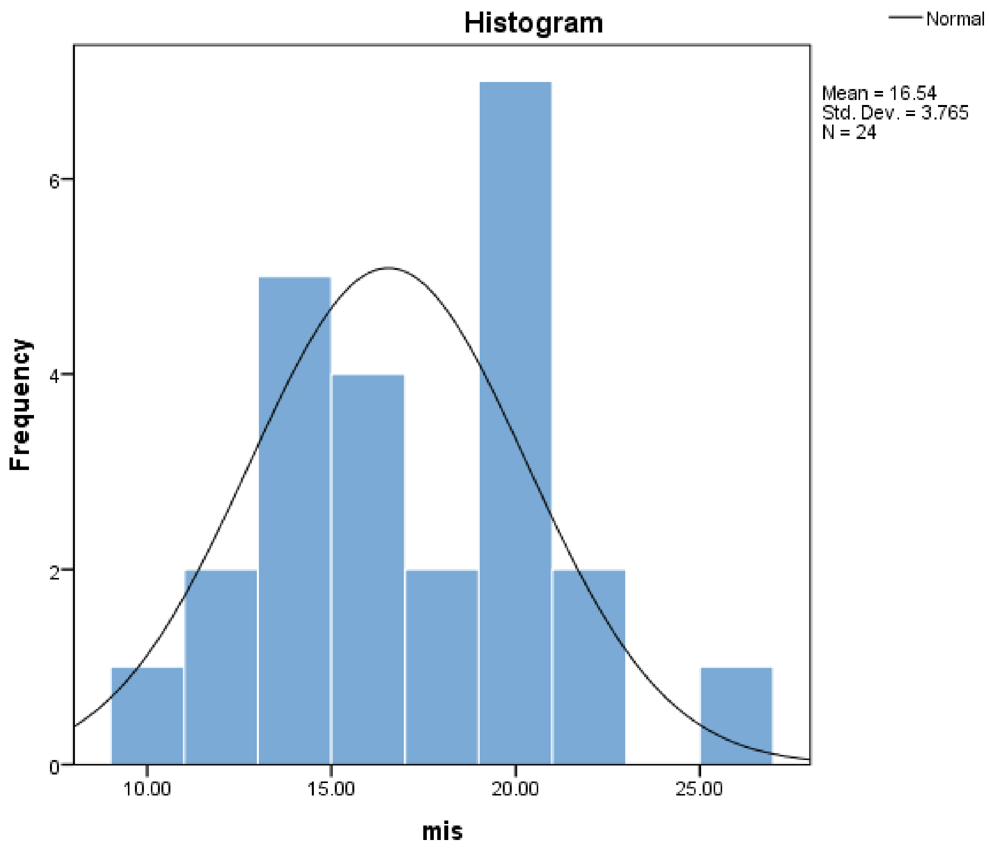
GRAPH 1.4: Normal distribution curve of DCDQ score showing mean 33.63 (SD=3.82) & p-value of 0.148, which was statistically significant (P > 0.05), indicating normal distribution of the data



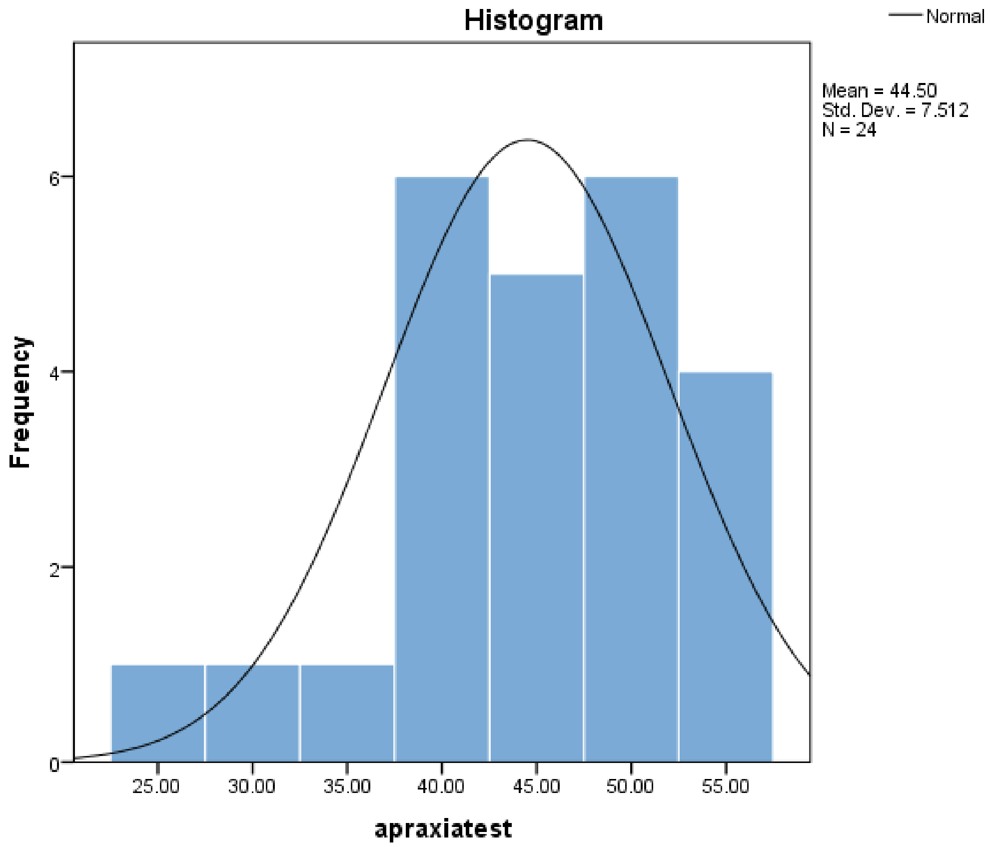
GRAPH 1.5: Normal distribution curve of SCQ score showing mean 17.04 (SD=1.39) & p-value of 0.51, which was statistically significant (P > 0.05), indicating normal distribution of the data



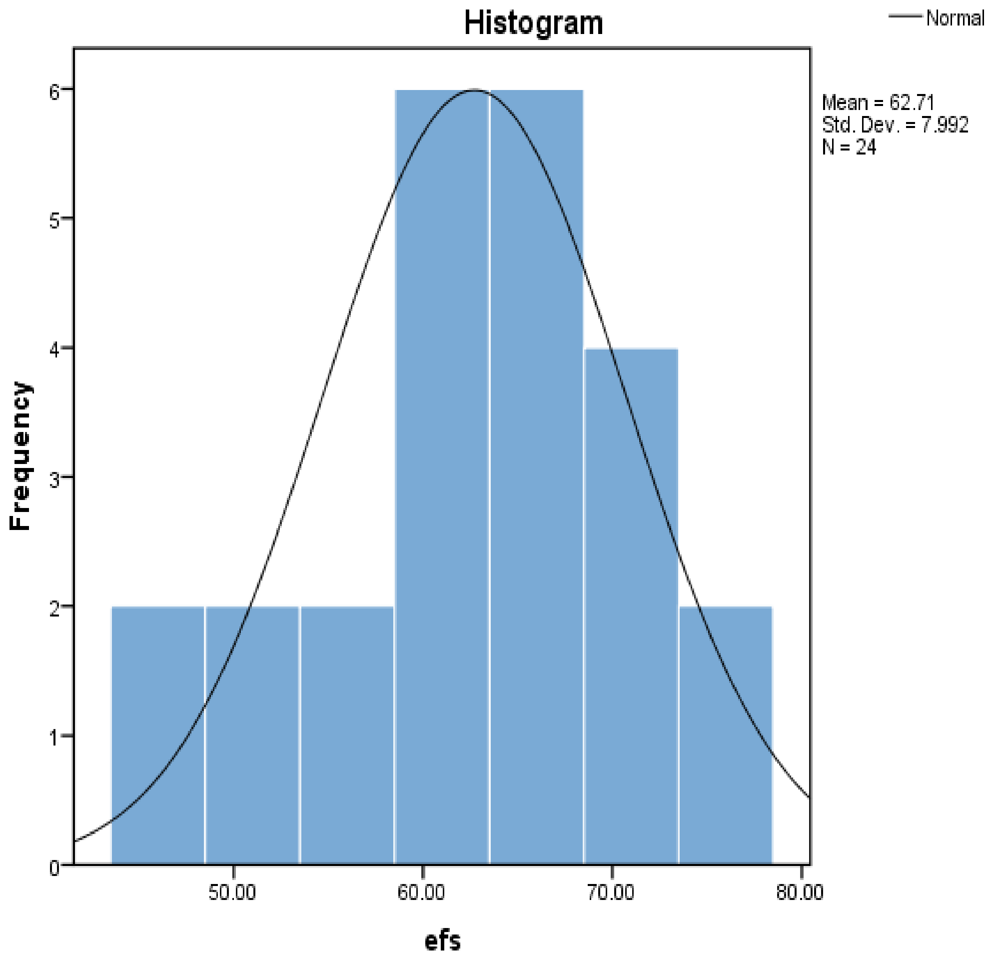
GRAPH 1.6: Normal distribution curve of SCS score showing mean 41.75 (SD=9.96) & p-value of 0.226, which was statistically significant (P > 0.05), indicating normal distribution of the data



GRAPH 1.7: Normal distribution curve of MIS score showing mean 16.54 (SD=3.76) & p-value of 0.581, which was statistically significant (P > 0.05), indicating normal distribution of the data



GRAPH 1.8: Normal distribution curve of APRAXIA TEST score showing mean 44.50 (SD=7.51) & p-value of 0.246, which was statistically significant (P > 0.05), indicating normal distribution of the data



GRAPH 1.9: Normal distribution curve of EFS score showing mean 62.70 (SD=7.99) & p-value of 0.427, which was statistically significant (P > 0.05), indicating normal distribution of the data

DESCRIPTIVE STATISTICS

Table 1.2: Descriptive statistics of pre-intervention scores EG & CG

VARIABLES	EG(N=12) Mean± SD	CG(N=12) Mean± SD	p-value
SCS	43.3±10.7	40.3±9.4	0.473
MIS	16.33±3.85	16.8±3.84	0.093
APAXIA TEST	47.00±4.02	42.00±9.39	0.104
EFS	64.8±4.49	60.7±10.21	0.218

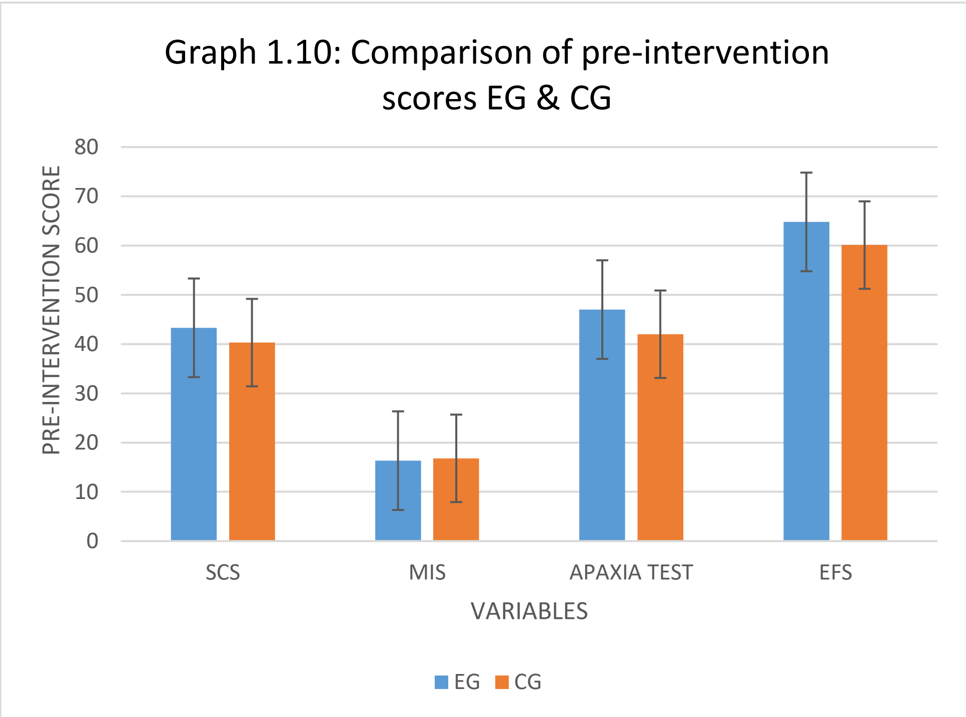
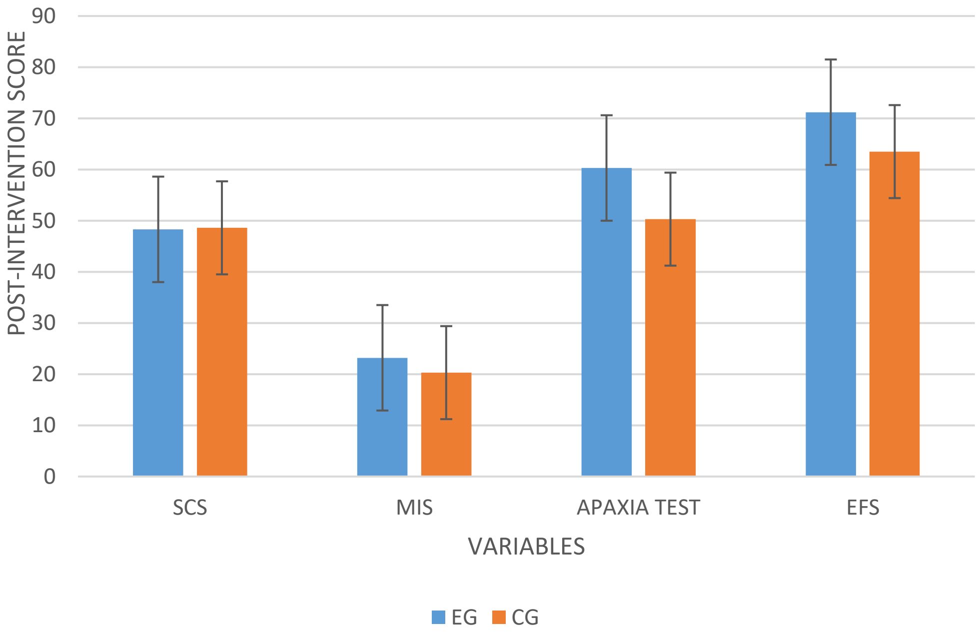


Table 1.3: Descriptive statistics of post-intervention scores EG & CG

VARIABLES	EG(N=12) Mean± SD	CG(N=12) Mean± SD	p-value
SCS	48.3±11.2	48.6±11.1	0.957
MIS	23.2±3.76	20.3±4.2	0.037
APAXIA TEST	60.3±4.72	50.3±8.82	0.002
EFS	71.2±6.52	63.50±9.83	0.035

Graph 1.11: Comparison of post-intervention scores EG & CG



INFERENTIAL STATISTICS

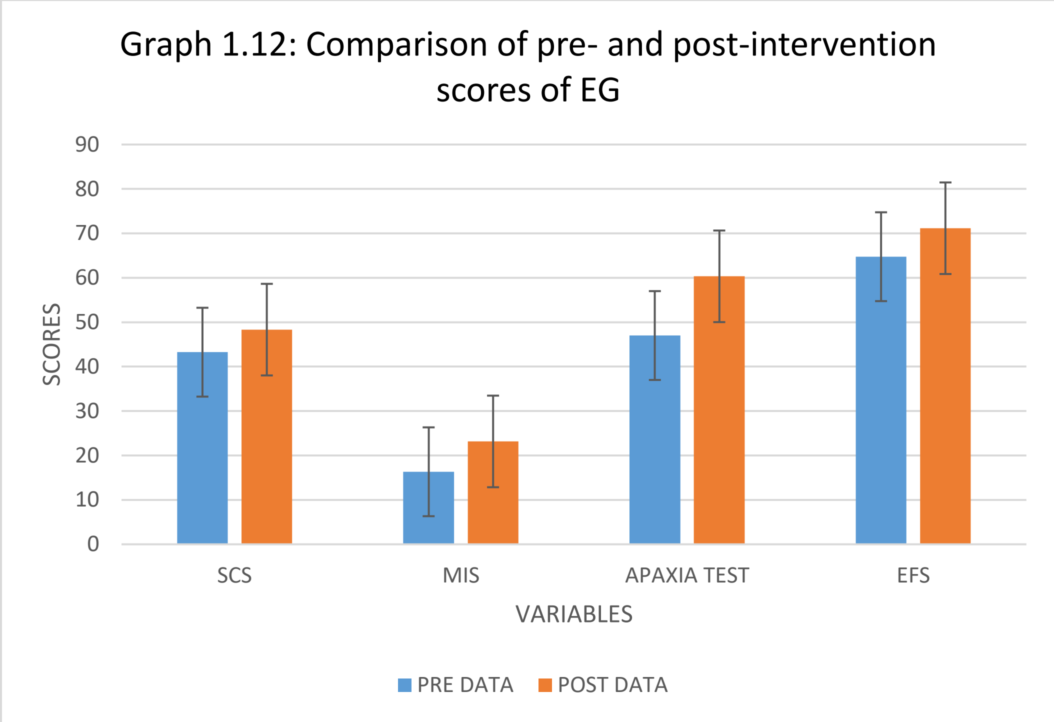
With in-group comparison

Paired t-test result

The statistical analysis for the EG (n=12) showed significant improvements across all outcome measures following AOT. Paired-samples t-tests revealed that post-intervention scores were significantly higher than pre-intervention scores for the SCS ($p < .001$, $d = -2.94$), MIS ($p < .001$, $d = -3.79$), Apraxia Test ($p < .001$, $d = -6.62$), and EFS ($p < .001$, $d = -1.59$), all indicating large effect sizes. The mean differences were -5.08, -6.83, -13.33, and -6.42, respectively, confirming clinically meaningful gains. Descriptive analysis further showed consistent increases in mean post-test scores (SCS: 43.3 → 48.3, MIS: 16.3 → 23.2, Apraxia test: 47 → 60.3, EFS: 64.8 → 71.2). These findings demonstrate that AOT produced significant improvements in social competence, motor imitation, apraxia, & executive functioning within the EG

Table 1.4: Comparison of pre- and post-intervention scores of EG

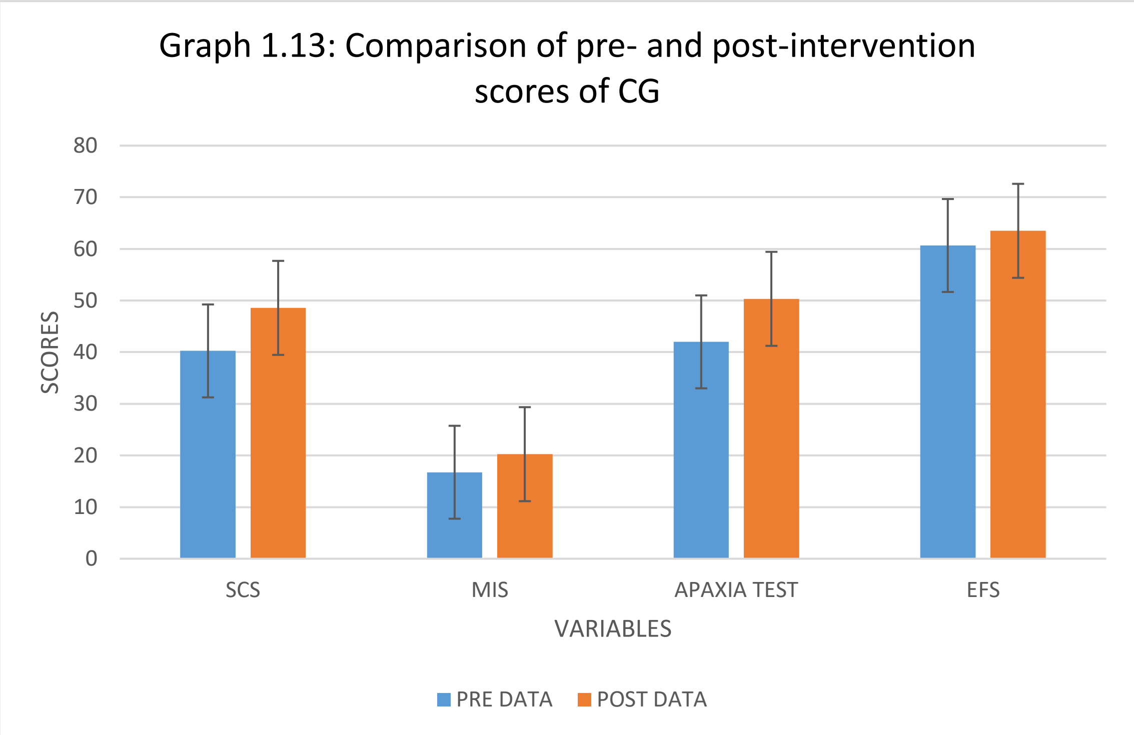
VARIABLES	Pre data Mean± SD	Post data Mean± SD	p-value	Effect Size (Cohen's d)
SCS	43.25±10.69	48.33±11.20	0.00	-0.37
MIS	16.33±3.84	23.16±3.76	0.00	-1.79
APAXIA TEST	47.00±4.022	60.33±4.71	0.00	-3.04
EFS	64.75±4.49	71.16±6.52	0.00	-1.14



The statistical analysis for the CG (n =12) showed significant improvements across all outcome measures following AOT. Paired t-tests revealed that post-intervention scores were significantly higher than pre-intervention scores, for the SCS ($p < .001$, $d = -2.54$), MIS ($p < .001$, $d = -2.82$), Apraxia Test ($p < .001$, $d = -2.90$), and EFS ($p < .001$, $d = -1.73$), indicating large effect sizes for all measures. The mean differences were -8.33, -3.5, -8.33, and -2.83, respectively, highlighting significant improvements. Descriptive statistics further showed consistent increases in mean post-test scores (SCS: 40.3 → 48.6, MIS: 16.8 → 20.3, Apraxia test: 42 → 50.3, EFS: 60.7 → 63.5). Thus, although the CG also improved significantly across social, motor, apraxia, and executive functioning measures, the magnitude of improvement was generally smaller compared to the EG.

Table 1.5: Comparison of pre- and post-intervention scores of CG

VARIABLES	Pre data Mean± SD	Post data Mean± SD	p-value	Effect Size (Cohen's d)
SCS	40.25±9.40	48.58±11.11	0.00	-0.80
MIS	16.75±3.38	20.25±4.20	0.00	-0.91
APAXIA TEST	42.00±9.39	50.33±10.20	0.00	-0.84
EFS	60.66±10.20	63.50±9.83	0.00	-0.28



Comparison of the mean change of scores in EG & CG

Table 1.5: Comparison of mean change of scores in EG & CG

VARIABLES	Group	Mean Difference (PRE-POST)	p-value	Effect Size (Cohen's d)	95% Confidence Interval	
SCS	EG	5.08	< .001	-2.94	-6.18	-3.98
	CG	8.33	< .001	-2.54	-10.42	-6.24
MIS	EG	6.83	< .001	-3.79	-7.97	-5.68
	CG	3.5	< .001	-2.82	-4.28	-2.71
Apraxia Test	EG	13.33	< .001	-6.62	-14.61	-12.05
	CG	8.33	< .001	-2.9	-10.15	-6.50
EFS	EG	6.42	< .001	-1.59	-8.97	-3.85
	CG	2.83	< .001	-1.73	-3.87	-1.78

Between-group comparison

Independent t-test result

The independent samples t-test comparing the mean difference (post–pre differences) revealed significant group differences. For the EFS, the EG showed a greater mean change (6.42 ± 4.03) compared to the CG (2.83 ± 1.64), with the difference being statistically significant (p = 0.009, Cohen’s d = -1.16), indicating a large effect size favoring the EG. For MIS, EG demonstrated a higher mean change (6.83 ± 1.80) compared to the CG (3.50 ± 1.24). This difference was highly significant (p < .001, Cohen’s d = -2.15), representing a very large effect size in favor of the EG. Similarly, for the Apraxia Test, the EG showed greater improvement (13.33 ± 2.02) than the CG (8.33 ± 2.87), with the difference being statistically significant (p < .001, Cohen’s d = -2.02), indicating a large effect size. These findings strongly support that AOT produced superior improvements in motor imitation, apraxia, & executive function compared to the MIP. In contrast, for the SCS, the CG demonstrated greater improvement (8.33 ± 3.28) compared to the EG (5.08 ± 1.73), with the difference being statistically significance (p = 0.006, Cohen’s d = 1.24).

Outcome Measure	**EG Change (Mean ± SD)**	**CG Change (Mean ± SD)**	**Mean Difference (EG–CG)**	**p-value**	**Effect Size (Cohen’s d)**	**95% Confidence Interval**	
SCS	5.08 ± 1.73	8.33 ± 3.28	-3.25	0.006	1.24	1.03	5.472
MIS	6.83 ± 1.80	3.50 ± 1.24	3.33	< .001	-2.15	-4.64	-2.02
Apraxia Test	13.33 ± 2.02	8.33 ± 2.87	5	< .001	-2.02	-7.1	-2.9
EFS	6.42 ± 4.03	2.83 ± 1.64	3.58	0.009	-1.16	-6.19	-0.976

DISCUSSION

The present study investigated the effect of Action Observation Therapy (AOT) compared to a standard Motor Intervention Program (MIP) in social and motor skills among school-going children aged between 6-12 years. The objective of the study to focus on social and motor impairments, diverging from prior research that has largely examined these domains independently. Targeting school-going children from low socioeconomic backgrounds in Sonepur, it addresses an underserved population. By leveraging AOT and the principle of perceptual–motor coupling, the study aimed to provide a holistic framework to enhance both motor execution and social functioning. Early dual-domain intervention highlights its potential to prevent long-term developmental delays and improve academic as well as social outcomes.

The results of the study revealed that both EG & CG showed significant pre-to-post improvements across all measured domains—social competence, motor imitation, apraxia, and executive functioning. Within-group analyses confirmed statistically significant gains in both groups, supported by large effect sizes and consistent mean score increases, indicating that both interventions were effective. However, between-group comparisons revealed important differences. The EG demonstrated significantly greater improvements in motor skills, with very large effect sizes, confirming the superior effectiveness of AOT in enhancing motor imitation, praxis & executive functioning. These findings underscore the strong clinical potential of AOT in addressing motor skills. In contrast, for social skills, the CG achieved significantly larger improvements than the EG, despite both groups improving significantly from pre- to post-intervention. This suggests that while AOT effectively targets motor Skills, MIP may have been more supportive of social skills in this context.

AOT—regular alternation of observing and executing actions—led to greater motor learning gains than either OL or MP alone. This superiority lies in the fact that AOT combines the strengths of both strategies: observation primes the motor system with the correct motor program, while execution consolidates it through proprioceptive and performance-based feedback. In MP, learning relies only on self-generated feedback (proprioceptive and performance-based), lacking external corrective cues. OL provides external visual information but lacks actual motor execution, so it misses proprioceptive feedback. AOT combines both: observation primes the motor system with correct representations, while execution strengthens them through practice. This synergy accelerates and enhances motor skill acquisition. Bazzini et al. (2022) reported that the neurophysiological mechanism underlying both action observation and execution involves the activation of overlapping fronto-parietal motor circuits. Alternation may reinforce motor engrams and facilitate chaining of motor acts into meaningful sequences. Mirror mechanisms, prefrontal involvement in motor program recombination, and contributions from basal ganglia and cerebellum are suggested to underpin AOT's effectiveness. [51] This dual mechanism directly addresses imitation and praxis deficits commonly observed in children with developmental coordination or praxis difficulties, explaining the significant improvements in these domains. The results highlight the potential value of training interventions that target the MNS, such as action observation and motor imagery training, which have shown promising outcomes in pilot studies. Since imitation also underpins social skill development, the findings raise broader questions about whether MNS dysfunction in DCD could also impact social and communicative abilities. [30]

Nuara et al. (2021) stated that Action observation modulates corticospinal excitability and intracortical inhibition, which are critical for motor skill acquisition in individuals with apraxia. Increases in motor-evoked potential amplitudes suggest enhanced excitability of the primary motor cortex, driven by excitatory inputs from premotor and parietal areas, direct descending mirror-related projections, or cortico-striatal mirror mechanisms. Concurrent transient reductions in intracortical inhibition facilitate motor output, while top-down prefrontal control may suppress overt movements when necessary. These neurophysiological mechanisms support motor learning and recovery by promoting plasticity in motor cortical circuits.[53]

Executive functioning also benefited from AOT, likely due to its repeated engagement of prefrontal and frontal–parietal–subcortical circuits, including the dorsolateral prefrontal cortex (DLPFC) and anterior cingulate cortex (ACC), which are involved in motor learning, planning, sequencing, working memory, cognitive flexibility, and inhibitory control. The structured alternation between observation and execution recruits not only motor but also cognitive control processes, supporting evidence that praxis and imitation tasks tax executive pathways [52]. Thus, Stolbkov Y.K. (2021) reported that through sensorimotor integration and the formation of internal action models, AOT enhances motor-related executive functioning.

Children with social skill impairments struggle with socially embedded movements such as imitation and interpersonal synchrony, which can negatively influence their interactions with peers and caregivers and hinder their long-term social-cognitive development. Although these skills are crucial for social functioning, neural mechanisms underlying such difficulties in school-aged children remain limited.

Conversely, the greater impact of MIP on social competence highlights the importance of contextualized, interactive, and top-down modulation of behavior. According to the Social Top-Down Response Modulation (STORM) model of Hamilton et al. (2013), social skills depend less on the fidelity of basic motor imitation and more on the integration of social context, intention understanding, and interpersonal responsiveness. The MIP provided structured opportunities for peer interaction, role-play, and cooperative motor tasks, which may have preferentially engaged higher-order social cognition networks, including the medial prefrontal cortex and temporo-parietal junction. This aligns with evidence that social gains in autism and related disorders are more likely when interventions explicitly scaffold social context and reciprocity rather than focusing solely on motor learning.

Recent research indicates that MIP, significantly enhance both motor and social skills. Ketcheson et al. (2017) reported that an intensive motor program with peer participation improved social and motor development in children aged 4–6 years. Similar benefits were observed in Inclusive Adapted Physical Activity programs, which enhanced peer interaction, leisure skills, and communication, and other exercise-based interventions reduced behavioral problems and increased adaptive behaviors. Well-structured motor programs encourage cooperation, self-control, and social participation, even when basic social skills exist but are underutilized due to low social motivation. Consistent with the literature, MIP improved cooperation, self-control, and both externalized and internalized behaviors, though self-expression remained unchanged. [54]

CONCLUSION

This study concluded that both interventions were effective, but AOT produced more significant improvements in motor imitation, apraxia, and executive functioning, whereas MIP showed greater progress in social competence. These findings highlight the domain-specific advantages of AOT, particularly for motor skills improvement, while pointing to the relative strength of the MIP in enhancing social skills.

LIMITATIONS & RECOMMENDATIONS FOR FUTURE STUDY

LIMITATIONS

- Limitation of the study includes the Short Duration of Intervention, which may not be sufficient to observe long-term functional changes or sustained benefits in motor and social outcomes.
- The number of participants in both the intervention and control groups was relatively small, reducing the statistical power and generalizability of the findings.
- The study did not include a long-term follow-up phase to evaluate the retention of therapeutic gains or delayed effects of the intervention, especially in real-life settings.
- Homogeneity of Participants in terms of age, socioeconomic status, or baseline severity also limits the applicability of findings to more diverse populations.
- Unequal memory and cognitive load across groups is a potential confounding factor that has influenced results, though unlikely to explain AOT's clear superiority.

RECOMMENDATIONS FOR FUTURE STUDY

- long-term follow-up (e.g., 3-, 6-, or 12-month post-intervention) to evaluate the sustainability of improvements in motor and social skills.
- Conducting multicentre RCTs with larger and more heterogeneous populations will increase the external validity.
- Dose–Response Analysis, which involves investigating the optimal frequency, duration, and intensity of AOT sessions needed to gain maximum benefit. Video parameters such as video length, perspective of view, Movement speed, and

sound can be analysed for AOT, which is suitable for school-going children or the paediatric population.

- exploring the combined effect of AOT with other evidence-based therapies (e.g., AOMI, Virtual reality, neuro-biofeedback, cognitive-behavioural training) may enhance outcomes, particularly in children with co-occurring social and motor difficulties.
- incorporating neurophysiological tools, e.g, EEG, fMRI, etc, can evaluate changes in brain activity (i.e., MNS activation) pre- and post-intervention.

SUMMARY

The study investigated the efficacy of AOT in social & motor skills among school-going children aged 6–12 years diagnosed with social and motor skill impairment.

Screening was conducted in two phases: Phase 1 utilized parent-reported tools (SCQ & DCDQ) & Phase 2 applied DSM-5 criteria [SCD (F80.89), DCD (F82)] for provisional diagnosis. 24 children meeting the eligibility criteria were randomized into two groups using a single-blind design, followed by baseline assessments. The EG received AOT (OL followed by MP) for 40 minutes/day, 6 days/week for 4 weeks, while the CG underwent a standard MIP (motor, social, & preacademic skills) with the same intensity and duration. Pre- & post-tests data were recorded using outcome measures SCS, MIS, Apraxia Test & EFS.

Results showed that both interventions led to significant improvements across all domains. However, the AOT group demonstrated greater gains in motor skills (imitation, praxis, and executive functioning), whereas the MIP group showed comparatively larger improvements in social competence. These findings suggest that AOT effectively enhances motor skill acquisition by leveraging the MNS and perceptual–motor coupling, while structured MIP may better support contextualized social skill development. As MIP focuses on the 3 developmental domains, the greater impact of MIP on social competence highlights the importance of contextualized, interactive, and Social Top-Down Response Modulation of behavior.

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ANNEXURES

ANNEXURE 1-CONSENT FORM

PARENTAL CONSENT FORM

Title –Effect of Action Observation Therapy on Social and Motor Skill in School-Going Children: A Single-Blinded Randomized Controlled Trial

Name of the Principal investigator	Participants Details
Rakshi Prativa Meher	Name
MPT (NEUROLOGY)	Age/Sex
ABSMARI	Name of Parent/guardian

Description of the study: The participants will be screened using two parent-reported questionnaires and DSM-V criteria. Participants will be selected according to inclusion and exclusion criteria. Pre-test data will be taken. followed by a 4 weeks intervention program and post-test data will be collected.

Risks or discomforts: The risks in this study are no greater than those ordinarily encountered in daily life or the performance of routine physical or psychological examinations or tests. There are no foreseeable discomforts or dangers to your child in participating in this study.

Benefits: There may be improvement in the social and motor skills of the child. Otherwise, there are no direct benefits to your child, but knowledge gained may benefit others.

Confidentiality of records: All records are kept confidential and will be available only to professional researchers and staff. If the results of this study are published, the data will be presented in group form and individual children will not be identified. Information collected as part of this research will not be used or distributed for future research studies.

Voluntary Participation: Your child's participation in this study is completely voluntary. We ask that you read this information to your child to ensure that he/she understands that participation is voluntary. He/she may stop or withdraw from the study at any time. If your child wishes to discontinue the research at any time; no information collected will be used.

CONSENT: I, ____willingly consent to my child's participation in above mentioned study. I have read this consent form (or it has been read to me) and I fully understand the contents of this document and voluntarily consent to participate in the study. All of my questions concerning this study have been answered. I understand that this consent ends at the conclusion of this study.

Signature of the Investigator	Signature of the Participant's Parent/guardian

ANNEXURE 2-NOC FROM SCHOOLS

NO OBJECTION CERTIFICATE

This is to certify that ____, has no objection to the participation of students from our school in the research work being conducted by **Rakshi Prativa Meher, MPT(NEURO)**. There are__________ students enrolled in class ______to______ (Aged _______ years) in our school. The students selected according to the inclusion and exclusion criteria have been granted permission to participate in the research project titled **Effect of Action Observation Therapy on Social and Motor Skill Impairment in School-Going Children: A Single-blinded Randomised Controlled Trial** under supervision. The school acknowledges that the research will be conducted in a safe and ethical manner, and we have no objections to their involvement.

We trust that the participation of our students in this research will be a valuable learning experience for them. Kindly ensure their safety and well-being throughout the research process.

N.B: -

Seal and signature of Principal/Head Master

Name of school:

Place:

Date:

ANNEXURE 3-CASE REPORT FORM

APPENDIX – XIV

CASE REPORT FORM (CRF)

SOAP FORMAT with Screening Criteria and Data Record Sheet

NAME:
AGE:
GENDER:
DOMINANCE:
PARENTS DETAILS:
ADDRESS:
SCHOOL ADDRESS:
CONTACT NUMBER:

HISTORY OF PRESENTING ILLNESS:

ENVIRONMENTAL HISTORY:

SOCIO-ECONOMIC HISTORY:

SCREENING OF PARTICIPANTS:

Phase 1

1. Social Communication Questionnaire (SCQ) score:
2. Developmental Coordination Disorder Questionnaire (DCDQ) score:

Phase 2: Diagnostic and Statistical Manual of Mental Disorders (DSM-V) Criteria

(F80.89): Social Communication Disorder

(F82): Developmental Coordination Disorder

OUTCOME MEASURES:

OUTCOME MEASURES	PRE- TEST VALUE	POST- TEST VALUE
Social Competence Scale		
Motor imitation Scale		
Apraxia test		
Executive functioning scale		

ANNEXURE 4- DIAGNOSIS CRITERIA

Diagnostic Criteria for Social (Pragmatic) Communication Disorder 315.39 (F80.89)

A. Persistent difficulties in the social use of verbal and nonverbal communication as manifested by all of the following:
   1. Deficits in using communication for social purposes, such as greeting and sharing information, in a manner that is appropriate for the social context.
   2. Impairment of the ability to change communication to match context or the needs of the listener, such as speaking differently in a classroom than on a playground, talking differently to a child than to an adult, and avoiding use of overly formal language.
   3. Difficulties following rules for conversation and storytelling, such as taking turns in conversation, rephrasing when misunderstood, and knowing how to use verbal and nonverbal signals to regulate interaction.
   4. Difficulties understanding what is not explicitly stated (e.g., making inferences) and nonliteral or ambiguous meanings of language (e.g., idioms, humor, metaphors, multiple meanings that depend on the context for interpretation).

B. The deficits result in functional limitations in effective communication, social participation, social relationships, academic achievement, or occupational performance, individually or in combination.

C. The onset of the symptoms is in the early developmental period (but deficits may not become fully manifest until social communication demands exceed limited capacities).

D. The symptoms are not attributable to another medical or neurological condition or to low abilities in the domains of word structure and grammar, and are not better explained by autism spectrum disorder, intellectual disability (intellectual developmental disorder), global developmental delay, or another mental disorder.

Diagnostic Criteria for Developmental Coordination Disorder 315.4 (F82)

A. The acquisition and execution of coordinated motor skills is substantially below that expected given the individual's chronological age and opportunity for skill learning and use. Difficulties are manifested as clumsiness (e.g., dropping or bumping into objects) as well as slowness and inaccuracy of performance of motor skills (e.g., catching an object, using scissors or cutlery, handwriting, riding a bike, or participating in sports).

B. The motor skills deficit in Criterion A significantly and persistently interferes with activities of daily living appropriate to chronological age (e.g., self-care and self-maintenance) and impacts academic/school productivity, prevocational and vocational activities, leisure, and play.

C. Onset of symptoms is in the early developmental period.

D. The motor skills deficits are not better explained by intellectual disability (intellectual developmental disorder) or visual impairment and are not attributable to a neurological condition affecting movement (e.g., cerebral palsy, muscular dystrophy, degenerative disorder).

Adapted from: Black DW, Grant JE, American Psychiatric Association. DSM-5 guidebook: the essential companion to the Diagnostic and Statistical Manual of Mental Disorders, fifth edition. Washington, Dc: American Psychiatric Publishing; 2014.

ANNEXURE 5- AOT PROTOCOL [55]

BIMANUAL TASKS	Session A	Session B	Session C
1.	The less non-dominant hand fixes the play dough, and the dominant hand detaches a piece from the opposite.	Both hands take the rolling pin and flatten the play dough.	The dominant hand takes the Mold and places it on the dough, impressing the shape. The non-dominant hand takes the Mold and puts it in pan.
2.	The dominant hand takes the paintbrush, inserts it in the glass, and mixes glue and water.	The dominant hand takes the glass; the non-dominant hand takes the paintbrush and spreads the glue in a square on the cardboard.	The dominant hand takes the picture card and places it in the square with the glue, the non-dominant hand spreads the glue with the paintbrush over the picture.
3.	The non-dominant hand opens the box; the dominant hand takes the ball inside the box and places it on the table.	The dominant hand takes the ball. Both hands unscrew the ball and place the two halves on the table.	The non-dominant hand fixes the half ball; the dominant hand takes the chocolate candy inside it and places it on the table.
4.	The non-dominant hand fixes the baguette; the dominant hand cuts a slice of bread.	The dominant hand holds the slice of bread; the non-dominant hand spreads the chocolate cream/butter	The non-dominant hand pours some pralines/crushed nuts on the dominant hand. The dominant hand pours the pralines/crushed nuts on the slice of bread.
5.	The non-dominant hand fixes the jar; the dominant hand unscrews the top and places it on the table.	The non-dominant hand fixes the plate; the dominant hand flips the beads onto the plate.	The non-dominant hand takes the wire; the dominant hand threads the beads to make a bracelet.
6.	The non-dominant hand holds the sheet of paper; dominant hand draws a circle with pencil.	The non-dominant hand holds the sheet of paper, dominant hand cut circle with pencil.	The non-dominant hand places the circle on the central placeholder; the dominant hand takes the stamp and leaves the print on the circle.
7.	The non-dominant hand fixes the school case, the dominant hand opens the zip, takes out the glue and places it on the table.	The non-dominant hand takes the glue; the dominant hand removes the glue cap and places it on the table.	The dominant hand holds the small ball up; non-dominant hand applies the glue on the base of the small ball. The dominant hand sticks it to the figure on the sheet.

ERRANTE, A., BECCANI, L., VERZELLONI, J., MAGGI, I., FILIPPI, M., BRESSI, B., ZICCARELLI, S., BOZZETTI, F., COSTI, S., FERRARI, A., & FOGASSI, L. (2024). Effectiveness of action observation treatment based on pathological model in hemiplegic children: a randomized-controlled trial. European Journal of Physical and Rehabilitation Medicine, 60(4). https://doi.org/10.23736/s1973-9087.24.08413-2

ANNEXURE 6- MASTER CHART

SL. NO.	Name	EG/CG	Gender	AGE	DCDQ SCORE	SCQ SCORE	SCS SCORE (PRE)	SCS SCORE (POST)	MIS SCORE (PRE)	MIS SCORE (POST)	APRAXIA TEST SCORE (PRE)	APRAXIA TEST SCORE (POST)	EFS SCORE (PRE)	EFS SCORE (POST)
1	PRITESH KUMBHAR	EG	Male	7	32	15	33	36	12	17	42	59	65	66
2	SONU ADAJUADI	EG	Male	8	31	15	44	48	13	21	49	61	61	68
3	YASHRAJ PRADHAN	EG	Male	8	43	15	44	50	15	23	45	57	60	74
4	RANI SA	EG	Female	7	28	16	53	56	13	23	45	58	62	70
5	CHANDAMANI SAHU	EG	Male	10	32	18	26	30	19	26	48	59	63	69
6	AMAN BHUE	EG	Male	11	29	15	33	40	14	19	43	54	66	75
7	KULAMANI BHUE	EG	Male	12	33	20	64	71	25	29	53	67	71	77
8	SUBHAM MALLIK	EG	Male	8	31	17	48	51	16	25	52	65	69	78
9	AGNIK HOTA	EG	Male	6	37	18	35	41	20	27	50	66	58	56
10	BIBHUTI NAIK	EG	Male	8	37	19	38	43	19	26	40	52	68	73
11	JYOYI MAHALING	EG	Male	12	36	17	51	59	13	18	49	62	72	80
12	PADMINI MALLIK	EG	Female	9	38	16	50	55	17	24	48	64	62	68
13	ADITYA BEHERA	CG	Male	10	30	17	40	52	10	13	30	39	46	48
14	SHUBHAM BAG	CG	Male	10	35	17	47	54	21	26	53	59	74	75
15	SOMNATH MEHER	CG	Male	12	38	17	36	43	16	22	42	56	50	55
16	AYUSH ROUT	CG	Male	10	37	18	36	36	13	15	25	35	64	65
17	CHHABIRA BHUE	CG	Male	11	31	19	63	75	19	22	35	42	69	73
18	SHUBHAM MAHAKUR	CG	Male	8	29	17	33	44	11	15	43	50	55	55
19	AYATAN DEEP	CG	Male	12	29	18	48	58	15	19	38	47	64	68
20	SUGYAN DEEP	CG	Female	8	38	18	26	32	19	22	42	55	48	52
21	RESHMA CHHANDA	CG	Female	9	35	18	35	44	22	26	54	59	63	66
22	HERO DEEP	CG	Male	7	32	17	44	52	19	21	56	64	76	78
23	MAMATA JAL	CG	Female	11	31	15	37	45	19	23	41	46	67	70
24	BIBHUDATTA NAG	CG	Male	12	35	17	38	48	17	19	45	52	52	57

ANNEXURE 7- INSTITUTIONAL ETHICAL COMMITTEE CLEARANCE

ABSMARI ETHICS COMMITTEE

ABHINAV BINDRA SPORTS MEDICINE AND RESEARCH INSTITUTE, BHUBANESWAR, ODISHA

CDSCO Reg. No.: ECR/1981/Inst/OD/24

Prof. (Dr.) E. Venkata Rao
Chairperson

Mr. Chinmaya Kumar Patra
Member Secretary

Ref. No. ABSMARI/IEC/2025/144

Date: 02/05/2025

APPROVAL LETTER
APPENDIX- VIII

MEMBERS

Dr. Smaraki Mohanty
Clinician

Dr. Satyajit Mohanty
Scientific Member

Mr. Shib Shankar Mohanty
Legal Expert

Ms. Annie Hans
Social Scientist

Ms. Subhashree Samal
Lay Person

Mr. Deepak Ku. Pradhan
Scientific Member

IEC-SECRETARIAT

Mr. Gouranga Ku. Padhy
Mr. Susant Ku. Raychudamani

To,

RAKSHI PRATIVA MEHER
ABSMARI
273, PAHAL, BHUBANEWAR-752101

Protocol Title: Effect of Action Observation Therapy on Social And Motor Skill Impairment In School-Going Children: A Single-blinded Randomised Controlled Trial

Protocol ID.: ABS-IEC-2025-PHY-064

Subject: Approval for the conduct of the above referenced study

Dear Mr./**Ms.**/Dr **RAKSHI PRATIVA MEHER**
With reference to your Submission letter dated 06/01/2025 the ABSMARI IEC has reviewed and discussed your application for conduct of the study on dated 25/04/2025.

The following documents were reviewed and discussed

S.N.	Documents	Document (Version/Date)
1	IEC Application Form	25/04/2025
2	Informed Consent Form	25/04/2025
3	Undertaking form PI	25/04/2025
4	CRF	25/04/2025
5	COI from the Investigators	25/04/2025

The following members were present at meeting held on 25-04-2025

ABSMARI ETHICS COMMITTEE
Dt...................
BHUBANESWAR

ABSMARI ETHICS COMMITTEE

ABHINAV BINDRA SPORTS MEDICINE AND RESEARCH INSTITUTE, BHUBANESWAR, ODISHA

CDSCO Reg. No.: ECR/1981/Inst/OD/24

Prof. (Dr.) E. Venkata Rao
Chairperson

Mr. Chinmaya Kumar Patra
Member Secretary

Ref. No. ABSMARI/IEC/2025/144

Date: 02/05/2025

S.N.	Name of the Member	Designation & Qualification	Representation as per NDCT 2019	Gender (M/F)	Affiliation with the Institution (Y/N)
1	Prof. Dr. E. Venkata Rao	Professor (MBBS, MD, Dept. of Community Med.) IMS & Sum Hospital, BBSR	Chair Person	M	N
2	Dr. Smaraki Mohanty	Asst. Prof-IMS & Sum Hospital/MBBS, MD (Community Med)	Clinician	F	N
3	Mr. Shiba Sankar Mohanty	Junior Counsel-Lt. Ramachandra Sarangi's Chamber / BA LLB	Legal Expert	M	N
4	Mr. Chinmaya Kumar Patra	Principal-ABSMARI, MPT	Member Secretary	M	Y
5	Ms. Annie Hans	Disability Inclusive Development Co-Ordinator in Humanity and Inclusion (India/Nepal/Srilanka). /MA in Social Work	Social Scientist	F	N
6	Ms. Subhashree Samal	Ret. Reader-Pol Sc.	Lay Person	F	N
7	Mr. Deepak Kumar Pradhan	Asst. Prof-ABSMARI, MPT	Scientific Member	M	Y

This is to confirm that only members who are independent of the Investigator and the Sponsor of the trial have voted/ provided opinion on the trial.

This Committee approves the documents and the conduct for the study in the presented form with necessary recommendation.

The ABSMARI IEC must be informed about the progress of the study in the prescribed format attached, any SAE occurring in the course of the study, any changes in the protocol and patient information/informed consent/assent and request to provide a copy of the final report.

The ABSMARI IEC follows procedures that are in compliance with the requirements of ICH (International Conference on Harmonization) guidance related to GCP (Good Clinical Practice) and applicable Indian regulations.

Yours sincerely

Mr. Chinmaya Kumar Patra
Member Secretary
ABSMARI Ethics Committee
Patia, Bhubaneswar

Member Secretary
ABSMARI ETHICS COMMITTEE

ABSMARI ETHICS COMMITTEE
Dt.............
BHUBANESWAR

ANNEXURE 8- TURNITIN PLAGARISM REPORT

Rakshi Prativa Meher

EFFECT OF ACTION OBSERVATION THERAPY ON SOCIAL AND MOTOR SKILL IMPAIRMENT IN SCHOOL-GOING CHILDREN: ...

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Rakshi Prativa Meher

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