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Neuroplasticity and Executive–Motor Integration Through a Structured Hopscotch-Based Intervention in a Mild Intellectual Disability Case

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ABSTRACT:
This neuropsychological study on a 13-year old male subject Veer diagnosed with mild intellectual disability explored how organized multisensory-motor activities affect attention, coordination and executive control. Based on a previous experiment conducted on the subject which had shown improvements in precision but had found inconsistency in performance, the current study investigated whether a rhythmic full-body movement based activity could enhance both accuracy as well as consistency.

ACC was used since deficits were observed in internalization of movement. Thus, the experiment was carried out in three phases namely, pre-test, intervention and post-test. Each subsequent phase employed auditory, visual and tactile cues to enable this shift. The activities attempted to activate key neural regions, such as, sensorimotor cortex, cerebellum and anterior cingulate cortex (ACC), which were involved in coordination, feedback processing and emotional regulation.

After a few sessions, Veer began showing gradual improvements in timing, movement precision and self-regulation. Errors in tasks eliminated completely by the post-test and the lap efficiency improved significantly, pointing towards procedural learning and motor skill consolidation. This indicated how structured feedback-based motor activities have the potential to stimulate neuroplastic reorganization and facilitate the transition from guided to independent motor skills in children.

Based on the concepts of Evidence-Based Practice in Psychology (EBPP), the study highlights that multisensory-motor interventions can enhance executive-motor integration, emotional balance and overall development for children facing developmental difficulties.

KEYWORDS: Hopscotch task; motor control; self regulation; supplementary motor area (SMA); prefrontal cortex; cerebellum; basal ganglia; anterior cingulate cortex (ACC); sensorimotor integration; executive motor integration; vestibular; proprioception; figure ground perception; position in space; mild intellectual disability; auditory cues; tactile feedback; decision making; procedural learning; neuroplasticity

INTRODUCTION:

According to a previous study, Veer showed significant improvements in accuracy and precision during tasks through structured fine and gross motor activities (Jajal, Patel, & Patel, 2025). However, his inconsistency across trials indicated that although external guidance had improved his immediate accuracy, yet the internalization of motor control and self-regulation had not occurred.

This drawback highlighted the necessity of adopting a procedure that could increase his accuracy besides stability and voluntary control over time. Hence, motor learning was employed, a dynamic process in which repetitive, guided actions transform into self-regulated and consistent movements (Franklin and Wolpert, 2011). Previous study indicated that the activation of the prefrontal-occipital-thalamic loop supported motor learning which led to integration of auditory, visual and tactile feedback with motor commands. This neural engagement caused gradual refinement of movements and improved motor control during tasks (Jajal et al., 2025). But for Veer, this transformation often occurs slowly, due to challenges faced in attention, feedback processing and executive regulation that interrupt the stability of learned movement patterns (Best, 2010; Diamond, 2000).

To address this gap, the current study used a multisensory-motor based activity, which involved engagement of auditory, visual and tactile systems in a rhythmic manner. It was anticipated that the activity would activate his core neural regions that contribute to motor consistency, emotional regulation and procedural learning (Johansen, Fields, and Manning, 2001).

Children with developmental or coordination difficulties often show challenges in vestibular balance, proprioceptive awareness, position in space and figure–ground perception. These sensory deficits can also affect balance, timing and spatial accuracy during movement (Tran et al., 2022; Elbasan et al., 2012). These are commonly seen in children with intellectual disabilities as well (Naim Salkić et al., 2025).

By targeting these foundational sensory systems, the hopscotch task was expected to support motor planning while promoting neuroplastic adaptability of Veer's developing brain.

PURPOSE OF THE STUDY:

The purpose of this study was to test whether interventions like hopscotch have any impact on a child with mild intellectual disability like Veer. The study evaluated this impact by focusing on Veer’s attention, coordination and execution. The aim was to use a combination of auditory, visual and tactile stimulation for testing Veer’s transition from external guidance to internally initiated movements. With repeated exposure to practice and feedback, Veer learned how to interpret sensory cues and tune his actions in accordance. Simultaneously the intervention was designed to work on strengthening his sensory level foundations like balance, spatial accuracy and body awareness (Tran et al., 2022; Elbasan et al., 2012; Naim Salkić et al., 2025). Moreover, the study also highlights how neural systems like sensorimotor strip, cerebellum and anterior cingulate cortex (ACC) restructure during complex movement learning wherein performance improvement is indicative of behavioural neuroplasticity. This research design conforms with findings from past study where prefrontal-occipital-thalamic sensorimotor loop was referred for psychological and motor recovery in children. (Jajal et al., 2025)

RELEVANCE OF THE STUDY:

This paper demonstrates that multisensory-motor tasks can become potentially valuable neuropsychological interventions in enhancing coordination, self-regulation and cognitive flexibility. By

engaging in structured activities like hopscotch, which involves combining visual, auditory and tactile inputs, Veer learned how to use sensory cues and feedback as a means of neural channel for learning.
In accordance with Evidence-Based Practice in Psychology (EBPP), the present study proposes guided and feedback-intensive physical activity as a means of evoking neuroplasticity. This adaptation provides a basis for increased motor coordination, sustained attention and behaviour consistency in Veer.
Additionally, the study attempts to bridge the gap between physical therapy and cognitive neuroscience by presenting movement not only as an exercise, but a formalized cognition that promotes brain development. With purposefully designed play that involves sensory and neural integration mechanisms, children like Veer will be able to improve and strengthen their motor abilities and high-order cognitive functions, such as decision-making, inhibitory control and problem-solving. Thus, this study establishes a holistic framework where the body becomes a pathway to training the mind.

LITERATURE REVIEW:

The motor learning is stimulated through recurring multisensory interaction wherein external information is coded in the muscle and neural memory, thus increasing accuracy and voluntary control (Franklin and Wolpert, 2011). The sensory input and the motor output are synchronized in the sensorimotor cortex whereas the planning and sequencing of actions is coordinated in the prefrontal cortex and supplementary motor area (SMA) or areas (Jajal et al., 2025).
Auditory stimulus, rhythmic or verbal cues enhance attention and timing, further coordinating perceptual and motor pathways (Driver & Noesselt, 2008). These multisensory patterns are registered in the cerebellum and basal ganglia over time, strengthening procedural learning (Diamond, 2000; Best, 2010). Previous research also indicates that core systems such as vestibular, proprioceptive and spatial perceptual processing play a significant role in defining movement stability and motor accuracy in developmental conditions (Tran et al., 2022; Elbasan et al., 2012; Naim Salkić et al., 2025).
The way an individual reacts to tactile feedback, i.e., emotionally and physiologically is governed by anterior cingulate cortex (ACC). This involves reinterpreting the unpleasant stimulus, developing proprioceptive awareness and improving self-regulation (Johansen, Fields, and Manning, 2001; Basbaum et al., 2019) . During multisensory-motor tasks, anterior cingulate cortex (ACC) supported Veer's transition by transforming tactile and proprioceptive inputs into controlled motor responses while simultaneously promoting emotional regulation and inhibitory control. (Jajal et al., 2025). Repeated engagement of ACC also promoted neuroplastic reorganization by strengthening pathways in neural areas that governed procedural learning, motor consistency and adaptive behaviour.
These interventions are designed based on concepts of Evidence-based Practice in Psychology (EBPP). It determines how children with coordination and learning problems can develop functional brain activity by performing controlled physical exercise and feedback-monitored tasks (Punar and Sevgin, 2024).

CASE STUDY:

Veer was referred to the clinic by his parents due to worries regarding his delayed development, poor academic performance and inability to carry out daily life activities. Veer was obedient and cooperative since childhood but lagged considerably behind in developmental milestones such as, language understanding and intellectual abilities. Veer faced difficulty in following simple instructions, yet displayed eagerness to try new things. As he progressed to school, he increasingly struggled with academics, requiring constant assistance and support by teachers. He also exhibited poor ability to implement newly learned concepts in real-life scenarios indicating constraints in cognitive flexibility and adaptability.

During clinical observation, Veer was compliant and physically healthy but displayed poor attentional capacity and perseverance to stay focused on a task. He was easily distractible and therefore had to be redirected repeatedly.

During the intervention, emerging motor abilities were noticed when it was observed that Veer could independently stand on one leg. Although he required auditory cueing and constant prompting to stay focused and follow task sequence, in each session, he still attempted to accomplish tasks and progress to the next phase. His determination and willingness to participate in structured activities were indicative of his desire to improve.

Based on his developmental history and outcomes of clinical assessment, he met the DSM-5 criteria of Mild Intellectual Disability (Intellectual Developmental Disorder) (Jajal et al., 2025).

METHODOLOGY:

Veer's study was conducted in three stages: pre-test, intervention and post to test how multisensory-motor tasks can influence his attention, coordination and executive functions. The design carefully blends movement and cognition at each stage so that Veer's progress can be easily tracked.

First, in the pre-test phase, he was asked to differentiate between his right and left leg by lifting them one at a time. Initially, Veer was more dependent on the auditory cues and verbal instructions ('right' or 'left'), later, during the silent trials, he was asked to do the task independently without any cues, i.e., he was asked to independently decide what to do. This provided a clear reflection of his baseline level coordination and attentional capacity. Even though at first Veer approached the task with enthusiasm, he relied heavily on the cues provided and often took short breaks between the tasks which highlighted that he still needed guidance for planning his movements.

Further, during the intervention phase, the tasks became more challenging. Veer was asked to practice jumping with both legs into two boxes, eventually alternate between single and double leg jumps, and then perform single leg jumps in consecutive boxes. The variation aimed to increase his coordination for motor planning, balance and cognition control. Tactile feedback was provided so that he would learn through correction and repetition. He was also reinforced with verbal praise, ensuring that he stayed focused on the task. The hopscotch task was chosen as it had the potential to naturally engage deeper sensory systems like- vestibular balance while he attempted jumps and landings, proprioceptive awareness while he used his limbs, position-in-space while he navigated through the box sequences, and figure–ground perception during visual tracking of patterns**.** Altogether, this helped him refine his motor planning eventually over the sessions.

Later, during the post-test phase, Veer had to perform the original pattern as well as the modified pattern of hopscotch. The original pattern examined his recall ability, while the modified pattern examined his transfer of learning to more novel motor situations. Veer's performance notably improved, reflecting better accuracy and trials without errors, showcasing increased self-initiated control and neuro-motor adaptation. Overall, the structured and playful format of hopscotch made it useful as a therapeutic activity that enabled Veer to holistically develop in attention, precision and self-reliance, supporting his cognitive as well as physical development.

TASKS	BRAIN REGIONS	ROLE
Right–Left Leg Differentiation	Auditory Cortex Wernicke's Area Prefrontal Cortex Motor Cortex Thalamus Somatosensory Cortex	Auditory cue processing Comprehension Decision-making (right/left discrimination) Motor initiation Proprioceptive feedback Coordination between auditory and motor systems
Bilateral Coordination	Premotor Cortex Cerebellum Corpus Callosum Sensorimotor Strip	Bilateral motor synchronization Balance control Interhemispheric communication Execution Proprioceptive adjustment
Sequential Switching	Supplementary Motor Area (SMA) Dorsolateral Prefrontal Cortex (DLPFC) Basal Ganglia Parietal Lobe	Cognitive flexibility Task switching Motor sequencing Planning Procedural learning Habit formation Spatial mapping Body positioning
Advanced Coordination	Cerebellum Prefrontal Cortex Motor Strip Somatosensory Cortex	Fine motor precision Dynamic balance Executive regulation of complex movements Continuous feedback correction Integration of sensory and motor inputs
Higher-Level Dynamic Control	SMA Cerebellum Basal Ganglia Anterior Cingulate Cortex (ACC) Prefrontal Cortex	Automation of learned patterns Coordinated refinement Emotional regulation of aversive feedback Integration of executive and emotional control
Original Pattern (Retention)	Motor Cortex Cerebellum SMA ACC	Retrieval of established motor programs Retention Error elimination Feedback regulation Emotional stability Efficient movement execution

Modified Pattern (Neuroplasticity)	DLPFC SMA Cerebellum Basal Ganglia Prefrontal Cortex	Task adaptation and generalization Transfer of procedural knowledge Integration of new spatial sequences Neuroplasticity

RESULTS:

1. PERFORMANCE DIFFERENCE WITH AND WITHOUT STIMULUS

PRE-TEST: WITH AND WITHOUT STIMULUS		
Trial Number	**Performance with Stimulus**	**Performance without Stimulus**
1	5.75	2.75
2	4.58	2.83
3	3.96	2.25
4	3.78	2.18
5	4.26	2.78
6	4.2	2.13
7	4.18	2.78
8	3.51	1.98
9	4.61	2.65
10	5	2.25
Mean time taken	**4.383**	**2.458**

2. COMPARISON BETWEEN PRE-TEST AND POST-TEST

PRE-TEST vs POST TEST		
Trial Number	**Pre-Test (Baseline)**	**Post-Test (Original Pattern)**
1	5.75	9.17
2	4.58	9.87
3	3.96	14.01
4	3.78	12.46

5	4.26	10.41
6	4.2	12.55
7	4.18	9.09
8	3.51	7.75
9	4.61	8.42
10	5	7.04
11	2.75	8.77
12	2.83	8.37
13	2.25	7.56
14	2.18	9.22
15	2.78	8.07
16	2.13	7.4
17	2.78	7.52
18	1.98	6.92
19	2.65	6.47
20	2.25	6.82
Mean time taken	**3.4205**	**8.8945**

3. PERFORMANCE DIFFERENCE ACROSS MOTOR SKILL PHASES

PERFORMANCE ACROSS MOTOR SKILL PHASES									
Trial No.	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Trial No.**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**
1	5.9	7.74	4.69	15.79	**21**	3.6	2.55	2.11	7.83
2	4.33	6.89	4.41	12.86	**22**	3.36	2.8	1.75	11.58
3	3.48	5.37	3.79	14.04	**23**	3.38	2.2	1.98	7.73
4	3.56	5.37	3.32	10.37	**24**	2.78	3.72	2.2	11.29

5	3.23	3.65	4.83	13.71	**25**	6.22	2	4.45	8.97
6	3.25	4.05	2.46	12.08	**26**	4.45	1.73	2.83	8.02
7	3.08	5.27	2.81	9.47	**27**	4.82	3.05	2.08	8.48
8	2.8	4.3	2.56	10.29	**28**	2.98	1.56	1.88	7.91
9	2.65	3.38	2.1	9.92	**29**	2.46	1.56	1.71	7.11
10	3.43	4.13	2.13	11.42	**30**	2.66	1.55	3.01	7.59
11	4.25	8.44	3.56	10.09	**31**	2.41	1.93	2.44	7.71
12	2.53	2.65	2.43	14.06	**32**	2.16	2.46	3.39	8.54
13	4.8	7.97	2.58	13.93	**33**	2.51	1.46	2.26	8.49
14	2.8	4.33	2.1	10.35	**34**	2.08	1.61	2.32	9.07
15	2.71	3.5	2.78	14.31	**35**	2.03	2.7	2.49	7.64
16	2.66	3.35	2.34	14.04	**36**	4.08	1.04	2.33	7.8
17	2.9	5.12	2.11	13.46	**37**	2.28	2.73	1.87	7.22
18	2.66	2.48	2.36	9.3	**38**	2.25	2.96	1.48	6.73
19	4.3	4.67	4.51	9.35	**39**	2.23	1.71	2.16	7.46
20	3.21	3.28	3.73	10.47	**40**	1.81	1.95	2.1	6.91

Phase	1	2	3	4
Mean time taken	3.227	3.48025	2.711	10.08475

4. ASSESSMENT OF POST-TEST (RETENTION AND NEUROPLASTICITY)

RETENTION vs NEUROPLASTICITY		
Trial Number	**Post-Test (Original Pattern)**	**Post-Test (Modified Pattern)**
1	9.17	13.46
2	9.87	12.4
3	14.01	11.05

4	12.46	10.38
5	10.41	14.01
6	12.55	11.61
7	9.09	10.91
8	8.75	9.58
9	8.42	8.28
10	8.04	7.11
11	8.77	7.56
12	8.37	8.81
13	7.56	7.38
14	9.22	7.6
15	7.07	7.46
16	7.42	8.33
17	7.52	7.93
18	6.92	7.56
19	6.47	8.77
20	6.82	7.61
Mean time taken	**8.9455**	**9.39**

5. TOTAL NUMBER OF ERRORS ACROSS STAGES (PRE-TEST, INTERVENTION, POST-TEST)

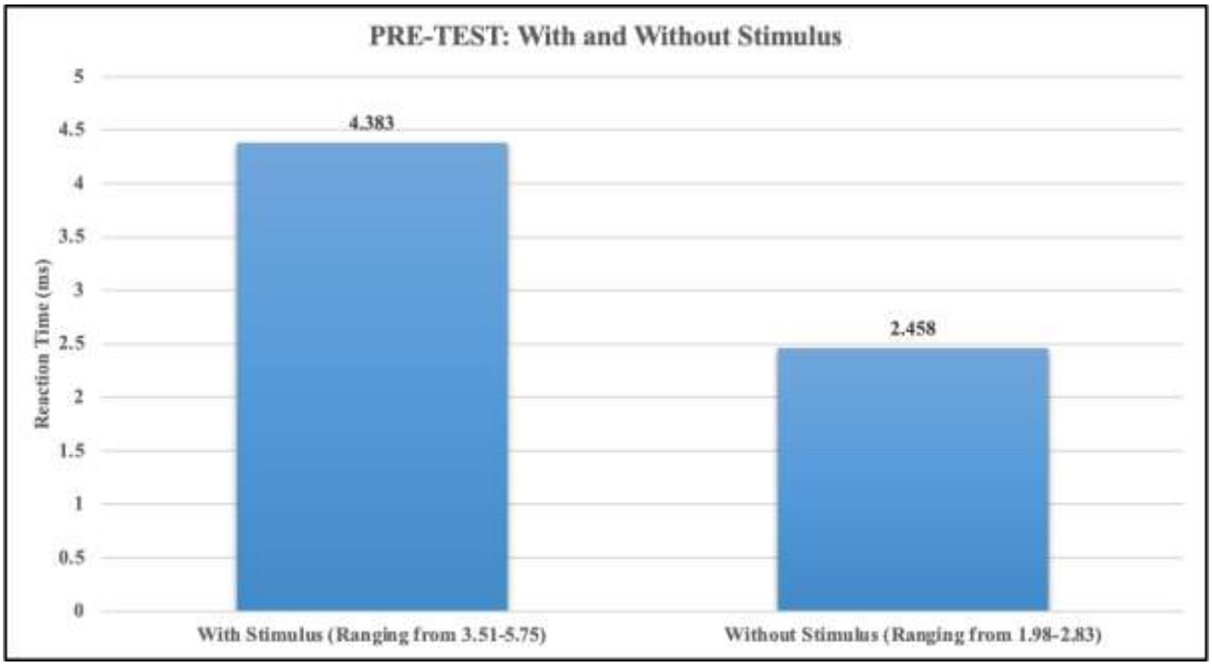
ERRORS IN TRIALS THROUGH THE STAGES						
Pre-Test (Baseline)	**Motor Skill Phase 1**	**Motor Skill Phase 2**	**Motor Skill Phase 3**	**Motor Skill Phase 4**	**Post-Test (Original Pattern)**	**Post-Test (Modified Pattern)**
2	12	13	10	4		
9	24	17	29	6		

10	26	25		18		
15	27	27		19		
23	30					
25						
28						

Stages	PRE-TEST	MOTOR SKILL PHASES				POST-TEST	
	Baseline	1	2	3	4	Original	Modified
Total number of errors	7	5	4	2	4	0	0

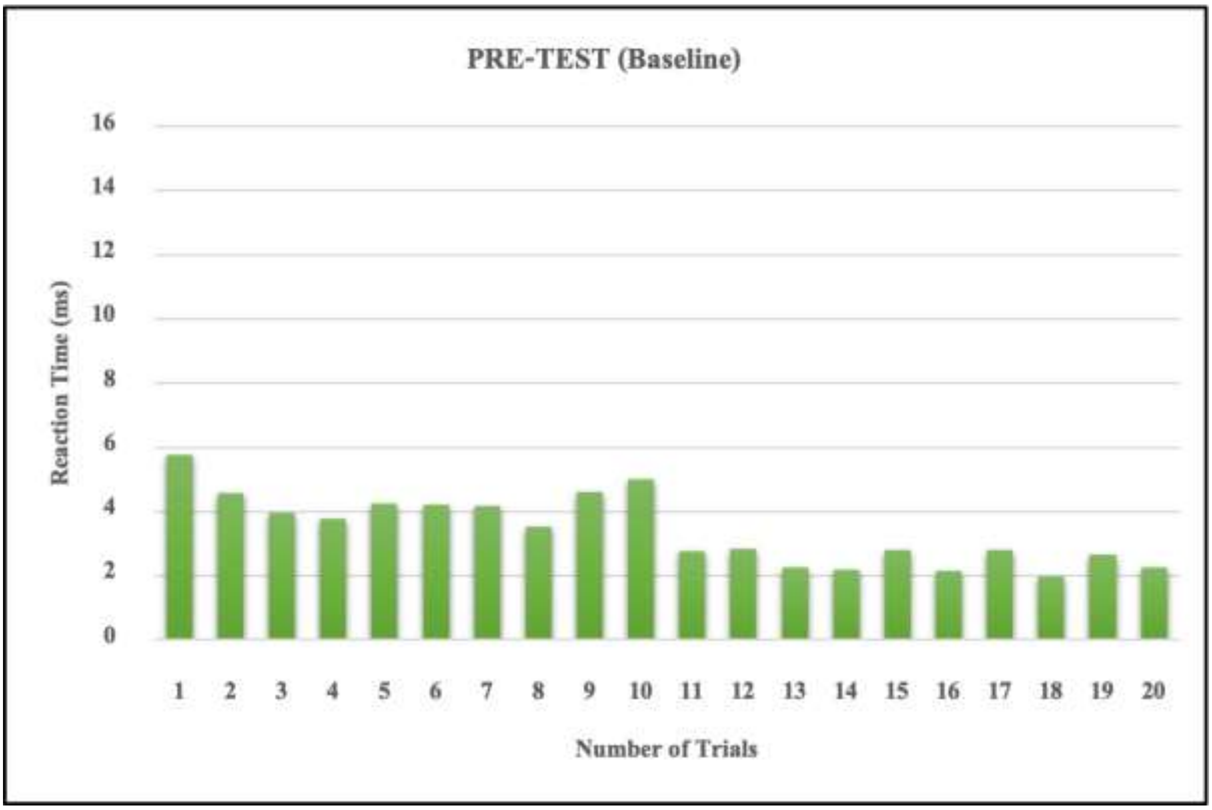
INTERPRETATION:

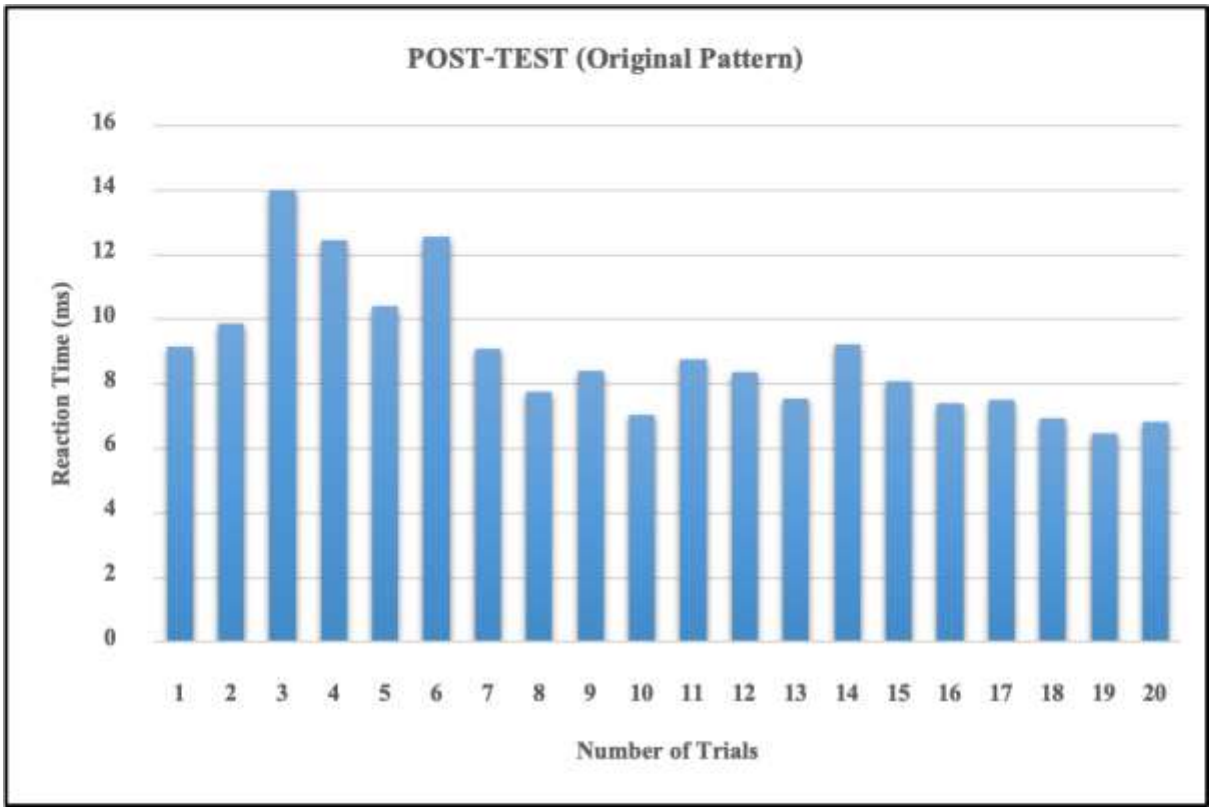
1. PERFORMANCE DIFFERENCE WITH AND WITHOUT STIMULUS



The following graph is a comparison of the subject's performance in trials (pre-test) where the auditory cues and verbal instructions are used and where the cues are not used. Mean performance was greater in stimulus condition (M = 4.38s) than in without stimulus condition (M = 2.46s). Initially, the added auditory stimuli increased cognitive load, slowing down motor responses reflecting an early reliance on external feedback rather than internal, body-based (proprioceptive) control. In spite of the increased speed of the silent trials, the subtle modification in timing across trials revealed that the subject was still learning to self-regulate movement. The first and last ten trials were assessed to eliminate the effects of possible fatigue, attention lapse and environmental distraction. Thus, only trials with stable patterns of performance were recorded.

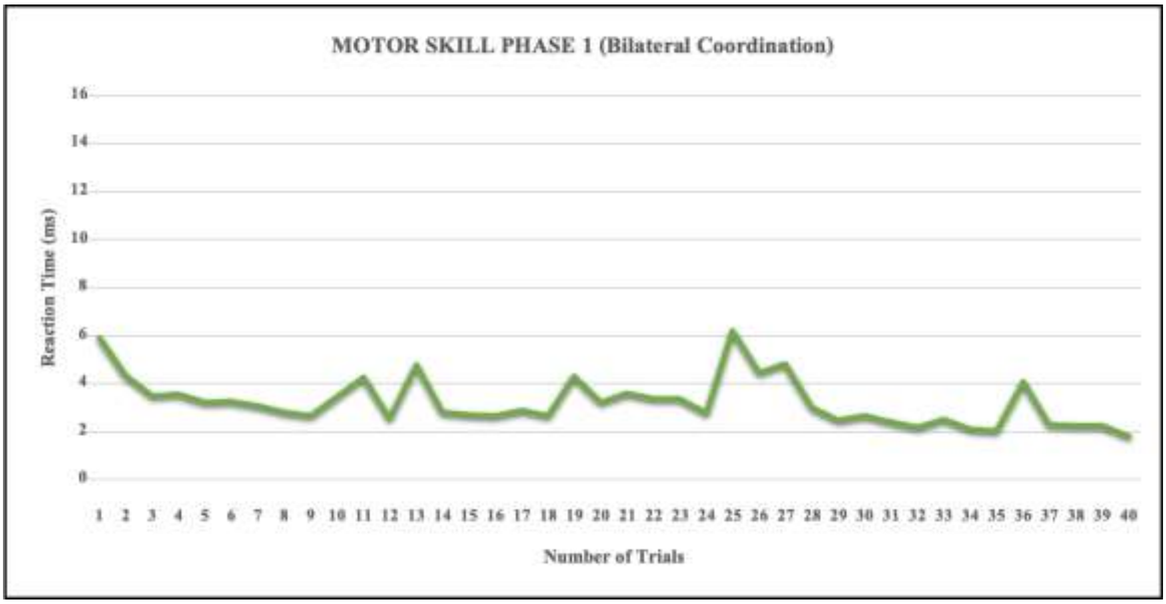
2. COMPARISON BETWEEN PRE-TEST AND POST-TEST

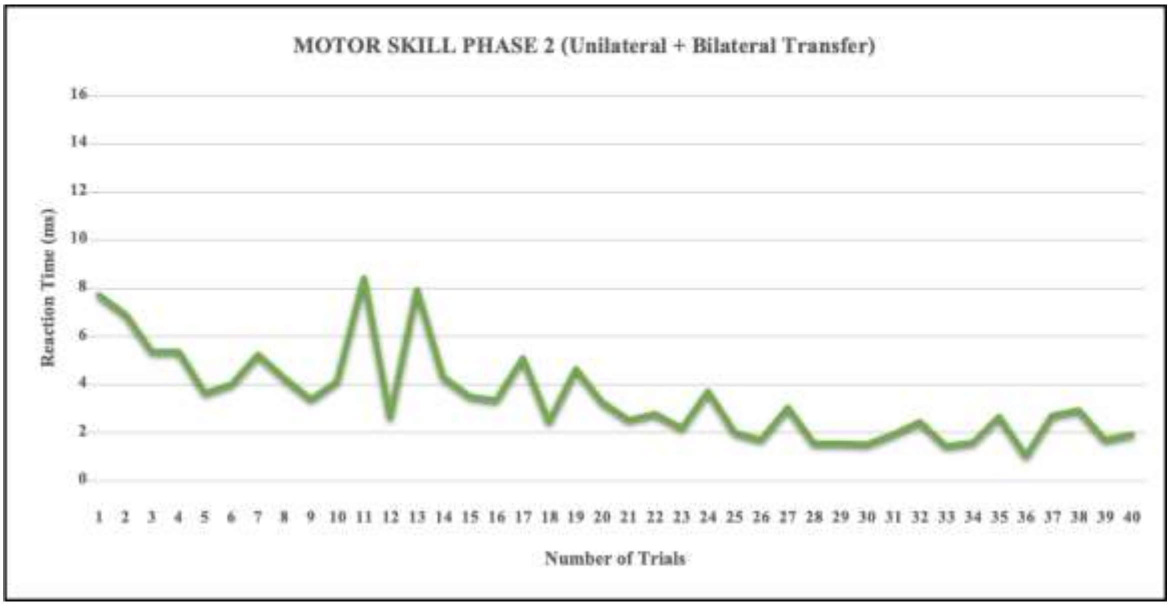


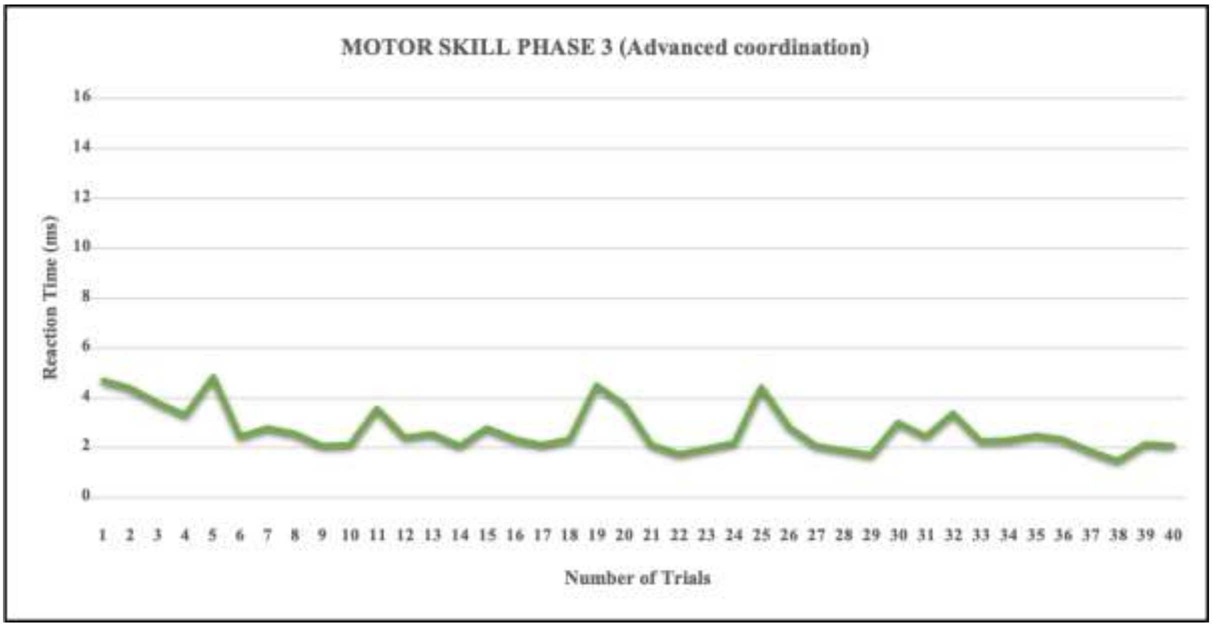


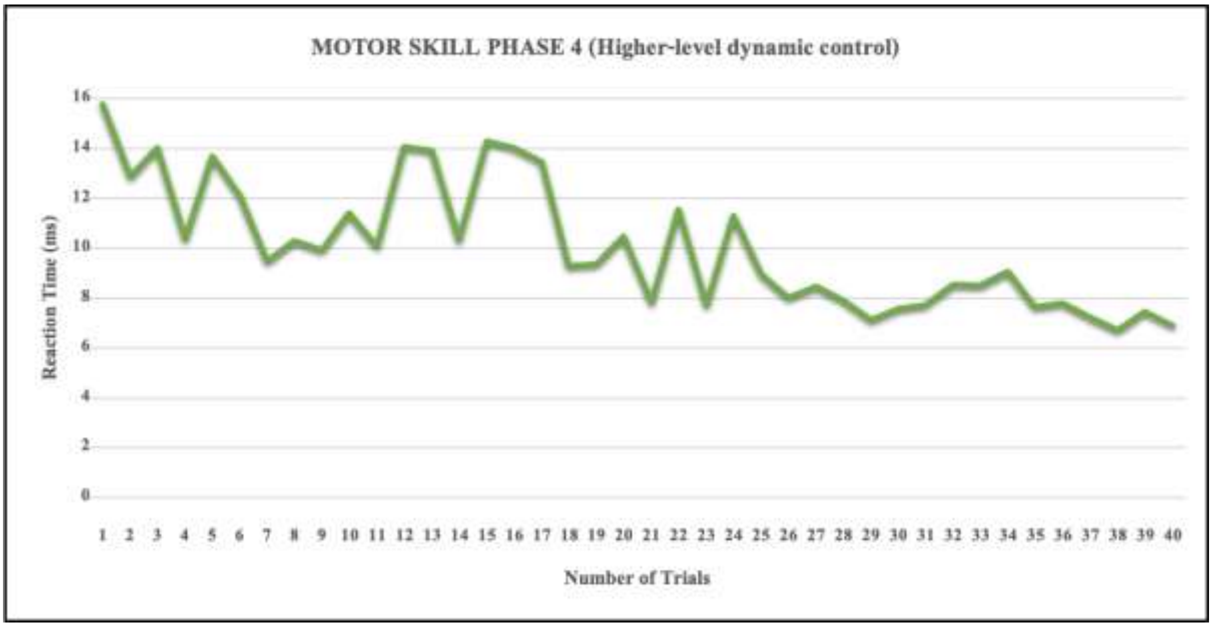
These two graphs demonstrate contrast between the subject's baseline performance (pre-test) on a simple right-left leg discrimination task and post-training performance on the original pattern (post-test) of a more complex hopscotch activity. A total of 20 pre-test and post-test trials were taken into account. In pre-test, the subject performed with auditory cues and verbal instructions, which affected movement and showed dependence on external stimuli to initiate the motor action. On the other hand, the post-test was conducted without auditory cues or verbal instructions hence, the subject had to plan, decide, sequence and execute all the complex tasks. The mean time of completion in the pre-test (3.42 seconds) and the post-test (8.89 seconds) is highly varied. This is a result of more cognitive and motor complexity of the post-test task rather than decline in efficiency. The aspects of the hopscotch pattern: visual sequencing, spatial awareness and balance control were assimilated at different stages during the intervention. The results showcased that the subject progressively possessed smoother transitions and stable pacing across tasks in intervention, which reflected more efficient motor planning, bilateral coordination and attentional regulation. The post-test, thus, reveals evidence of strategic processing and conscious control and shows successful sensorimotor consolidation and multisensory integration acquired during the systematized training (intervention period).

3. PERFORMANCE DIFFERENCE ACROSS MOTOR SKILL PHASES



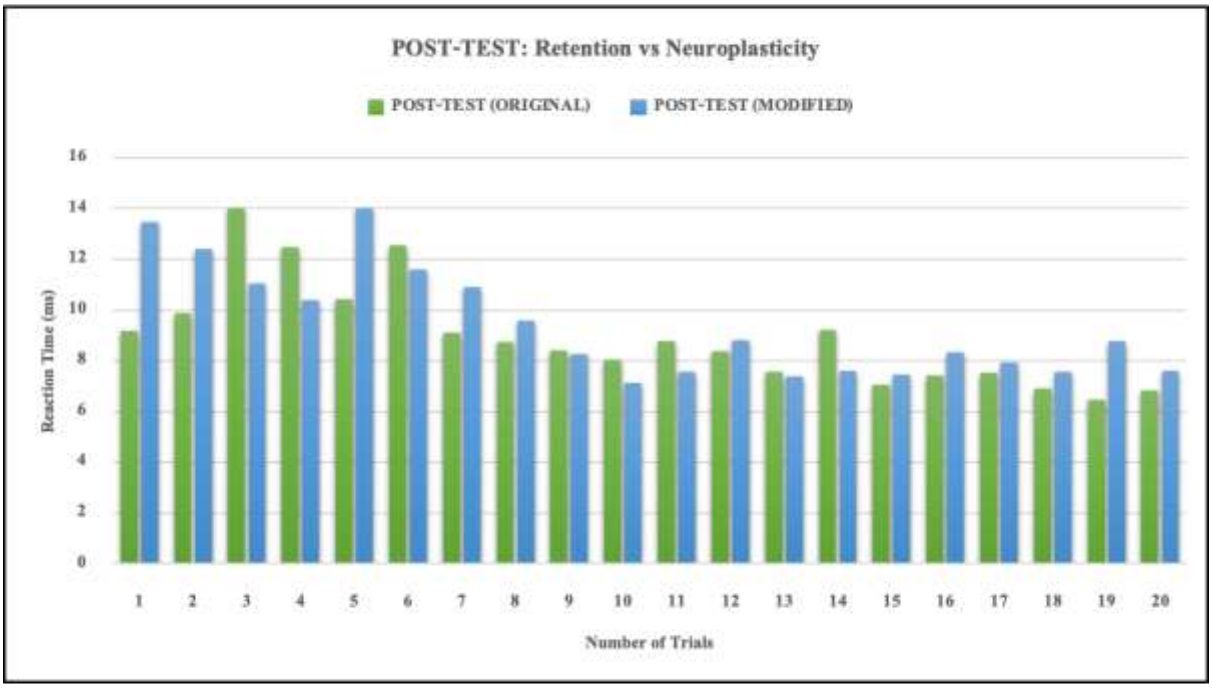






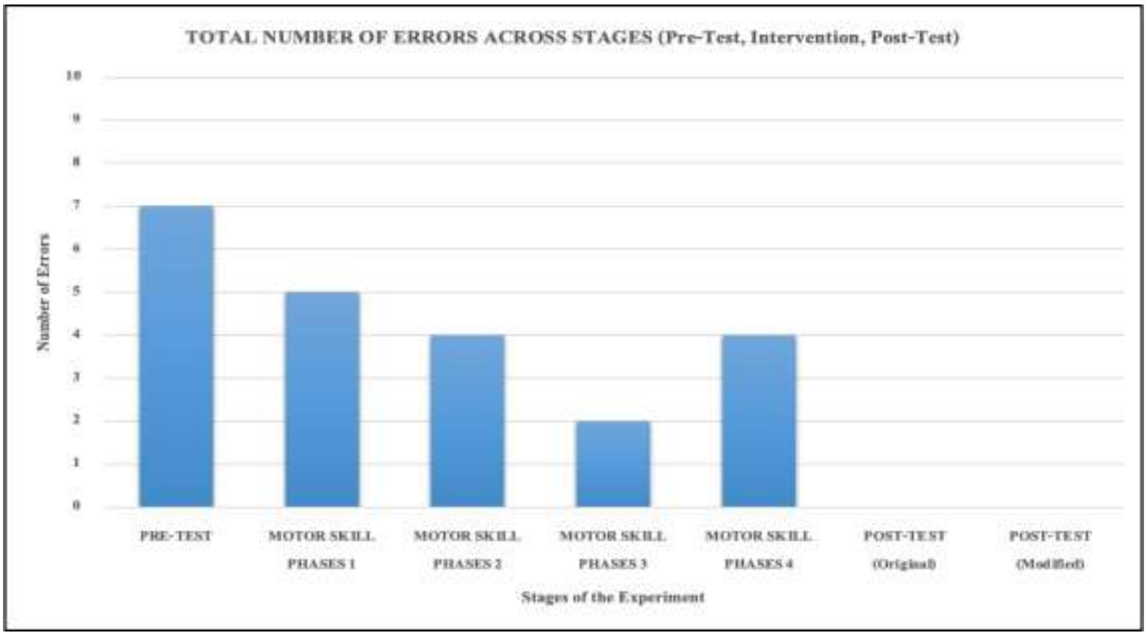
These graphs reveal the subject's performance in four successive motor skill phases, wherein each subsequent phase required a higher level of coordination and balance. The steady drop in mean time from Phase 2 (M = 3.48s) to Phase 3 (M = 2.71s) is a sign of motor learning and task familiarization. The increase in Phase 4 (M = 10.08s) is a sign of introduction of higher-order and novel coordination demands. Such an increase in time suggests neural reorganization and adjustment to new motor learning as opposed to performance regression. The ability to perform more complex tasks shows an improvement in motor flexibility, proprioceptive control and cognitive engagement, which are consistent with the mechanism of neuroplastic reorganization.

4. ASSESSMENT OF POST-TEST (RETENTION AND NEUROPLASTICITY)



This graph contrasts performance between the original and the modified pattern to assess retention and transfer of learning. The similarity between the original pattern mean value (M = 8.95s) and the modified pattern mean value (M = 9.39s) implies that the subject retained learned motor pattern as well as that his coordination ability can be projected to a novel spatial configuration. This depicts a stable motor mapping as well as neural consolidation of movement. The successful learning of the modified pattern of hopscotch by the subject is an indication of long-term neuroplastic change that enables flexibility in applying learned and acquired skills to new contexts which is one of the primary features of long-term sensorimotor learning.

5. TOTAL NUMBER OF ERRORS ACROSS STAGES (PRE-TEST, INTERVENTION, POST-TEST)



The error analysis across stages reveals a clear decline in performance errors as the subject persisted through the hopscotch intervention. During the pre-test, errors (N=7) were common, which indicated initial issues with spatial judgment, right-left discrimination and coordination. The errors decreased as the subject traversed across the motor skill stages at N=5 in Phase 1, N=4 in Phase 2 and a low of N=2 in Phase 3, which suggests an overall enhancement of the proprioceptive awareness and motor control. A small increase of errors in Phase 4 (N=4) represented the result of introducing increased task demand but it also showed active reorganization of the neural system and adaptive learning. The original and the modified hopscotch patterns (post-test) were performed without any errors which shows occurrence of retention, transfer of learning and motor accuracy. The reason for the decreased number of errors from pre-test to intervention to post-test is evidence that auditory, visual and tactile feedback were effectively incorporated as part of the training process, aiding in the development of improved executive control, spatial sequencing and neuromotor stability. Overall, the findings indicate that systematic hopscotch training was effective. Thus, the subject was able to transfer the acquired motor strategies to novel patterns in a flexible manner.

From all the sessions, it can be interpreted that Veer’s progress has reflected real improvement. Faster lap timings and reduction in number of errors depicted how his senses and movements were now aligned. With each passing session, although the task difficulty increased, he showed improved balance, precision in limb placement and body awareness while navigating through boxes. Now, he could comfortably alternate between original and modified hopscotch patterns, reflecting better visual tracking and spatial understanding. These outcomes aided his ability to plan movements with improved consistency, execute movements with enhanced coordination and adapt to novel tasks effectively.

LIMITATIONS:

- There was only one participant in this research which restricted the possibility of extending the outcome of this study to a population of children with mild intellectual disabilities.
- The subject’s performance in some trials was influenced by attentional fluctuation and sensory overload. These factors could have caused variation in his speed and accuracy.
- The absence of standardized psychometric measures or neuroimaging restricted direct linking of behavioural improvement to neural changes. Incorporating neurocognitive assessment in future could firmly establish the occurrence of neuroplasticity.

RECOMMENDATIONS:

- For future research, comparative studies would be helpful towards determining the precise applicability of hopscotch-based interventions.
- Comparisons with other multisensory tasks, hopscotch to other movement-based or cognitive training interventions might reveal the relative efficiency of the method. This would increase the possibility of labelling hopscotch as a model of evidence-based neuro-motor intervention.
- Long term post-intervention observation for weeks or months might be helpful to determine long-lasting retention, transfer and real world effects of the skills learned.
- Changes observed in academic, social and contextual environments post-experiment, if comprehensively examined, could add to the knowledge base of long-term neurodevelopmental gains in children with mild intellectual disabilities.

CONCLUSION:

The study revealed that the systematic multisensory-motor based activity of hopscotch improved Veer's attention, coordination and executive functions. Over time, the gradual decrease in reliance on externally guided movement and shift towards self-initiated movement was a sign of behavioural and neuroplastic adaptation in his motor and cognitive systems. The repeated trials, sensory integration and feedback-aided correction further strengthened neural connections between cerebellum, prefrontal cortex and parietal region; areas that are involved in coordination, planning and emotional regulation. Additionally, the hopscotch task also engaged his vestibular and proprioceptive sensory systems which enhanced Veer's bodily awareness of position in space and figure-ground perception; skills essential for motor planning and coordination in developmental learning.

The anterior cingulate cortex (ACC) contributed significantly in enabling Veer to develop sustained attention, track his performance and improve cognitive control. From a neuropsychological perspective, the optimal functioning of this area in terms of emotions, attention and motor control was indicated by Veer's ability to maintain a steady pace and switch between altered movement patterns.

Overall, the findings indicate that a well-structured and fun activity- hopscotch, has the potential to be an extremely effective therapeutic tool. It not only strengthened Veer's motor learning and balance but also fostered his cognitive engagement, emotional regulation and adaptive behaviour. Thus, this study highlights the existence of a close interconnection between brain, body and behaviour in developmental learning.

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