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Research Article

The Effects of a Family-Based Responsive Instructional Pacing Program Based on Functional Reading on Executive Functions and Adaptive Functioning in Children with Down Syndrome

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Abstract

Objectives: Given that children with Down syndrome (DS) face various challenges in cognitive and behavioral functioning, the present study aimed to investigate the effects of a family-based responsive instructional pacing program based on functional reading on the executive functions and adaptive functioning in children with DS.

Method: The present study employed a quasi-experimental design with a pretest, posttest, and a three-month follow-up. The statistical population of the present study consisted of all children aged 9 to 12 years with DS who were referred to the Pardis Rehabilitation Center in Rasht, Iran, in 2025, and their parents. The sample consisted of 15 children with DS selected through convenience sampling and assigned to the experimental group. The instruments used included the Tower of Hanoi, the Stroop Test, the Wisconsin Card Sorting Test, and the Adaptive Behavior Assessment System. The training program was implemented for the parents in the experimental group in the form of eight 90-minute sessions. Data were analyzed using one-way repeated-measures univariate and multivariate analyses of variance with Bonferroni post hoc tests in SPSS-27.

Results: The results of the analysis of variance indicated that significant improvements in executive functions and adaptive functioning were observed following the intervention in children with DS ($p < 0.05$). Post hoc test results also confirmed that the intervention gains were maintained at follow-up, demonstrating the durability of the program effects.

Conclusion: Based on the findings, the family-based responsive instructional pacing program based on functional reading can have important implications for improving the executive and behavioral skills of children with DS and appears to be a promising intervention.

Keywords: Responsive Teaching, Instructional Pacing, Executive Function, Adaptive Behavior, Health Behavior, Down Syndrome.

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Extended Abstract

Background and Objectives

Down syndrome (DS) is a chromosomal condition caused by trisomy 21 that affects approximately 5.8 million people worldwide and occurs in about 1 in every 800–1000 live births. Clinical manifestations of the syndrome include premature aging, neurological and cognitive impairments, cardiovascular and immune dysfunction, thyroid disorders, and celiac disease. In addition to general cognitive delays, individuals with DS often exhibit persistent deficits in executive functions, including planning, selective attention, and cognitive flexibility. These deficits are associated with early structural differences in the brain and are influenced by both biological and environmental factors. Because executive functions support self-regulation and goal-directed behavior, they are closely linked to adaptive functioning. However, individuals with DS typically perform below developmental expectations in conceptual, social, and practical domains, which may contribute to social withdrawal, anxiety, low self-esteem, and behavioral difficulties. Moreover, children with DS often have difficulty generalizing skills acquired through highly structured interventions, while family-based integrated programs for this population remain insufficiently studied. The family-based responsive instructional pacing program based on functional reading integrates structured Applied Behavior Analysis (ABA) techniques with functional reading and responsive teaching principles, providing a naturalistic framework for enhancing both executive functions and adaptive functioning in children with DS. Therefore, the present study aimed to investigate the effects of the family-based responsive instructional pacing program based on functional reading on executive functions and adaptive functioning in children with DS.

Materials and Methods

This applied study used a quasi-experimental pretest–posttest design with a three-month follow-up and was conducted with 15 children aged 9 to 12 years with DS and their parents, who were selected through convenience sampling from the Pardis Rehabilitation Center in Rasht in 2025. Assessment tools included the Tower of Hanoi, the Stroop Test, the Wisconsin Card Sorting Test, and the Adaptive Behavior Assessment System (ABAS-3). The intervention consisted of a family-based responsive instructional pacing program based on functional reading that combined ABA, family-based intervention, and functional reading approaches. It was delivered to the parents in the experimental group through eight weekly 90-minute group sessions, accompanied by a functional reading book for home practice. After the pretest assessment, the intervention was implemented. A week later, the posttest was administered, and a follow-up assessment was conducted three months later. Data were analyzed using one-way repeated-measures univariate and multivariate analysis of variance and Bonferroni post hoc tests in SPSS-27.

Results

The study sample consisted of 15 children with DS and their parents. Among the children, 9 (60%) were boys, and 6 (40%) were girls, with a mean age of 10.40 years (SD = 1.06). The mean age of the mothers was 37.80 years (SD = 5.12), and the mean age of the fathers was 41.20 years (SD = 5.87).

A one-way repeated-measures ANOVA, which met the assumptions of sphericity and normality, examined within-group changes in executive functions over time and revealed significant differences across pretest, posttest, and follow-up for all measures derived from the Tower of Hanoi, Stroop Test, and Wisconsin Card Sorting Test ($p < 0.05$), except for the Stroop square color-naming errors. Bonferroni-adjusted pairwise comparisons showed significant improvements

from pretest to both posttest and follow-up for these components, while no significant differences emerged between posttest and follow-up for most measures, with the sole exception of Stroop word color-naming errors, indicating that intervention gains were largely maintained and the effects were sustained.

A one-way repeated-measures MANOVA examined the within-group effect of time on adaptive functioning, with assumption checks confirming univariate normality (non-significant Shapiro–Wilk tests) and acceptable multicollinearity (Pearson r = 0.39–0.65). The multivariate effect was significant, Pillai's trace = 0.58, p = 0.002, representing a large effect (58% of variance explained). Follow-up within-subjects analyses revealed significant time effects on all adaptive functioning components ($p < 0.05$). Bonferroni-adjusted pairwise comparisons indicated significant gains from pretest to posttest and from pretest to follow-up for every component, but from posttest to follow-up only Health and Safety and Self-Direction differed significantly, with all other components maintaining their improvements. Overall, substantial improvements in adaptive functioning were observed following the intervention relative to baseline, and these gains persisted at follow-up for most domains.

Discussion and Conclusion

Improvements in executive functions were observed following the intervention and were maintained at follow-up, consistent with prior studies. These gains stem from structured learning cycles that integrate response inhibition, working memory, selective attention, and cognitive flexibility, requiring the child to maintain information, inhibit impulsive responses, shift between stimuli, and self-regulate during parent interaction. Similarly, improvements in adaptive functioning were observed following the intervention and were largely maintained at follow-up, consistent with prior studies. As adaptive functioning is a multidimensional construct requiring cognitive, practical, and psychosocial support, the program enhanced outcomes by increasing motivation, promoting durable learning through distributed practice, strengthening reading-related cognitive processes, and extending learning opportunities through parent-mediated support. Furthermore, the use of natural consequences and functional reading activities embedded in everyday contexts increased engagement and facilitated the development of conceptual, social, and practical adaptive skills across home, school, and community settings.

Introduction

Down syndrome (DS) is a complex chromosomal condition caused by trisomy 21, affecting approximately 5.8 million people worldwide, with an incidence of about 1 in 800–1000 live births (0.9 per 1000 live births in Iran) (Rezaei Hemami et al., 2021). Many of the clinical manifestations of DS, including premature aging, neurological and cognitive impairments, congenital and acquired cardiovascular diseases, immune dysfunction, thyroid disorders, and celiac disease, have been attributed to accelerated cellular aging and increased oxidative stress caused by DS (Rahbar Karbasdehi et al., 2024). Beyond general cognitive delays, individuals with DS exhibit specific impairments in executive functions, including executive planning, selective attention, and cognitive flexibility, which are necessary for goal-directed behavior. From early infancy, anatomical differences have been observed in brain regions associated with these functions, including reduced volumes of the frontal lobe, the brainstem, and the cerebellum, narrowing of the superior temporal gyrus, abnormalities in myelination, and a 20–50% reduction in cortical neurons. These executive function deficits often persist into adulthood and are influenced by both biological and environmental factors (Schworer et al., 2019; Rezaei

Niyasr et al., 2017).

Because executive functions support self-regulation and goal-directed behavior, they are closely associated with adaptive functioning, which encompasses the conceptual, social, and practical skills required for everyday life. Higher levels of adaptive functioning are associated with greater academic achievement, fewer maladaptive behaviors, and increased independence in adulthood. Individuals with DS typically demonstrate adaptive skills below developmental expectations, and deficits in adaptive and social functioning may contribute to low self-esteem, depression, social withdrawal, and anxiety. Parents frequently report mood changes and increasing social withdrawal during the transition to adolescence (Onnivello et al., 2024; Bahrami et al., 2025). Communication difficulties are associated with increased disruptive behaviors and academic challenges, whereas the use of functional language by school-age children predicts more favorable long-term outcomes, highlighting the need for effective interventions (Rahbar Karbasdehi et al., 2024).

The most common evidence-based treatment option for DS is Applied Behavior Analysis (ABA) (Soccorso et al., 2024). The family-based responsive instructional pacing program based on functional reading offers an integrative framework that combines the structural components of ABA (such as intertrial interval and within-trial interval) with the principles of naturalistic interventions and responsive teaching. This integration aims to enhance responsiveness, improve acquisition rates, and promote skill generalization in real-world contexts through task variety, mixed maintenance and acquisition trials, targeted reinforcement, and the use of natural consequences (Matson, 2023). Moreover, the centrality of functional reading (everyday texts) enables learning to move beyond a sign/symbol level and become applicable in social and academic situations—an essential feature for compensating for the slow acquisition and weak generalization that are characteristic of purely structural methods (De Albuquerque & De Melo, 2023).

Regarding the effects of ABA-based interventions on executive functions, Lax et al. (2023) found that naturalistic environment training was most effective for cognitive and verbal development in toddlers with autism spectrum disorder (ASD), while discrete trial training proved superior in reducing autism symptom severity. Similarly, Hosseinian Por & Yar-Ahmadi (2022) demonstrated that ABA intervention significantly improved cognitive and social skills in children with ASD. Additionally, Tababaie Navai Nobari et al. (2021) showed that both Pivotal Response Treatment (PRT) and ABA reduced the severity of autism symptoms and improved executive functions, although PRT was more effective. Other studies have also indicated that ABA therapy improves inhibition, attention shifting, and planning, particularly among children with intellectual disability (Demehri et al., 2019; Nikookholgh et al., 2020). Moreover, Mahoney et al. (2006) found that responsive teaching enhanced pivotal developmental behaviors, including attention, initiation, persistence, and self-regulation, in children with DS. Beyond ABA-based approaches, other instructional methods have shown promise for related outcomes; for instance, Prahl et al. (2025) found that functional reading instruction significantly improved comprehension strategy use and reading comprehension in young adults with intellectual and developmental disabilities.

With respect to adaptive functioning, Han et al. (2026), in a mixed-methods systematic review and meta-analysis, reported significant improvements in adaptive behavior, daily living skills, language, and joint attention following ABA-based interventions compared to control groups. Consistent with these findings, Collins et al. (2025) found that ABA interventions produced large effects on receptive language and moderate effects on adaptive behaviors and cognitive abilities, with higher dosage and duration associated with greater

improvements in adaptive behavior. Furthermore, Da Silva et al. (2023) noted that ABA therapy improved social, conceptual, and daily living skills in children with ASD. Similarly, Neil et al. (2021), in a meta-analysis of 125 single-case studies, found that ABA interventions produced a moderate overall effect on improving skills and reducing challenging behaviors in individuals with DS. However, Azizi et al. (2023) compared ABA therapy and the TEACCH method and found that the TEACCH method contributed more to improving social skills, conceptual skills, and verbal comprehension in children with ASD. Although ASD and DS differ etiologically, both conditions involve executive functioning difficulties and adaptive behavior deficits. Therefore, findings from ASD interventions may provide a useful conceptual framework.

Despite evidence supporting the benefits of ABA and other structured interventions for children with neurodevelopmental disorders, several important gaps remain in addressing the needs of children with DS. First, most intervention studies targeting executive functions and adaptive functioning have been conducted with children with ASD, whereas evidence specific to children with DS—particularly within integrated family-based programs—remains limited. Second, children with DS exhibit a distinctive profile of executive functioning difficulties associated with syndrome-specific neurodevelopmental alterations, suggesting that findings derived from ASD populations may not fully generalize to this group. Third, many children with DS experience substantial difficulty generalizing skills acquired in structured intervention settings to everyday home, school, and community environments. Such difficulties in skill transfer may undermine long-term outcomes, contributing to poorer social participation, academic performance, and behavioral adjustment. Finally, many existing interventions are primarily delivered in clinic-based settings and offer limited parental involvement and few opportunities to apply skills in natural contexts.

Given these gaps—limited DS-specific evidence, restricted family involvement, insufficient attention to skill generalization, and a lack of ecologically valid intervention contexts—there is a clear need for an intervention that: (a) targets the executive and adaptive skill profiles characteristic of DS; (b) integrates functional reading as a meaningful everyday medium that engages executive functions (e.g., working memory, selective attention, and cognitive flexibility) alongside adaptive skills (e.g., functional academics, self-direction, and community use); and (c) promotes skill generalization through parent-mediated implementation in the home environment, thereby extending learning opportunities beyond clinical settings to everyday contexts. Such a family-based and ecologically grounded approach may help address several limitations of existing interventions. Accordingly, the present study aimed to investigate the effects of the family-based responsive instructional pacing program based on functional reading on executive functions and adaptive functioning in children with DS.

Method

This applied study employed a quasi-experimental pretest–posttest design with a three-month follow-up.

Participants

The statistical population consisted of all children aged 9 to 12 years with DS who were referred to the Pardis Rehabilitation Center in Rasht in 2025, along with their parents. An a priori power analysis was conducted using G*Power 3.1 (Faul et al., 2009) to determine the minimum sample size required for a one-group, within-subjects design with three measurement occasions (pretest, posttest, and follow-up). In the absence of directly comparable previous studies examining this intervention in children with DS, a medium-to-large effect size

(Cohen's f = 0.35) was assumed based on Cohen's (1988) conventional benchmarks and the expectation of clinically meaningful intervention effects. Assuming a significance level of α = 0.05, statistical power of 0.80, a correlation of 0.50 among the repeated measures, and sphericity (ε = ١), the analysis indicated that a minimum of ١٥ participants was required. The study sample comprised 15 children with DS (9 boys and 6 girls), who were selected through convenience sampling based on the inclusion and exclusion criteria and assigned to the experimental group. The inclusion criteria were: (a) age between 9 and 12 years, (b) an IQ between 50 and 70, (c) enrollment in grades 3–6 of elementary school, and (d) parental education of at least a high school diploma. The exclusion criteria included the parents being separated or not living in the same household, concurrent participation in similar educational or therapeutic interventions by either the parents or the child, parental use of psychiatric medications, and unwillingness to participate in or to continue participating in the study.

Ethical Statements

To ensure adherence to ethical standards, data collection was conducted only after obtaining informed consent from the participants. Participants were also assured of confidentiality regarding their personal information and that the results would be reported anonymously, without any identifying details. The study was approved by the Ethics Committee of the Faculty of Psychology and Education at the University of Tehran under the code IR.UT.PSYEDU.REC.1404.037 on 2025/07/12.

Measures

***Tower of Hanoi (TOH)*:** This task was introduced by Hayes and Simon in 1974 to assess executive planning, information processing, and problem-solving. It consists of three pegs attached to a flat base and three disks of different sizes. The participant must transform the initial configuration into the goal configuration by moving the disks across the pegs. The disks can be transferred from position A to position C in seven moves, provided that only one disk is moved at a time and that a larger disk is always placed below a smaller disk. To score the task, the number of moves and the time taken by the participant to solve the task are calculated. The validity coefficient, based on correlations with the Tower of London Test, was 0.78, and the reliability coefficient (Cronbach's alpha) was 0.90 (Humes et al., 1997). In Iran, test–retest reliability was reported as 0.72, and a validity coefficient of 0.57 was obtained through correlations with the Metacognitive Strategies Test (Ghasemi & Ahadi, 2003). In the present study, Cronbach's alpha coefficient for the TOH ranged from 0.83 to 0.89.

Stroop Test (ST): This test was designed by Stroop in 1935 to assess attentional processing and response inhibition. It consists of four cards: word reading, square color naming, reading words while ignoring ink color, and naming ink colors while ignoring the written words. Each card contains 25 stimuli arranged in a 5 × 5 grid. Scores on this test range from 0 to 25 for each card. The test measures error rates and reaction times. The test–retest reliability coefficient for reaction time in the first phase was 0.60, and for the number of errors it was 0.55. In the second phase, the reliability coefficient for reaction time was reported as 0.83, and for the number of errors as 0.78. Furthermore, in the third phase, the reliability coefficient for both reaction time and number of errors was 0.79 (Faria et al., 2024). In Iran, the test–retest reliability has been reported in a range between 0.80 and 0.91 (Abolghasemi et al., 2015), and its validity, through correlation with the Children's Trail Making Test, ranged from 0.54 to 0.66 (Nejati et al., 2021). In the present study, Cronbach's alpha coefficients for the reaction time and error indices ranged from 0.79 to 0.92.

Wisconsin Card Sorting Test (WCST): This test was developed by Grant and Berg (1948) to assess cognitive

flexibility and executive functioning. It consists of 64 dissimilar cards with various shapes (such as triangle, star, cross, and circle) and various colors. The WCST can be scored in different ways, the most common of which is recording the number of categories achieved and the total number of errors. The validity of this test for identifying cognitive deficits was reported as 0.86, and its reliability based on the inter-rater agreement coefficient was 0.83 (Spreen & Strauss, 2006). In Iran, the reliability of the test using the test–retest method was 0.85 (Khalaf Beigi et al., 2013), and its validity, as measured by correlation with the Bender-Gestalt test, was reported as 0.60 (Javanmard et al., 2008). In the present study, Cronbach's alpha coefficients ranged from 0.87 to 0.94.

Adaptive Behavior Assessment System (ABAS-3): This questionnaire was developed by Harrison and Oakland (2015) to assess adaptive functioning in individuals aged 5 to 21 years based on parent-report ratings. It comprises 211 items across nine subscales (Communication, Community Use, Functional Academics, Home Living, Health and Safety, Leisure, Self-Care, Self-Direction, and Social), with each item being rated on a 0–3 scale based on ability and frequency. The developers reported Cronbach's alpha coefficients of 0.89–0.99, test–retest reliability of 0.73–0.85, and convergent validity with the Vineland Adaptive Behavior Scales, Second Edition (r = 0.67) (Harrison & Oakland, 2015). In Iran, the reliability of this questionnaire, as measured by Cronbach's alpha coefficient, ranged from 0.94 to 0.96, and was 0.99 for the total score. Using the intraclass correlation coefficient, the values exceeded 0.75 for eight subscales, and were only 0.67 for the leisure subscale (Soleimani et al., 2024). In the present study, Cronbach's alpha coefficients for the ABAS-3 subscales ranged from 0.84 to 0.93.

Intervention

The family-based responsive instructional pacing program based on functional reading is grounded in an integrated theoretical framework combining three approaches: ABA (encompassing instructional pacing and responsive teaching), family-based intervention, and functional reading. The program was designed and validated by Rahbar Karbasdehi (2026). To integrate theoretical instruction with practical application, the book *Functional Reading: For Slow-Paced Children with Down Syndrome* was developed as a supplementary package for the intervention. The content of the eight training sessions and the six book chapters, together with an evaluation checklist, was reviewed by ten specialists. The mean Content Validity Ratio (CVR) and Content Validity Index (CVI) were 0.875 and 0.94, respectively, for the training program, and 0.867 and 0.93 for the functional reading book (Rahbar Karbasdehi, 2026). The program was delivered by the researcher to the parents in the experimental group across eight group sessions, each lasting 90 minutes. The content of each session is presented in Table 1.

Table 1. Content of the training program sessions

Session	Content of session
1st	Be physically available, play frequently, and use imitation or parallel play to join the child's activities. Take turns and pause deliberately, practice turn-taking with sounds, and intentionally reduce verbal input to create communication opportunities. Use short sentences and simple vocabulary, and pause 3–5 seconds after each sentence.
2nd	Engage in face-to-face games without toys, extend repetitive and predictable play routines, and participate in the child's preferred repetitive play activities. Observe closely, adopt the child's perspective, and remain sensitive to emotional and behavioral states. Break skills into small components and avoid introducing multiple new skills simultaneously. Use brief review and repetition.

3rd	Treat vocalizations, facial expressions, and gestures as meaningful communication and respond as if they are part of a meaningful conversation. Recast unclear vocalizations and approximate words using appropriate language models. Break complex skills into smaller steps and teach each step separately. Include a 2–5 second pause between practice attempts.
4th	Integrate responsive strategies into daily activities. Limit excessive questioning, imitate the child's communicative behaviors, and provide opportunities for choice-making. Wait at least 5 seconds after a question or instruction before offering assistance. Monitor reaction time and allow sufficient response time.
5th	Expand the child's behavior and speech toward the next developmental level, extend topics, and use deliberate pauses to encourage fuller responses. Be energetic, playful, and humorous. Repeat exercises with brief breaks. Provide modeling and verbal assistance, and gradually fade support (full guidance → partial guidance → minimal cues).
6th	Make enjoyment the primary goal of interaction, transform daily routines into games, and repeat preferred activities. Use gentle physical contact and respond warmly to bids for attention. Employ pictures, symbols, and schedules as visual supports. Record and analyze errors to adjust instructional pacing.
7th	Value the child's actions and efforts, and treat fears and concerns as meaningful. Interpret behavior from a developmental perspective and communicate in ways consistent with the child's abilities. Monitor the number of steps learned per session and adapt instruction accordingly. Review skills over time and practice them in diverse settings.
8th	Interpret the child's behavior as an indicator of interests and follow the child's attentional focus. Adapt interactions to the child's behavioral style and sensory experiences while maintaining developmentally appropriate expectations. Provide immediate, brief, and positive reinforcement following correct responses. Adjust the number of practice trials to the child's capacity and use short, frequent sessions.

Procedure

Before data collection, the necessary permissions were obtained from the University of Tehran. Participants were recruited from the Pardis Rehabilitation Center in Rasht. After the center's administrators were informed about the objectives and procedures of the study, 15 children with DS were selected through convenience sampling based on the inclusion and exclusion criteria, and their parents were invited to participate. Following the pretest assessment, the family-based responsive instructional pacing program based on functional reading was implemented for the parents in the experimental group. The intervention was delivered in a group format over eight weekly sessions, each lasting 90 minutes, across two months. In addition, parents received a functional reading book for home-based practice and were instructed to complete the related activities with their child. The posttest assessment was conducted one week after completion of the intervention, and a follow-up assessment was carried out three months later to evaluate the maintenance of treatment effects. Descriptive statistics (means and standard deviations) and inferential analyses (one-way repeated-measures univariate and multivariate analyses of variance with Bonferroni post hoc tests) were performed using SPSS-27. Written informed consent was obtained from all participating parents, who were assured that all collected information would remain confidential. The study was approved by the Ethics Committee of the Faculty of Psychology and Education, University of Tehran (Code: IR.UT.PSYEDU.REC.1404.037).

Results

The study sample consisted of 15 children with DS and their parents. Among the children, 9 (60%) were boys

and 6 (40%) were girls, with a mean age of 10.40 years (SD = 1.06). Regarding grade level, 3 participants (20%) were in third grade, and 4 participants (26.7%) were in each of the fourth, fifth, and sixth grades. The mean age of the mothers was 37.80 years (SD = 5.12), and the mean age of the fathers was 41.20 years (SD = 5.87).

To examine the within-subject effect of time on executive function, a one-way repeated-measures ANOVA was conducted. Given that the executive function measures were derived from three different instruments and yielded distinct, incommensurable indices with varying measurement properties (e.g., number of moves, completion time, number of errors, and number of categories achieved), each index was analyzed separately using repeated-measures ANOVA. Assumption checks indicated that the data met the assumptions required for repeated-measures analyses, including normality and sphericity. Mauchly's test of sphericity was non-significant ($p > 0.05$), supporting the assumption of sphericity, and Shapiro–Wilk tests confirmed normality for all variables at each assessment point ($p > 0.05$). One-way repeated-measures ANOVAs were conducted for each index of executive function to examine the effect of time. Bonferroni-adjusted pairwise comparisons were then performed to identify significant differences between assessment points. The results are presented in Table 2, and the three-stage change trends across all executive function measures are illustrated in Figure 1.

Table 2. Descriptive statistics and one-way repeated measures ANOVA with Bonferroni post hoc tests for executive functions

Variable	Status	Mean (SD)	F	p	η^2	Comparison	Mean difference	Standard error	p
Tower of Hanoi (Moves)	Pretest	16.82 (2.10)	24.58	0.001	0.64	Pre-post	5.46	0.84	0.001
	Posttest	11.36 (1.78)				Pre-follow-up	4.73	0.84	0.001
	Follow-up	12.09 (1.82)				Post-follow-up	-0.73	0.84	0.099
Tower of Hanoi (Time)	Pretest	155.31 (5.80)	22.31	0.001	0.61	Pre-post	35.82	1.04	0.001
	Posttest	119.49 (4.65)				Pre-follow-up	32.07	1.04	0.001
	Follow-up	123.24 (5.10)				Post-follow-up	-3.75	1.04	0.081
Stroop: Word reading (Time)	Pretest	61.14 (3.54)	17.98	0.001	0.56	Pre-post	11.48	0.89	0.001
	Posttest	49.66 (2.74)				Pre-follow-up	8.86	0.89	0.001
	Follow-up	52.28 (2.63)				Post-follow-up	-2.62	0.89	0.082
Stroop: Square color naming (Time)	Pretest	58.21 (2.74)	6.52	0.005	0.32	Pre-post	9.07	1.00	0.001
	Posttest	49.14 (1.89)				Pre-follow-up	5.89	1.00	0.001
	Follow-up	52.32 (2.58)				Post-follow-up	-3.18	1.00	0.066
Stroop: Word reading ignoring color (Time)	Pretest	73.43 (3.26)	5.21	0.011	0.27	Pre-post	12.22	1.04	0.001
	Posttest	61.21 (2.17)				Pre-follow-up	10.19	1.04	0.001
	Follow-up	63.24 (2.62)				Post-follow-up	-2.03	1.04	0.079
Stroop: Word color naming (Time)	Pretest	78.42 (4.33)	9.29	0.001	0.40	Pre-post	14.28	0.98	0.001
	Posttest	64.14 (3.43)				Pre-follow-up	10.70	0.98	0.001
	Follow-up	67.72 (4.21)				Post-follow-up	-3.58	0.98	0.074
Stroop: Word reading (Error)	Pretest	9.23 (1.72)	3.99	0.029	0.22	Pre-post	4.82	0.64	0.001
	Posttest	4.41 (1.52)				Pre-follow-up	3.96	0.64	0.001
	Follow-up	5.27 (1.29)				Post-follow-up	-0.86	0.64	0.089
Stroop: Square color naming (Error)	Pretest	7.11 (1.93)	1.48	0.245	0.10	Pre-post	3.90	0.73	0.069
	Posttest	3.21 (1.39)				Pre-follow-up	3.76	0.73	0.074
	Follow-up	3.35 (1.55)				Post-follow-up	-0.14	0.73	0.061

Stroop: Word reading ignoring color (Error)	Pretest	13.41 (2.12)	10.12	0.001	0.42	Pre-post	5.20	0.77	0.001
	Posttest	8.21 (2.76)				Pre-follow-up	4.56	0.77	0.001
	Follow-up	8.85 (1.61)				Post-follow-up	-0.64	0.77	0.640
Stroop: Word color naming (Error)	Pretest	14.71 (2.31)	7.19	0.003	0.34	Pre-post	5.48	0.81	0.001
	Posttest	9.23 (2.25)				Pre-follow-up	3.30	0.81	0.001
	Follow-up	11.41 (1.47)				Post-follow-up	-2.18	0.81	0.057
Wisconsin Card Sorting Test (Categories)	Pretest	1.72 (0.63)	8.18	0.002	0.37	Pre-post	-1.66	0.38	0.001
	Posttest	3.38 (0.94)				Pre-follow-up	1.30	0.38	0.002
	Follow-up	3.02 (0.82)				Post-follow-up	0.36	0.38	0.074
Wisconsin Card Sorting Test (Errors)	Pretest	18.42 (3.21)	3.61	0.038	0.21	Pre-post	6.03	0.88	0.001
	Posttest	12.39 (3.14)				Pre-follow-up	4.95	0.88	0.001
	Follow-up	13.47 (2.87)				Post-follow-up	-1.08	0.88	0.081

The results presented in Table 2 indicated significant differences across the pretest, posttest, and follow-up assessments for all executive function measures derived from the TOH, the Stroop Test, and the WCST ($p < 0.05$), with the exception of the square color-naming error measure in the Stroop Test. Bonferroni-adjusted pairwise comparisons revealed significant differences between the pretest and posttest, as well as between the pretest and follow-up, for all executive function measures except the square color-naming error measure in the Stroop Test. In contrast, no significant differences were observed between the posttest and follow-up assessments for most measures, with the exception of the word color-naming error measure in the Stroop Test. Overall, these findings indicate that the improvements observed following the intervention were largely maintained at follow-up, suggesting sustained treatment effects.

Figure 1. Three-Stage Change Trends in Executive Functions (Pretest–Posttest–Follow-up)

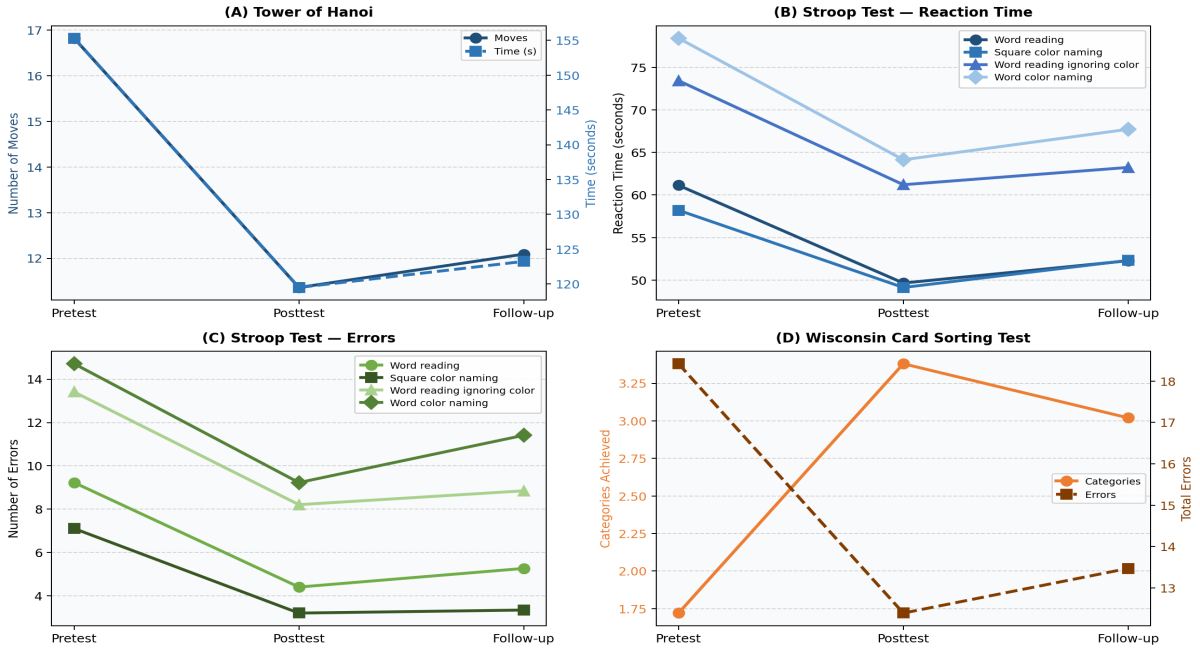


Figure 1. Three-stage change trends in executive functions (pretest–posttest–follow-up)

To examine the within-group effect of time on adaptive functioning, a one-way repeated-measures MANOVA was conducted. Assumption checks indicated that the data met the required criteria. Shapiro–Wilk tests were non-significant ($p > 0.05$) for each adaptive functioning component at each assessment point, supporting the assumption of univariate normality. Pearson correlation coefficients among the nine adaptive functioning components ranged from 0.39 to 0.65, indicating acceptable linear relationships without evidence of severe multicollinearity (all $r < 0.70$). The MANOVA revealed a significant multivariate effect of time on adaptive functioning, Pillai's trace = 0.58, $p = 0.002$, partial $\eta^2 = 0.58$, indicating a large effect size. Subsequently, repeated-measures ANOVAs and Bonferroni-adjusted pairwise comparisons were conducted for each adaptive functioning component to identify the specific changes across time (see Table 3 and Figure 2).

Table 3. Descriptive statistics and one-way repeated measures MANOVA with Bonferroni post hoc tests for adaptive functioning

Variable	Status	Mean (SD)	F	p	η^2	Comparison	Mean difference	Standard error	P
Communication	Pretest	38.24 (3.27)	5.22	0.012	0.27	Pre-post	-17.51	1.42	0.001
	Posttest	55.75 (2.79)				Pre-follow-up	-15.04	1.38	0.001
	Follow-up	53.28 (2.25)				Post-follow-up	2.47	1.21	0.061
Community Use	Pretest	12.36 (1.89)	12.12	0.001	0.46	Pre-post	-17.97	1.11	0.001
	Posttest	29.33 (1.57)				Pre-follow-up	-15.05	1.08	0.001
	Follow-up	27.41 (1.35)				Post-follow-up	2.92	0.96	0.073
Functional Academics	Pretest	23.87 (2.74)	15.89	0.001	0.53	Pre-post	-23.94	1.51	0.001
	Posttest	47.81 (2.24)				Pre-follow-up	-20.40	1.44	0.001
	Follow-up	44.27 (1.65)				Post-follow-up	3.54	1.22	0.069
Home Living	Pretest	29.17 (1.24)	10.55	0.002	0.43	Pre-post	-16.19	1.08	0.001
	Posttest	45.36 (2.45)				Pre-follow-up	-13.39	1.04	0.001
	Follow-up	42.56 (2.32)				Post-follow-up	2.80	0.97	0.127

Variable	Status	Mean (SD)	F	p	η^2	Comparison	Mean difference	Standard error	P
Health and Safety	Pretest	32.58 (2.91)	6.11	0.010	0.30	Pre-post	-11.14	1.03	0.001
	Posttest	43.72 (2.47)				Pre-follow-up	-8.20	0.98	0.001
	Follow-up	40.78 (2.13)				Post-follow-up	2.94	0.91	0.006
Leisure	Pretest	33.63 (1.26)	5.87	0.007	0.39	Pre-post	-7.64	0.85	0.001
	Posttest	41.27 (1.17)				Pre-follow-up	-7.08	0.80	0.001
	Follow-up	40.71 (1.29)				Post-follow-up	0.56	0.76	0.470
Self-Care	Pretest	47.84 (2.84)	3.97	0.042	0.22	Pre-post	-2.38	0.78	0.009
	Posttest	50.22 (2.32)				Pre-follow-up	-1.44	0.72	0.050
	Follow-up	49.28 (2.17)				Post-follow-up	0.94	0.68	0.187
Self-Direction	Pretest	26.39 (1.92)	7.44	0.006	0.35	Pre-post	-21.10	0.91	0.001
	Posttest	47.49 (2.01)				Pre-follow-up	-17.33	0.88	0.001
	Follow-up	43.72 (1.89)				Post-follow-up	3.77	0.84	0.001
Social	Pretest	46.18 (2.32)	5.95	0.011	0.32	Pre-post	-9.29	0.95	0.001
	Posttest	55.47 (2.35)				Pre-follow-up	-7.21	0.91	0.001
	Follow-up	53.39 (2.19)				Post-follow-up	2.08	0.88	0.064

Table 3 indicates a significant within-subjects effect of time on all components of adaptive functioning ($p < 0.05$). The largest effect sizes were observed for Functional Academics and Community Use, and Home Living and Self-Direction also demonstrated relatively large effects. Although Self-Care exhibited the smallest effect size among the components, the change remained statistically significant. Bonferroni-adjusted pairwise comparisons revealed significant differences between the pretest and posttest, as well as between the pretest and follow-up, across all adaptive functioning components. Significant differences between the posttest and follow-up were found only for Health and Safety and Self-Direction, whereas the remaining components showed no significant changes during this interval. Overall, these findings indicate that the intervention

significantly improved adaptive functioning relative to baseline and that these gains were largely maintained at follow-up for most components.

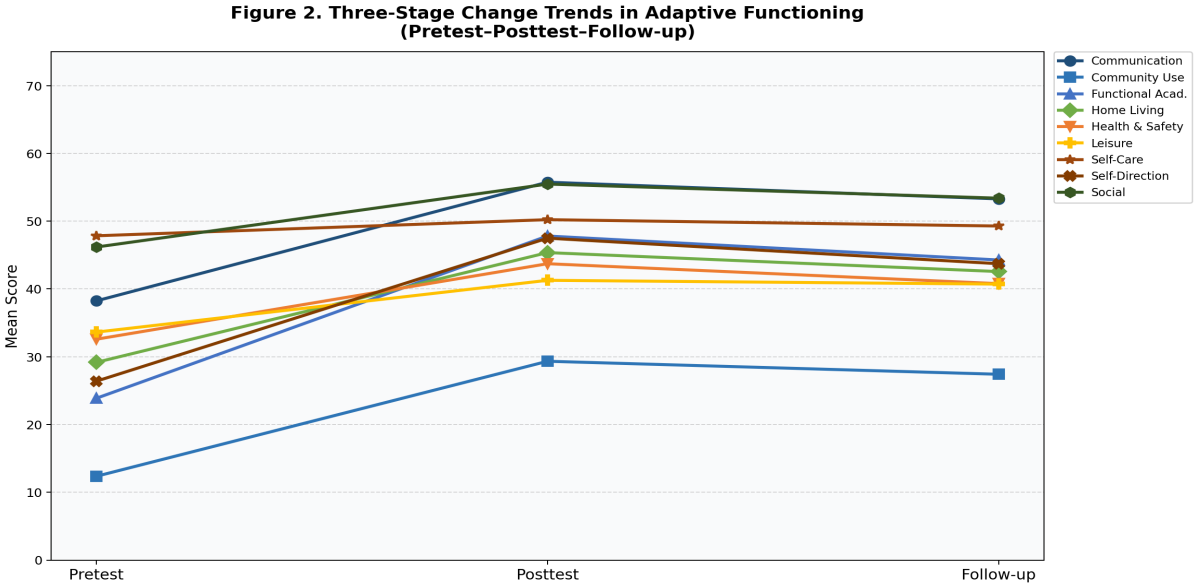


Figure 2. Three-stage change trends in adaptive functioning subscales (pretest–posttest–follow-up)

Discussion

This study aimed to investigate changes in executive functions and adaptive functioning following participation in the family-based responsive instructional pacing program based on functional reading in children with DS. It should be noted at the outset that these findings are preliminary and should be interpreted with caution. The results indicated that initial improvements in executive functions were observed following the intervention, and these gains appeared to be maintained over time. According to Cohen's (1988) benchmarks ($\eta^2 < 0.06$ = small, 0.06–0.14 = moderate, ≥ 0.14 = large), all significant executive function outcomes demonstrated large effect sizes ($\eta^2 = 0.21$–0.64), with the largest effects observed for the Tower of Hanoi measures. The only exception was Stroop square color-naming errors, which showed a moderate effect size ($\eta^2 = 0.10$). These findings suggest substantial improvements in planning, attention, inhibition, and cognitive flexibility. These findings are consistent with those reported by Lax et al. (2023), Hosseinian Por & Yar-Ahmadi (2022), Prahl et al. (2025), Tababaie Navai Nobari et al. (2021), Demehri et al. (2019), Nikookholgh et al. (2020), and Mahoney et al. (2006). Although the studies used for comparison were primarily conducted with children with ASD, such comparisons are justified because both ASD and DS are characterized by executive functioning difficulties, making executive functions an important target for intervention across these neurodevelopmental conditions.

In explaining these findings, it can be stated that deficits in executive functions, such as difficulty in response inhibition, can disrupt adherence to multi-step instructions; poor cognitive flexibility can also adapt to environmental changes difficult; and deficiencies in executive planning can affect functional independence.

The observed improvements in executive functions may reflect the structured engagement of processes related to response inhibition, working memory, selective attention, and cognitive flexibility during the learning cycles incorporated into the program. One possible explanation is that the learning trials encouraged children to maintain information, inhibit impulsive responses, shift between stimuli, and regulate their behavior during interactions with their parents. The purposeful repetition of these learning activities, together with adjusted cognitive demands and opportunities for retrieval practice, may have contributed to the gradual and relatively stable improvements observed in executive functions (De Albuquerque & De Melo, 2023).

At the interactional level, the family-based responsiveness component may promote processes consistent with co-regulation; that is, through sensitive responding, gradual guidance, and providing natural consequences, the parent initially shares the regulatory load with the child and then gradually transfers control to the child. This process may facilitate a gradual transition from external regulation to greater self-regulation, which could support the development of behavioral inhibition and cognitive flexibility. Moreover, the integration of functional reading into the program is a process beyond mechanical decoding and involves understanding meaning, predicting, responding to questions, and shifting between visual and linguistic information. The continuous practice of these multimodal activities in meaningful life contexts, combined with appropriate temporal distribution and the gradual transfer of responsibility to the child, may increase the likelihood of skill generalization to new situations and may help reduce avoidant behaviors (Matson, 2023).

Furthermore, the preliminary findings showed that initial improvements in adaptive functioning were observed following the intervention, and these gains appeared to be maintained over time. Similarly, all significant adaptive functioning domains demonstrated large effect sizes ($\eta^2 = 0.22–0.53$), indicating considerable practical significance across conceptual, social, and practical adaptive skills. The strongest effects were observed for Functional Academics and Community Use, suggesting that the program may be particularly effective in promoting everyday functional independence. These findings are consistent with those of Han et al. (2026), Collins et al. (2025), Da Silva et al. (2023), Neil et al. (2021), and Azizi et al. (2023). Although the studies used for comparison were conducted with children with ASD, adaptive behavior deficits are common to both ASD and DS. Therefore, findings from ASD interventions provide a useful conceptual framework for interpreting intervention-related changes in adaptive functioning among children with DS.

These results can be interpreted in light of evidence indicating that mental health and quality of life in youth with DS are closely associated with adaptive functioning. Deficits in social adaptation and daily living skills may reduce self-esteem and increase anxiety, depression, and social withdrawal. Accordingly, interventions that focus solely on technical skills, without psychological and social support, may yield limited outcomes. Adaptive functioning in DS is therefore a dynamic and multifactorial construct requiring intervention across cognitive, practical, and psychosocial domains (Onnivello et al., 2024). One possible explanation for the observed gains in adaptive functioning is that the program may operate through several pathways, including increased motivation, distributed practice with multiple exemplars, engagement of reading-related cognitive processes such as visual memory and selective attention, and greater learning opportunities provided through parent-mediated support. These mechanisms are consistent with evidence from ABA and naturalistic developmental interventions (Matson, 2023).

By adjusting within-trial and intertrial intervals and embedding natural consequences based on children's interests, the program may have enhanced intrinsic motivation and engagement. Functional reading tasks

embedded in daily life may provide immediate reinforcement, increase engagement, and potentially reduce escape-maintained behaviors. Consequently, improvements in conceptual, social, and practical adaptive skills may emerge through repeated practice in authentic contexts such as home, school, and community settings (De Albuquerque & De Melo, 2023). Because the intervention consisted of multiple integrated components, it is not possible to determine which component contributed most strongly to the observed outcomes.

Conclusion

The findings of the present study provide preliminary evidence that the family-based responsive instructional pacing program based on functional reading may be effective in improving executive functions and adaptive functioning in children with DS. Several limitations should be considered when interpreting the findings of the present study. First, the study employed convenience sampling, which may have introduced selection bias. Second, the relatively small sample size, largely due to the low prevalence of DS and the strict inclusion criteria, limits the generalizability of the findings. Third, the absence of a control group restricts causal inference regarding the effectiveness of the intervention. Fourth, participants were recruited from a single rehabilitation center, which may reduce external validity. Fifth, adaptive functioning was assessed using a parent-report measure (ABAS-3), which may have been influenced by reporting bias. Sixth, outcome assessments were not conducted by blinded evaluators, increasing the possibility of assessment bias. Finally, the intervention was delivered by the developer of the program, which may have introduced therapist allegiance and investigator expectancy effects.

Future studies are encouraged to employ larger multi-center samples, include randomized controlled designs, use blinded assessors, and replicate the findings with independent intervention providers. In addition, examining the effectiveness of this program among parents of children with other genetic, neurodevelopmental, and psychiatric disorders may facilitate broader comparisons and enhance the generalizability of the findings. It is also recommended that special education schools provide this program to parents as part of parent-training initiatives, that functional reading be incorporated into Persian language and life-skills curricula for children with DS to promote greater independence, and that rehabilitation centers use this program to support parent-mediated intervention and facilitate the generalization of children's skills from clinical settings to natural home, school, and community environments.

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Authors' contribution

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Conflict of interest

The authors declare that there is no conflict of interest in relation to the findings of this study.

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