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Structural Relationships among Executive Functions and Behavioral Brain Activities with Social Skills of Children with Autism: The Mediating Role of Cognitive Emotion Regulation Strategies

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A B S T R A C T

The purpose of this applied study was to determine the extent of the relationship between executive functions and behavioral brain activities with the social skills of children with autism, mediated by cognitive emotion regulation strategies. In terms of purpose, the study was applied, and in terms of method and nature, it was a descriptive–correlational study using structural equation modeling. The statistical population consisted of children diagnosed with autism at the Tehran Autism Center. Based on Green's formula, 235 questionnaires were distributed among the sample using non-random purposive sampling. Data were collected using the Coolidge Executive Function Inventory (2002), the Autism Social Skills Profile by Bellini and Hopf (2007), the Cognitive Emotion Regulation Questionnaire by Garnefski et al. (2001), and the Behavioral Inhibition/Behavioral Activation Systems Scale by Carver and White (1994). Structural equation modeling and SmartPLS software (version 3) were used to test the research hypotheses. The findings indicated that executive functions and behavioral brain activities were related both directly to the social skills of children with autism and indirectly through the mediating role of cognitive emotion regulation strategies ($p < .05$). The results can be utilized by centers working with children with autism and by their families to improve these children's communication skills.

Keywords: *executive functions; behavioral brain activities; social skills; children with autism; cognitive emotion regulation strategies.*

1. Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental condition characterized by persistent difficulties in social communication and interaction, alongside restricted and repetitive patterns of behavior, interests, or activities. These core features emerge early in development and exert long-term effects on cognitive, emotional, and social functioning across the lifespan. Among these domains, social skills deficits are considered one of the most functionally impairing aspects of ASD, as they directly influence peer relationships, academic participation, family functioning, and overall quality of life. Social skills in children with autism encompass a broad range of abilities, including initiating and maintaining interactions, understanding others' emotions and perspectives, responding appropriately to social cues, and regulating behavior within interpersonal contexts. Empirical research consistently indicates that impairments in these skills are not isolated phenomena but are closely intertwined with underlying neurocognitive and emotional processes that shape how children perceive, interpret, and respond to social information (1-3).

In recent years, increasing attention has been directed toward executive functions as a central cognitive mechanism underlying social competence in children with ASD. Executive functions refer to a set of higher-order cognitive processes, including planning, inhibition, working memory, cognitive flexibility, and goal-directed behavior, that enable individuals to regulate thoughts and actions in accordance with situational demands. Deficits in executive functions are widely documented in children with autism and are associated with difficulties in adapting behavior, shifting attention, controlling impulses, and organizing social responses in dynamic interpersonal situations (4, 5). From a developmental perspective, executive dysfunction can limit a child's capacity to integrate social cues, anticipate others' reactions, and select context-appropriate behaviors, thereby exacerbating social communication challenges. Interventions targeting executive functions have demonstrated positive effects on attention, anxiety, and social skills in neurodevelopmental populations, suggesting that executive processes play a pivotal role in shaping social outcomes (6, 7).

Parallel to executive functions, neurobiological models of behavior have emphasized the role of behavioral brain systems in explaining individual differences in motivation, affect, and social engagement. Gray's reinforcement sensitivity theory conceptualizes behavior as regulated by two major systems: the Behavioral Activation System (BAS), which governs approach behavior, reward sensitivity, and positive affect, and the Behavioral Inhibition System (BIS), which regulates avoidance behavior, sensitivity to punishment, and anxiety. Alterations in these systems have been observed in individuals with autism and are believed to contribute to atypical emotional reactivity, social withdrawal, and reduced motivation for social interaction (8, 9). Empirical findings suggest that heightened BIS activity may be associated with increased anxiety and social avoidance, whereas reduced or dysregulated BAS activity may limit reward-driven social engagement, both of which negatively affect social skill development.

Advances in neuroimaging and neurobiological research further support the relevance of brain structure and function to emotion regulation and social behavior in autism. Structural and functional brain differences in regions implicated in emotion processing, executive control, and reward sensitivity have been linked to difficulties in regulating emotions and engaging in adaptive social behavior (10, 11). Moreover, emerging evidence indicates that interventions aimed at modulating brain regulation processes, such as neurofeedback, can lead to affective and behavioral changes in adolescents with ASD, underscoring the malleability of these systems and their relevance for psychosocial functioning (12).

While executive functions and behavioral brain systems each contribute independently to social functioning, growing evidence suggests that their effects are partially mediated through emotion regulation processes. Emotion regulation refers to the strategies individuals use to monitor, evaluate, and modify emotional responses in order to achieve personal goals or adapt to environmental demands. In children with autism, emotion regulation difficulties are common and manifest as intense emotional reactions, limited use of adaptive coping strategies, and reliance on maladaptive responses such as rumination, catastrophizing, or self-blame (13, 14). These difficulties can interfere with social learning by disrupting attention, increasing anxiety in social contexts, and impairing the interpretation of others' emotional states.

Cognitive emotion regulation strategies, in particular, represent a critical mechanism linking cognition, emotion, and behavior. These strategies involve conscious, cognitive efforts to manage emotional experiences, such as positive reappraisal, acceptance, refocusing on planning, or putting situations into perspective. Research indicates that adaptive cognitive emotion regulation strategies are associated with better social adjustment and interpersonal functioning, whereas maladaptive strategies are linked to social withdrawal, aggression, and behavioral problems (15, 16). In children with autism, the development of effective cognitive emotion regulation strategies may be constrained by executive function deficits and atypical behavioral brain system activity, suggesting a complex, interdependent relationship among these constructs.

Empirical studies increasingly highlight the mediating role of cognitive emotion regulation in the relationship between neurocognitive factors and psychosocial outcomes. For example, behavioral brain systems activity has been shown to influence psychological outcomes through

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emotion regulation strategies, indicating that the way children cognitively manage emotions may determine whether underlying neurobiological sensitivities translate into adaptive or maladaptive social behavior (8). Similarly, executive functions are closely linked to the selection and implementation of emotion regulation strategies, as processes such as inhibitory control and cognitive flexibility enable children to shift away from maladaptive emotional responses and engage in more constructive coping (14, 17).

Within the context of autism, social skills development is further shaped by language and communication abilities, sensory processing patterns, and environmental factors. Difficulties in expressive and receptive communication can compound challenges in emotion expression and regulation, limiting opportunities for successful social interaction (18, 19). Multilingual and culturally diverse contexts may introduce additional complexity, as social norms and communicative expectations vary across settings, requiring flexible executive control and nuanced emotion regulation (2). Moreover, interventions that incorporate autistic perspectives and strengths have been shown to enhance the effectiveness of social skills programs, emphasizing the importance of individualized and context-sensitive approaches (3, 20).

Despite the growing body of research, several gaps remain in the literature. First, many studies have examined executive functions, behavioral brain systems, emotion regulation, and social skills in isolation, without integrating these constructs into a comprehensive explanatory model. Second, there is limited empirical evidence simultaneously testing the direct and indirect pathways through which executive functions and behavioral brain activities influence social skills in children with autism. Third, while cognitive emotion regulation strategies are increasingly recognized as critical mechanisms, their mediating role within structural models of social functioning in ASD has received insufficient attention, particularly in non-Western contexts.

Addressing these gaps is essential for both theoretical and practical reasons. From a theoretical standpoint, an integrated structural model can clarify the mechanisms through which neurocognitive and neurobiological factors interact to shape social outcomes in autism. From a clinical perspective, identifying mediating processes such as cognitive emotion regulation can inform the design of targeted interventions that go beyond surface-level social skills training and address underlying cognitive-emotional processes. Such insights are particularly valuable for developing comprehensive, evidence-based programs that enhance social competence and adaptive functioning in children with autism.

Accordingly, the present study aims to examine the structural relationships between executive functions and behavioral brain activities with social skills in children with autism, considering the mediating role of cognitive emotion regulation strategies.

2. Methods and Materials

2.1. Study Design and Participants

In terms of purpose, this study was applied, and in terms of method and nature, it was a descriptive–correlational study using structural equation modeling. The statistical population consisted of children diagnosed with autism at the Tehran Autism Center. In the present study, Green's formula was used to determine the sample size. Green suggests a minimum sample size of 104 + k, where k is the number of independent variables. Therefore, given two independent variables in the present study, the sample size should not be less than 106 participants. Accordingly, to enhance the generalizability of the results and to account for possible questionnaire attrition, the researcher distributed 250 questionnaires, of which 235 valid questionnaires were collected using non-random purposive sampling. It should be noted that the questionnaires were completed by the parents of the children.

The inclusion criteria for participation in the study were willingness to cooperate and a diagnosis of autism with an active case file at the autism center. The exclusion criteria included unwillingness to continue participation at any stage of the study and the presence of a concurrent disorder other than autism spectrum disorder.

2.2. Measures

Coolidge Executive Function Inventory (CEFI). The Coolidge Executive Function Inventory (Coolidge, 2002) consists of 19 items and is completed by parents or teachers. The items of this instrument were developed based on the criteria of the American Psychiatric Association (APA) and

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were standardized on a sample of 329 children aged 5 to 8 years (169 boys and 160 girls). This questionnaire is derived from the 200-item Coolidge Neuropsychological and Personality Questionnaire, which was developed by Coolidge et al. (2002) to assess several neuropsychological and behavioral disorders in children and adolescents aged 5 to 17 years. The inventory assesses deficits in executive functions. Each disorder in this instrument has a distinct subscale, and two of these subscales, comprising 19 items, evaluate executive functions. The response format is a 4-point Likert scale: 1 = never, 2 = sometimes, 3 = usually, and 4 = always, with scores of 0, 1, 2, and 3 assigned, respectively. Items 1 to 8 assess decision-making and planning, items 9 to 16 assess organization, and items 17 to 19 assess inhibition. Coolidge et al. reported a Cronbach's alpha reliability coefficient of .84 and a test–retest reliability of .81 for this scale. Alizadeh and Zahedi Pour (2004) reported internal consistency coefficients using Cronbach's alpha of .91 for the two subscales overall, and separately .81 for organization, .82 for decision-making/planning, and .52 for inhibition.

Autism Social Skills Profile (ASSP). This 48-item questionnaire was developed by Bellini and Hopf (2007) exclusively for treatment planning and for determining the extent of treatment progress, with the aim of behaviorally assessing a broad range of social behaviors in children and adolescents with autism spectrum disorder aged 6 to 17 years. It is particularly sensitive to changes resulting from intervention. The questionnaire can be completed by parents, teachers, or any adult familiar with the child's social behaviors. Completion time ranges from 15 to 20 minutes. Items are rated on a four-point Likert scale ranging from never (1), rarely (2), often (3), to always (4). Higher scores indicate more positive social behaviors. Test–retest reliability over a three-week interval has been reported as .97, with reliability coefficients of .96 for social interaction, .74 for social participation, and .96 for detrimental social behaviors. The validity and reliability of this questionnaire were also confirmed in a study by Pour-Etemad et al. (2017).

Cognitive Emotion Regulation Questionnaire (CERQ). This questionnaire consists of 36 items and is designed to assess the subscales of cognitive emotion regulation, including self-blame, acceptance, rumination, positive refocusing, refocus on planning, positive reappraisal, putting into perspective, catastrophizing, and other-blame. The questionnaire was developed by Garnefski et al. (2001) to evaluate the cognitive strategies individuals use after experiencing threatening events or life stressors. Responses are rated on a Likert-type scale. The instrument comprises nine subscales, each assessing a specific cognitive strategy: self-blame, other-blame, acceptance of the event, refocusing on planning how to deal with the event, positive refocusing on pleasant issues instead of thinking about the actual event, rumination, positive reappraisal, putting into perspective (thoughts about the relativity of the event compared to other events), and catastrophizing. Among these strategies, self-blame, other-blame, rumination, and catastrophizing are considered maladaptive emotion regulation strategies, whereas acceptance, refocus on planning, positive refocusing, positive reappraisal, and putting into perspective are considered adaptive emotion regulation strategies. Each strategy score is obtained by summing the scores of the items comprising that strategy and ranges from 4 to 20, while the total score ranges from 36 to 180. To calculate the score for each dimension, the scores of the items related to that dimension are summed, and the overall questionnaire score is obtained by summing all item scores. Garnefski et al. (2001) reported Cronbach's alpha coefficients of .91, .87, and .93 for the questionnaire. In Iran, construct validity was examined through correlations between the total score and subscale scores, yielding coefficients ranging from .40 to .68, with a mean of .56, all of which were statistically significant. In 2003, Yousefi reported a Cronbach's alpha reliability coefficient of .82 for the total cognitive scales in the Iranian cultural context.

Behavioral Inhibition/Behavioral Activation Systems Scale (BIS/BAS). This scale consists of 24 items and was developed by Carver and White (1994). The BIS subscale includes seven items and measures sensitivity of the behavioral inhibition system, reflecting responsiveness to threat cues and the experience of anxiety when confronted with such cues. The BAS scale includes 13 items and measures sensitivity of the behavioral activation system. This scale comprises three subscales: Drive (4 items), Reward Responsiveness (5 items), and Fun Seeking (4 items). Reward Responsiveness assesses the extent to which rewards elicit positive emotions, whereas Drive measures the individual's tendency to actively pursue desired goals.

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The Fun Seeking subscale assesses the tendency to pursue rewarding goals and to seek new rewards and potentially rewarding events through impulsive engagement. Four additional items are included as filler items and do not contribute to the assessment of BIS or BAS (Abdollahi Mojarrishani, 2010). Carver and White (1994) reported internal consistency coefficients of .74 for the BIS subscale and .73, .76, and .66 for the Reward Responsiveness, Drive, and Fun Seeking subscales, respectively.

2.3. Data Analysis

Data analysis in this study was conducted in two stages: descriptive statistics and inferential statistics. First, demographic indices (e.g., age, education, etc.) were examined. Subsequently, descriptive statistics (mean, standard deviation, etc.) were calculated for each variable. Finally, structural equation modeling was employed to test the research hypotheses using SmartPLS software, version 3.

3. Findings and Results

In this study, 53.91% of the participants were girls and 46.09% were boys. In addition, the majority of the participants (42.13%) were second-born children, whereas the smallest proportion (27.66%) were first-born children.

Table 1

Descriptive Statistics of the Variables of the Behavioral Brain Activities Questionnaire

Variable	Mean	Standard Deviation	Skewness	Kurtosis	Minimum	Maximum	Cutoff Point
Drive	10.08	2.338	−0.090	−0.259	4	16	10
Fun Seeking	9.88	2.767	0.122	−1.043	5	16	10
Reward Responsiveness	12.42	3.569	0.148	−0.918	5	20	13
BIS	17.09	4.540	−0.004	−0.817	8	27	18
Behavioral Brain Activities	49.49	12.025	−0.005	−1.073	23	75	60
Executive Functions	31.37	13.672	−0.362	−0.982	3	55	48
Understanding Emotions and Others' Perspectives	31.50	8.385	−0.241	−1.123	13	46	30
Initiating Interaction with Others	33.46	7.849	−0.410	−0.797	14	46	30
Maintaining Interaction with Others	31.50	7.932	−0.527	−0.315	12	48	30
Responding to Others	30.29	8.197	−0.271	−0.801	12	47	30
Social Skills	126.77	27.850	−0.327	−0.728	66	179	120
Self-Blame	13.59	2.028	−0.123	−0.698	9	18	12
Acceptance	13.81	3.027	−0.023	−0.617	7	20	12
Rumination	13.34	2.381	−0.296	−0.621	8	18	12
Positive Refocusing	13.74	2.636	−0.213	−0.692	8	19	12
Refocus on Planning	14.02	2.887	−0.438	−0.476	6	20	12
Positive Reappraisal	14.31	2.998	−0.624	−0.051	5	20	12
Putting into Perspective	13.90	2.882	−0.162	−0.937	8	19	12
Catastrophizing	13.52	2.407	−0.213	−0.840	8	18	12
Other-Blame	13.57	2.370	−0.015	−1.040	9	19	12
Cognitive Emotion Regulation Strategies	123.83	5.910	−0.493	0.227	106	139	108

According to Table 1, among the variables of the Behavioral Brain Activities Questionnaire, the BIS variable obtained the highest score (M = 17.09, SD = 4.540), whereas the Fun Seeking variable obtained the lowest score (M = 9.88, SD = 2.767). The overall Behavioral Brain Activities index had a mean of 49.49 and a standard deviation of 12.025. Based on the cutoff point, the mean score of behavioral brain activities was lower than the cutoff value (60); therefore, it was evaluated as being below the average level. The Executive Functions index yielded a mean of 31.37 and a standard deviation of 13.672, and considering the cutoff point, the mean score of executive functions was lower than the cutoff value (48); thus, it was also evaluated as being below the average level. Among the variables of the Social Skills Questionnaire, the highest score was obtained for Initiating Interaction with Others (M = 33.46, SD = 7.849), and the lowest score was obtained for Responding to Others (M = 30.29, SD = 8.197). The overall Social Skills index had a mean of 126.77 and a standard deviation of 27.850. Based on the cutoff point, the mean score of social

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skills was higher than the cutoff value (120); therefore, it was evaluated as being above the average and at a desirable level. Furthermore, among the variables of the Cognitive Emotion Regulation Strategies Questionnaire, the highest score was related to Positive Reappraisal (M = 14.31, SD = 2.998), whereas the lowest score was related to Rumination (M = 13.34, SD = 2.381). The overall Cognitive Emotion Regulation Strategies index had a mean of 123.83 and a standard deviation of 5.910. Considering the cutoff point, the mean score of cognitive emotion regulation strategies was higher than the cutoff value (108); thus, it was evaluated as being above the average and at a desirable level.

Table 2

One-Sample Kolmogorov–Smirnov Test for the Study Indices

Index	Test Statistic	Significance Level	Test Result
Behavioral Brain Activities	0.084	0.001	Non-normal
Executive Functions	0.087	0.001	Non-normal
Social Skills	0.067	0.012	Non-normal
Cognitive Emotion Regulation Strategies	0.091	0.001	Non-normal

As indicated by the data presented in Table 2, the significance levels of the Kolmogorov–Smirnov test for all study indices were smaller than 0.05. Therefore, all study indices demonstrated non-normal distributions.

To examine the relationships among the study variables, given the results of the Kolmogorov–Smirnov test and the non-normal distribution of the data, Spearman's rank-order correlation coefficient was used. The results of this test are presented in the table below.

Table 3

Spearman Correlation Coefficients Among the Study Variables

No.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	23
1	.64**	.63**	.65**	.77**	.36**	.20**	.16**	.18**	.14*	.20**	−.36**	.41**	−.41**	.43**	.37**	.44**	.41**	−.42**	−.49**	.35**
2	—	.85**	.83**	.91**	.48**	.34**	.29**	.24**	.30**	.34**	−.53**	.57**	−.55**	.59**	.49**	.59**	.58**	−.59**	−.63**	.49**
3	—	—	.88**	.94**	.55**	.35**	.35**	.30**	.34**	.38**	−.55**	.57**	−.57**	.59**	.57**	.57**	.57**	−.64**	−.63**	.46**
4	—	—	—	.95**	.58**	.39**	.33**	.26**	.35**	.39**	−.58**	.59**	−.61**	.62**	.61**	.58**	.59**	−.65**	−.68**	.48**
5	—	—	—	—	.56**	.37**	.32**	.27**	.33**	.37**	−.57**	.60**	−.60**	.62**	.59**	.61**	.61**	−.65**	−.69**	.50**
6	—	—	—	—	—	.43**	.34**	.36**	.37**	.43**	−.59**	.58**	−.57**	.59**	.58**	.54**	.59**	−.62**	−.58**	.49**
7	—	—	—	—	—	—	.72**	.52**	.57**	.83**	−.48**	.56**	−.51**	.52**	.53**	.44**	.47**	−.56**	−.47**	.42**
8	—	—	—	—	—	—	—	.67**	.66**	.88**	−.44**	.55**	−.41**	.42**	.47**	.35**	.35**	−.45**	−.37**	.40**
9	—	—	—	—	—	—	—	—	.71**	.82**	−.42**	.48**	−.49**	.49**	.46**	.37**	.37**	−.52**	−.36**	.40**
10	—	—	—	—	—	—	—	—	—	.85**	−.49**	.50**	−.50**	.48**	.53**	.33**	.39**	−.47**	−.40**	.34**
11	—	—	—	—	—	—	—	—	—	—	−.53**	.60**	−.55**	.55**	.58**	.43**	.46**	−.55**	−.46**	.45**
12	—	—	—	—	—	—	—	—	—	—	—	−.76**	.76**	−.74**	−.78**	−.73**	−.77**	.82**	.80**	−.53**
13	—	—	—	—	—	—	—	—	—	—	—	—	−.83**	.80**	.71**	.77**	.79**	−.80**	−.81**	.74**
14	—	—	—	—	—	—	—	—	—	—	—	—	—	−.82**	−.71**	−.76**	−.79**	.83**	.80**	−.58**
15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.75**	.75**	.77**	−.80**	−.81**	.72**
16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.70**	.75**	−.77**	−.74**	.74**
17	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.88**	−.82**	−.81**	.79**
18	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	−.86**	−.86**	.76**
19	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.92**	−.58**
20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	−.59**
23	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

1. Drive; 2. Fun Seeking; 3. Reward Responsiveness; 4. BIS; 5. Behavioral Brain Activities; 6. Executive Functions; 7. Understanding Emotions and Perspectives; 8. Initiating Interaction; 9. Maintaining Interaction; 10. Responding to Others; 11. Social Skills; 12. Self-Blame; 13. Acceptance; 14. Rumination; 15. Positive Refocusing; 16. Refocus on Planning; 17. Positive Reappraisal; 18. Putting into Perspective; 19. Catastrophizing; 20. Other-Blame; 23. Cognitive Emotion Regulation Strategies

**p<.01, *p<0.05

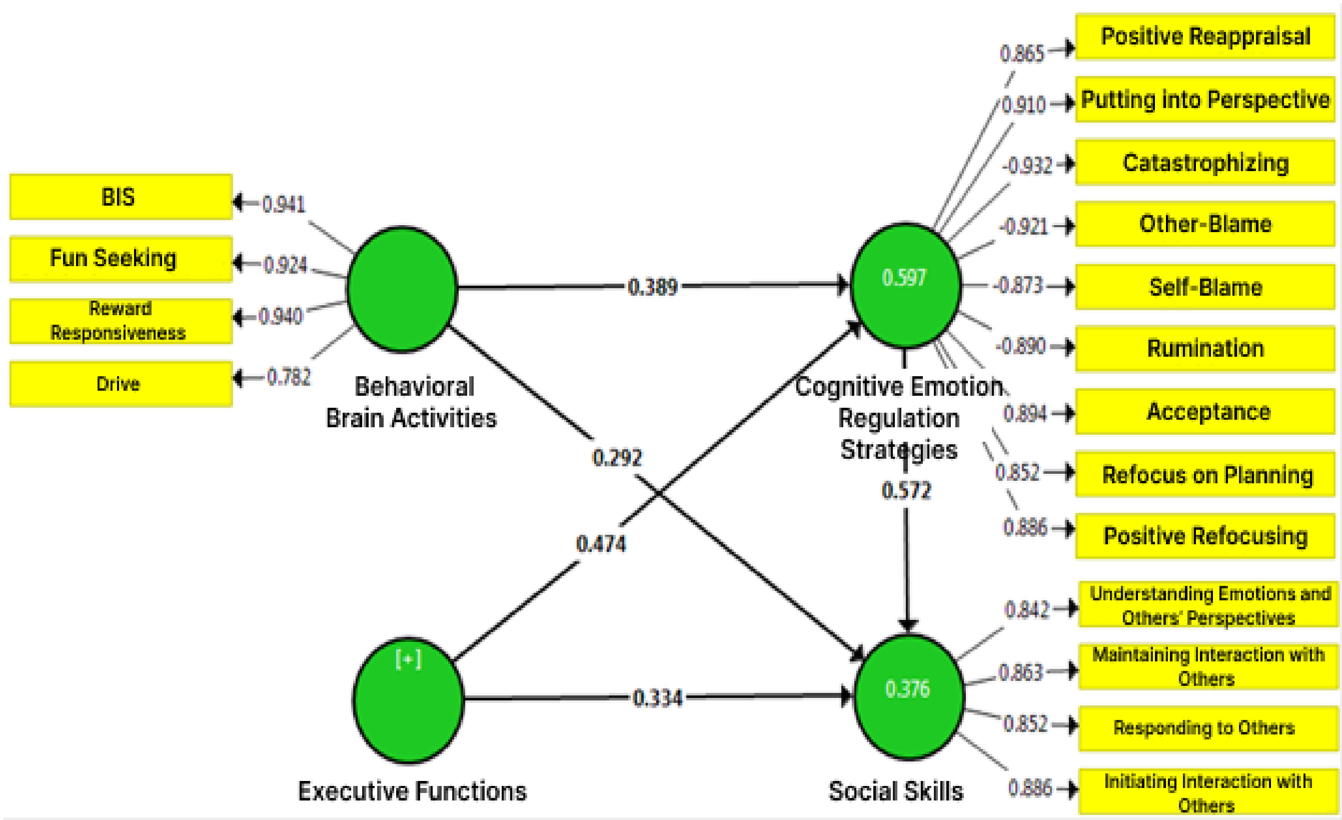
As shown in the data presented in Table 3, the significance levels of the correlation coefficients among the study variables were smaller than .05. Therefore, the relationships among the study variables were statistically significant at the 95% confidence level.

Given the positive correlation coefficients between behavioral brain activities and their components, and executive functions with social skills and their components, acceptance, positive refocusing, refocus on planning, positive reappraisal, putting into perspective, and cognitive emotion regulation strategies, it can be concluded that these relationships are direct. That is, higher levels of behavioral brain activities and their components and executive functions are associated with higher levels of social skills and their components, acceptance, positive refocusing, refocus on planning, positive reappraisal, putting into perspective, and cognitive emotion regulation strategies.

Considering the negative correlation coefficients between behavioral brain activities and their components and executive functions with self-blame, rumination, catastrophizing, and other-blame, it can be concluded that these relationships are inverse. That is, higher levels of behavioral brain activities and their components and executive functions are associated with lower levels of self-blame, rumination, catastrophizing, and other-blame.

Figure 1

Standardized path coefficients of the conceptual research model



The numbers displayed on the paths represent the path coefficients. To test the significance of the path coefficients, Student's *t* values were calculated using the bootstrapping method. If the Student's *t* value is greater than 1.96, the path coefficient is statistically significant at the .05 level.

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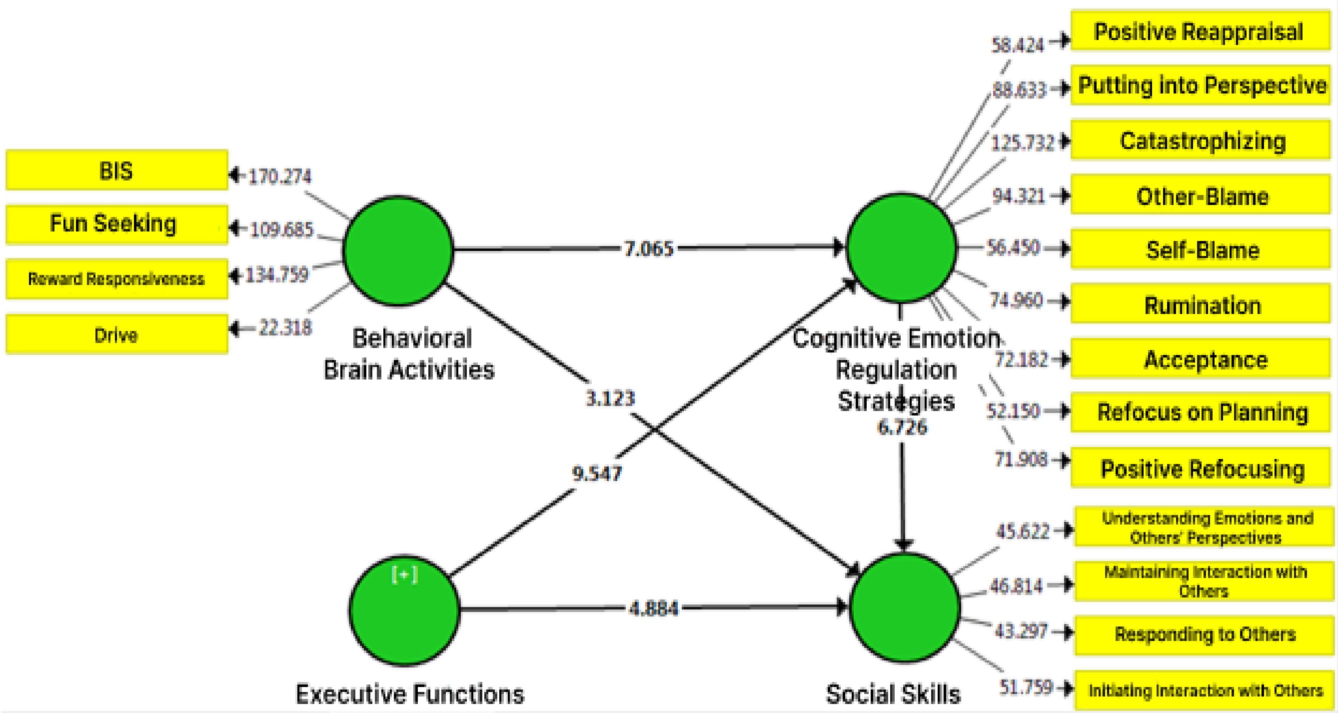
Figure 2

Results of the Student's t test for examining the significance of the path coefficients



The criterion refers to the endogenous (dependent) latent variables of the model. It is an index that indicates the effect of an exogenous variable on an endogenous variable, and values of 0.19, 0.33, and 0.67 are considered benchmark values for weak, moderate, and strong effects, respectively. The value reported in the table below approximately confirms the adequacy of the structural model fit.

Table 4

R^2 Values for the Study Variables

Row	Variable	R^2
1	Cognitive Emotion Regulation Strategies	0.597
2	Social Skills	0.376

The Q^2 criterion indicates the predictive power of the model. If its value for an endogenous construct reaches 0.02, 0.15, and 0.35, it indicates weak, moderate, and strong predictive power, respectively, for that construct (or the related exogenous construct[s]). The values reported in the table below indicate adequate predictive power of the model for the endogenous constructs of the study and confirm the acceptable fit of the structural model.

Table 5

Q^2 Values for the Study Variables

Row	Variable	Q^2
1	Cognitive Emotion Regulation Strategies	0.441
2	Social Skills	0.256

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Another index introduced by Tenenhaus et al. (2005) for model fit is the global goodness-of-fit (GOF), which is calculated as the geometric mean of the average communality (AVE) and the average R^2, as shown below.

This index, similar to LISREL model-fit indices, ranges from 0 to 1, with values closer to 1 indicating better model quality. It should be noted, however, that unlike chi-square–based indices in LISREL models, this index does not assess the degree of fit between the theoretical model and the observed data; rather, it evaluates the overall predictive capability of the model and whether the tested model has been successful in predicting the endogenous latent variables.

Table 6

Overall Model Fit Based on the GOF Criterion

Mean AVE (Communality)	Mean R^2	GOF
0.572	0.486	0.529

As shown in Table 5, the mean of the communality (AVE) values was 0.572 and the mean R^2 value was 0.486; based on the formula, the GOF value was 0.529, which is greater than the benchmark value of 0.30 and indicates that the model has adequate predictive power for the endogenous latent variables.

To examine the hypotheses and test the significance of the path coefficients among the variables, the software output was used. The path coefficients and the significance results are presented in the table below.

Table 7

Results of Structural Model Evaluation for Testing the Study Hypotheses

Row	Path	Path Coefficient (β)	t Value	Test Result
1	Behavioral Brain Activities → Cognitive Emotion Regulation Strategies	0.389	7.065	Supported
2	Behavioral Brain Activities → Social Skills	0.292	3.123	Supported
3	Executive Functions → Cognitive Emotion Regulation Strategies	0.474	9.547	Supported
4	Executive Functions → Social Skills	0.334	4.884	Supported
5	Cognitive Emotion Regulation Strategies → Social Skills	0.572	6.726	Supported

Next, based on the output of the conceptual model, the research hypotheses are described and examined.

According to Table 7, the t statistic for the relationship between executive functions and social skills was 4.884, which is greater than 1.96, indicating that the relationship between executive functions and social skills is statistically significant at the 95% confidence level. In addition, the path coefficient between these two variables was 0.334, indicating a positive effect of executive functions on social skills. In other words, a one-unit change in executive functions leads to a 0.334-unit increase in social skills. This means that executive functions have a positive and direct effect on social skills; therefore, the research hypothesis is supported.

According to Table 7, the t statistic for the relationship between behavioral brain activities and social skills was 3.123, which is greater than 1.96, indicating that the relationship between behavioral brain activities and social skills is statistically significant at the 95% confidence level. In addition, the path coefficient between these two variables was 0.292, indicating a positive effect of behavioral brain activities on social skills. In other words, a one-unit change in behavioral brain activities leads to a 0.292-unit increase in social skills. This means that behavioral brain activities have a positive and direct effect on social skills; therefore, the research hypothesis is supported.

According to Table 7, the t statistic for the relationship between executive functions and cognitive emotion regulation strategies was 9.547, which is greater than 1.96, indicating that the relationship between executive functions and cognitive emotion regulation strategies is statistically significant at the 95% confidence level. In addition, the path

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coefficient between these two variables was 0.474, indicating a positive effect of executive functions on cognitive emotion regulation strategies. In other words, a one-unit change in executive functions leads to a 0.474-unit increase in cognitive emotion regulation strategies. This means that executive functions have a positive and direct effect on cognitive emotion regulation strategies; therefore, the research hypothesis is supported.

According to Table 7, the t statistic for the relationship between behavioral brain activities and cognitive emotion regulation strategies was 7.065, which is greater than 1.96, indicating that the relationship between behavioral brain activities and cognitive emotion regulation strategies is statistically significant at the 95% confidence level. In addition, the path coefficient between these two variables was 0.389, indicating a positive effect of behavioral brain activities on cognitive emotion regulation strategies. In other words, a one-unit change in behavioral brain activities leads to a 0.389-unit increase in cognitive emotion regulation strategies. This means that behavioral brain activities have a positive and direct effect on cognitive emotion regulation strategies; therefore, the research hypothesis is supported.

According to Table 7, the t statistic for the relationship between cognitive emotion regulation strategies and social skills was 6.726, which is greater than 1.96, indicating that the relationship between cognitive emotion regulation strategies and social skills is statistically significant at the 95% confidence level. In addition, the path coefficient between these two variables was 0.572, indicating a positive effect of cognitive emotion regulation strategies on social skills. In other words, a one-unit change in cognitive emotion regulation strategies leads to a 0.572-unit increase in social skills. This means that cognitive emotion regulation strategies have a positive and direct effect on social skills; therefore, the research hypothesis is supported.

Table 8

Bootstrapping Results for Testing the Significance of the Indirect Effect

Independent Variable	Mediator	Dependent Variable	Indirect Effect	Bootstrapped Upper CI	Bootstrapped Lower CI	t Value	SE	p
Executive Functions	Cognitive Emotion Regulation Strategies	Social Skills	0.271	0.359	0.184	5.958	0.045	0.001

According to Table 8, the significance level was 0.001, which is smaller than 0.05, and the confidence interval did not include zero. Therefore, the research hypothesis is supported.

Table 9

Bootstrapping Results for Testing the Significance of the Indirect Effect

Independent Variable	Mediator	Dependent Variable	Indirect Effect	Bootstrapped Upper CI	Bootstrapped Lower CI	t Value	SE	p
Behavioral Brain Activities	Cognitive Emotion Regulation Strategies	Social Skills	0.222	0.318	0.125	4.469	0.050	0.001

According to Table 9, the significance level was 0.001, which is smaller than 0.05, and the confidence interval did not include zero. Therefore, the research hypothesis is supported.

4. Discussion

The present study examined the structural relationships between executive functions and behavioral brain activities with social skills in children with autism, with particular emphasis on the mediating role of cognitive emotion regulation strategies. The findings provide empirical support for a comprehensive model in which neurocognitive and neurobehavioral systems jointly contribute to social functioning, both directly and indirectly through cognitive–emotional mechanisms. Overall, the results indicate that executive functions and behavioral brain activities are significant predictors of social skills and that cognitive emotion regulation strategies play a critical mediating role in this relationship.

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The results demonstrated a significant and positive direct relationship between executive functions and social skills. This finding is consistent with a substantial body of research indicating that executive functions are foundational to adaptive social behavior in children with autism. Executive processes such as inhibitory control, planning, and cognitive flexibility enable children to manage social demands, regulate impulses, and adjust behavior in response to social cues. Previous studies have shown that deficits in executive functioning are associated with poorer social communication, reduced peer engagement, and difficulties in maintaining reciprocal interactions (4, 5). The present findings extend this literature by confirming that stronger executive functioning is associated with higher levels of social skills, reinforcing the view that executive functions serve as a cognitive scaffold for social competence.

In line with prior intervention research, the positive association between executive functions and social skills also aligns with evidence that training executive processes can lead to improvements in social behavior. Studies focusing on executive function training have reported gains in attention regulation, behavioral control, and social responsiveness, suggesting that executive functions are not only correlationally but also causally related to social outcomes (6, 7). From a developmental perspective, children with stronger executive capacities may be better equipped to integrate social information, anticipate consequences, and select contextually appropriate responses, thereby facilitating more effective social interactions.

The study also found a significant direct relationship between behavioral brain activities and social skills. Behavioral brain systems, particularly the Behavioral Activation System (BAS) and Behavioral Inhibition System (BIS), play a crucial role in regulating approach–avoidance tendencies, emotional reactivity, and motivational processes. Dysregulation in these systems has been linked to social withdrawal, heightened anxiety, and reduced engagement in social contexts among individuals with autism (8, 9). The present findings suggest that more adaptive behavioral brain activity patterns are associated with higher social skills, highlighting the importance of neurobiological motivational and affective systems in social functioning.

This result is supported by neurobiological and neuroimaging studies demonstrating that atypical brain structure and function in regions associated with reward processing, emotion regulation, and executive control are related to social difficulties in autism. Alterations in neural circuits involved in motivation and affective regulation may reduce the intrinsic reward value of social interaction, thereby limiting opportunities for social learning and practice (10, 11). Consequently, children with more balanced behavioral brain system activity may experience greater emotional readiness and motivational engagement in social situations, leading to better social skill development.

A central contribution of the present study lies in demonstrating the mediating role of cognitive emotion regulation strategies in the relationship between executive functions, behavioral brain activities, and social skills. The results indicated that executive functions significantly predicted cognitive emotion regulation strategies, which in turn predicted social skills. This finding is theoretically coherent, as executive functions are closely involved in the selection, monitoring, and modification of emotion regulation strategies. Processes such as inhibitory control and cognitive flexibility allow children to suppress maladaptive emotional responses and adopt more adaptive cognitive strategies, such as positive reappraisal or refocusing on problem-solving (14, 17).

The mediating effect observed in this study suggests that executive functions may influence social skills not only directly but also indirectly by enhancing children's capacity to regulate emotions cognitively. Children with stronger executive control are more likely to employ adaptive emotion regulation strategies, which in turn facilitate more effective social interactions. This finding aligns with previous research demonstrating that emotion regulation training can lead to improvements in social skills among children with autism (15). It also supports broader models of social functioning that emphasize emotion regulation as a key mechanism linking cognitive processes to observable social behavior.

Similarly, cognitive emotion regulation strategies were found to mediate the relationship between behavioral brain activities and social skills. Behavioral brain systems influence emotional sensitivity, stress reactivity, and motivational orientation, all of which shape how children

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experience and interpret social situations. However, the way these emotional experiences are cognitively regulated appears to determine whether underlying neurobiological tendencies translate into adaptive or maladaptive social outcomes. This finding is consistent with previous evidence indicating that behavioral brain system activity affects psychological and behavioral outcomes through emotion regulation processes (8). Children who are able to cognitively manage heightened emotional arousal or anxiety may be better positioned to engage socially, even in the presence of neurobiological vulnerabilities.

The strong direct effect of cognitive emotion regulation strategies on social skills observed in this study underscores the importance of emotion regulation as a core component of social competence in autism. Adaptive strategies such as acceptance, positive refocusing, planning, and positive reappraisal were associated with higher social skills, whereas maladaptive strategies have been linked in prior research to social withdrawal, aggression, and interpersonal difficulties (13, 16). These findings suggest that social skills deficits in autism cannot be fully understood without considering how children regulate their emotional experiences in social contexts.

The present results also resonate with research highlighting the interplay between emotion regulation, communication, and social learning in autism. Difficulties in language and communication can constrain children's ability to express emotions and negotiate social situations, increasing reliance on maladaptive emotion regulation strategies (18, 19). Conversely, improving cognitive emotion regulation may create a more stable emotional foundation that supports communication development and social engagement. Moreover, interventions that incorporate the perspectives and strengths of autistic individuals have been shown to enhance social outcomes, suggesting that emotion regulation strategies should be embedded within individualized, strength-based approaches (3, 20).

5. Conclusion

Taken together, the findings of this study support an integrative model in which executive functions and behavioral brain activities influence social skills both directly and indirectly through cognitive emotion regulation strategies. This model aligns with contemporary neurodevelopmental frameworks that emphasize the interaction of cognitive, emotional, and neurobiological processes in shaping social behavior. By empirically validating these pathways, the present study contributes to a more nuanced understanding of social functioning in children with autism and highlights potential targets for intervention.

6. Limitations and Suggestions

Despite its contributions, this study has several limitations that should be considered when interpreting the findings. First, the cross-sectional design precludes causal inferences about the directionality of the relationships among executive functions, behavioral brain activities, cognitive emotion regulation strategies, and social skills. Second, the reliance on parent-report questionnaires may introduce response bias and limit the objectivity of the measurements. Third, the sample was drawn from a specific cultural and clinical context, which may limit the generalizability of the findings to other populations of children with autism.

Future research should employ longitudinal and experimental designs to clarify the causal pathways among executive functions, behavioral brain systems, emotion regulation, and social skills. Incorporating multi-informant and multi-method assessments, including behavioral observations and neurophysiological measures, would strengthen the validity of findings. Additionally, future studies could examine potential moderating variables, such as age, language ability, or intervention history, to better understand individual differences in these relationships.

From a practical perspective, the findings suggest that interventions aimed at improving social skills in children with autism may benefit from explicitly targeting executive functions and cognitive emotion regulation strategies alongside traditional social skills training. Clinicians and educators should consider integrated programs that enhance planning, inhibitory control, and cognitive flexibility while simultaneously teaching adaptive emotion regulation strategies. Such comprehensive approaches may lead to more robust and sustainable improvements in social functioning.

Authors' Contributions

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S.E.M. was responsible for the conceptualization and design of the study, selection of instruments, data collection, and implementation of the research procedures. The author conducted the statistical analyses using structural equation modeling, interpreted the findings, and drafted the manuscript. S.E.M. also reviewed and approved the final version of the manuscript and takes full responsibility for the integrity and accuracy of the work.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

This study was conducted in accordance with institutional and national guidelines for the care and use of laboratory animals. This article was approved by the Research Council of Tehran North Branch with the ethics code IR.IAU.TNB.REC.2024.030.

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