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ORIGINAL RESEARCH

Comparative Analysis Between Directly Measured and Parent-Evaluated Executive Function: Predicting Children's Academic Achievement and Social Development in a One-Year Longitudinal Study

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Purpose: The purpose of this study was to examine differences between directly measured and parent-evaluated executive function in predicting children's academic achievement and social development, and to explore the mediating roles of peer status and social competence in the effects of executive function on social behavior.

Patients and Methods: The study followed 106 first-grade children in an elementary school in China for one year. Regression and mediation analyses were conducted using SPSS 26.0 and AMOS 21.0 to test the hypotheses.

Results: First, in a comparison of the predictive role of directly measured and parent-evaluated executive function, directly measured executive function played a more important role in predicting academic achievement, while parent-evaluated executive function played a greater role in predicting social development. Second, parent-evaluated executive function influenced social behavior primarily through social competence and peer status, with social competence playing a more significant mediating role than peer status.

Conclusion: Compared with previous studies, the results of the present study provide more direct evidence for the relationship and differences between directly measured and parent-evaluated executive function, further suggesting that they have different efficacy and predictive goals, while the present study also describes the pathways through which executive function influences social behavior: the mediating role of peer status and social competence. This suggests that, on the one hand, educators or researchers need to choose appropriate measures of executive function for their own purposes and, on the other hand, in order to promote the development of children's social behavior, they need to focus on the development of children's executive function, social competence and peer relationships.

Keywords: peer status, social behavior, social competence, cognitive control, measurement

Introduction

Executive function (EF) generally refers to a series of top-down mental processes that a person performs to overcome his or her automatic responses, instincts, or intuitions when focusing attention.[1] Miyake et al found that executive function is not a single cognitive structure, but a collection of cognitive functions, including inhibitory control, working memory updating, and cognitive flexibility.[2] The three subcomponents are related to each other. The three subcomponents are interconnected but fundamentally different and functionally separate,[3] and on the basis of these subcomponents, individuals are able to construct more advanced executive functions such as reasoning, problem solving, and planning.[4,5] Furthermore, Zelazo et al divided executive functions into two categories: "hot" executive functions associated with the orbitofrontal cortex and "cool" executive functions associated with the dorsolateral prefrontal

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cortex.[6] The former is characterised by a high degree of emotional involvement, requiring flexible evaluation of the emotional significance of stimuli; the latter is more likely to be triggered by relatively abstract, decontextualised problems. Executive function is not only closely related to academic achievement and social development in young children,[7–9] but it is also an important and stable predictor of children's academic achievement and social development.[10–15] Good executive function (good performance on inhibitory control, working memory, and cognitive flexibility) can help individuals better plan, regulate attention, and retain relevant information in learning or social environments, thereby promoting their academic achievement or social development.[16,17]

However, previous research exploring the relationship between executive function and academic achievement or social behavior in young children often did not consider the potential impact of the measurement method of executive function on the research conclusions.[18–22] Additionally, there has been a scarcity of studies investigating potential mediating factors between executive function and social behavior. Given this, it is necessary to further research the predictive or influencing role of executive function on academic achievement or social development, in order to deepen researchers' understanding of the relationships between these variables.

The Impact of Measurement Methods of Executive Function on Its Predictive Role

Directly measured executive function rely on cognitive performance tests.[23] These tests are administered under highly standardised conditions where the presentation of stimuli is precisely controlled to ensure that each subject experiences and completes the task in a consistent manner. Assessment criteria are primarily based on subjects' accuracy, reaction time, and ability to respond quickly under time constraints. Common measures of executive function include the Wisconsin Card Sorting Test (WCST),[24] the go/no-go test,[25] and the digit span backwards.[26] As an example, the Wisconsin Card Sorting Test (WCST) requires subjects to maintain task sets, respond flexibly to feedback, avoid persistent tendencies, and inhibit prior responses that are no longer appropriate.[27] A key assessment metric of the WCST is the total number of sets of 10 consecutive correct matches.

Parent-evaluated of executive function are designed to provide ecological validity and valid indicators of an individual's ability to perform executive function in complex, everyday, problem-solving situations.[28] One of the assumptions underlying the use of relevant assessment scales is that they measure behaviors that are closely related to the processes assessed by directly measured executive function assessment methods. The most commonly used executive function assessment scale is the Behavior Rating Inventory of Executive Function (BRIEF).[29] The scale contains a total of 86 entries describing subjects' difficulties with daily living, each rated on a 1–3 scale (1 = never, 2 = sometimes, 3 = often) and categorised as inhibition, shift, and emotional control, Initiative, Working Memory, Plan/Organize, Organization of Materials, and Monitor, among several subscales. In addition, the Children's Executive Functioning Inventory (CHEXI) can be used to measure inhibition and working memory.[30]

Direct measurement and parental evaluation are the two most common methods used by researchers to measure executive function. Although researchers have used these two methods interchangeably to assess executive function and often conflate results from different measurement types, researchers have found that directly measured and parent-evaluated executive function are weakly correlated. Some researchers have measured both in children or adolescents and found only a significant weak correlation between the two,[31,32] while others have conducted meta-analyses of correlational studies and found that the overall correlation coefficient between the two was only 0.19.[33] This weak correlation suggests that the directly measured and the parent-evaluated executive function may be inherently different, and thus the two may not be interchangeable.

For the low correlation between the two measurement methods, three main explanations are proposed according to related studies:[33–35]

First, the cognitive level or constructs assessed by the two methods differ. Some researchers have argued that directly measured executive function utilizes algorithmic thinking, while parent-evaluated executive function relys on reflective thinking.[33,36] Algorithmic thinking is related to information processing mechanisms, including input encoding, sensory registration, working memory, and long-term memory. In contrast, reflective thinking focuses on an individual's goals, beliefs related to these goals, and rational action choices under these goals and beliefs.[36] Therefore, direct measurements of executive function assess the processing efficiency in behavioral control, reflecting an individual's optimal

performance in laboratory tasks. In contrast, parental evaluations assess behavior conducive to goal achievement in real-world environments, reflecting an individual's executive function performance in daily life.[33] Moreover, in the 20 studies analyzed by Toplak et al,[33] the direct measurement tasks used were all "cool" executive function tasks, which are relatively abstract and decontextualized, while parental evaluations reflect children's executive function in emotionally involved situations. Thus, the difference may also reflect the distinction between "cool" and "hot" executive function.

Second, the two measurement methods differ in their variability stability. Many direct measurement tasks of executive function were initially developed to ensure the replicability of experimental effects. Such tasks, by maximizing within-person differences, inherently sacrifice between-person variability, thereby fundamentally reducing measurement reliability or variability stability.[34,37] For example, in the color-naming Stroop task, the aim is to maximize the within-person differences between congruent conditions (eg, naming the word "red" as "red") and incongruent conditions (eg, naming the word "red" as "green"). The results showed that while nearly all participants exhibited a Stroop interference effect, the between-person differences in this interference effect were relatively small, which in turn reduced the reliability or stability of the measure.[37] In contrast, parental evaluations of executive function typically have higher variability stability.[29]

Third, the two measurement methods are differently influenced by the evaluator.[33,37] In directly measured executive function, the subjects' responses are more influenced by the testing environment, instructions, and tester's hints. Although the assessment is also influenced by the tester's interpretation of the subject's responses, this influence is relatively minor. In parental evaluations of executive function, the subjects' executive function are largely determined by the evaluator (parent), who must select instances from daily life corresponding to the questions or structure and provide estimates of the frequency of certain types of events.[38] Different evaluators might make different estimates.

These differences may also make the two different predictors of academic achievement or social development. Some studies have found that directly measured executive function is a stronger predictor of academic achievement than parent- or teacher-evaluated executive function,[39] and some studies have found that directly measured executive function is a stronger predictor of neurocognitive performance and parent-evaluated executive function is a stronger predictor of impaired social function in patients with schizophrenia or ADHD.[40,41] However, previous studies have either not simultaneously examined the predictive role of both on academic achievement as well as on social development, or have not included normally developing children as subjects, which is not conducive to further exploration of the relationship between the two. Thus, it is necessary to measure the two at the same time, to examine their differences in predicting academic achievement and social development, and to explore the relationship more directly in terms of cognitive level or conceptualisation, stability of variance, and degree of influence by the evaluator.

The Mediating Role of Peer Status and Social Competence in the Impact of Executive Function on Social Behavior

The integrative model of social cognitive abilities establishes a dynamic relationship between executive function and social development. This model, proposed by Beauchamp and Anderson,[42] suggests that cognitive and emotional factors determining social behavior include attention, executive function, and socio-emotional skills. These processes are interconnected at both behavioral and neurological levels, forming a functional system. Executive function interact with mediators affecting social competence (such as brain structure/function, biological factors, and environment) and also directly impact an individual's ability to engage in social interactions and navigate environments.

According to the integrative model of social cognitive abilities and related studies, components of executive function can promote the development of social behavior (manifestations of social development in everyday domains, including positive social behaviors and problem behaviors) by influencing social competence (the ability to coordinate various processes and resources to meet social needs and achieve social goals, including emotional regulation, adherence to group norms, and self-awareness) or peer status (the degree of acceptance by peers). Firstly, inhibitory control allows individuals to adjust and adapt their behavior to comply with established social norms, playing a crucial role in the development of children's social behavior. For instance, preschoolers often conflict with peers, and sometimes other children may interfere with their activities (like taking away toys they are playing with). Children who can inhibit

impulses and resolve issues through communication are likely to be seen as better playmates by classmates and teachers, thus having better sociality. Conversely, those unable to inhibit impulses may exhibit externalized problem behaviors, such as physical aggression, and could be viewed as undesirable playmates, leading to potential internalized problems.[43–45] Secondly, a robust working memory helps children remember the behavioral ways of social norms and maintain social goals,[1,46,47] aiding them in enacting positive social behaviors. For example, reminding children that "it is better to communicate than to use violence if a classmate takes away the toy they are playing with" can increase their likelihood of exhibiting communicative behaviors in peer conflicts. Thirdly, cognitive flexibility aids individuals in flexibly adapting to environmental demands and viewing problems from different perspectives. This benefits children in creatively solving problems (eg, children with stronger cognitive flexibility are more likely to engage in communication and find solutions or behaviors that satisfy both parties when others play with their toys), thereby enhancing self-efficacy, promoting self-awareness development, and further advancing their positive social behaviors.[21]

In conclusion, although previous studies have explored the interrelations among various factors, there has been a lack of research analyzing the overall relationship between these factors. Therefore, further exploration is needed into the mediating role of peer status and social competence in the impact of executive function on social behavior.

Research Hypotheses

This study aims to explore the predictive effects of executive function, both directly measured and parent-evaluated, on the academic achievement and social development of children, as well as to investigate the mediating role of peer status and social competence in the impact of executive function on social behavior. Considering that the first grade of elementary school is a critical period for the development of children's executive function, academic achievement, and social development,[48] this study focuses on first-grade children as its subjects. Given that academic achievement is usually obtained from children's language and mathematics test scores (a direct measurement, similar to directly measured executive function), and social development is typically obtained through adult evaluations (similar to parent-evaluated executive function), this study hypothesizes that, after controlling for the impact of family economic status and gender, directly measured executive function have a better predictive effect on academic achievement, and parent-evaluated executive function have a better predictive effect on social development (Hypothesis 1). Furthermore, considering the role of executive function in influencing social behavior, including peer status and social competence, this study hypothesizes that, after controlling for family economic status and gender, peer status and social competence mediate the relationship between executive function and social behavior (Hypothesis 2).

Materials and Methods

Participants

This study was conducted with all children (106 in total) in three first-grade classes in a primary school in Changchun City. There was no subject attrition during the study period, and teachers reported that all children were normally developing. The mean age of the participants was 6.7 (±0.5) years, and 50.9% were boys. More information about the participants can be found in the Table 1.

Measurement Tools

Executive Function

Direct Measurement 1: Fish Flanker Task

This task is a classic one for assessing children's inhibitory control.[49] Participants sit in front of a computer screen and respond to a fish facing left or right in the center of the screen by pressing "left" or "right" buttons on the keyboard. The central target fish is flanked by two fish on each side. In congruent trials, the flanking fish face the same direction as the target fish, and in incongruent trials, they face the opposite direction. Each stimulus is presented for a maximum of 3000 ms (until the participant presses a key, as shown in Figure 1). The participant's inhibitory control is measured by subtracting the reaction time in congruent trials from that in incongruent trials; a larger value indicates poorer inhibitory control.

Table 1 Basic Information of Subjects

Variable	Frequency	Percentage (%)
Mother's education level		
Primary school and below	4	3.8
Junior high school	17	16.0
High school or secondary school	28	26.4
College	32	30.2
University	20	18.9
Master's degree or above	1	0.9
Not reported	4	3.7
Father's education level		
Primary school and below	1	0.9
Junior high school	21	19.8
High school or secondary school	25	23.6
College	28	26.4
University	23	21.7
Master's degree or above	3	2.8
Not reported	5	4.7
Mother's occupation		
Jobless, unemployed and semi-unemployed	24	22.6
Employees in service and manual labour	26	24.5
Employees in transactional work	9	8.5
Self-employed with no or few employees	19	17.9
Owners of large and medium-sized enterprises	0	0
Middle managers of enterprises	8	7.5
Military or police officers	0	0
Professionals and technicians	15	14.2
National public officials	0	0
Not reported	5	4.7
Father's occupation		
Jobless, unemployed and semi-unemployed	3	2.8
Employees in service and manual labour	38	35.8
Employees in transactional work	4	3.8
Self-employed with no or few employees	26	24.5
Owners of large and medium-sized enterprises	4	3.8
Middle managers of enterprises	10	9.4
Military or police officers	0	0
Professionals and technicians	13	12.3
National public officials	1	0.9
Not reported	7	6.6

Direct Measurement 2: Self-Ordered Pointing Task

This study uses a computerized version of this task. Several images (starting from 2 and increasing progressively) are displayed on a computer screen. Participants must first point out one of the images, then in the subsequent trial, point to a different image, and so on, until they repeat a previously indicated image or correctly identify all images on the screen. The difficulty of the test increases as the number of images increases, continuing until the participant fails to correctly identify the images (the task with image number 2 is shown in Figure 2). The number of consecutively correctly identified images reflects the participant's working memory span.[50] Working memory capacity is indicated by the working memory span; a larger value indicates better working memory.

Direct Measurement 3: Picture-Symbol Task

Based on the number-letter task by Miyake et al,[2,51] a bigram composed of a picture and a symbol appears in one of the

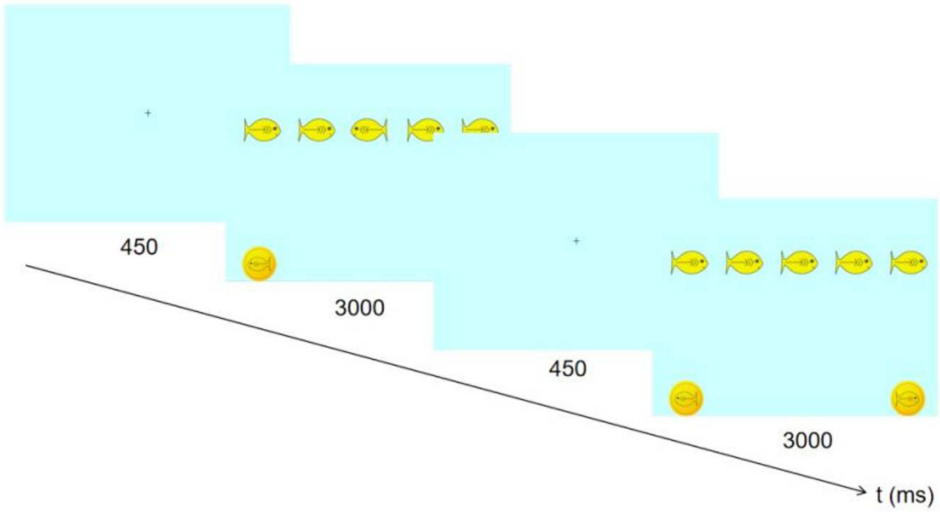


Figure 1 Flowchart of the Fish Flanker Task.

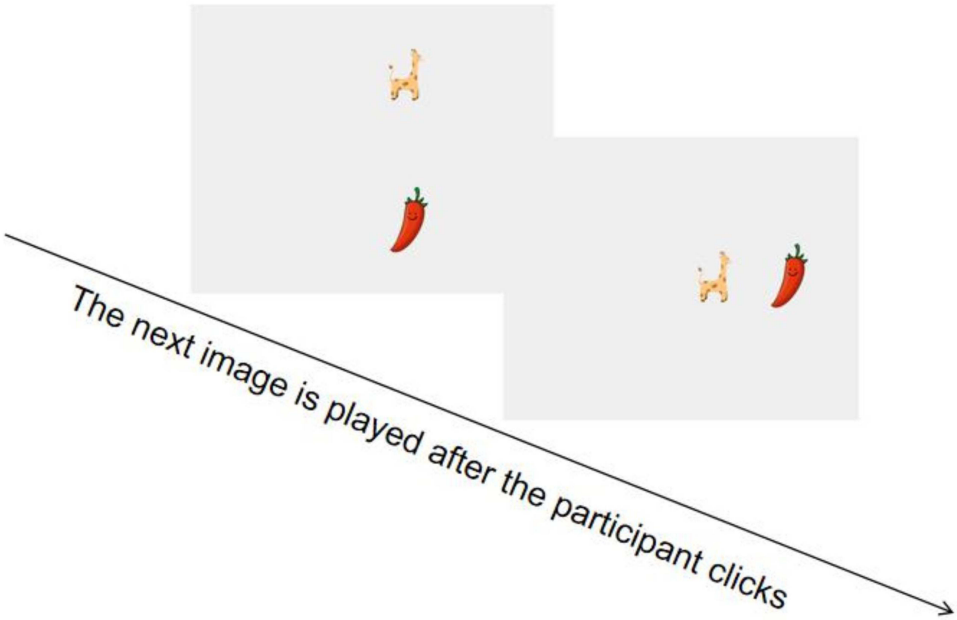


Figure 2 Flowchart of the Self-Ordered Pointing Task.

four quadrants of the computer screen (displayed for up to 3000 ms). Participants must decide if the picture in the bigram is an animal when it appears in the first or second quadrant, or if the symbol is a number when it appears in the third or fourth quadrant (as shown in Figure 3). Each presentation of a bigram is followed by a voice asking "Animal?" or "Number?". The participant's response accuracy in this task reflects their cognitive flexibility. In this study, the response accuracy rate is used as an indicator; a higher value indicates better cognitive flexibility.

Parental Evaluation: BRIEF Parent Rating Scale

This study uses the behavior rating inventory of executive function (BRIEF),[52] which has been modified. The inventory consists of 66 items, each scored on a 1–3 scale (1=Never, 2=Sometimes, 3=Often), and includes subscales for inhibition (eg, "Talks at the wrong time"), shifting (eg, "Becomes upset with new situations"), emotional control (eg, "Has explosive, angry outbursts"), initiation (eg, "Has trouble getting started on homework or chores"), working memory

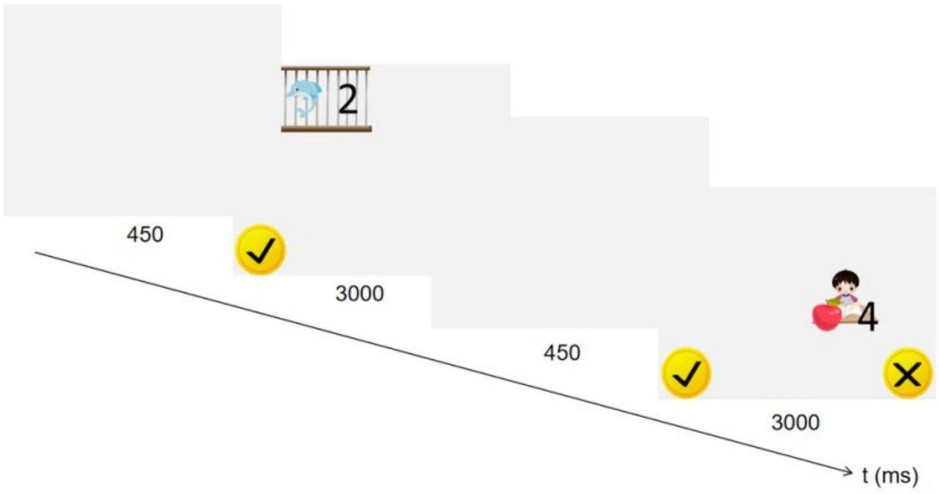


Figure 3 Flowchart of the Picture-Symbol Task.

(eg, "Has trouble with chores or tasks that have more than one step"), plan/organize (eg, "Gets caught up in details and misses the big picture"), organization of materials (eg, "Forgets to hand in homework, even when completed"), and monitor (eg, "Makes careless errors"). The Cronbach's alpha for the scale in this study is 0.97, with subscale alphas ranging from 0.70 to 0.87. The structural validity from confirmatory factor analysis is: χ^2/df=1.99, GFI = 0.96, IFI = 0.63, CFI = 0.62, RMSEA = 0.10. The total score on this inventory is used as an indicator in this study, with a higher score indicating poorer executive function as evaluated by parents.

Social Development

Peer Status

Peer status was measured using the peer nomination method.[53] Children were given a class roster and asked two questions: "When you have a birthday, who are the three best friends you would most like to invite?" and "The class is going to do activities in groups, which three people would you least like to be in a group with?". The number of nominations received for each question was divided by the total number of children in the class to calculate the proportions of positive and negative nominations. Peer status was determined by the difference between these two proportions. In this study, this difference was used as an indicator, with a larger value indicating higher peer status.

Social Competence

Social competence was assessed using the social competence subscale of the children's social scale (CSS) developed by Zhuang.[54] Parents completed this scale online, rating 21 items on a 3-point scale, assessing children's emotional regulation (eg, "When parents do not immediately fulfill the child's request, the child usually"), self-awareness (eg, "When seeing other children struggling with something, the child will"), and group norm compliance (eg, "During class, when the teacher asks for quiet and good behavior, the child will"). The overall Cronbach's alpha for the social competence scale in this study was 0.86, with alphas for emotional regulation, self-awareness, and group norms being 0.65, 0.78, and 0.57 respectively. The confirmatory factor analysis showed structural validity: χ^2/df=1.39, GFI = 0.83, IFI = 0.85, CFI = 0.84, RMSEA = 0.06. The score on this scale was used as an indicator, with higher scores indicating better social development in respective dimensions.

Social Behavior

Social behavior was assessed using the problem behaviors subscale of the strengths and difficulties questionnaire (SDQ) and the positive social behavior subscale of the CSS. Teachers completed the SDQ,[55] which comprises 20 items (3 items were omitted due to reliability issues) assessing emotional symptoms (eg, "Often unhappy, down-hearted or tearful"), conduct problems (eg, "Often lies or cheats"), hyperactivity/inattention (eg, "Often restless, overactive, cannot stay still

for long") and peer relationship problems (eg, "Has one or more good friends"). The questionnaire uses a 3-point scale, from 0 to 2, indicating "Not True" to "Certainly True". The CSS positive social behavior subscale, completed by parents, consists of 11 items assessing behaviors such as sharing (eg, "When the child has snacks and encounters other children, the child will"), cooperation (eg, "When building blocks with other children, the child will"), helping others (eg, "When another child falls, the child will"), and empathetic concern (eg, "When seeing another child crying, the child will"). The scale also uses a 3-point scale, from 1 to 3, indicating "Not True" to "Certainly True". The overall Cronbach' s alpha for the social behavior scale in this study was 0.78, with confirmatory factor analysis showing structural validity: χ^2/df=1.72, GFI = 0.75, IFI = 0.83, CFI = 0.82, RMSEA = 0.08. The alphas for the problem behavior and positive social behavior scales were 0.81 and 0.78, respectively. The total social behavior score was generated by averaging the standard scores of the problem behaviors and social behavior scales; a higher score indicates better social behavior development.

Academic Achievement

In this study, academic achievement was reflected through participants' language arts and mathematics scores. These subjects' tests, based on national new curriculum standards by respective experts (end-of-semester examination papers), were conducted in classrooms in a one-hour timed setting. Both language arts and mathematics had a maximum score of 100. Academic achievement was represented by the mean of the z-scores of these two subjects; higher scores indicated better academic performance.

Socioeconomic Status

Socioeconomic Status (SES) was measured by reporting the educational level and occupation of the child's parents. Educational levels included: A. elementary school or below; B. junior high school; C. high school or vocational school; D. junior college; E. university; F. master's degree or above; G. unknown. Occupational categories included: A. unemployed or semi-unemployed; B. service and manual labor (eg, workers, farmers, waiters); C. clerical staff (eg, secretaries, salespeople); D. self-employed with no or few employees; E. owners of medium to large businesses; F. mid-level corporate managers; G. military personnel or police officers; H. professionals (eg, doctors, teachers, engineers, accountants, lawyers, designers); I. government officials; J. unknown. Following the method of Shi and Shen,[56] these variables were coded and transformed, and their z-scores were combined to determine the child's family SES, with higher values indicating higher SES. In this study, this variable was used as a control variable.

Research Procedure

This study measured variables such as executive function, social development, family SES, and academic achievement of first-grade students at two time points. At the first time point (Fall semester of 2022), children's executive function and family SES were measured. Direct measurements of executive function were conducted by researchers in two quiet and tidy elementary school classrooms. Family economic status and parental evaluations of executive function were obtained through online questionnaires completed by the children's parents. At the second time point (Spring semester of 2023), children's social development and academic achievement were measured. Children completed peer nomination for peer status and academic achievement tests in classroom settings. Teachers filled out the SDQ paper questionnaires, and parents completed the CSS scale online.

Data Processing

Before data analysis, the normality of the data was assessed (all variables were normally distributed), and regression was used to replace outliers (values more than three standard deviations from the mean) and missing values. Additionally, for first-grade children, the various components of EF (such as working memory, inhibition, shifting) are highly integrated,[57–59] and it is standard practice to combine measures of EF components into a single composite variable. Therefore, this study created a composite variable "EF_{Direct}" based on the average of the standardized scores of the three EF components.

Descriptive statistics, regression, and mediation analyses were conducted using SPSS 26.0 and AMOS 21.0.

Results

Test for Common Method Bias

Considering that the 66 items from the BRIEF parent rating scale, the strengths and difficulties questionnaire, and the children's social scale were all assessed by adults, which might affect the research conclusions, this study employed the Harman single-factor test for common method bias. The results showed that there were 34 factors with eigenvalues greater than 1, and the first factor accounted for 21.32% of the variance (less than the critical standard of 40%). This indicates that common method bias is not a serious concern in this study.

Descriptive Statistics of Variables and Test of Gender Differences

Descriptive statistics were conducted for sample size, minimum, maximum, mean, and standard deviation of each variable, and t-tests were used to examine gender differences in the variables. The results (as shown in Table 2) revealed significant gender differences in academic achievement and peer status. Boys had significantly higher academic achievement than girls ($p = 0.04$, $d = 0.42$), and girls had significantly higher peer status than boys ($p = 0.04$, $d = 0.41$).

Correlation Analysis of Executive Function, Academic Achievement, and Social Development

After controlling for gender and age, partial correlation analyses were conducted for each variable, as shown in Table 3. The results indicated that direct measurement of EF was significantly correlated with academic achievement ($r = 0.19$, $p = 0.050$). Parentally evaluated EF was significantly correlated with social competence ($r = -0.45$, $p < 0.001$), peer status ($r = -0.26$, $p = 0.008$), and social behavior ($r = -0.40$, $p < 0.001$).

Hierarchical Linear Regression Analysis of Executive Function, Academic Achievement, and Social Development

A hierarchical linear regression model was used to explore the predictive effects of directly measured EF and parent-evaluated EF on academic achievement and social development. The variables were introduced into the equation in three

Table 2 Descriptive Statistics and Gender Differences Test for Each Variable

Variable	Sample size	Min Value	Max Value	Boy	Girl	*t* value	*p* value
EF_{Direct}	106	−1.66	1.61	0.00±0.70	−0.01±0.64	0.10	0.92
EF_{Parent}	106	66.00	154.00	95.09±20.15	95.47±22.07	−0.09	0.93
Academic achievement	106	−1.78	1.94	0.15±0.71	−0.16±0.75	2.14	0.04
Social competence	106	−2.46	1.16	−0.06±0.92	0.05±0.75	−0.63	0.53
Peer status	106	−0.59	0.32	−0.03±0.16	0.03±0.13	−2.05	0.04
Social behavior	106	−2.67	1.01	−0.08±0.75	0.08±0.67	−1.20	0.23

Table 3 Partial Correlation Analysis of Executive Function, Academic Achievement, and Social Development

Variable	1	2	3	4	5	6
1.EF_{Direct}	—					
2.EF_{Parent}	−0.03	—				
3.Academic achievement	0.19*	0.03	—			
4.Social competence	0.07	−0.45***	−0.05	—		
5.Peer status	0.16	−0.26**	0.19	0.16	—	
6.Social behavior	0.14	−0.40***	−0.01	0.61***	0.39***	—

Notes: *p<0.05, **p<0.01, ***p<0.001.

Abbreviations: EF_{Direct}, Direct measurement of executive function; EF_{Parent}, the composite executive score of the BRIEF scale, A higher value indicates more severe executive function deficits.

steps: first, gender and SES were entered; second, directly measured EF was added; and third, parent-evaluated EF was included. The dependent variables were academic achievement, social competence, peer status, and social behavior. The results (as shown in Table 4) indicated that, after controlling for gender and SES, directly measured EF significantly and positively predicted academic achievement (with significant model, regression coefficients, and ΔR^2), whereas parent-evaluated EF significantly predicted children's peer status, social competence, and social behavior (with significant model, regression coefficients, and ΔR^2).

Test of the Indirect Effect of Executive Function on Social Behavior

The mediation analysis was conducted using the Bootstrap method with 5000 resamples and a 95% bias-corrected confidence interval. An effect was considered significant if the confidence interval did not include zero.[60] Considering that directly measured EF had no significant correlation with the variables of sociality, and it did not significantly predict any of the social variables, this part of the analysis only used the total score of parent-evaluated executive function as the indicator of executive function. The parallel multiple mediation effects of social competence and peer status between executive function and social behavior were tested. The fit indices for this model were good: $\chi^2/df=0.44$, GFI = 1.00, IFI = 1.01, CFI = 1.00, RMSEA = 0.00. The results (as shown in Figure 4) indicated that the mediating effects of social competence and peer status were significant. The mediating effect of peer status was −0.07, accounting for 23.33% of the total effect, with a 95% confidence interval of [−0.18, −0.01]. The mediating effect of social competence was −0.23, accounting for 76.67% of the total effect, with a 95% confidence interval of [−0.38, −0.13].

Discussion

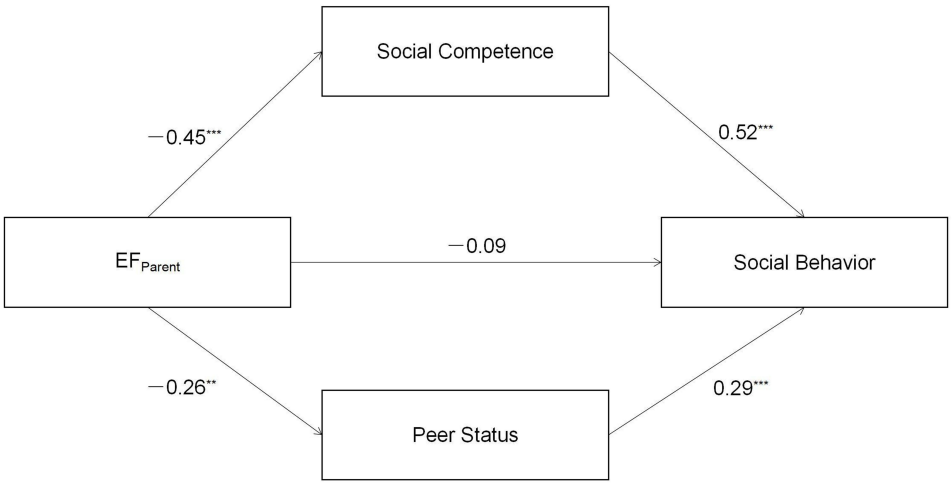
Differences in Predictive Effects of Directly Measured and Parent-Evaluated Executive Function on Academic Achievement and Social Development in First-Grade Children

This study, employing a longitudinal design and controlling for SES and gender, explored differences in predictive effects of directly measured and parent-evaluated executive function on the academic achievement and social development of first-grade children. The results revealed that directly measured executive function had a significant advantage in predicting academic achievement, whereas parent-evaluated executive function were more predictive of social development variables such as peer status, social competence, and social behavior. This finding is generally consistent with the

Table 4 Hierarchical Linear Regression Model for Predicting Academic Achievement

Dependent Variable	Step	Independent Variable	B	SE B	β	F	ΔR^2
Academic achievement	Step 1: Enter	SES	−0.19	0.26	−0.07	20.75	0.05
		Gender	−30.49	10.54	−0.22*		
	Step 2: Enter	EF_{Direct}	20.76	10.25	0.21*	30.54*	0.04*
	Step 3: Enter	EF_{Parent}	0.01	0.04	0.02	20.64*	0.00
Social competence	Step 1: Enter	SES	−0.00	0.03	−0.01	0.20	0.00
		Gender	0.10	0.17	0.06		
	Step 2: Enter	EF_{Direct}	0.06	0.14	0.05	0.20	0.00
	Step 3: Enter	EF_{Parent}	−0.02	0.00	−0.46***	60.74***	0.21***
Peer status	Step 1: Enter	SES	0.04	0.05	0.06	30.59*	0.07*
		Gender	0.82	0.31	0.25*		
	Step 2: Enter	EF_{Direct}	0.13	0.26	0.05	20.46	0.00
	Step 3: Ente	EF_{Parent}	−0.02	0.01	−0.25**	30.75**	0.06**
Social behavior	Step 1: Enter	SES	−0.02	0.02	−0.10	10.20	0.02
		Gender	0.16	0.14	0.11		
	Step 2: Enter	EF_{Direct}	0.14	0.11	0.13	10.44	0.02
	Step 3: Enter	EF_{Parent}	−0.01	0.00	−0.39***	50.89***	0.15***

Notes: *p<0.05, **p<0.01, ***p<0.001.
Abbreviations: B, unstandardized coefficient; SE B, standard error of B; *β*, standardized coefficient; F, the ratio of the sum of squares of deviation between groups to the number of degrees of freedom.



Note: *p<0.05, **p<0.01, ***p<0.001. All path coefficients are standardized coefficients.

Abbreviations: EF_{parent}, the composite executive score of the BRIEF scale.

Figure 4 Parallel multiple mediating effects of social competence and peer status between executive function and social behavior.

research hypotheses and with Graziano et al's finding (that directly measured executive functions play a greater role in predicting academic achievement than parent-evaluated executive functions),[39] and can be explained in the following ways:

Firstly, in terms of the cognitive level or constructs measured, directly measured executive function primarily reflect an individual's processing efficiency in behavioral control situations, focusing on optimal performance in laboratory tasks. Parent-evaluated executive function, on the other hand, reflect behaviors that facilitate goal achievement in real-world environments, focusing on executive function performance in daily life.[33] Therefore, directly measured executive function may predict academic achievement better because the assessment methods used in this study, focused on children's processing efficiency in numerical operations and verbal comprehension, are similar to direct measurement in cognitive level or constructs. Parent-evaluated executive function may predict social development better because indicators of social development, such as social competence or social behavior, focus on psychological or behavioral characteristics reflecting sociality in life, making them more similar in cognitive level or constructs to parent evaluation.

Second, in terms of stability of variance, directly measured executive function has lower between-person variability and thus lower stability of variance, whereas parent-evaluated executive function has higher between-person variability and thus higher stability of variance.[34,35,37] Therefore, directly measured executive function may predict academic achievement better because the assessment of academic achievement as direct measurement involves lower between-person variability or variability stability, akin to the nature of direct measurement of executive function. Parent-evaluated executive function may predict social development better because the assessment of social development as social evaluation involves higher between-person variability or variability stability, similar to parent evaluation of executive function.

Thirdly, from the perspective of the influence of evaluators, both directly measured executive function and academic achievement primarily involve children completing specific tests, although the assessments are somewhat influenced by evaluators' interpretation of the responses. In contrast, most indicators of parent-evaluated executive function and social development are assessed by adults, requiring them to select corresponding instances from life and provide estimates of the frequency of relevant events, thus being more influenced by the evaluators. Hence, there are differences in the predictive effects of directly measured and parent-evaluated executive function.[33,37]

The results of this study indicate that direct measurement and parental evaluation of executive function cannot replace each other. They differ significantly in the content measured, clarity of children's response expectations, and the degree of evaluator influence, showing substantial differences in predicting different child development variables (academic

achievement and social development). Therefore, using both methods together to measure executive function can help researchers better understand the predictive role of executive function in academic achievement and social development.

The Indirect Effect of Executive Function on Social Behavior

This study aimed to explore the mediating role of peer status and social competence in the influence of directly measured and parent-evaluated executive function on social behavior. The results showed that peer status and social competence played mediating roles between parent-evaluated executive function and social behavior. The parallel mediation model of peer status and social competence indicated that parent-evaluated executive function do not directly affect social behavior, but rather influence social behavior by affecting peer status and social competence, consistent with the study hypothesis and the integrative model of social cognitive abilities. This finding echoes the research by Martarelli et al,[61] who measured executive function, social competence, and social adaptation level a year later in 6-7-year-old children and found that children's social adaptation level was highest only when both executive function and social competence were high. Additionally, Elliott found that executive function could not fully explain children's problem behaviors,[62] and this study provides an explanation: executive function primarily influence social behavior through peer status and social competence.

Executive function can influence social behavior through this mediating pathway. First, from the perspective of social information processing theory,[63] children with stronger executive function might have the following advantages in information processing: 1. Better inhibition of attention to irrelevant cues, thus gaining more relevant social cues; 2. More flexible and rich interpretation of information, enabling deeper interpretation of social cues; 3. Ability to retain sufficient information to ensure effective assessment of response methods; 4. Greater self-control in response execution, inhibiting impulsive reactions. Secondly, the advantages in information processing can translate into advantages in social competence or peer status: efficient processing of social cues and effective execution of appropriate response methods help children better understand social situations, adhere to group norms, and develop self-awareness, thereby promoting the development of social competence. Simultaneously, this helps them adjust response methods in peer conflicts, enhancing peer status. Finally, advantages in social competence or peer status can lead to changes in social behavior. For example, children who can effectively control their emotions are more likely to avoid conflict behaviors, and children with higher peer status may exhibit more cooperative or communicative behaviors, rather than aggressive behaviors, in interactions with peers.

In summary, the results of this study suggest that cognitive factors in children (such as executive function) can influence the development of their social behavior by affecting social factors (such as peer status and social competence). Therefore, when fostering children's social behavior, the role of cognitive abilities (such as executive function) should be valued and utilized.

Research Inspiration and Practical Suggestions

The present study found that in a comparison of the predictive role of directly measured executive function versus parent-evaluated executive function, directly measured executive function was a greater predictor of academic achievement, while parent-evaluated executive function was a greater predictor of social development; parent-evaluated executive function influenced social behavior primarily through social competence and peer status, with the mediating role of social competence being more pronounced than the mediating role of peer status. Based on these findings, the following research insights and practice recommendations are made:

First, a rational choice of executive function measures. When exploring the relationship between executive function and other variables, the following characteristics of other variables need to be considered: whether the response expectations are clear, whether the cognitive level assessed is algorithmic or reflective thinking and the degree to which the measurement is influenced by the assessor, and the corresponding measurement should be selected based on the similarity between direct measurement/parental evaluation of executive function and other variables in terms of these characteristics. For example, when it is necessary to consider the relationship between executive function and some cognitive abilities that reflect the processing speed of the subjects (eg, arithmetic ability), it may be more appropriate to choose the direct measurement of executive function; and when it is necessary to consider the relationship between

executive function and some variables that reflect the typical psychological or behavioural characteristics of the subjects' lives (eg, social ability), it may be more appropriate to choose the parental evaluation of executive function.

Second, attention should be paid to the development of executive function in young children. Executive function is closely related not only to children's academic achievement but also to their social development, and it is a crucial competency in children's family, school and social life. Early childhood is a developmentally sensitive period, teachers or parents need to pay attention to the development of executive function of young children. In addition, in order to promote executive function of young children, teachers or parents may consider allowing children to participate in pretend play.[64] Conduct mindfulness training,[65] increase their cognitive engagement during exercise,[66] and give them more responses or feedback in their daily interactions with children.[67]

Third, emphasis is placed on the development of social competence and improvement of peer relationships for young children. The development of children's social behaviors is very often mediated by social competence and peer relationships,[68] thus to promote children's social behaviors, it is necessary to develop their social competence as well as to improve their peer relationships. Teachers or parents should develop children's emotional control in their daily educational and teaching activities, help them understand and comply with group norms, promote the development of their self-awareness with the help of encouragement or guidance, as well as promote the development of their peer interaction skills by creating more peer interaction activities, so as to reduce their problematic behaviors and promote the development of their positive social behaviors.

Limitations and Future Directions

This study aimed to explore the differences in the predictive effects of directly measured and parent-evaluated executive function on academic achievement and social development, and to analyze the mediating role of peer status and social competence between executive function and social behavior. However, there are several limitations in this study. First, although the present study revealed significant differences in the predictive effects of direct measures and parent-evaluated executive functions on academic achievement and social development, future research needs to control for more variables for in-depth analyses in order to accurately identify potential mechanisms or causes, such as determining the effects of factors such as cognitive level or constructs, stability of variation, and degree of influence by the evaluator. Second, there are limitations in the selection of the study population. This study involved only first-grade students in a primary school in Changchun City. Future studies should consider expanding the sample to include a more diverse group of participants and take cultural specificities into account. Third, because the directly measured and parent-evaluated executive function measures used in this study measured different levels of executive function (directly measured executive function measures included the fish flanker, self-ordered pointing, and picture symbol tasks, which require depletion of inhibition, working memory, and switching of executive function, and parent-evaluated executive function measures included the BRIEF Parent Rating Inventory, which includes not only inhibition, working memory and switching, but also emotional control and higher-order executive functions such as planning and organisation), so the results of the present study may have been affected by this issue, and future research could consider means to control for or attenuate the effect. Fourth, the present study had a short follow-up period, and longer follow-up studies may be needed in the future to validate the findings of this paper. Fifth, although the present study found that executive function influences social behavior primarily through social competence and peer status, with social competence being a more significant mediator, further research is nonetheless needed to explore the underlying mechanisms of these relationships, as well as to explore whether interventions aimed at improving executive function can contribute to social developmental outcomes. Finally, in terms of parent-evaluated measures of executive function and social development, this study primarily used questionnaires, which can be very burdensome for parents and teachers and may result in some questionnaires being filled out in a sloppy manner, which may affect the accuracy of the findings. Future research could mitigate this effect by using a variety of methods (eg, experimental, observational, and interview methods).

Conclusion

This study, through a longitudinal design, examined the differences in the predictive effects of directly measured and parent-evaluated executive function on academic achievement and social development, as well as the indirect effect of

executive function on social behavior. The results found that: First, in a comparison of the predictive role of direct measures and parental assessments of executive function, directly measured executive function played a more important role in predicting academic achievement, while parent-evaluated executive function played a greater role in predicting social development. Second, parent-evaluated executive function influenced social behavior primarily through social competence and peer status, with social competence playing a more significant mediating role than peer status.

Ethics Statement

The study complies with the Declaration of Helsinki. The study involving human participants were reviewed and approved by Institutional Review Board of Northeast Normal University. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin. No potential conflicts of interest.

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Disclosure

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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