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ORIGINAL RESEARCH

The Interplay of Non-Verbal Intelligence and Cognitive Functions in Understanding Emotions in Preschool Children

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Objective: Emotions are known to play a vital role in the lives of children; however, not all children possess an equal understanding of emotions. This suggests the influence of cognitive abilities and functions on the development of emotion understanding during different developmental phases. This study aims to explore the link between non-verbal intelligence and emotion understanding in children. Also, it examines a mediation model to assess the extent to which cognitive functions mediate this link. Finally, it aims to compare the strength of mediation paths between boys and girls through testing a moderated mediation model.

Methods: To test the research hypotheses, a sample of 272 children (M = 63.40 months, SD = 3.74) including 81 boys and 138 girls was recruited. The parents of the remaining 53 children chose not to specify their children's gender. Participants responded to scales on non-verbal intelligence, executive cognitive functions and emotion understanding.

Results: The results suggested that there is a statistically positive relationship between non-verbal intelligence and emotion understanding. Also, the executive cognitive functions were positively associated with both non-verbal intelligence and emotion understanding. The results of multiple mediation analysis revealed that only the inhibition mediated the link between non-verbal intelligence and emotion understanding.

Conclusion: These findings suggest that not all executive cognitive functions can explain the underlying mechanism between non-verbal intelligence and emotion understanding, however, inhibition emerged as the stronger mediator in this relationship.

Keywords: non-verbal intelligence, cognitive functions, emotion understanding, preschool children

Introduction

Intelligence and emotions are interconnected constructs that have received considerable research attention.[1,2] Although neuroscience findings introduce the limbic system which includes two structures of amygdala and hippocampus as the site of producing emotions in the brain in both adults and children,[3,4] psychological studies support the idea that emotions may be used differently by these two groups. In children, emotions play a crucial role in social development, interaction and understanding others, resolving conflicts and developing constructive relations with others[5] or they may even use negative emotions to cope with distress or demonstrate their disagreement with adults.[6]

Most studies differentiate emotional intelligence from cognitive or non-verbal intelligence.[7,8] Emotional intelligence is defined as the ability to perceive, express, understand, and manage emotions effectively, and it has a key role in personal and professional success[2,8] which require individuals to use these functions in their social and interpersonal communications. In contrast, non-verbal intelligence is considered a cognitive ability that is indeed a component of overall intelligence, and it is associated with functions such as pattern recognition, spatial awareness, fluid reasoning,[8] and problem-solving abilities without communication or use of words.[9]

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As the non-verbal intelligence level in different developmental stages may change,[7] this change may be assumed to be associated with changes in emotions. In other words, individuals with varying degrees of perceptual non-verbal intelligence may exhibit different degrees of understanding emotions.[10] This idea can be supported in children with autism where the differences between high non-verbal intelligence and low emotional processing may lead to difficulties in reading emotions in social interactions.[11] This may provoke the idea that these two variables do not always change together, and it indeed highlights the role of factors that may mediate or moderate the link between non-verbal intelligence and emotion understanding. According to Pons and Harris,[12] emotion understanding is the ability to comprehend nature, causes and effects of emotions in oneself and others. Its basic main function includes identifying, describing, explaining, predicting, controlling the expression and regulating the experience of emotions in daily life. Most of the current studies focus on the emotional factors that can contribute to emotion understanding, and no study so far has tested the cognitive factors that may mediate this link.

There is a growing volume of recent studies that distinguish intelligence, which is a cognitive ability, from cognitive functions, which are known as cognitive skills and develop over time. The distinction between non-verbal intelligence and cognitive functions is well-supported. Executive functions are known as a set of high-level cognitive processes that include abilities such as response inhibition, working memory updating, and switching and are all essential for goal-directed behavior. These executive functions are related to the frontal lobes of the brain and are distinct from general intelligence, which includes non-verbal intelligence.[13] Although some studies have shown that intelligence and executive functions may have some overlap, other studies demonstrated that executive functions and intelligence are separable constructs that should not be confused.[14] In this regard, some studies reported that intelligence is associated with updating working memory, however there are many recent studies that reported a low or non-significant association between intelligence and executive functions such as inhibition or switching.[15–18] The recent studies provide more support for the assumptions that intelligence and executive functions are not the same.[13,15,18–21] Moreover, genetic studies on twin pairs also support the idea that intelligence and executive functions are genetically distinct constructs.[18] Neuroimaging studies (CT and MRI) have shown some overlapping but distinct brain patterns for fluid intelligence and executive functions.[17]

There are numerous studies that support the positive association between intelligence and emotion understanding. For example, a meta-analysis of 133 samples suggested a significant positive association between various intelligence types (fluid, crystallized, spatial, memory, information processing speed and efficiency) and emotion recognition ability.[7,22,23] However, the specific relationship between non-verbal intelligence and emotion understanding, as well as the underlying mechanism of this relationship, is not yet clear or comprehensively studied.

The relationship between executive cognitive functions and emotions has been studied. Some studies suggest that set shifting, a component of executive functions, is particularly associated with emotion understanding in children.[24] Other functions such as inhibition and updating are associated with emotion regulation strategies.[25] One study also suggested a bidirectional relationship between emotions and executive functions in young children in that early executive functions can predict the development of emotion understanding over time, and subsequently improvements in emotion understanding can enhance executive functions.[26] However, most studies used only one or a few executive functions and have not investigated the relations between all executive functions and emotion understanding. Furthermore, there is a lack of research on what type of intelligence and cognitive skill are stronger predictors of emotion understanding. Thus, the first aim of this study is to assess the relations between both non-verbal intelligence and all executive functions simultaneously in relation to emotion understanding in order to clarify the strength and the direction of the link among them.

There is also a lack of studies demonstrating the underlying mechanisms that can explain the connection between non-verbal intelligence and how individuals understand emotions, particularly in children. More recent studies suggest that cognitive functions can mediate the association between cognitive abilities and emotion understanding in children.[27] However, the role of all cognitive functions has not been thoroughly examined. To further identify the factors that mediate the link between intelligence and emotion understanding in children, we propose to examine the role of four main executive functions between non-verbal intelligence and emotion understanding. This forms the second aim of this study. Additionally, the mediation effects will be compared across genders using a moderated mediation model to assess the impact of gender on the mediation paths.

A Review of the Existing Literature

In understanding emotions, intelligence plays a crucial role. Studies show that individuals with higher non-verbal intelligence can more precisely identify and understand the emotions of surrounding people and build more solid social relationships.[28] They can also recognize and respond to emotional cues in social interactions more effectively.[29] This ability can contribute to enhancing the emotional intelligence of individuals.[30] This suggests that non-verbal intelligence may enable individuals, through providing interpretations of facial and body language, to process information and act more situationally in complex social interactions.

Similar studies also suggested that non-verbal intelligence is associated with empathy,[31] allowing them to have deeper emotional connections with others. In addition, it has been found that non-verbal intelligence is associated with emotional regulation,[32] enabling individuals to regulate and control emotions in different circumferences and cope with stressful and challenging situations.[33] This means individuals with high non-verbal intelligence are more likely to act actively in both personal and professional environments through their social skills such as active empathy, conflict resolution and listening.

Some researchers have tried to demonstrate the role of verbal and non-verbal communication in developing emotional intelligence.[34,35] According to a recent study conducted on Russian schoolchildren, storytelling, analyzing art samples, using games and dramatization can positively enhance the development of emotional intelligence in schoolchildren.[34] The relation between non-verbal intelligence and emotion understanding can be understood by the theory of working memory.

According to this theory,[36,37] working memory is a cognitive system that enables individuals to hold, store and manipulate information in short periods, which enables them to do cognitively complex tasks such as emotion recognition and emotion regulation. Emotion understanding can be understood based on this theory because working memory enables individuals to process and interpret non-verbal cues such as facial expressions and body gestures. Lambrecht[38] suggested that a decrease in basic cognitive abilities such as vision and hearing does not completely account for the age-related decline in the ability of individuals to recognize emotions, implying that higher-order cognitive functions are essential for maintaining emotion understanding.

Studies show that the capacity of working memory in individuals is directly associated with emotional intelligence and the ability to identify and interpret emotions in themselves and others.[39] It is suggested that individuals with greater non-working intelligence are more likely to have greater capacity of working memory for processing, interpreting and remembering non-verbal emotional cues,[40] which is assumed to enhance emotion understanding. Besides, there is neuroscientific evidence that supports these findings. For example, Smith[41] found that the maintenance of emotional information in working memory can activate the left lateral frontal-parietal network which includes the anterior insula and posterior dorsomedial frontal cortex. This evidence suggests that the ability to keep and process emotional information in working memory relates to non-verbal intelligence.

Most of the previous studies have focused on understanding the relationship between verbal intelligence and emotion understanding and have suggested a positive link between age, language and emotion understanding.[42–45] Less attention has been paid to the specific association between non-verbal intelligence and emotion understanding. In this study, relying on working memory theory, we would like to understand how changes in non-verbal intelligence are associated with emotion understanding, leading us to present the following hypothesis:

Hypothesis 1. Non-verbal intelligence is positively associated with emotion understanding of preschool children.

The Meditating Roles of Cognitive Functions

Non-verbal intelligence may not always directly influence emotion understanding among children. According to the study of Albanese et al,[7] cognitive non-verbal factors are found to be the only predictors of more complex emotion comprehension in children. They found a stronger connection between cognitive non-verbal intelligence and emotion understanding as the age of children increases from 3 to 10 years old. Their findings were also supported by a similar study that was previously conducted in the UK.[44] These findings suggest that the growth of emotion understanding is not only a function of age but also it is associated with the development of cognitive functions that naturally occur during children's developmental phases. This is consistent with Harris,[46] who believed:

> Children become aware of the emotional determinants of complex emotional states, such as pride, shame, and guilt, and they start to realize that the way they feel can be changed by how they think.

The growth of these cognitive functions, known as executive cognitive functions, helps children recognize and understand more complex emotional patterns.

It has not yet been investigated which of the current executive cognitive functions have the potential to transmit the influence of non-verbal intelligence to emotion understanding. In other words, the contribution of executive cognitive function in mediating the contribution of non-verbal intelligence to emotion understanding and growth is unclear.

Executive cognitive functions are known as a set of higher-level cognitive processes or mental abilities that enable individuals to have attentional control, planning, abstract reasoning, goal planning and self-mentoring.[47,48] Executive cognitive functions are essential for decision-making, cognitive resources management and goal-oriented behaviors.[47,49,50] The prefrontal cortex of the brain is associated with the activity of executive cognitive functions.[51,52] The executive cognitive functions include the following functions: naming, inhibition, motor persistence, visual memory and verbal memory.

Naming refers to the cognitive process whereby objects, concepts, and ideas are given labels or names. It involves the ability to recover from memory the appropriate word or label for a stimulus and to associate it with the presented stimulus. Naming thus plays a major role in language understanding, communication, and the general grouping of information into meaningful categories.[53] Inhibition is the ability to control impulses, disregard distractions, and suppress automatic reactions. In other words, it's the ability to prevent oneself not just from doing an action or thinking a thought, but also from having it which in turn serves to increase self-control and attention.[47] Body Persistence deals with spatial awareness and representation of the body. It involves the capacity to maintain a mental image of one's body position, movement, and orientation in space. It is a crucial function as it is used for special reasoning, navigation and motor coordination.[54] Visual memory refers to the cognitive process that enables individuals to retain and recall visual (non-verbal) information in the brain. By this function, individuals can store and retrieve visual shapes, images, patterns, spatial relations and colors. It is crucial for identifying objects, faces and scenes and visual problem-solving.[55] Verbal memory refers to the cognitive process that enables individuals to store and recall verbal information, such as words, sentences, and stories, by the ability to encode, store, and recall it from memory. Verbal memory is responsible for learning new words, retrieving information from conversations, and language comprehension.[56]

Recent studies indicate that cognitive functions may mediate the relationship between cognitive abilities, ie non-verbal intelligence and emotion understanding in children.[27] Amani[57] in a mediation model showed that executive functions mediate the link between intelligence and behavioral problems, including mood and emotion disorder in children. There are more studies suggesting that there are individual differences in executive functions, particularly inhibitory control and cognitive flexibility that influence emotional process and regulation, suggesting that they can integrate and bridge the cognitive (intelligence), and emotional processes (ie emotion understanding).[47,58,59]

This can be understood using the theory of working memory.[36,55] Individuals with higher intelligence typically have greater working memory capacity, allowing them to process and manipulate more information simultaneously.[60] This capacity supports complex reasoning, problem-solving, and learning. Working memory allows individuals to maintain goal-relevant information (eg, stay calm) while inhibiting distracting emotional stimuli (eg, frustration or anger).[59] Cognitive functions can mediate the relationship between intelligence and emotions by enabling individuals to apply their cognitive abilities effectively in emotionally charged situations. An intelligent person with strong working memory can use his cognitive functions to reappraise a demanding situation and reduce his emotional responses. On the other hand, an intelligent person with poor cognitive functions may further struggle to regulate and understand emotions in a demanding situation and as a result shows more negative maladaptive reaction.[61] The current evidence supports the idea that cognitive functions can act as mediator of the link between intelligence and understanding emotions as reflected in following hypotheses:

Hypothesis 2. The relation between non-verbal intelligence and emotion understanding is mediated by the a) inhibition, b) motor persistence, c) visual-spatial working memory, d) verbal working memory.

Methodology

Procedure

Ethics approval was requested and granted by the Ethics Committee of the Faculty of Psychology at Lomonosov Moscow State University (Ethics No: 2018/43). The research team communicated with authorities to recruit the participants from public kindergartens in Moscow, Russia. The families of participants were informed and signed written consent forms before their children could participate in the study. Also, they were informed that their identity would remain confidential, and they were free to leave the study at any stage they wished. The data were collected from all the participants in the morning between 8:00 and 11:00 am. Children were assessed while present in their kindergarten and each assessment lasted no more than 20 minutes. This study complies with the Declaration of Helsinki.

Participants

Subjects were recruited from 11 kindergartens in Moscow, Russia, using a simple random method where every child, regardless of individual differences, had an equal chance of being selected for the study. Note that the selected kindergartens in different districts are characterized by the same level of infrastructure and are designed to accommodate primarily medium-income families. Since children in Russia are normally assigned to kindergartens according to their registered residence address, this allows us to infer that the sample is homogeneous in terms of the families' socio-economic status. The G*power statistical program[62] was used to calculate the required number of participants. 272 children of different ages around 5 years old (M = 63.40 months, SD = 3.74) were sampled. 138 participants were female (M = 63.62 months, SD = 3.62) and 81 participants were male (M = 63.99 months, SD = 3.50). 53 participants (M = 61.86 months, SD = 4.05) preferred not to specify their gender.

Scales

Non-Verbal Intelligence

It was measured using Raven Progressive Matrices (RPM) developed by Raven.[63] In this study, we used a Russian adaptation of *Raven's Colored Progressive Matrices* (CMPM).[64] This test is designed to measure human intelligence level and logical thinking as non-verbal manifestations of fluid intelligence.[65] It is a common test and is used to measure non-verbal intelligence in individuals from 5 years up to the elderly age using 60 multiple-choice items that make up five groups or series of items. The items of this test are arranged from the easiest to the hardest. Each of these items asks the participant to complete patterns and figures using the identification of missing elements. In each task, the child can choose one out of four choices that correctly match the missing element. The number of correct answers is recorded until the child makes a wrong answer in a row, which results in stopping the testing process. The responses are scored from 0 to 36.

Cognitive Functions

These functions were measured using the Developmental Neuropsychological Assessment (NEPSY-II) developed by Korkman, Kirk and Kemp.[66] It has six components, and it can be used for children aged 5 to 16 years. This test aims to measure the neurocognitive development of children in the following components: language, social perception, sensor-imotor functions, attention, memory and executive functions. The test can be completed in 45 to 60 minutes. The following subtests of this test were used in this study:

Inhibition

The Inhibition subset of this test was used. This subset consists of two tasks: (1) Naming means the child had to quickly identify the shapes of figures (black and white circles) on a page, and (2) Inhibition means the child had to name figures that were the opposite of those shown (for instance, square instead of circles). Errors, including corrected and uncorrected by the child, and the time spent to complete these tasks were recorded.

Motor Persistence

The subset of this test is used to measure motor persistence. A kid must keep a still posture for 75 seconds with their eyes closed. The experimenter makes sure that the child does not respond to any sound distractions. Four scores are computed for the Statue

subtest, which includes: Statue, Body Movement, Eye Opening and Vocalization. In five-seconds intervals, the examiner notes how many times the child moves (for example, head-turning, opening eyes or making noise/laughing).

Visual-Spatial Working Memory

To evaluate visual-spatial working memory, the Memory for Designs subtest of this test was used. The parameters measured include memorization of images (recognizing those pictures that were presented in a model by picking them from a sum of nearly identical ones) and spatial arrangement of images recall (remembering where each card was laid out based on some example).

Verbal Working Memory

A subset of this test was used to assess the verbal working memory using the 17 Sentences Repetition where their complexity in terms of syntactical structure and length was increased from the first to the last sentence.

Emotion Understanding

It was measured by the Russian version of the Test of Emotion Comprehension.[67] The original version of this test was developed by Pons and Harris.[68] This test measures the emotion understanding of children. This test includes an illustrated book with some simple stories. After the examiner reads a story to the child, the child is asked to choose one out of four facial expressions to the story characters' feelings. This test assesses the emotion understanding of a participant at three levels: External, Mental and Reflexive. The scoring in each level ranges from 0 to 3. An overall score between 0 and 9 can be obtained based on the performance of the participant in the three levels.

Data Analysis

To analyze the descriptive statistics and draw graphs, we used JASP and JAMOVI statistical programs. We also used simple Pearson correlation analysis using IBM SPSS statistics version 25 to draw correlation metrics. In this study, a mediation model and a moderated mediation model were examined using Macro program version 4.2.

Results

Descriptive Statistics

The results of descriptive statistics including mean and standard deviation of research variables are presented in Table 1. In addition, Table 1 shows the distribution of demographic information such as gender, socioeconomic and maternal education.

Correlational Results

Table 2 tabulates the results of Pearson correlation analysis between the research variables. As the table shows, gender did not have any statistically significant relationship with non-verbal intelligence, cognitive functions and emotion

Table 1 Descriptive Statistics of the Research Variables in the Present Study (n = 272)

Variable	Mean	Std. Deviation	Minimum	Maximum
1. Gender	1.630	0.484	1.000	2.000
2. Non-verbal intelligence	14.842	7.988	1.000	34.000
3. Inhibition	9.122	3.176	1.000	17.000
4. Motor persistence	23.793	6.218	4.000	30.000
5. Visual-spatial working memory	70.801	22.143	0.000	120.000
6. Verbal working memory	17.471	4.182	0.000	26.000
7. Emotion Understanding	4.841	1.567	1.000	8.000

Table 2 Correlation Coefficients Between the Research Variables in This Study (n = 272)

Variable	1	2	3	4	5	6	7	8	9
1. Gender	–								
2. Socio-economic status	0.019	–							
3. Maternal education	0.023	0.173	–						
4. Non-verbal intelligence	−0.063	0.170	−0.069	–					
5. Inhibition	−0.055	0.034	−0.116	0.284***	–				
6. Motor persistence	0.124	0.124	−0.042	0.223***	0.110	–			
7. Visual-spatial working memory	−0.112	0.207*	0.028	0.439***	0.330***	0.251***	–		
8. Verbal working memory	−0.012	−0.003	0.007	0.180**	0.223***	0.149*	0.327***	–	
9. Emotion Understanding	−0.082	0.133	−0.069	0.299***	0.314***	0.196**	0.238***	0.137*	–

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

understanding. Similarly, there was no significant relationship between maternal education and the study variables. As for socioeconomic status, the results suggested only a positively significant relationship between socioeconomic status and visual-spatial memory ($r = 0.207$, $p < 0.01$).

Non-verbal intelligence was found to have a statistically significant positive relationship with all cognitive functions. More specifically, the non-verbal intelligence was positively associated with inhibition ($r = 0.284$, $p < 0.001$), motor persistence ($r = 0.223$, $p < 0.001$), visual-spatial memory (r=0.439, $p < 0.001$), and verbal working memory ($r = 0.180$, $p < 0.01$). In addition, the non-verbal intelligence was significantly associated with emotion understanding ($r = 0.299$, $p < 0.01$). All cognitive functions were also positively associated with emotion understanding.

Regression Results

A regression model was examined to test the predictive power of non-verbal intelligence as well as five executive cognitive functions in estimating emotion understanding. The results are presented in Table 3. As the table shows, the regression analysis revealed that non-verbal intelligence statistically predicts emotion understanding ($\beta = 0.190$, $P < 0.006$). In addition, only one out of five executive cognitive functions predicted emotion understanding. More specifically, the

Table 3 Results of Regression Analysis of Intelligence and Cognitive Functions in Predicting Emotion Understanding (n = 272)

Predictor	Outcome	Unstandardized	*SE*	Standardized	t	*P*	95% Confidence Interval	
							Lower	Upper
Intercept	Emotion Understanding	2.245	0.566		3.967	<0.001	1.130	3.360
Non-verbal intelligence		0.037	0.013	0.190*	2.792	0.006	0.011	0.064
Inhibition		0.125	0.036	0.251*	3.470	<0.001	0.054	0.196
Motor persistence		0.028	0.016	0.111	1.772	0.078	−0.003	0.059
Visual-spatial working memory		0.003	0.005	0.046	0.646	0.519	−0.007	0.014
Verbal working memory		0.008	0.026	0.018	0.297	0.767	−0.043	0.059

Note: *p <0.001.

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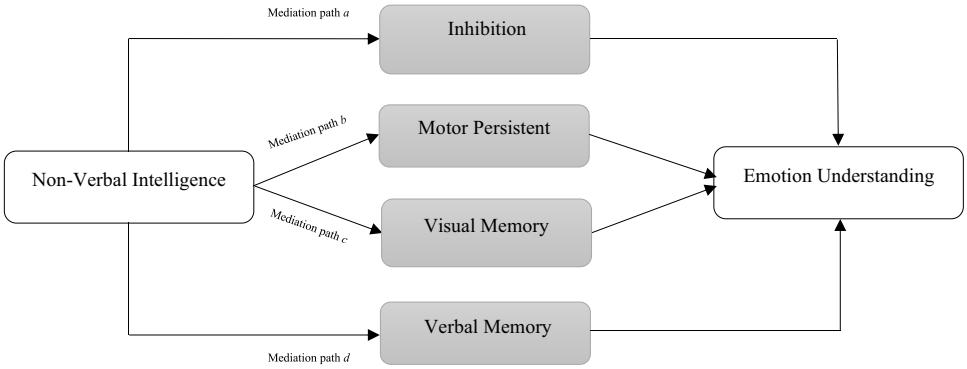

Figure 1 A conceptual model of the relations between research variables.

inhibition function positively predicted emotion understanding ($\beta = 0.251$, $P < 0.001$), while motor persistence marginally predicted emotion understanding; however, the regression coefficient was not statistically significant ($\beta = 0.111$, $P < 0.078$).

Testing the Mediating Role of Executive Cognitive Functions

To test the mediating hypotheses, a regression model based on Figure 1 was constructed. Model 4 of the PROCESS Macro program[69] was selected to test the effects of potential mediators in the relation between non-verbal intelligence and emotion understanding. Following some studies[70–74] the standardized scores (z scores) were used to test the hypotheses. The results are displayed in Table 4. As the table shows, the direct effect ($\beta = 0.190$, $p < 0.005$) and the total effect of non-verbal intelligence on emotion understanding were statistically significant. Only the inhibition cognitive function mediated the association between non-verbal intelligence and emotion understanding ($\beta = 0.068$, $p < 0.001$). Other executive cognitive functions did not mediate this association. Figure 2 shows a multiple-mediation model of five cognitive functions between intelligence and emotion understanding.

Testing the Moderating Role of Gender

To test the moderation hypotheses, a regression model based on Figure 3 was constructed. Model 58 of the Macro Process program[69] was selected to test the effects of gender on the relation between non-verbal intelligence and emotion understanding. As Table 5 shows, in the moderated mediation model the effect of non-verbal intelligence on emotion understanding was statistically significant ($\beta = 0.270$, $p = 0.0002$). Although the effect of inhibition on emotion understanding was significant ($\beta = 0.257$, $p = 0.0003$), the interaction effect of gender and inhibition on the non-verbal intelligence-emotion understanding link was not significant. Although the overall moderating role of gender

Table 4 Results of Multiple Mediation Analysis of Cognitive Functions in Intelligence-Emotion Understanding Relation (n = 272)

Effects	*β*	*SE*	*t*	*p*	*LLCI*	*ULCI*
Direct effect of non-verbal intelligence > emotion understanding	0.1906*	0.0683	2.7921	0.0057	0.0561	0.3251
Non-verbal intelligence > Inhibition > emotion understanding	0.0685*	0.0246	–	–	0.0260	0.1218
Non-verbal intelligence > Motor persistence > emotion understanding	0.0258	0.0169	–	–	−0.0016	0.0637
Non-verbal intelligence > Visual-spatial working memory > emotion understanding	0.0215	0.0309	–	–	−0.0384	0.0827
Non-verbal intelligence > Verbal working memory > emotion understanding	0.0038	0.0142	–	–	−0.0231	0.0357
Total effect of non-verbal intelligence > emotion understanding	0.1132	0.0365	–	–	0.0467	0.1895
	R^2 =0.1681; $F(6, 241)$ =8.1177, p =0.0000					

Note: *p <0.001.

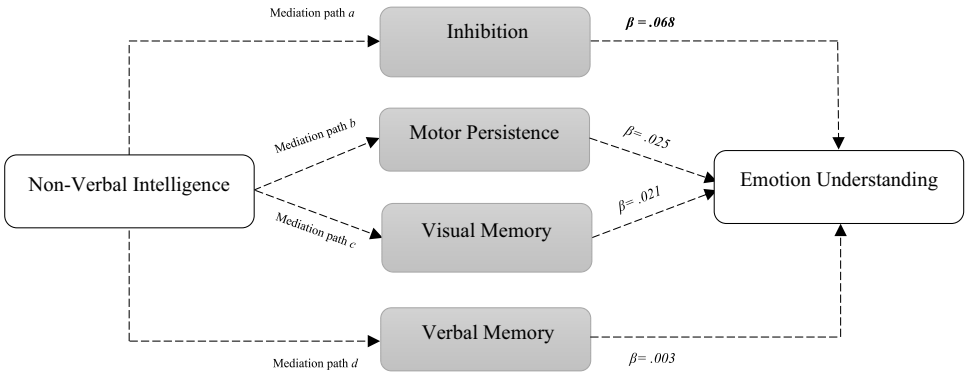

Figure 2 A multiple mediation model of five cognitive functions in relation between intelligence and emotion understanding. Bolded data represent the significant mediation effect of inhibition (β=0.068, p <0.001).

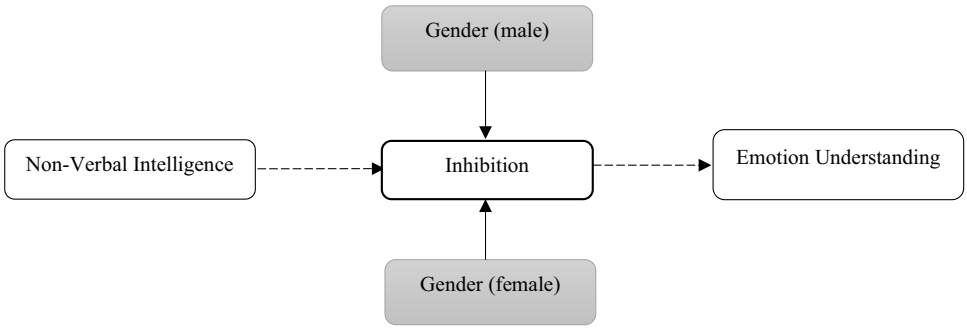

Figure 3 A moderated mediation model of relation between intelligence and emotion understanding through inhibition.

in the moderated mediation model was not statistically significant, the conditional effect for females was only significant (β = 0.350, p = 0.0001).

Figure 4 illustrates the relation between non-verbal intelligence and emotion understanding based on the changes in male and female scores in inhibition cognitive function.

Table 5 Results of Moderated Mediation Role of Gender on Executive Cognitive Functions-Emotion Understanding Relation (n = 272)

Effect	***β***	***SE***	***t***	***p***	***LLCI***	***ULCI***
Constant	0.0593	0.0666	0.8910	0.3741	−0.0720	0.1907
Effect of non-verbal intelligence on emotion understanding	0.2705**	0.0707	3.8254	0.0002	0.1310	0.4100
Effect of inhibition on emotion understanding	0.2571**	0.0693	3.7089	0.0003	0.1204	0.3938
Effect of gender on emotion understanding	−0.0352	0.0660	−0.5330	0.5946	−0.1653	0.0950
Interaction gender × inhibition in non-verbal intelligence-emotion understanding link	0.1247	0.0665	1.8767	0.0621	−0.0064	0.2559
	R^2 =0.1747; F(4, 192) =10.1594, p =0.0000					
Conditional effect of moderator	***β***	***SE***	***t***	***p***	***LLCI***	***ULCI***
Male gender	0.0911	0.1099	0.8284	0.4085	−0.1258	0.3079
Female gender	0.3505**	0.0871	4.0236	0.0001	0.1787	0.5223
Index of moderated mediation model for gender	0.0533	0.0501	–	–	−0.0378	0.1628

Note: **p <0.001.

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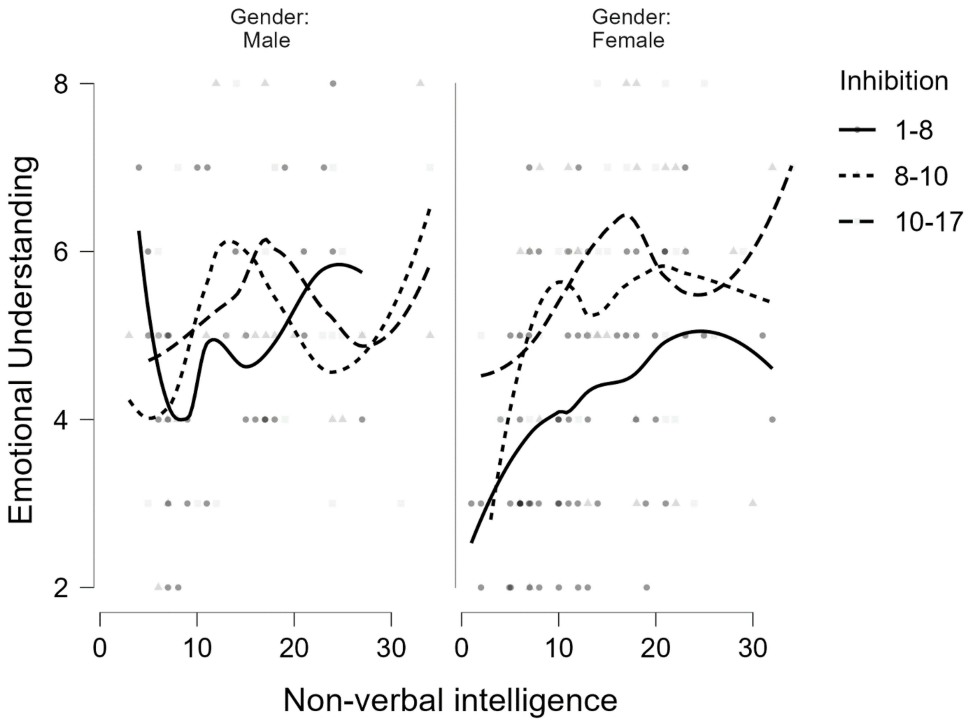

Figure 4 The relation between non-verbal intelligence and emotion understanding based on gender.

Discussion

Emotion understanding in children is influenced by complex cognitive processes, including non-verbal intelligence and executive functions like working memory. The present study aimed to explore the relationship between non-verbal intelligence and emotion understanding in children, by testing the executive cognitive mechanisms that can mediate this link. The findings provided significant insights into the cognitive mechanisms underlying emotion understanding in children.

The results of this study indicate a significant positive relationship between non-verbal intelligence and emotion understanding in children. This finding consistently replicated previous studies conducted in Italy[7,8] and provided additional empirical evidence suggesting that cognitive abilities, including non-verbal intelligence, play a crucial role in the development of emotion understanding. Non-verbal intelligence, which encompasses skills such as pattern recognition and problem-solving without the use of language, appears to facilitate children's ability to comprehend and interpret emotional cues. This relationship underscores the interconnectedness of cognitive and emotional development, suggesting that enhancing non-verbal cognitive skills may also promote better emotion understanding. An explanation for this finding is that non-verbal intelligence facilitates the recognition and interpretation of emotional cues, which is crucial for developing emotional competence.[7,28] Thus, it may enhance the cognitive resources and working memory capacity of children. According to working memory theory, children with more cognitive resources[75] and higher working capacity[37] are better able to process, understand and integrate emotional information.

Cognitive functions were positively associated with both non-verbal intelligence and emotion understanding. However, as can be seen in Table 2, two out of five executive functions, inhibition and visual memory, appeared to have stronger associations with both non-verbal intelligence and emotion understanding than other cognitive functions. The results of regression supported this finding that only inhibition function significantly predicted emotion understanding in children. This increased the likelihood that the contribution of non-verbal intelligence to emotion understanding may be passed partially through these two specific cognitive functions. To examine this hypothesis, a multiple mediation model was constructed and examined. As the mediation results revealed only inhibition cognitive function mediated this association.

The findings suggest that children with better inhibition abilities are more likely to suppress impulsive responses and reactions and focus on relevant emotional cues, thus enhancing their emotion understanding. This is consistent with the definition of inhibition presented by Diamond.[47] According to Diamond,[47] inhibition refers to

> The ability to control impulsive responses and focus attention, is crucial for processing emotional information and regulating emotional responses.

The other cognitive functions did not mediate this path, which suggests that these functions are not directly involved in the relation between non-verbal intelligence and emotion understanding. This might be related to the specific nature of emotional tasks that require immediate, relevant and context-specific responses that are managed by inhibitory control than to other executive functions.[37] The findings of this study are consistent with previous studies that demonstrate the importance of cognitive abilities in developing emotion understanding.[76] The findings highlight the specific contribution of inhibition to the development of emotion understanding in children suggesting that inhibition, which is a kind of self-regulation skill, is particularly crucial for emotion understanding.

Gender Differences in Moderated Mediation Model

This study also examined the effect of gender on the way the inhibition of cognitive function influences the association between non-verbal intelligence and emotion understanding. Although we expected to find a difference in inhibition mediation role between female and male participants when it was low (1–8 score), the results of the moderated mediation model did not support this hypothesis. However, after we tested the conditional moderating role of gender it appeared that this link is moderated among female participants. This finding contrasts with some previous studies that suggested gender differences in emotional regulation and cognitive-emotional processing.[35,43] One explanation for the lack of a similar finding may be associated with our imbalanced sample in which the female participants were overrepresented.

Research and Practical Implications

The findings of this study lead to some implications. First, they underline the critical role of non-verbal intelligence in developing emotion understanding and suggest that interventions designed to enhance cognitive abilities might also have a positive effect on emotional development. Second, the identification of inhibition as a partial mediator points to the fact that, compared with other aspects of emotional processing, self-regulation skills are more important. Educational and therapeutic programs that aim at enhancing inhibitory control may thus be valuable in promoting emotion understanding of children. Third, although gender did not moderate the mediating role of inhibition, probably due to an imbalanced sample, the comparison of results showed differences between the two genders that may be investigated by future studies and larger sample sizes.

Limitations and Suggestions

This study has several limitations that are presented here. First, this cross-sectional nature of the study restricts making any causality between variables. Longitudinal studies would have clarified how intelligence-emotion understanding may change over time in children. Second, using self-report scales for data collection may have increased the risk of social desirability among participants. We suggest future studies to apply more comprehensive and objective assessments such as observational assessments or interviews. Third, female participants in this study were overrepresented which may have influenced the findings. As such, we recommend future researchers to use more balanced samples in terms of gender. This could be particularly important when we test the role of gender in a moderated mediation model.

Conclusion

This study provided evidence verifying the role of cognitive abilities in shaping emotion understanding during childhood development. The positive relation between non-verbal intelligence and emotion understanding reveals that the two variables are interconnected. However, this correlation or covariation of these two constructs appears not to occur consistently or fully. That is why studying and testing mediating variables may further provide insights to explain the contribution of non-verbal intelligence to emotion understanding in children. Inhibition is a key mediator in this

relationship, while other executive functions appear less influential. These findings highlight the complex nature of cognitive-emotional interactions in children, and more studies are required to detect how cognitive-emotional interactions may occur in different developmental phases.

Data Sharing Statement

The data will be available upon request at: mortezacharkhabi@yahoo.com.

Ethical Information

Ethics approval was granted by the Ethics Committee of the Faculty of Psychology at Lomonosov Moscow State University (Ethics No: 2018/43).

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Disclosure

The authors declare that they have no conflicts of interest in this work.

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