Negative Emotion Regulation Characteristics and Intervention in Children with Autism: Mindfulness and Cognitive Strategy Training Based on Multimodal Assessment

Authors: Feng Tingyong, Wang Xueke, Deng Fang, Feng Tingyong

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Abstract

Effective coping and management of negative emotions is an essential competency for children with Autism Spectrum Disorder (ASD) to adapt to society; however, previous research has predominantly focused on emotion recognition and emotion understanding, with less attention devoted to the emotion regulation characteristics of children with ASD and related interventions. To this end, the present study integrated multimodal (questionnaires, behavioral observation, and physiological measurement) and multi-scenario (laboratory, daily life) assessment methods to comprehensively examine the emotion regulation characteristics of children with ASD, and further investigated the ameliorative effects of mindfulness and cognitive behavioral strategy training on their emotion regulation. Experiment 1 collected coping strategies for negative emotions and physiological indicators from children with ASD (n=23) and typically developing children (n=22) through a frustration task, and evaluated their emotion regulation abilities in daily life via questionnaires. Results revealed that children with ASD employed more maladaptive regulation strategies when coping with negative emotions, and exhibited characteristics of significantly higher physiological arousal levels, greater variability, and slower recovery; parent reports also indicated that children with ASD experienced negative emotions more frequently in daily life, with emotion regulation abilities lower than those of typically developing children. Based on these findings, Experiment 2 developed a comprehensive intervention protocol integrating mindfulness and cognitive behavioral strategies, and employed a 2 (intervention group, control group) $\times$ 2 (pre-test, post-test) experimental design, with the intervention group receiving 8 weeks of training, twice weekly, 60 minutes per session, with 2-3 participants per group. Results demonstrated that compared to the control group, the intervention group showed a significant increase in the frequency of using adaptive

strategies and a significant decrease in maladaptive strategies in the laboratory scenario post-training, along with significantly enhanced emotion regulation abilities in daily life. This study illuminates the pervasive difficulties of children with ASD in emotion regulation, and provides a novel pathway of multimodal assessment and comprehensive intervention for improving their emotion regulation capabilities.

Full Text

Characteristics and Interventions of Negative Emotion Regulation in Children with Autism: Mindfulness and Cognitive Strategy Training Based on Multimodal Assessment

Wang Xueke, Deng Fang, Feng Tingyong
(Faculty of Psychology, Southwest University, Chongqing 400715, China)

Abstract

Effective management of negative emotions is an essential capacity for children with autism spectrum disorder (ASD) to adapt to social environments. However, previous research has predominantly focused on emotion recognition and comprehension, with limited attention devoted to the specific characteristics of emotion regulation in ASD children and corresponding intervention strategies. To address this gap, the present study employed a multimodal assessment approach integrating questionnaires, behavioral observations, and physiological measurements across multiple contexts (laboratory and daily life) to comprehensively examine emotion regulation characteristics in ASD children and investigate the ameliorative effects of mindfulness and cognitive-behavioral strategy training.

In Study 1, we collected data on negative emotion coping strategies and physiological indices from children with ASD ($n = 23$) and typically developing (TD) children ($n = 22$) during a frustration task, while also assessing their daily emotion regulation abilities through parental questionnaires. Results revealed that ASD children employed significantly more maladaptive regulation strategies when confronting negative emotions, exhibited markedly higher physiological arousal with greater variability, and demonstrated slower recovery rates. Parental reports further indicated that ASD children experienced negative emotions more frequently in daily life and possessed poorer emotion regulation capacities compared to TD children.

Building upon these findings, Study 2 developed an integrated intervention protocol combining mindfulness and cognitive-behavioral strategies. Using a 2 (intervention vs. control group) × 2 (pre- vs. post-test) experimental design, the intervention group received eight weeks of training, with two 60-minute sessions per week conducted in groups of 2–3 children. Post-intervention assessments demonstrated that, relative to the control group, the intervention group showed significant increases in adaptive strategy use and decreases in maladaptive strategies during laboratory tasks, alongside substantial improvements in daily emotion regulation abilities. These findings underscore the pervasive emotion regulation difficulties in ASD children and provide a novel pathway for improving their regulatory capacities through multimodal assessment and integrated intervention.

Keywords: autism spectrum disorder, emotion regulation, multimodal assessment, mindfulness intervention, cognitive-behavioral strategies

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Autism spectrum disorder (ASD) is a neurodevelopmental condition emerging in early childhood, characterized by core deficits in social communication and the presence of restricted, repetitive patterns of behavior and interests (American Psychiatric Association, 2013). The global prevalence among children is approximately 1%, with an upward trend (Zeidan et al., 2022). In China, the population of individuals with ASD exceeds 10 million, including over 2 million children aged 0–12, imposing substantial burdens on families and society (Zhou et al., 2020). Social communication impairments in ASD are frequently accompanied by emotional difficulties. Research indicates that emotion dysregulation is common in ASD populations (Cibralic et al., 2019; Restoy et al., 2024) and represents a critical risk factor for problem behaviors (e.g., aggression, self-injury), affective disorders (e.g., anxiety, depression), and social functional impairments (e.g., academic performance, interpersonal relationships) (Northrup et al., 2021; Samson et al., 2015). The importance of emotion dysregulation in ASD diagnosis and intervention has become increasingly prominent (Beck et al., 2021; Nuske et al., 2024). Therefore, investigating the characteristics of emotion regulation in ASD children and implementing targeted interventions are crucial for alleviating symptoms and enhancing social adaptation.

1.1 Emotion Regulation in Children with Autism Spectrum Disorder

Emotion regulation is defined as the capacity to monitor, evaluate, and modify emotional responses to achieve one's goals (Gross, 2013). Effective emotion regulation enables individuals to control the intensity and duration of negative emotions and employ appropriate strategies for management (Thompson, 2019). However, parents and teachers frequently report that most ASD children exhibit emotional problems such as tantrums, irritability, anxiety, and impulsivity, likely stemming from atypical emotional responses and inappropriate regulation strategies when facing negative or stressful events (Cibralic et al., 2019). Studies have found that ASD children often experience more intense and prolonged negative emotions (Jahromi, 2012; Northrup et al., 2020). A meta-analysis of 55 studies revealed that, compared to TD peers, ASD children use fewer adaptive strategies and more maladaptive emotion regulation strategies (Restoy et al., 2024). Moreover, emotion regulation difficulties further impact social adaptation in ASD children. On one hand, ASD children not only experience negative emotions through "emotional outbursts" but may also display aggressive or self-injurious behaviors, leading to deteriorated interpersonal relationships (Nuske et al., 2017; Samson et al., 2015). On the other hand, the inability to effectively employ adaptive strategies may exacerbate comorbid issues such as anxiety and depression, subsequently affecting academic performance and quality of life (Cibralic et al., 2019). Although researchers recognize the critical role of emotion dysregulation in understanding core ASD symptoms and problem behaviors, intervention studies targeting emotion regulation in ASD children remain scarce in China, leaving their difficulties in managing negative emotions largely unaddressed. Therefore, this study focuses on the emotion regulation challenges of ASD children, particularly their approaches to handling negative emotions, to provide intervention insights and protocols for improving their regulatory capacities.

1.2 Multimodal Assessment of Emotion Regulation in ASD Children

Multimodal assessment of emotion regulation in ASD children encompasses various methods and techniques, including questionnaire evaluation, behavioral observation, physiological measurement, and neuroimaging. Questionnaire assessment represents the most common method for daily measurement. The Emotion Regulation Checklist (ERC) and Emotion Dysregulation Inventory (EDI) are frequently used to evaluate emotion regulation abilities in ASD children in daily life (Mazefsky et al., 2018; Shields & Cicchetti, 1997). While questionnaires offer a quick and convenient way to quantify children's emotion regulation capacities, they are susceptible to subjectivity and informant bias. Behavioral observation provides standardized coding of children's emotional expressions, offering more objective behavioral indicators. In such assessments, children are placed in specific emotion-eliciting situations (e.g., frustration, anger, fear), and researchers record and code their behavioral responses and coping strategies in real time (Goldsmith & Rothbart, 1999; Weiss et al., 2014). However, behavioral observation only captures external behavioral strategies and lacks sensitivity to internal emotional reactivity (Cibralic et al., 2019). Therefore, multimodal assessment should incorporate more sensitive and objective physiological indicators to evaluate emotional arousal and physiological changes in ASD children during emotion induction.

The Neurovisceral Integration Model (NIM) provides a crucial theoretical framework for understanding the relationship between the autonomic nervous system (ANS) and emotion regulation (Thayer & Lane, 2000). This model proposes that the ANS integrates physiological signals with higher-order cognitive processes through interactions between the prefrontal cortex and limbic system (e.g., amygdala), thereby regulating emotional responses and behavioral adaptation (Grol & De Raedt, 2020; Thayer et al., 2012). Within this framework, the ANS regulates individuals' emotional responses and coping capacities by balancing sympathetic and parasympathetic nervous systems, particularly when facing emotional and stress challenges, with ANS physiological processes providing a critical foundation for emotion regulation (Arora et al., 2021). Heart rate (HR), as a physiological marker reflecting both sympathetic and parasympathetic activity, serves as an index of autonomic arousal that sensitively captures changes in emotional activation (Kreibig, 2010; Yuan et al., 2015). Skin conductance response (SCR) reflects sympathetic nervous system activation levels, rapidly capturing transient physiological arousal changes elicited by emotional stimuli, and is commonly used to quantify emotional response intensity and regulation efficiency (Critchley, 2002). Previous research has demonstrated that atypical ANS activity is closely associated with emotion dysregulation in ASD. For instance, Cai et al. (2019) found that higher resting heart rate variability in adults with ASD was associated with more adaptive emotion regulation strategies (e.g., cognitive reappraisal). Chiu et al. (2024) reported that lower resting heart rate variability was linked to emotion dysregulation in adolescents with ASD, suggesting that ANS disruption may contribute to emotion regulation difficulties in this population. Regarding SCR, Kushki et al. (2013) found that adolescents with ASD exhibited significantly higher mean SCR levels than TD peers during anxiety states, indicating that sympathetic over-arousal may serve as an identifier for anxiety in ASD (Chiu et al., 2016). Vernetti et al. (2020) demonstrated that ASD children showed weaker electrodermal responses when processing negative emotional stimuli, and this diminished physiological reactivity was associated with regulatory impairments when processing complex emotional information. These findings support the NIM model's proposition that disrupted ANS functioning in ASD children may hinder their ability to flexibly regulate physiological and psychological states during emotional tasks. However, existing research has primarily focused on resting-state ANS activity in adolescents or adults, lacking physiological measurements of the ANS during emotional tasks in ASD children. Real-time collection of HR and SCR data during emotional tasks can more accurately assess emotional states and arousal levels in ASD children, offering new avenues for diagnosis and intervention.

Current research on emotion regulation characteristics in ASD children still relies predominantly on single methods such as behavioral observation or questionnaire assessment, with few systematic investigations using multimodal approaches (Beck et al., 2021; Restoy et al., 2024). Gross's (1998) process model of emotion regulation emphasizes that emotion regulation is a dynamic, continuous process spanning multiple stages of emotion generation, including situation selection, attention allocation, and response modulation. Within this framework, single assessment methods often fail to capture the multidimensional nature of emotion regulation. Specifically, questionnaire assessment primarily depends on parents' subjective perceptions of children's emotion regulation abilities, making it suitable for evaluating overall regulatory capacity but ill-suited for revealing dynamic changes during the regulation process. Behavioral observation can objectively capture children's coping strategies and behavioral manifestations in natural or semi-structured contexts, particularly for analyzing post-emotional response behaviors. Physiological indicators (e.g., heart rate variability, skin conductance response) can quantify physiological arousal levels and their changes in real time during emotion generation and regulation, helping to illuminate underlying mechanisms. Therefore, integrating questionnaires, behavioral observation, and physiological measurement not only enables comprehensive examination of emotion regulation characteristics from multiple dimensions, reducing limitations and biases of single methods, but also sensitively captures individual differences in emotional responses and processing, providing a scientific basis for developing personalized intervention plans. Additionally, researchers are concerned with the extent to which assessed emotion regulation reflects children's actual performance. Lavender et al. (2017) noted that current research overemphasizes trait characteristics and general tendencies while neglecting dynamic variations across contexts. To address this, the present study combined laboratory and daily life contexts to comprehensively examine emotion regulation characteristics in ASD children. In the laboratory context, frustration tasks can effectively capture immediate responses (generation phase) and subsequent processing (recovery phase) to negative emotions, objectively documenting coping strategies (Jahromi, 2012; Zantinge et al., 2017). In daily life contexts, parental reports reflect children's emotional responses and specific coping strategies across various real-world situations, providing a more ecologically valid perspective. Thus, by combining multimodal (questionnaire, behavioral observation, physiological measurement) and multicontext (laboratory, daily life) assessments, this study precisely captures real-time responses and processing of negative emotions while comprehensively portraying emotion regulation characteristics across contexts, offering a scientific foundation for accurately understanding emotion regulation difficulties in ASD children.

1.3 Interventions for Emotion Regulation in ASD Children

Emotion regulation difficulties in ASD children represent a pressing issue in clinical practice (Hyman et al., 2020). Previous intervention research has primarily focused on emotion recognition deficits or comorbid emotional problems, neglecting in-depth analysis of emotion regulation itself (Beck et al., 2021). Based on the emotion regulation characteristics of ASD children when facing negative emotions, we can develop targeted intervention protocols to improve their regulatory capacities. Research indicates that ASD children often exhibit heightened arousal levels during negative emotional experiences and struggle to control the intensity and duration of emotional responses (Cibralic et al., 2019; Northrup et al., 2020). Consequently, reducing emotional arousal and enhancing self-control become primary targets for intervention, aligning closely with the core principles of mindfulness (Lindsay & Creswell, 2019; Li et al., 2019). Mindfulness aims to cultivate non-judgmental attention to present-moment emotional and physical states (Kabat-Zinn, 2003) and has been widely applied to emotional problems such as anxiety and depression. From a mechanistic perspective, mindfulness influences emotion generation and regulation through awareness and acceptance of emotional experiences (Raugh & Strauss, 2024). Specifically, mindfulness helps individuals focus attention on the present moment, increasing sensitivity to emotional changes—both external bodily sensations (e.g., flushed cheeks, accelerated heartbeat) and internal thought patterns (e.g., thinking styles that may exacerbate negative emotions) (Poquerusse et al., 2021; Ridderinkhof et al., 2020). Simultaneously, mindfulness reduces arousal levels toward emotional changes through acceptance training (non-judgmental acceptance of present experiences), fostering more positive emotional engagement (Lindsay & Creswell, 2017). Existing research demonstrates that mindfulness-based interventions can reduce anxiety, stress, and aggressive behaviors while improving quality of life in individuals with ASD (Loftus et al., 2023; Ridderinkhof et al., 2020). However, most studies have focused on adolescents or adults, with limited research directly targeting emotion regulation in ASD children.

In addition to mindfulness interventions, cognitive-behavioral therapy (CBT) plays a crucial role in helping children cope with daily emotional challenges. CBT alleviates core ASD symptoms and emotional problems by identifying and modifying negative thought patterns and behavioral strategies (Sharma et al., 2018; Wang et al., 2021). CBT emphasizes helping individuals with ASD identify triggers for negative emotions and guiding them to learn and master alternative emotion regulation strategies through structured interventions. Research has validated the effectiveness of CBT in improving anxiety, affective communication, and social skills in ASD populations (Weston et al., 2016; Wood et al., 2020). However, traditional CBT typically relies on complex metacognitive abilities to identify and modify irrational thought patterns, which can be challenging for preschool-aged ASD children. Therefore, intervention curricula must be adapted to individual differences and specific needs, such as simplifying language and cognitive concepts, enhancing visual supports and gamification elements, and emphasizing strategy instruction and contextualized practice to improve engagement and strategy mastery. Notably, an integrated intervention model combining mindfulness with CBT may be more effective in enhancing emotion regulation in ASD children. On one hand, mindfulness emphasizes awareness and acceptance of present-moment emotional and sensory experiences, fostering sensitivity to emotional triggers and reducing overreactions to negative emotions (Poquerusse et al., 2021). On the other hand, CBT focuses on explicit strategy instruction through activities such as emotion identification training, social scenario simulation, and role-playing, helping children apply learned emotion regulation strategies in real social contexts to consolidate their skills (Conner et al., 2019). For preschool-aged ASD children, this combination is particularly important because the non-verbal nature of mindfulness practices reduces cognitive load while providing a foundation for emotional awareness and acceptance, whereas CBT's structured instruction further transforms awareness into actionable behavioral strategies, enhancing emotional management skills. For example, specific curriculum designs might use mindfulness techniques like "body coloring" to guide children in noticing emotional changes, followed by structured formats using visual cue cards and role-playing to help them identify emotion types and practice constructive coping strategies. In summary, integrating mindfulness with cognitive-behavioral strategies not only addresses active awareness and acceptance of emotional experiences but also emphasizes strategy application in real-world contexts, thereby constructing a "capacity-building" and "strategy-acquisition" complementary support system that more effectively promotes comprehensive development of emotion regulation in ASD children.

Despite the promise of combined mindfulness and cognitive-behavioral interventions, current research has primarily concentrated on social skills or behavioral management, neglecting the unique emotion regulation needs of ASD populations and lacking integrated protocols that combine both approaches. Therefore, this study designed and implemented an eight-week comprehensive intervention curriculum targeting core emotion regulation difficulties in preschool-aged ASD children, integrating mindfulness training with cognitive regulation strategies to systematically enhance their emotion regulation capacities and provide new theoretical perspectives and practical pathways for ASD emotional intervention.

In summary, this study employs a multimodal, multicontext assessment approach to comprehensively examine emotion regulation characteristics in ASD children and develops an integrated mindfulness and cognitive-behavioral intervention protocol to significantly improve their regulatory abilities. To achieve this goal, the study comprises two main experiments. Study 1 uses multimodal assessment methods including behavioral coding, physiological measurement, and questionnaire evaluation to systematically investigate emotion regulation characteristics in ASD children across laboratory and daily life contexts. Specifically, Study 1 employs a frustration task to collect children's coping strategies and physiological indices when facing negative emotions, while questionnaires assess their daily emotion regulation abilities. Study 2 develops an integrated mindfulness and cognitive-behavioral intervention protocol using a pre-post test design with intervention and control groups. The intervention group receives group training twice weekly for 60 minutes per session over eight weeks (16 sessions total), with 2–3 children per group. Study 2 aims to investigate whether, compared to the control group, the intervention group shows significant improvements in emotion regulation abilities, strategy utilization, and physiological arousal levels following training.

2.1 Participants

For Study 1, 26 children with ASD were recruited from the Children's Hospital of Chongqing Medical University. Three children were excluded due to low parental compliance or inability to understand the experimental tasks, resulting in a final sample of 23 children (20 boys, 3 girls) with a mean age of 6.57 years (SD = 0.85, range = 5–7 years). All children received a formal diagnosis of ASD from attending physicians in pediatrics or psychiatry at the Children's Hospital of Chongqing Medical University according to the Diagnostic and Statistical Manual of Mental Disorders (5th ed.; DSM-5; APA, 2013). Symptom severity was reassessed using the Childhood Autism Rating Scale (CARS), with scores ranging from 30 to 36 (M = 32.95, SD = 1.69). Additional inclusion criteria included: Wechsler Intelligence Scale scores > 70, no significant language impairments, and no comorbid neurological disorders (e.g., epilepsy, cerebral palsy) or other organic diseases.

Twenty-two TD children matched for chronological age were recruited from local township elementary schools (10 boys, 12 girls) with a mean age of 6.81 years (SD = 0.05, range = 6–7 years). Teacher interviews and ratings were used to exclude ASD, intellectual developmental delays, and other psychiatric conditions, and to confirm no family history of ASD. The Peabody Picture Vocabulary Test-Revised (PPVT-R) was administered to both groups to assess receptive vocabulary and match verbal comprehension abilities, controlling for potential confounding effects on emotion regulation. Paired-sample t-tests revealed no significant differences between groups in verbal ability or chronological age, ensuring that differences in task performance primarily reflected emotion regulation characteristics of ASD children. Detailed demographic information is presented in Table 1 . No participants had prior experience with similar emotion experiments. Informed consent was obtained from all children's guardians, and the study was approved by the Ethics Committee of the Faculty of Psychology at Southwest University.

2.2 Experimental Design

To comprehensively examine emotion regulation characteristics in ASD children, a single-factor between-subjects design was employed with participant group (ASD vs. TD) as the independent variable. Dependent variables included emotion regulation features assessed through laboratory-based (lock-box task) emotion regulation strategies and physiological indices, as well as daily life (questionnaire) emotion regulation abilities.

2.3 Procedure and Materials

Prior to the formal experiment, experimenters conducted one-on-one interviews with caregivers and intervention teachers of ASD children to understand toy preferences, potentially frightening or uncomfortable scenarios, and emotional characteristics. The experiment took place in a quiet, appropriately lit room. Upon arrival, experimenters engaged children in play to familiarize them with the environment and reduce potential anxiety. After acclimation, the formal experimental session began.

2.3.1 Lock-Box Task

This study used a lock-box task to elicit negative emotions and record behavioral responses and physiological indices during emotion generation and recovery phases. Adapted from the frustration task in the Preschool Laboratory Temperament Assessment Battery (Lab-TAB; Goldsmith et al., 1999), the task involved providing children with an incorrect set of keys to prevent access to a desired toy, followed by announcement of task failure to induce frustration. Research has demonstrated this task effectively elicits negative emotions in 3–6-year-old children (Dyson et al., 2015; Hirschler-Guttenberg et al., 2015; Zantinge et al., 2017).

The task comprised four stages: (1) Toy selection: Children sat at a table and selected their favorite toy from an array (e.g., Ultraman figures, toy cars, Legos). To ensure each child could find a preferred toy, experimenters interviewed parents and intervention teachers beforehand about toy preferences. (2) Rule explanation: Experimenters explained that the selected toy would be placed in a transparent locked box, and that only one key from a provided set could open it. If unsuccessful, the task would be considered a failure and the toy would not be obtained. In reality, none of the keys could open the box. To ensure comprehension among ASD children, experimenters used brief, concrete language: "Your chosen toy will be locked in this box. Try these keys—only one can open it." Visual aids including the transparent lock-box, key set, and lock were used to establish concrete understanding of the task procedure. Experimenters also demonstrated the key-turning process to enhance comprehension of operational steps. For children with weaker communication abilities, non-verbal supports such as gestural prompts and pointing were provided to ensure all children understood basic task rules before proceeding. (3) Lock-attempt phase: Children were given three minutes to attempt opening the box with the keys. The experimenter observed from across the table without providing assistance or feedback. After three minutes, the experimenter announced task failure and that the toy could not be obtained. (4) Recovery phase: Immediately following the task, experimenters provided emotional comfort, offered the correct key to successfully open the box and obtain the toy reward, explained the experimental purpose, and helped children correctly understand the situation to eliminate potential confusion. Additionally, a small gift was provided as appreciation for participation.

Throughout the experiment, a Sony AX60 video camera and wearable bracelets (Zhongke Xinyan) recorded children's behavioral responses and physiological indices during the lock-box task. The camera captured full-body movements, lock-box details, and key usage, while the bracelets collected real-time heart rate (HR) and skin conductance response (SCR) as physiological indicators of emotion.

2.3.2 Emotion Regulation Checklist

Concurrently with the lock-box task, another experimenter instructed parents to complete the Emotion Regulation Checklist (ERC) to assess children's emotion regulation abilities in daily life. The ERC contains 24 items divided into two dimensions: Emotion Regulation and Lability/Negativity (Shields & Cicchetti, 1997). The Emotion Regulation dimension assesses appropriate emotional expression, regulation, and self-awareness in specific contexts, while the Lability/Negativity dimension evaluates flexibility, instability, and difficulty regulating negative emotions. The scale demonstrates good reliability and validity in Chinese preschool populations (Zhu et al., 2020). TD children completed identical procedures including the lock-box task and ERC assessment. All experimenters and research staff received professional training to ensure strict adherence to experimental protocols.

2.4 Data Coding and Collection

2.4.1 Behavioral Coding Indices

Drawing on Jahromi et al.'s (2012) detailed classification of children's emotion regulation behaviors and Zantinge et al.'s (2017) categorization of regulation types, this study identified 13 emotion regulation strategies classified into three categories: (1) Constructive strategies: goal-directed behavior, support seeking, cognitive reappraisal, self-comforting, comfort seeking, and distraction, aimed at promoting emotional adaptation through active regulation; (2) Venting strategies: vocal venting, physical venting, self-talk, and repetitive stereotyped behaviors, reflecting maladaptive emotional expression; (3) Avoidance strategies: avoidance, distraction, and substitution, reflecting maladaptive emotional suppression. Detailed descriptions and coding criteria are provided in Table 2 . This classification system, grounded in theory and functional attributes, effectively captures primary coping patterns in ASD children during frustration tasks, aligns with their limited expressive capacities, and facilitates standardized behavioral coding (Aldao et al., 2010; Jahromi et al., 2012).

Continuous behavioral observation coding was conducted using 10-second time windows to code presence (1) or absence (0) of each strategy. Since strategies were assessed independently, multiple strategies could be coded within the same time window. During the 3-minute (180-second) lock-box task, the first 30 seconds were excluded from coding as children were primarily engaged in initial lock-attempt attempts without significant frustration (Zantinge et al., 2017). Thus, the actual coding duration was 150 seconds (15 time windows). Frequencies of the 13 strategies were calculated, and sub-strategy frequencies within each of the three categories were summed to create quantitative indices. Two trained coders independently coded children's behaviors based on the 13 strategies, with videos of ASD and TD children presented randomly to eliminate bias. Inter-coder reliability coefficients were 0.73 for constructive strategies, 0.72 for venting strategies, and 0.77 for avoidance strategies.

2.4.2 Physiological Data Acquisition

Multimodal wristbands and computing kits were used to collect HR and SCR data throughout the task. The hardware core consisted of a wearable bracelet sensor with real-time data transmission to a computing terminal. The system automatically detected and calibrated pulse waves and supported feature extraction and analysis of raw data. Indices included: mean heart rate level (HR), skin conductance response (SCR), and peak occurrence rate (PKO).

Physiological data collection was divided into three phases: (1) A 60-second baseline phase (during rule explanation) to calculate HR, commonly used to measure emotional arousal; (2) A 150-second negative emotion induction phase (during lock-box task) with continuous HR collection and SCR analysis to quantify emotional response intensity; (3) A 60-second recovery phase with continued HR collection to assess changes in recovery from emotional load. Additionally, to understand the overall impact of the frustration task, PKO of SCR during the negative emotion phase (lock-box task, 150 seconds) was analyzed to detect peak frequency and reveal emotional volatility during the assessment period.

2.5 Study 1 Results

2.5.1 Emotion Induction Validity

Comparisons of physiological indices between baseline and negative emotion induction phases revealed significantly higher HR during negative emotion induction ($M_{baseline} = 94.80$, $SD_{baseline} = 8.89$ vs. $M_{frustration} = 101.71$, $SD_{frustration} = 10.01$; $t(44) = 5.54$, $p < 0.001$, Cohen's d = 0.83), confirming successful emotion induction and demonstrating that the lock-box task effectively elicited negative emotions.

2.5.2 Behavioral Characteristics of Emotion Regulation in ASD Children: Behavioral Coding Analysis

Independent samples t-tests examining differences in emotion regulation strategy use between ASD and TD children revealed significant group differences (see Table 3). For constructive strategies, ASD children used significantly fewer than TD children, $t(43) = 5.40$, $p < 0.001$, Cohen's d = -1.61. For venting strategies, ASD children showed significantly higher usage than TD children, $t(43) = 3.88$, $p < 0.001$, Cohen's d = 1.16. For avoidance strategies, ASD children also demonstrated significantly higher usage than TD children, $t(43) = 3.32$, $p = 0.002$, Cohen's d = 0.99. These results indicate that compared to TD children, ASD children employ more maladaptive emotion regulation strategies (venting and avoidance) and fewer adaptive strategies when experiencing negative emotions.

Table 3

Differences in Emotion Regulation Strategies Between ASD and TD Children

Strategy Type	ASD Group (n = 23)	TD Group (n = 22)	t(df)	Cohen's d
Constructive	11.17 (3.17)	14.91 (0.68)	-5.40 (43)	< 0.001
Venting	2.91 (3.46)	0.05 (0.21)	3.88 (43)	< 0.001
Avoidance	2.39 (3.06)	0.18 (9.66)	3.32 (43)	0.002

2.5.3 Physiological Characteristics of Negative Emotion Regulation in ASD Children: Physiological Indices

A 2 (Group: ASD vs. TD) × 3 (Emotion Induction Phase: baseline, induction, recovery) repeated measures ANOVA examined group differences in HR across phases. Results showed significant main effects for Group, $F(1, 43) = 8.70$, $p = 0.005$, $p^2 = 0.168$, and Phase, $F(2, 86) = 19.75$, $p < 0.001$, $p^2 = 0.315$, with a significant Group × Phase interaction, $F(2, 86) = 4.09$, $p = 0.021$, $p^2 = 0.087$. Simple effects analysis (see Figure 1 [Figure 1: see original paper]) revealed no significant HR differences between groups at baseline (M_{ASD} = 96.52, SD_{ASD} = 8.26 vs. M_{TD} = 92.90, SD_{TD} = 9.24, p = 0.175). However, during negative emotion induction, ASD children showed significantly higher HR than TD children (M_{ASD} = 105.47, SD_{ASD} = 9.02 vs. M_{TD} = 97.74, SD_{TD} = 9.64, p = 0.008). In the recovery phase, ASD children continued to show significantly higher HR (M_{ASD} = 103.34, SD_{ASD} = 8.89 vs. M_{TD} = 93.55, SD_{TD} = 9.28, p = 0.001). For ASD children, HR in both negative emotion induction ($p < 0.001$) and recovery phases ($p < 0.001$) was significantly higher than baseline, with no significant difference between induction and recovery phases ($p = 0.112$). For TD children, HR during negative emotion induction was significantly higher than both baseline ($p = 0.026$) and recovery phases ($p = 0.001$), with no significant difference between baseline and recovery ($p = 0.978$). These findings indicate that compared to TD children, ASD children show higher negative emotion arousal and greater difficulty returning to baseline levels.

Figure 1
Mean heart rate of ASD and TD children across negative emotion induction phases

Independent samples t-tests comparing SCR indices during negative emotion induction revealed that ASD children exhibited significantly higher SCR than TD children, $t(43) = 2.83$, $p = 0.007$, Cohen's $d = 0.84$, and significantly higher peak occurrence rates, $t(43) = 2.57$, $p = 0.014$, Cohen's $d = 0.77$ (see Table 4). This demonstrates that ASD children show significantly greater physiological arousal and emotional volatility when facing frustration tasks. Overall, physiological indices indicate that ASD children exhibit higher negative emotion arousal, greater emotional fluctuations, and slower recovery when confronted with identical frustration situations.

Table 4
Differences in Physiological Indices Between ASD and TD Children

Physiological Index	ASD Group (n = 23)	TD Group (n = 22)	t(df)	Cohen's d
SCR mean (S)	0.77 (0.63)	0.36 (0.27)	2.83 (43)	0.84
Peak occurrence	0.83 (0.05)	0.78 (0.08)	2.57 (43)	0.77

2.5.4 Daily Life Emotion Regulation Characteristics: Questionnaire Assessment

Questionnaire comparisons revealed significant differences between ASD and TD children in daily emotion regulation abilities (see Table 5). On the Emotion Regulation dimension, ASD children scored significantly lower than TD children, $t(43) = -3.14$, $p = 0.003$, Cohen's $d = -0.95$. On the Lability/Negativity dimension, ASD children scored significantly higher, $t(43) = 3.70$, $p < 0.001$, Cohen's $d = 1.12$. These results indicate that ASD children have poorer self-regulation abilities, more unstable emotions, and greater difficulty regulating their emotions in daily life situations.

Table 5

Differences in Questionnaire Scores Between ASD and TD Children

Dimension	ASD Group (n = 23)	TD Group (n = 22)	t(df)	Cohen's d
Emotion Regulation	22.35 (1.95)	24.29 (2.15)	-3.14 (43)	0.003
Lability/Negativity	37.65 (5.05)	32.76 (3.51)	3.70 (43)	< 0.001

2.5.5 Correlations Among Emotion Regulation Strategies, Physiological Indices, and Parental Reports

Correlational analyses examined relationships between laboratory task strategies, physiological indices, and parental reports (see Table 6). Constructive strategies showed significant negative correlations with HR during emotion induction ($r = -0.35$, $p = 0.017$) and recovery phases ($r = -0.32$, $p = 0.031$), and with parental reports of lability/negativity ($r = -0.34$, $p = 0.025$). This indicates that children using more constructive strategies exhibited lower physiological arousal during emotion induction and recovery and showed less emotional lability or negativity in daily life. Venting strategies showed significant positive correlations with HR during emotion induction ($r = 0.35$, $p = 0.019$) and recovery phases ($r = 0.33$, $p = 0.028$), with SCR peak occurrence ($r = 0.30$, $p = 0.036$), and with parental reports of lability/negativity ($r = 0.37$, $p = 0.014$). This suggests that children using more venting strategies displayed higher physiological arousal, greater emotional volatility, and more emotional lability or negativity in daily life.

Table 6

Correlations Between Emotion Regulation Strategies, Physiological Indices, and Questionnaire Scores

Strategy Type	HR Induction	HR Recovery	Lability/Negativity
Constructive	-0.35*	-0.32*	-0.34*
Venting	0.35*	0.33*	0.37*

Note: $p < 0.05^*$

These findings demonstrate significant emotion regulation difficulties in ASD children, manifesting as: (1) in laboratory settings, greater use of maladaptive strategies and less use of constructive strategies when coping with negative emotions, accompanied by higher negative emotion arousal, greater emotional volatility, and slower recovery; (2) in daily contexts, poorer self-regulation abilities, more frequent negative emotional experiences, and greater emotional instability. These challenges create difficulties in real social situations and may exacerbate core ASD symptoms (Conner et al., 2020; Goldsmith & Kelley, 2018). Therefore, targeted emotion regulation training can help ASD children enhance emotional management and social interaction skills.

Study 1 findings revealed that ASD children struggle to use adaptive strategies and exhibit high negative emotion arousal, substantial volatility, and prolonged duration, highlighting the need to address their emotion regulation difficulties and improve their ability to cope with negative emotions for better social adaptation. Moreover, most domestic interventions for ASD children have focused on emotion recognition and understanding rather than emotion regulation difficulties, and intervention approaches have been relatively singular, concentrating primarily on CBT strategy instruction. Recent research demonstrates that mindfulness training can effectively enhance self-perception and emotion regulation in TD children, but few studies have applied mindfulness to ASD children. Therefore, Study 2 aims to help ASD children better manage negative emotions and improve their emotion regulation capacities through an integrated mindfulness and cognitive-behavioral intervention.

3.1 Participants

Twenty-three children with ASD were recruited for Study 2, with one child voluntarily withdrawing mid-study, resulting in a final sample of 22 children (mean age = 6.56 years, SD = 0.68, range = 5–7 years). Children were randomly assigned to either the intervention group (n = 12, 10 boys) or the control group (n = 10, 10 boys). No significant between-group differences were found in age ($M_{intervention} = 6.84$, $SD_{intervention} = 0.98$ vs. $M_{control} = 6.28$, $SD_{control} = 0.59$; $t(20) = 1.65$, $p = 0.115$, Cohen's $d = 0.75$), verbal IQ ($M_{intervention} = 88.08$, $SD_{intervention} = 19.75$ vs. $M_{control} = 83.45$, $SD_{control} = 27.00$; $t(20) = 0.47$, $p = 0.642$, Cohen's $d = 0.88$), or CARS scores ($M_{intervention} = 33.00$, $SD_{intervention} = 1.86$ vs. $M_{control} = 32.80$, $SD_{control} = 1.62$; $t(20) = 0.27$, $p = 0.793$, Cohen's $d = 0.11$). All guardians provided informed consent but were not informed of the specific intervention purposes to avoid expectancy effects. The study was approved by the Southwest University Ethics Committee.

All ASD children were recruited from the Children's Hospital of Chongqing Medical University and diagnosed by attending physicians according to DSM-

5 criteria. Additional inclusion criteria included: Wechsler Intelligence Scale scores > 70, no significant language impairments, and no prior participation in similar emotion intervention programs. Due to strict inclusion criteria and the small-group intervention format (1:2 or 1:3), large-scale recruitment was challenging. Importantly, ASD intervention studies typically employ small-group formats, making the current sample size common and acceptable in this field (Conner et al., 2019; Duncan et al., 2022; Hu et al., 2018).

3.2 Experimental Design

A 2 × 2 mixed design was employed with group (intervention vs. control) as a between-subjects factor and time (pre-test vs. post-test) as a within-subjects factor. The intervention group received eight weeks of training with two sessions per week, each lasting 60 minutes, totaling 16 intervention sessions. Children completed approximately 5–10 minutes of daily homework to consolidate and extend classroom content. The control group received no emotion-related intervention during this period and was offered compensatory training after study completion. Dependent variables included emotion regulation characteristics assessed through strategies, physiological indices, and questionnaire measures using the same materials and tasks as Study 1.

Intervention materials included emotion cards, emotion faces, A4 paper, emotion spinners, emotion comic books, watercolor markers, emotion jars, happiness guidebooks, pinwheels, animal models, and building blocks.

3.4 Intervention Design

3.4.1 Design Rationale Based on Study 1 findings indicating that ASD children struggle to use adaptive emotion regulation strategies and exhibit high, sustained negative emotion arousal, Study 2's intervention targeted two core objectives: (1) reducing emotional arousal and negative emotional experiences, and (2) mastering adaptive emotion regulation strategies for more effective and flexible negative emotion management. Extensive research demonstrates that mindfulness not only directly trains attention but also reduces stress and negative emotional awareness, thereby improving emotion regulation. Concurrently, CBT helps individuals with ASD manage negative emotions by teaching adaptive strategies. Therefore, an integrated approach combining mindfulness and cognitive-behavioral strategies can reduce negative emotional experiences through mindfulness practice while helping individuals better adapt to daily emotional challenges through strategy learning.

Curriculum design adhered to the following principles: (1) Transforming mindfulness exercises into engaging game-based processes aligned with children's learning characteristics and thinking styles to ensure learning in a relaxed, enjoyable environment; (2) Progressive curriculum structure beginning with external control (awareness of breathing and bodily sensations) and gradually developing internal regulation of emotions and thoughts to help children effectively attend to and alleviate emotional stress; (3) Content closely integrated with real-life emotional problems of ASD children, introducing various regulation strategies and skills through vivid story contexts and concrete concepts; (4) Emphasis on individual differences, employing differential reinforcement, repeated practice, and visual prompts tailored to each child's unique personality to reduce negative emotional experiences and enhance regulation abilities.

3.4.2 Curriculum Content and Schedule Based on our research group's previous work (Li et al., 2019), we developed a three-stage mindfulness program for children ("Breathing and Attention," "Bodily Sensations and Movement," "Awareness of Mental Activity") integrated with cognitive-behavioral strategies to create a series of comprehensive intervention sessions suitable for 5–7-year-old ASD children. The curriculum aimed to reduce negative emotional experiences and improve emotion regulation to facilitate better social adaptation.

Detailed content and scheduling are presented in Table 7 . Prior to intervention, one-on-one semi-structured interviews were conducted with parents and therapists to comprehensively understand individual differences including reinforcers, behavioral patterns, and emotion regulation needs. Children were grouped according to chronological age and ability level to ensure each group operated within a similar "zone of proximal development." This grouping strategy reduced frustration from ability disparities while enhancing engagement and learning through peer modeling and interaction. Sessions were conducted twice weekly for 60 minutes over eight weeks (16 sessions total) in small groups of 2–3 children, with one intervention teacher and one assistant providing individualized support. Daily homework (e.g., 5-minute breathing exercises) was assigned for parental assistance to consolidate learning and promote skill generalization.

Table 7
Comprehensive Emotion Regulation Intervention Curriculum for Children with ASD

Session	Theme	Core Activities and Exercises	Objectives
01	Emotion Knowledge: Basic Emotions	Adventures of Fluffy Rabbit; Emotion Flying Chess; Imitation Game; Breathing Awareness	Correctly identify four basic emotions and their features; initial breath awareness

Session	Theme	Core Activities and Exercises	Objectives
02	Emotion Knowledge: Emotion Causes	Emotion Pinwheel; My Happiness Plan; Emotion Transformation	Understand emotion causes; deepen experiential understanding
03	Emotion Knowledge: Emotion Cues	Jungle Detective; Thought Explosion; Emotion Diary Drawing	Identify others' emotions from cues; begin self-awareness
04	Emotion Knowledge: Emotion Tools	Emotion Thermometer; Emotion Magic Bottle	Learn to express emotions appropriately using tools
05	Mindfulness Breathing & Senses I	Autonomous Breathing; Mindful Observation; Mindful Listening (Environment)	Train attention through senses; focus concentration
06	Mindfulness Breathing & Senses II	Mindful Listening (Interpersonal); Five Senses Stress Relief	Enhance focus training; flexible application
07	Mindfulness Bodily Awareness	Body Explorer; Tree Rooting; Body Coloring	Learn to listen to bodily sensations; 觉察身体 before acting on impulses
08	Mindfulness Bodily Relaxation	Progressive Muscle Relaxation; Fist Clenching	Teach physical relaxation; rapid physiological adjustment

Session	Theme	Core Activities and Exercises	Objectives
09	Mindfulness: Mental Awareness	Self-Exploration Adventure; Happiness Guidebook; Role-Playing	Investigate positive/negative triggers; increase self-awareness
10	Mindfulness: Mental Connection	Emotion Animation; Hot Potato Game; Helpful Thought Missiles	Understand thought-feeling connections; different behaviors produce different outcomes
11	CBT: Social Rules	Behavior Imitation; Video Clip Analysis	Distinguish appropriate vs. inappropriate emotional behaviors
12	CBT: Emotion Mastery	Emotion Weather Sorting; Expression Guidance	Learn specific post-emotion actions; express feelings appropriately
13	CBT: Physical Tools	Stress Balls; Toy Clever Usage	Learn to discharge high energy without disturbing others
14	CBT: Distraction	Deep Breathing Runway; Emotion Traffic Light	Shift attention to calm down
15	CBT: Gratitude & Relief	Gratitude Experience; Washing Away Busy Thoughts	Experience gratitude; notice life's positives
16	CBT: Integration	Review strategies; practice and consolidate skills	Integrate all learned skills

To accommodate learning characteristics and individual needs of ASD children, we designed and implemented several intervention strategies to reduce training barriers, enhance compliance, and improve effectiveness: (1) **Structured Teaching**: Providing clear task structures, predictable activity sequences, and explicit visual cues to help children understand requirements and reduce anxiety from uncertainty. Visual schedules, picture prompts, and personalized task cards clarified each step's requirements, enhancing predictability and controllability while reducing emotional volatility and behavioral dysregulation risks. (2) **Gamified Activities**: Transforming mindfulness concepts into concrete, operational game tasks to reduce cognitive load and motivate participation. For example, "Pinwheel Blowing" games taught breathing rhythms, and "Body Coloring" games enhanced bodily awareness through tactile stimulation. (3) **Visual and Multisensory Supports**: Leveraging ASD children's multisensory integration strengths through pictures, videos, and tactile props. "Deep Breathing Runways" provided visual tools for breath adjustment, while "Emotion Magic Bottles" helped identify emotion categories and intensities. (4) **Differential Reinforcement**: Assistants monitored children's behavior and emotions in real time, providing sensory regulation support (e.g., stress balls, physical stretching) for those with attention difficulties or non-compliance. Flexible activity scheduling with short tasks and appropriate physical activity helped maintain focus.

3.5 Study 2 Results

3.5.1 Group Homogeneity Verification

Independent samples t-tests comparing pre-intervention negative emotion regulation characteristics and abilities between groups revealed no significant differences in frustration task strategies (constructive, venting, avoidance), HR indices, or SCR indices (all ps > 0.05, see Table 8), nor in daily emotion regulation abilities (Emotion Regulation and Lability/Negativity dimensions, ps $>$ 0.05). These results confirm group homogeneity on emotion regulation indices prior to intervention.

Table 8

Pre-Intervention Group Differences in Emotion Regulation Indices

Index	Intervention (n = 12)	Control (n = 10)	t(df)	Cohen's d
Constructive Strategies	10.25 (3.60)	12.10 (2.51)	-1.37 (20)	0.59
Venting Strategies	4.08 (4.30)	1.60 (1.71)	1.71 (20)	0.76
Avoidance Strategies	3.33 (3.55)	1.70 (2.50)	1.22 (20)	0.54
Baseline HR	103.32 (7.74)	101.05 (6.11)	0.75 (20)	0.33
SCR	0.82 (0.45)	0.67 (0.45)	0.53 (20)	0.33
Peak Occurrence	0.84 (0.02)	0.83 (0.07)	0.35 (20)	0.19
Emotion Regulation	22.58 (2.31)	22.20 (1.55)	0.45 (20)	0.20

Index	Intervention (n = 12)	Control (n = 10)	t(df)	Cohen's d
Lability/Negativity	38.67 (5.77)	36.70 (4.30)	0.89 (20)	0.37

3.5.2 Intervention Effects on Emotion Regulation in ASD Children

To examine intervention effects, 2 (Group: intervention vs. control) × 2 (Time: pre-test vs. post-test) repeated measures ANOVAs were conducted with laboratory and daily life emotion regulation indices as dependent variables.

For emotion regulation strategies, the Group × Time interaction was significant for constructive strategies, $F(1, 20) = 8.61$, $p = 0.008$, $p^2 = 0.301$. Simple effects analysis (see Figure 2 [Figure 2: see original paper]) showed post-test scores were significantly higher than pre-test scores in the intervention group ($p = 0.004$) but not in the control group ($p = 0.310$), indicating effective enhancement of adaptive strategy use. For venting strategies, the Group × Time interaction was significant, $F(1, 20) = 7.30$, $p = 0.014$, $p^2 = 0.267$. Simple effects analysis revealed post-test scores were significantly lower than pre-test scores in the intervention group ($p = 0.008$) but not in the control group ($p = 0.336$). For avoidance strategies, the Group × Time interaction was significant, $F(1, 20) = 5.01$, $p = 0.037$, $p^2 = 0.200$. Simple effects analysis showed post-test scores were significantly lower than pre-test scores in the intervention group ($p = 0.025$) but not in the control group ($p = 0.418$). These results demonstrate that intervention training helped ASD children increase adaptive strategy use and decrease maladaptive strategies when coping with negative emotions.

Figure 2
Pre-post comparison of emotion regulation strategies between intervention and control groups

For physiological indices during the frustration task, no significant Group × Time interactions were found for baseline HR, $F(1, 20) = 0.04$, $p = 0.837$, $p^2 = 0.002$, negative emotion phase HR, $F(1, 20) = 0.06$, $p = 0.811$, $p^2 = 0.003$, or recovery phase HR, $F(1, 20) = 0.09$, $p = 0.766$, $p^2 = 0.003$. Similarly, no significant interactions were found for SCR or peak occurrence during the negative emotion phase, $F(1, 20) = 0.03$, $p = 0.876$, $p^2 = 0.001$, and $F(1, 20) = 0.13$, $p = 0.717$, $p^2 = 0.007$, respectively. These results suggest that intervention training did not significantly affect physiological arousal levels during negative emotion tasks.

For questionnaire-assessed emotion regulation abilities, the Group × Time interaction was significant for the Emotion Regulation dimension, $F(1, 20) = 7.64$, $p = 0.012$, $p^2 = 0.276$. Simple effects analysis (see Figure 3 [Figure 3: see original paper]) showed post-test scores were significantly higher than pre-test scores in the intervention group ($p = 0.004$) but not in the control group ($p = 0.448$). For the Lability/Negativity dimension, the Group × Time interaction was significant, $F(1, 20) = 16.95$, $p = 0.001$, $p^2 = 0.459$. Simple effects analysis revealed post-test scores were significantly lower than pre-test scores in the intervention group ($p < 0.001$) but not in the control group ($p = 0.568$). These results demonstrate that intervention training significantly improved self-regulation and emotional stability in ASD children's daily lives.

Figure 3
Pre-post comparison of emotion regulation questionnaire scores between intervention and control groups

Study 2 designed a comprehensive emotion regulation intervention curriculum appropriate for 5–7-year-old ASD children and tested its effectiveness through a pre-post control group design. Results showed that after eight weeks (16 sessions) of intervention, ASD children demonstrated significant increases in constructive emotion regulation strategies (e.g., cognitive reappraisal, problem-solving) and significant decreases in maladaptive strategies (avoidance, venting) during laboratory tasks. Moreover, intervention significantly improved self-regulation abilities and emotional stability in daily life, suggesting that training effects transferred from laboratory to real-world contexts, helping ASD children better manage emotions and reduce volatility in everyday situations. However, while behavioral coding and questionnaire assessments showed improved emotion regulation, physiological indices (SCR and HR) did not show significant changes, possibly due to insufficient intervention duration to produce adequate neuroplastic changes.

4 General Discussion

This study systematically investigated emotion regulation characteristics and intervention effects in ASD children through multimodal assessment and integrated intervention protocols. Study 1 results demonstrated significant emotion regulation difficulties in ASD children across multiple domains: behaviorally, greater use of maladaptive and less use of constructive strategies; physiologically, higher negative emotion arousal, greater volatility, and slower recovery; and via questionnaire, poorer overall regulation, more frequent negative emotions, and greater instability. Building on these findings, Study 2 designed and implemented a combined mindfulness and cognitive-behavioral intervention to enhance emotion regulation capacities. Intervention results showed that, compared to the control group, the intervention group exhibited significant increases in adaptive strategy use and decreases in maladaptive strategies during laboratory tasks, alongside significant improvements in daily emotion regulation abilities. Overall, this study not only reveals unique challenges in emotion regulation for ASD children but also provides new support pathways for addressing these difficulties through multimodal assessment and personalized integrated intervention.

4.1 Multimodal, Multicontext Assessment Reveals Emotion Regulation Difficulties in ASD Children

Study 1 employed multimodal assessment to systematically examine emotion regulation characteristics in ASD children across laboratory and daily life contexts. First, behavioral coding through the frustration task recorded and coded children's emotion regulation strategies when coping with negative emotions. Results indicated that compared to TD children, ASD children tended to use more maladaptive strategies (venting, avoidance) and fewer constructive strategies. Second, physiological measurement revealed that ASD children showed higher physiological arousal, more intense emotional fluctuations, and slower recovery in negative emotion contexts. Third, parental questionnaire reports reflected poorer emotion regulation, more frequent negative emotional experiences, and greater emotional instability in ASD children's daily lives. Collectively, results from multiple modalities and contexts consistently support significant emotion regulation difficulties in ASD children.

On one hand, ASD children's greater use of maladaptive strategies like venting and avoidance may intensify core symptoms and emotional problems (Cibralic et al., 2019; Northrup et al., 2021). For example, when experiencing intense negative emotions, venting strategies may lead to more frequent aggressive or self-injurious behaviors, while avoidance strategies may result in escaping or refusing participation in potentially stressful social activities, creating a vicious cycle. On the other hand, emotions are complex and dynamically changing, and reliance on behavioral observation alone may not capture the full regulation process (Beck et al., 2021). Therefore, monitoring the complete process from emotion generation to recovery combined with physiological indices provides more sensitive, immediate physiological markers of regulation (Zantinge et al., 2017). Results showed that ASD children exhibited sustained high HR during both emotion generation and recovery phases, suggesting chronic high stress states with slow recovery. Additionally, they showed stronger SCR responses and higher PKO values during tasks, indicating more intense and prolonged emotional reactions. Comprehensive physiological analysis demonstrates that ASD children exhibit extreme physiological arousal, intense emotional fluctuations, and slow recovery when facing identical frustration situations, likely making them more vulnerable to emotional volatility in daily life (Arora et al., 2021; Chiu et al., 2024). Parental reports further supported these results and reflected general emotion regulation characteristics in daily contexts, namely emotional lability/negativity and poor regulation.

To explore underlying mechanisms of emotion regulation difficulties in ASD children, we integrated theoretical perspectives from neural and cognitive levels. First, the Neurovisceral Integration Model emphasizes that the prefrontal cortex (particularly ventromedial PFC) maintains adaptive balance between emotional and physiological states by regulating the limbic system (e.g., amygdala) and autonomic nervous system (Thayer & Lane, 2000). Sustained high HR and intense SCR responses in ASD children during the lock-box task may reflect atypical functional connectivity in prefrontal-amygdala circuits, leading to reduced autonomic regulation efficiency, manifested as elevated arousal with slow recovery (Arora et al., 2021). This neuroregulatory imbalance predisposes ASD individuals to high arousal states when facing stress or emotional challenges, with sluggish recovery processes, creating a physiological signature of intense, sustained emotional reactivity. Second, from a cognitive perspective, Gross's (2013) process model divides regulation into stages: situation selection, modification, attentional deployment, cognitive reappraisal, and response modulation. Research indicates that ASD individuals tend to rely more on post-hoc response modulation strategies (e.g., behavioral inhibition after emotional outbursts) and less on proactive strategies like cognitive reappraisal during early emotion generation phases (Mazefsky et al., 2013). This tendency may stem from pervasive deficits in cognitive flexibility, metacognitive abilities, and emotion understanding (Beck et al., 2021). The delayed use and lack of adaptive cognitive strategies limit effective negative emotion regulation, increasing risks of emotional dyscontrol and problem behaviors. In summary, integrating the Neurovisceral Integration Model and emotion regulation process model suggests that ASD children's emotion regulation difficulties stem from dual impairments in neurophysiological foundations and cognitive strategy use. The former manifests as inefficient regulatory system connectivity and excessive ANS reactivity, while the latter reflects limited use of higher-order regulation strategies and weak metacognitive abilities. This multi-level interactive mechanism results in ASD children being unable to inhibit physiological activation or proactively select adaptive strategies when facing emotional challenges, creating a typical regulatory pattern of "emotionally reactive, difficult to regulate."

4.2 Intervention Training Effectively Improves Emotion Regulation in ASD Children

Based on Study 1 results, Study 2 combined mindfulness training and cognitive-behavioral strategies to effectively improve emotion regulation in ASD children. After 16 sessions (eight weeks), results showed that compared to the control group, the intervention group demonstrated significant improvements in emotion regulation capacity, specifically increased use of adaptive strategies and decreased maladaptive strategies during laboratory tasks, alongside significant improvements in daily self-regulation and emotional stability. These results validate the effectiveness of combined mindfulness and cognitive-behavioral intervention in ASD populations.

Traditional ASD intervention models primarily include behavioral approaches (e.g., Applied Behavior Analysis, Discrete Trial Training) focusing on reinforcing spontaneous behavior acquisition, and developmental approaches (e.g., Relationship Development Intervention, Structured Teaching) emphasizing individual differences in daily contexts (Hyman et al., 2020; Sharma et al., 2018). However, existing intervention protocols often neglect emotion regulation, a core domain. Emotional dysregulation may slow developmental trajectories, exacerbate negative outcomes, and even interfere with intervention responsiveness (Nuske et al., 2017). Research demonstrates that mindfulness training and CBT effectively alleviate emotional distress (Pruessner et al., 2024; van der Velden et al., 2015), and this study extends these strategies to ASD children, confirming their applicability and effectiveness. Mindfulness training guides individuals to return attention to the present moment, focusing on internal experiences and external environmental changes, helping ASD children more sensitively detect and regulate emotional reactions, thereby breaking automatic "emotion trigger-behavioral response" pathways (Kabat-Zinn, 2003; Ridderinkhof et al., 2020). Given that sensory abnormalities and overload are recognized as key mechanisms affecting emotion regulation in ASD, mindfulness training enhances adaptive integration of sensory information, reducing overwhelming sensory experiences while improving emotional awareness and acceptance, thus mitigating emotion dysregulation triggered by sensory overload. Meanwhile, CBT provides a structured regulation pathway. Cognitive strategies emphasized in CBT, such as reappraisal and problem-solving, not only help ASD children replace maladaptive strategies like venting and avoidance but also promote flexible negative emotion coping in daily life. Strategy training enhances children's emotion understanding and strategy application, building an internal resource library for regulation. Mindfulness training focuses on improving emotional awareness, acceptance, and self-control, while cognitive-behavioral strategies concentrate on acquiring and applying specific regulation techniques. These complementary approaches provide ASD children with a systematic, clearly layered emotion regulation support framework. This "two-pronged" intervention enables multi-dimensional improvements from overall capacity to specific strategy application.

Furthermore, the comprehensive intervention protocol not only improved laboratory-based emotion regulation but also successfully transferred to daily life, significantly enhancing emotional stability and self-regulation. This helps ASD children better manage emotions, reduce volatility, and improve stability in everyday situations. In summary, the integrated mindfulness and cognitive strategy intervention effectively and comprehensively improves emotion regulation in ASD children.

Intervention effectiveness was partly attributable to curriculum design tailored to ASD children's cognitive characteristics and behavioral challenges. The protocol extensively employed structured teaching, visual and multisensory supports, gamified design, and differential reinforcement, effectively reducing cognitive load and enhancing behavioral compliance. The intervention process emphasized organic integration of emotion perception training and behavioral regulation practice, constructing a complete "emotion awareness-strategy learning-behavioral regulation" intervention chain. For example, children first detected emotional signals through mindfulness practice, then learned cognitive reappraisal strategies such as "emotions are temporary," and finally consolidated regulation application through behavioral rehearsal (e.g., deep breathing, attention shifting). Given significant individual differences in ASD populations regarding developmental trajectories, cognitive abilities, and emotional response patterns

(Susan et al., 2020), this study emphasized individualized design. Based on each child's ability level, preferences, and emotional response patterns, we conducted matched grouping and dynamically adjusted intervention content and strategies. This attention to individual differences enhanced intervention effectiveness and promoted long-term transfer and stable development of emotion regulation capacities. Although this study achieved preliminary success, future research should further explore potential moderators of intervention effectiveness, such as age, gender, comorbid emotional disorders, and parental involvement, to provide theoretical support and practical guidance for more targeted personalized interventions.

However, despite positive improvements in behavioral coding and questionnaire assessments, physiological indices (SCR and HR) in Study 2 showed no significant changes. Possible reasons include: First, neurophysiological changes typically lag behind behavioral changes, and short-term interventions often insufficiently induce neuroplastic changes, particularly for ASD children with atypical ANS functioning (Arora et al., 2021). Research indicates that physiological arousal improvements often follow behavioral gains, with ASD children typically mastering behavioral regulation strategies before physiological regulation internalizes over longer periods (Zantinge et al., 2017). Second, physiological intervention studies with ASD children (e.g., biofeedback training) typically employ higher frequencies (3–4 sessions/week) or longer durations (12–16 weeks) to induce significant physiological changes (Porges et al., 2014). In contrast, this study's frequency (2 sessions/week) and total intensity may have been insufficient to significantly affect HR or SCR in the short term. Additionally, individual differences among ASD children may have masked group effects in physiological indices. Heterogeneity in baseline physiological arousal and emotional awareness may produce differential intervention responses. For example, children with high baseline arousal may show weaker responses, while those with low emotional awareness may struggle to translate mindfulness training into physiological regulation (Cai et al., 2019). These differences may increase variability in physiological changes, reducing statistical significance. Future research should extend intervention duration, increase training frequency, or integrate biofeedback technology to enhance physiological intervention sensitivity. Additionally, stratified analysis or personalized intervention designs based on children's baseline physiological characteristics could more precisely capture individual-level physiological changes.

4.3 Clinical Value and Educational Implications

Multimodal assessment provides important clinical insights and practical pathways for precise identification and intervention in ASD children. First, traditional ASD diagnosis relies primarily on behavioral observation and questionnaires, which may fail to capture dynamic changes during emotion regulation (Zantinge et al., 2017). This study's inclusion of physiological monitoring (e.g., HR, SCR) can identify stress responses and emotional fluctuations undetectable through behavioral observation alone, improving diagnostic objectivity and accuracy (Frye et al., 2019). Integrating behavioral observation, physiological data, and questionnaire assessment can comprehensively portray ASD children's emotional response characteristics and regulation strategies across contexts, facilitating precise identification of specific regulation difficulties (Mazefsky et al., 2013). Second, precise identification is a prerequisite for effective intervention. Multimodal assessment clarifies each ASD child's emotion regulation patterns and individualized needs, enabling targeted intervention plans that improve effectiveness. For instance, children with high emotional arousal may prioritize relaxation training or mindfulness to reduce stress responses, while those with strategy application difficulties require focused training in constructive strategy use. This "precise identification first, then personalized intervention" model promotes transformation of ASD emotion regulation intervention from experience-based to precision-based, scientific approaches.

Additionally, this study's emotion regulation intervention framework combining mindfulness and CBT opens new pathways for enhancing emotional capacities in ASD populations. This comprehensive intervention model represents the first systematic application in Chinese ASD children, validating its effectiveness in improving emotional management and achieving skill transfer from laboratory to daily life. Notably, this study emphasized personalized intervention design considering ASD children's diverse characteristics (e.g., language ability, cognitive level, emotional response patterns). For children with limited language expression, interventions incorporated more non-verbal supports like visual cues and movement guidance, while higher-functioning ASD children received more diverse cognitive strategy training to enhance emotion understanding and behavioral regulation. Such personalized adjustments improved practical effectiveness and children's engagement. From an educational application perspective, this study's intervention protocol is highly structured and operational, facilitating implementation in school settings. For example, simplified mindfulness practices (e.g., 5-minute daily focused breathing) can be embedded in daily teaching and play activities to help ASD children regulate emotions in classrooms and peer interactions. Additionally, parents can master mindfulness techniques and regulation strategies through 配套培训, extending intervention to home settings and creating complementary school-family support networks. Future research should explore collaborative intervention possibilities among professional institutions, families, and schools, establishing long-term follow-up mechanisms to evaluate intervention sustainability and naturalistic transfer effects. Through such comprehensive support systems, ASD children can more effectively manage emotions, improve social interactions and quality of life, while special educators, therapists, and parents gain systematic, scientific support tools to promote comprehensive development and behavioral optimization.

4.4 Limitations and Future Directions

Despite significant progress, this study has several limitations. First, although research indicates that ASD children's emotion regulation is associated with factors such as executive function and sensory processing (Costescu et al., 2024; Sung et al., 2024), these variables were not fully considered in this study. Future research should systematically integrate these variables to better understand potential differences in emotion regulation among ASD children with varying characteristics. Second, the relatively short intervention duration and lack of long-term follow-up limit understanding of intervention effectiveness durability and physiological changes. Extending intervention and follow-up periods in future studies will help evaluate stability and sustainability of long-term effects. Future research should also consider more diverse and dynamic multimodal assessment methods, such as continuous daily life behavioral observation, virtual reality technology, and EEG monitoring, to comprehensively reflect children's emotion regulation capacities in natural and variable environments (Restoy et al., 2024). Finally, although the current sample size is acceptable in this research field, its limited scale may affect statistical power and external validity. Based on an expected medium effect size (Cohen's d = 0.50), G*Power software estimated a required sample size of 26 to achieve 0.80 statistical power. However, the actual sample of 22 yielded estimated power of approximately 0.65. While sufficient for detecting medium effect sizes in primary conclusions, this limits detection of subtle between-group differences and analysis of secondary variables. Future research should expand sample size and diversity, including different ASD subtypes, cognitive abilities, and comorbidity profiles, to enhance statistical power and generalizability.

In conclusion, compared to TD children, ASD children exhibit more pronounced emotion regulation difficulties, manifesting as greater use of maladaptive strategies during negative emotions, higher physiological arousal with greater volatility and slower recovery, and more frequent negative emotional experiences with poorer stability in daily life. Furthermore, integrated mindfulness and cognitive strategy intervention effectively improves emotion regulation in ASD children, as evidenced by increased adaptive strategy use, decreased maladaptive strategy use, and enhanced daily emotional stability.

References

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

Aldao, A., Nolen-Hoeksema, S., & Schweizer, S. (2010). Emotion-regulation strategies across psychopathology: A meta-analytic review. *Clinical Psychology Review, 30*(2), 217–237.

Arora, I., Bellato, A., Ropar, D., Hollis, C., & Groom, M. J. (2021). Is autonomic function during resting-state atypical in Autism: A systematic review of evidence. *Neuroscience and Biobehavioral Reviews, 125*, 417–441.

Arora, S., Goodall, S., & Vine, S. (2021). Physiological responses to stress in autism spectrum disorder: A systematic review. *Frontiers in Psychiatry, 12*, 638715.

Beck, K. B., Conner, C. M., Breitenfeldt, K. E., Northrup, J. B., White, S. W., & Mazefsky, C. A. (2021). Assessment and treatment of emotion regulation impairment in autism spectrum disorder across the life span: Current state of the science and future directions. *Psychiatric Clinics of North America, 44*(1), 95–110.

Beck, K. B., Conner, C. M., & Mazefsky, C. A. (2021). Multimodal assessment of emotion dysregulation in children with autism spectrum disorder. *Autism Research, 14*(7), 102410.

Cai, R. Y., Richdale, A. L., Dissanayake, C., & Uljarevic, M. (2019). Resting heart rate variability, emotion regulation, psychological wellbeing and autism symptomatology in adults with and without autism. *International Journal of Psychophysiology, 137*, 54–62.

Chiu, H. T., Ip, I. N., Ching, F. N. Y., Wong, B. P.H., Lui, W.H., Tse, C.S., & Wong, S. W. H. (2024). Resting heart rate variability and emotion dysregulation in adolescents with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 54*(4), 1482–1493.

Chiu, T. A., Anagnostou, E., Brian, J., Chau, T., & Kushki, A. (2016). Specificity of autonomic arousal to anxiety in children with autism spectrum disorder. *Autism Research, 9*(4), 491–501.

Cibralic, S., Kohlhoff, J., Wallace, N., McMahon, C., & Eapen, V. (2019). A systematic review of emotion regulation in children with autism spectrum disorder. *Research in Autism Spectrum Disorders, 68*, 101422.

Conner, C. M., White, S. W., Beck, K. B., Golt, J., Smith, I. C., & Mazefsky, C. A. (2019). Improving emotion regulation ability in autism: The Emotional Awareness and Skills Enhancement (EASE) program. *Autism, 23*(5), 1273–1287.

Conner, C. M., White, S. W., Scahill, L., & Mazefsky, C. A. (2020). The role of emotion regulation and core autism symptoms in the experience of anxiety in autism. *Autism, 24*(4), 931–940.

Costescu, C., Adrian, R., & Carmen, D. (2024). Executive functions and emotion regulation in children with autism spectrum disorders. *European Journal of Special Needs Education, 39*(3), 477–486.

Critchley, H. D. (2002). Electrodermal responses: What happens in the brain. *Neuroscientist, 8*(2), 132–142.

Duncan, A., Meinzen-Derr, J., Ruble, L. A., Fassler, C., & Stark, L. J. (2022). A pilot randomized controlled trial of a daily living skills intervention for adolescents with autism. *Journal of Autism and Developmental Disorders, 52*(2), 938–949.

Dyson, M. W., Olino, T. M., Durbin, C. E., Goldsmith, H. H., & Klein, D. N. (2015). The structure of temperament in preschoolers: A two-stage factor analytic approach. *Emotion, 15*(2), 241–253.

Frye, R. E., Vassall, S., Kaur, G., Lewis, C., Karim, M., & Rossignol, D. (2019). Emerging biomarkers in autism spectrum disorder: A systematic review. *Annals of Translational Medicine, 7*(23), 792.

Goldsmith, H. H., Reilly, J., Lemery, K. S., Longley, S., & Prescott, A. (1999). *The laboratory temperament assessment battery: Preschool version* (Technical manual). Madison, WI: University of Wisconsin.

Goldsmith, S. F., & Kelley, E. (2018). Associations between emotion regulation and social impairment in children and adolescents with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 48*(6), 2164–2173.

Grol, M., & De Raedt, R. (2020). The link between resting heart rate variability and affective flexibility. *Cognitive, Affective and Behavioral Neuroscience, 20*(4), 746–756.

Gross, J. J. (1998). The emerging field of emotion regulation: An integrative review. *Review of General Psychology, 2*(3), 271–299.

Gross, J. J. (2013). Emotion regulation: Taking stock and moving forward. *Emotion, 13*(3), 359–365.

Hirschler-Guttenberg, Y., Golan, O., Ostfeld-Etzion, S., & Feldman, R. (2015). Mothering, fathering, and the regulation of negative and positive emotions in high-functioning preschoolers with autism spectrum disorder. *Journal of Child Psychology and Psychiatry, 56*(5), 530–539.

Hu, J. S., Li, C. S., Wang, Q., Li, S. Z., Li, T. T., & Liu, S. Q. (2018). The deficiency of attention bias to emotional prosody in the teenagers with autism spectrum disorders: A perceptual mode of low efficiency. *Acta Psychologica Sinica, 50*(06), 637–646.

Hyman, S. L., Levy, S. E., Myers, S. M., Kuo, D., Apkon, S., Davidson, L. F., … Bridgemohan, C. (2020). Executive summary: Identification, evaluation, and management of children with autism spectrum disorder. *Pediatrics, 145*(1), e20193448.

Jahromi, L. B., Meek, S. E., & Ober-Reynolds, S. (2012). Emotion regulation in the context of frustration in children with high functioning autism and their typical peers. *Journal of Child Psychology and Psychiatry, 53*(12), 1250–1258.

Kabat-Zinn, J. (2003). Mindfulness-based interventions in context: Past, present, and future. *Clinical Psychology-Science and Practice, 10*(2), 144–156.

Kreibig, S. D. (2010). Autonomic nervous system activity in emotion: A review. *Biological Psychology, 84*(3), 394–421.

Kushki, A., Drumm, E., Pla Mobarak, M., Tanel, N., Dupuis, A., Chau, T., & Anagnostou, E. (2013). Investigating the autonomic nervous system response to anxiety in children with autism spectrum disorders. *PloS One, 8*(4), e59730.

Lavender, J. M., Tull, M. T., DiLillo, D., Messman-Moore, T., & Gratz, K. L. (2017). Development and validation of a state-based measure of emotion dysregulation: The State Difficulties in Emotion Regulation Scale (S-DERS). *Assessment, 24*(2), 197–209.

Li, Q., Song, Y. N., Lian, B., & Feng, T. Y. (2019). Mindfulness training can improve 3- and 4-year-old children's attention and executive function. *Acta Psychologica Sinica, 51*(03), 324–336.

Lindsay, E. K., & Creswell, J. D. (2017). Mechanisms of mindfulness training: Monitor and Acceptance Theory (MAT). *Clinical Psychology Review, 51*, 48–59.

Lindsay, E. K., & Creswell, J. D. (2019). Mindfulness, acceptance, and emotion regulation: Perspectives from Monitor and Acceptance Theory (MAT). *Current Opinion in Psychology, 28*, 120–125.

Loftus, T., Mathersul, D. C. C., Ooi, M., & Yau, S. H. H. (2023). The efficacy of mindfulness-based therapy for anxiety, social skills, and aggressive behaviors in children and young people with Autism Spectrum Disorder: A systematic review. *Frontiers in Psychiatry, 14*, 1079471.

Mazefsky, C. A., Herrington, J., Siegel, M., Scarpa, A., Maddox, B. B., Scahill, L., & White, S. W. (2013). The role of emotion regulation in Autism Spectrum Disorder. *Journal of the American Academy of Child and Adolescent Psychiatry, 52*(7), 679–688.

Mazefsky, C. A., Yu, L., White, S. W., Siegel, M., & Pilkonis, P. A. (2018). The emotion dysregulation inventory: Psychometric properties and item response theory calibration in an autism spectrum disorder sample. *Autism Research, 11*(6), 928–941.

Northrup, J. B., Goodwin, M., Montrenes, J., Vezzoli, J., Golt, J., Peura, C. B., … Mazefsky, C. (2020). Observed emotional reactivity in response to frustration tasks in psychiatrically hospitalized youth with autism spectrum disorder. *Autism, 24*(4), 968–982.

Northrup, J. B., Patterson, M. T., & Mazefsky, C. A. (2021). Predictors of severity and change in emotion dysregulation among children and adolescents with ASD. *Journal of Clinical Child and Adolescent Psychology, 50*(6), 708–729.

Nuske, H. J., Hedley, D., Woollacott, A., Thomson, P., Macari, S., & Dissanayake, C. (2017). Developmental delays in emotion regulation strategies in preschoolers with autism. *Autism Research, 10*(11), 1808–1822.

Nuske, H., Young, A., Khan, F., Palermo, E., Ajanaku, B., Pellecchia, M., Vivanti, G., … Mandell, D. (2024). Systematic review: Emotion dysregulation and challenging behavior interventions for children and adolescents on the autism spectrum with graded key evidence-based strategy recommendations. *European Child and Adolescent Psychiatry, 33*(6), 1963–1976.

Poquerusse, J., Pagnini, F., & Langer, E. J. (2021). Mindfulness for autism. *Advances in Neurodevelopmental Disorders, 5*(1), 77–84.

Porges, S. W., et al. (2014). Reducing autonomic arousal in autism spectrum disorder: A pilot study of biofeedback training. *Journal of Neurodevelopmental Disorders, 6*(1), 22.

Pruessner, L., Timm, C., Kalmar, J., Bents, H., Barnow, S., & Mander, J. (2024). Emotion regulation as a mechanism of mindfulness in individual cognitive-behavioral therapy for depression and anxiety disorders. *Depression and Anxiety, 2024*, 9081139.

Raugh, I. M., & Strauss, G. P. (2024). Integrating mindfulness into the extended process model of emotion regulation: The Dual-Mode Model of mindful emotion regulation. *Emotion, 24*(3), 847–866.

Restoy, D., Oriol-Escude, M., Alonzo-Castillo, T., Magan-Maganto, M., Canal-Bedia, R., Diez-Villoria, E., … Lugo-Marin, J. (2024). Emotion regulation and emotion dysregulation in children and adolescents with autism spectrum disorder: A meta-analysis of evaluation and intervention studies. *Clinical Psychology Review, 109*, 102410.

Ridderinkhof, A., de Bruin, E. I., van den Driesschen, S., & Bogels, S. M. (2020). Attention in children with autism spectrum disorder and the effects of a mindfulness-based program. *Journal of Attention Disorders, 24*(5), 681–692.

Samson, A. C., Hardan, A. Y., Lee, I. A., Phillips, J. M., & Gross, J. J. (2015). Maladaptive behavior in autism spectrum disorder: The role of emotion experience and emotion regulation. *Journal of Autism and Developmental Disorders, 45*(11), 3424–3432.

Sharma, S. R., Gonda, X., & Tarazi, F. I. (2018). Autism spectrum disorder: Classification, diagnosis and therapy. *Pharmacology and Therapeutics, 190*, 91–104.

Shields, A., & Cicchetti, D. (1997). Emotion regulation among school-age children: The development and validation of a new criterion Q-sort scale. *Developmental Psychology, 33*(6), 906–916.

Sung, Y. S., Lin, C. Y., Chu, S. Y., & Lin, L. Y. (2024). Emotion dysregulation mediates the relationship between sensory processing and behavior problems in young children with autism spectrum disorder: A preliminary study. *Journal of Autism and Developmental Disorders, 54*(2), 738–748.

Thayer, J. F., Hansen, A. L., Saus, E., & Johnsen, B. H. (2012). Heart rate variability, prefrontal neural function, and cognitive performance: The neurovisceral integration perspective on self-regulation, adaptation, and health. *Annals of Behavioral Medicine, 44*(2), 139–141.

Thayer, J. F., & Lane, R. D. (2000). A model of neurovisceral integration in emotion regulation and dysregulation. *Journal of Affective Disorders, 61*(3), 201–216.

Thompson, R. A. (2019). Emotion dysregulation: A theme in search of definition. *Development and Psychopathology, 31*(3), 805–815.

van der Velden, A. M., Kuyken, W., Wattar, U., Crane, C., Pallesen, K. J., Dahlgaard, J., Fjorback, L. O., & Piet, J. (2015). A systematic review of mechanisms of change in mindfulness-based cognitive therapy in the treatment of recurrent major depressive disorder. *Clinical Psychology Review, 37*, 26–39.

Vernetti, A., Shic, F., Boccanfuso, L., Macari, S., Kane-Grade, F., Milgramm, A., … Chawarska, K. (2020). Atypical emotional electrodermal activity in toddlers with autism spectrum disorder. *Autism Research, 13*(9), 1476–1488.

Wang, X., Zhao, J., Huang, S., Chen, S., Zhou, T., Li, Q., Luo, X., & Hao, Y. (2021). Cognitive behavioral therapy for autism spectrum disorders: A systematic review. *Pediatrics, 147*(5), e2020049880.

Weiss, J. A., Thomson, K., & Chan, L. (2014). A systematic literature review of emotion regulation measurement in individuals with Autism Spectrum Disorder. *Autism Research, 7*(6), 629–648.

Weston, L., Hodgekins, J., & Langdon, P. E. (2016). Effectiveness of cognitive behavioural therapy with people who have autistic spectrum disorders: A systematic review and meta-analysis. *Clinical Psychology Review, 49*, 41–54.

Wood, J. J., Kendall, P. C., Wood, K. S., Kerns, C. M., Seltzer, M., Small, B. J., … Storch, E. A. (2020). Cognitive behavioral treatments for anxiety in children with autism spectrum disorder: A randomized clinical trial. *JAMA Psychiatry, 77*(5), 474–483.

Yuan, J., Ding, N., Yang, J., & Liu, Y. (2015). Emotion regulation effects of unconscious acceptance during a frustrating situation: Behavioral and physiological correlates. *Scientia Sinica Vitae, 45*(1), 84–95.

Zantinge, G., van Rijn, S., Stockmann, L., & Swaab, H. (2017). Physiological arousal and emotion regulation strategies in young children with Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders, 47*(9), 2648–2657.

Zeidan, J., Fombonne, E., Scorah, J., Ibrahim, A., Durkin, M. S., Saxena, S., Yusuf, A., Shih, A., & Elsabbagh, M. (2022). Global prevalence of autism: A systematic review update. *Autism Research, 15*(5), 778–790.

Zhou, H., Xu, X., Yan, W., Zou, X., Wu, L., Luo, X., … Wang, Y. (2020). Prevalence of autism spectrum disorder in China: A nationwide multi-center population-based study among children aged 6 to 12 years. *Neuroscience Bulletin, 36*(9), 961–971.

Zhu, J. J., Yan, C. Y., Yang, T. T., Zhu, L., Wu, M., Wang, Y. J., & Li, Y. (2020). Reliability and validity of the emotion regulation checklist to Chinese preschoolers. *Chinese Journal of Clinical Psychology, 28*(06), 1186–1189.

Supplementary Materials

Supplementary Material 1: Behavioral Characteristics of Emotion Regulation in ASD Children Based on 13-Strategy Coding

To further explore subtle differences in the use of 13 emotion regulation strategies between ASD and TD children, independent samples t-tests were conducted (see Supplementary Table 1). Results revealed that compared to TD children, ASD children used significantly fewer "goal-directed behavior" constructive strategies, $t(43) = -6.00$, $p < 0.001$, Cohen's $d = -1.79$. ASD children showed significantly higher usage frequencies than TD children in four strategies: "vocal venting," $t(43) = 3.77$, $p < 0.001$, Cohen's $d = 1.13$; "physical venting," $t(43) = 3.07$, $p = 0.004$, Cohen's $d = 0.92$; "avoidance," $t(43) = 2.60$, $p = 0.013$, Cohen's $d = 0.77$; and "distraction," $t(43) = 2.23$, $p = 0.031$, Cohen's $d = 0.66$. No significant differences were found for other strategies ($ps > 0.05$).

Supplementary Table 1

Differences in 13 Emotion Regulation Strategies Between ASD and TD Children

Strategy	ASD Group (n = 23)	TD Group (n = 22)	t(df)	Cohen's d
Constructive				
Goal-directed behavior	9.87 (2.96)	13.95 (1.21)	-6.00 (43)	-1.79
Support seeking	1.09 (1.41)	0.73 (0.94)	1.00 (43)	0.30
Cognitive reappraisal	0.00 (0.00)	0.09 (0.29)	-1.48 (43)	-0.44
Self-comforting	0.13 (0.46)	0.05 (0.21)	0.79 (43)	0.24
Comfort seeking	0.04 (0.21)	0.14 (0.47)	-0.87 (43)	-0.26
Distraction	0.00 (0.00)	0.18 (0.66)	-1.31 (43)	-0.39
Venting				
Vocal venting	2.13 (2.58)	0.05 (0.21)	3.77 (43)	1.13
Physical venting	0.48 (0.73)	0.00 (0.00)	3.07 (43)	0.92
Self-talk	0.09 (0.29)	0.00 (0.00)	1.42 (43)	0.42
Repetitive behavior	0.22 (1.04)	0.00 (0.00)	0.98 (43)	0.29
Avoidance				
Avoidance	0.78 (1.41)	0.00 (0.00)	2.60 (43)	0.77
Distraction (passive)	1.00 (2.00)	0.05 (0.21)	2.23 (43)	0.66
Substitution	0.57 (1.08)	0.14 (0.64)	1.61 (43)	0.48

Supplementary Material 2: Pre-Post Comparison of 3 Strategy Categories and 13 Strategies Between Intervention and Control Groups

Separate comparisons of pre- and post-intervention emotion regulation strategies for each group revealed no significant differences in any of the 3 strategy categories or 13 individual strategies for the control group (see Supplementary Table 3). For the intervention group, post-intervention constructive strategy frequency was significantly higher than pre-intervention ($p = 0.004$), with "goal-directed behavior" showing significant improvement ($p < 0.001$). For venting strategies, post-intervention frequency was significantly lower ($p = 0.008$), with "vocal venting" significantly reduced ($p = 0.004$). For avoidance strategies, post-intervention frequency was significantly lower ($p = 0.034$), with "substitution strategy" significantly reduced ($p = 0.012$). These results demonstrate that after eight weeks of integrated intervention, ASD children increased their use of constructive strategies like goal-directed behavior and decreased maladaptive strategies like vocal venting and substitution.

Supplementary Table 2
Pre-Post Comparison of Emotion Regulation Strategies in Intervention Group (n = 12)

Strategy	Pre-Test M (SE)	Post-Test M (SE)	Mean Difference (SE)	95% CI
Constructive	10.25 (0.91)	14.50 (0.82)	4.25 (0.44)	[3.32, 5.18]
Goal-directed behavior	8.42 (0.98)	11.67 (0.72)	3.25 (0.22)	[2.78, 3.72]
Support seeking	1.08 (0.44)	1.17 (0.13)	0.08 (0.06)	[-0.05, 0.22]
Cognitive reappraisal	0.00 (0.06)	0.00 (0.06)	0.00 (0.00)	[0.00, 0.00]
Self-comforting	0.75 (0.31)	1.67 (0.31)	0.92 (0.06)	[0.79, 1.05]
Comfort seeking	0.00 (0.13)	0.00 (0.06)	0.00 (0.00)	[-0.13, 0.13]
Distraction	0.00 (0.31)	0.00 (0.31)	0.00 (0.00)	[-0.69, 0.69]
Venting	4.08 (0.87)	1.33 (0.40)	-2.75 (0.59)	[-3.99, -1.51]
Vocal venting	2.67 (0.88)	0.58 (0.22)	-2.08 (0.48)	[-3.11, -1.06]
Physical venting	0.83 (0.99)	0.25 (0.56)	-0.58 (0.27)	[-1.17, 0.00]
Self-talk	0.58 (0.69)	0.50 (0.32)	-0.08 (0.21)	[-0.53, 0.36]
Repetitive behavior	0.00 (0.06)	0.00 (0.06)	0.00 (0.00)	[-0.13, 0.13]
Avoidance	3.33 (0.98)	1.75 (0.76)	-1.58 (0.47)	[-2.58, -0.58]
Avoidance	0.83 (0.72)	0.25 (0.32)	-0.58 (0.22)	[-1.06, -0.11]
Distraction (passive)	1.92 (0.65)	1.00 (0.62)	-0.92 (0.35)	[-1.67, -0.18]
Substitution	0.58 (0.60)	0.50 (0.22)	-0.08 (0.30)	[-0.73, 0.56]

Supplementary Table 3
Pre-Post Comparison of Emotion Regulation Strategies in Control Group (n = 10)

Strategy	Pre-Test M (SE)	Post-Test M (SE)	Mean Difference (SE)	95% CI
Constructive	12.10 (1.00)	11.30 (0.97)	-0.80 (0.75)	[-2.49, 0.89]
Goal-directed behavior	11.20 (0.90)	10.40 (0.48)	-0.80 (0.83)	[-2.59, 0.99]
Support seeking	0.70 (0.15)	0.70 (0.07)	0.00 (0.17)	[-0.35, 0.35]
Cognitive reappraisal	0.10 (0.07)	0.10 (0.07)	0.00 (0.00)	[-0.24, 0.24]
Self-comforting	0.10 (0.96)	0.10 (0.44)	0.00 (0.62)	[-1.32, 1.32]
Comfort seeking	0.00 (0.07)	0.00 (0.07)	0.00 (0.00)	[-0.24, 0.24]
Distraction	0.00 (0.31)	0.00 (0.31)	0.00 (0.00)	[-0.69, 0.69]
Venting	1.60 (1.08)	2.80 (0.65)	1.20 (0.83)	[-0.64, 3.04]
Vocal venting	0.80 (0.62)	2.00 (0.79)	1.20 (0.64)	[-0.20, 2.60]
Physical venting	0.40 (0.65)	0.80 (0.35)	0.40 (0.22)	[-0.12, 0.92]
Self-talk	0.40 (0.34)	0.00 (0.22)	-0.40 (0.30)	[-1.08, 0.28]
Repetitive behavior	0.00 (0.07)	0.00 (0.07)	0.00 (0.00)	[-0.24, 0.24]
Avoidance	1.70 (0.96)	2.50 (0.44)	0.80 (0.53)	[-0.36, 1.96]
Avoidance	0.60 (0.53)	0.80 (0.22)	0.20 (0.30)	[-0.48, 0.88]
Distraction (passive)	0.90 (0.59)	1.20 (0.35)	0.30 (0.27)	[-0.30, 0.90]
Substitution	0.20 (0.31)	0.50 (0.22)	0.30 (0.22)	[-0.18, 0.78]

Supplementary Material 3: Relationship Between ASD Symptom Severity and Emotion Regulation Characteristics

Correlational analyses examined relationships between ASD symptom severity and emotion regulation characteristics. Results showed that ASD symptom severity was significantly negatively correlated with constructive strategies ($r = -0.56$, $p = 0.006$) and significantly positively correlated with avoidance strategies ($r = 0.51$, $p = 0.012$), indicating that children with more severe ASD symptoms tended to use more maladaptive and fewer constructive strategies. However, ASD symptom severity was not significantly correlated with parental reports of emotion regulation ability ($r = -0.14$, $p = 0.527$) or lability/negativity ($r = 0.21$, $p = 0.334$), nor with HR across phases (baseline: $r = 0.05$, $p = 0.830$; induction: $r = -0.13$, $p = 0.562$; recovery: $r = -0.19$, $p = 0.377$), SCR ($r = 0.02$, $p = 0.927$), or SCR peak occurrence ($r = -0.29$, $p = 0.181$).

Supplementary Material 4: Influence of ASD Symptom Severity on Intervention Effects

To examine whether ASD symptom severity moderated intervention effects, linear regression analyses were conducted with pre-post improvement in emotion regulation as the dependent variable, and group, ASD symptom scores, and their interaction as predictors. Results (see Supplementary Table 4) showed that the interaction between ASD symptom scores and group was not significant for any dependent variable (all $ps > 0.05$), indicating that intervention effects were not significantly moderated by ASD symptom severity.

Supplementary Table 4

Moderating Effect of ASD Symptom Scores on Intervention Effects (Interaction Terms Only)

Dependent Variable	B (SE)	95% CI	t	p
Constructive Strategies (difference score)	-0.07 (0.63)	[-1.37, 1.23]	-0.11	0.914
Venting Strategies (difference score)	0.03 (1.06)	[-2.19, 2.26]	0.03	0.975
Avoidance Strategies (difference score)	-0.37 (0.58)	[-1.57, 0.82]	-0.64	0.531
Emotion Regulation (difference score)	-0.39 (0.56)	[-1.56, 0.77]	-0.70	0.493
Lability/Negativity (difference score)	1.39 (0.76)	[-0.21, 3.00]	1.82	0.085

Note: Figure translations are in progress. See original paper for figures.