Atypical Facial Expression Characteristics in Children with Autism Spectrum Disorder and Their Application in Early Screening

Authors: Yang Ping, Fang Runqiu, Weng Xuchu, Weng Xuchu

Date: 2024-12-11T00:19:00+00:00

Abstract

Children with Autism Spectrum Disorder (ASD) exhibit characteristic atypical facial expression features, including a predominance of neutral expressions, reduced positive expressions, low frequency of social smiling, and impaired spontaneous facial expression imitation ability. These features remain stable from early childhood through childhood and have become important markers for ASD risk assessment. However, traditional research methods (such as manual evaluation and facial electromyography) suffer from limitations in analyzing facial expressions of children with ASD, including strong subjectivity, time-consuming procedures, and difficulty in generalization. In recent years, the rapid development of artificial intelligence has enabled the application of automated expression recognition technology based on computer vision and deep learning, which not only significantly improves analytical efficiency but also reduces subjective errors in human evaluation, providing strong support for large-scale early screening of ASD based on atypical facial expression features. Future research can further optimize recognition models by designing elicitation paradigms that more closely approximate naturalistic contexts, deeply explore the diverse facial expression characteristics of children with ASD, and simultaneously enhance model accuracy and sensitivity to advance the development of early screening and intervention for ASD.

Full Text

Preamble

Atypical Facial Expression Characteristics in Children with Autism Spectrum Disorder and Their Application in Early Screening

YANG Ping[1], FANG Runqiu[2], WENG Xuchu[2]
([1] School of Psychology, Guizhou Normal University, Guiyang 550025, China)

([2] Institute of Brain Research and Rehabilitation, South China Normal University, Guangzhou 510898, China)

Abstract

Children with Autism Spectrum Disorder (ASD) exhibit distinctive atypical facial expression characteristics, including a predominance of neutral expressions, reduced positive expressions, low frequency of social smiling, and insufficient spontaneous facial expression imitation. These features remain stable from early childhood through later developmental stages and have become important markers for ASD risk assessment. However, traditional research methods (such as manual evaluation and facial electromyography) suffer from limitations including strong subjectivity, time consumption, and difficulty in large-scale application when analyzing facial expressions in children with ASD. In recent years, rapid advances in artificial intelligence have enabled the application of automated expression recognition technology based on computer vision and deep learning. This approach not only significantly improves analytical efficiency but also reduces subjective errors in human evaluation, providing strong support for large-scale ASD early screening based on atypical facial expression characteristics. Future research can further optimize recognition models by designing induction paradigms that more closely approximate natural contexts, deeply exploring the diverse facial expression characteristics of children with ASD, while simultaneously enhancing model accuracy and sensitivity to advance the development of ASD early screening and intervention.

Keywords: autism spectrum disorder, facial expression, computer automatic recognition

1 Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized primarily by social impairments, difficulties in verbal and nonverbal communication, and repetitive and stereotyped behaviors (First, 2013). ASD not only poses significant challenges for patients and their families but also creates substantial economic burdens for society. Although no clear cognitive-neural markers or effective treatment methods have been identified to date (Saral et al., 2023), research indicates that early identification and intervention can significantly improve language abilities, cognitive development, and behavioral performance in children with ASD, thereby enhancing their long-term quality of life (Thabtah & Peebles, 2019). Consequently, efficient early screening forms the foundation for subsequent precise intervention and is crucial for the overall development of children with ASD (Wieckowski et al., 2021).

In recent years, atypical facial expression characteristics have gradually been recognized as important clues for early screening of ASD (Egger et al., 2018; Hashemi et al., 2021). Compared to children with typical development (TD), children with ASD typically exhibit more neutral expressions, fewer positive expressions, and lower frequencies of social smiling, while their spontaneous facial expression imitation abilities are also weaker (Manfredonia et al., 2019). These atypical facial expression characteristics directly impact their social competence and emotional communication (Keating & Cook, 2021) and are considered important contributors to their social and communication impairments (Wieckowski et al., 2021), difficulties in emotion understanding, and delayed empathy development (Grazzani et al., 2018). Therefore, early screening methods based on atypical facial expression characteristics provide important evidence for ASD diagnosis.

Assessment methods for atypical facial expression characteristics in children with ASD have undergone three main developmental stages. The first stage primarily relied on subjective judgment methods such as manual evaluation, home video analysis, and retrospective interviews to assess facial expression characteristics in children with ASD (Adrien et al., 1993; Clifford & Dissanayake, 2008). This approach required professional evaluators to make judgments based on standardized tools. While professionally robust, it suffered from high subjectivity and consumed substantial human resources and time. The second stage employed electromyography (EMG) sensor technology to capture facial muscle movement information for identifying atypical facial expression characteristics in children with ASD (Beall et al., 2008; 马伟娜, 朱蓓蓓, 2014). Although this method improved measurement objectivity, it required children to wear contact devices such as EMG electrodes, which could cause discomfort and inhibit natural expressions, affecting data authenticity and validity. Additionally, its operational complexity limited application in large-scale screening. The third stage has benefited from the rapid development of computer vision and artificial intelligence technologies, which record facial expression data through non-contact 摄像 devices and analyze it using automated recognition algorithms (Egger et al., 2018; Hashemi et al., 2021; 唐传高等, 2020; 廖梦怡等, 2021). This approach effectively reduces the impact of human intervention on evaluation results while significantly improving efficiency and accuracy, making it particularly suitable for large-scale screening scenarios. In the future, automated expression recognition technology is expected to become an important tool for ASD risk assessment.

With the rapid growth of literature on children's facial expressions, early screening methods based on atypical facial expression characteristics are considered to have significant developmental potential. This article provides a systematic review of empirical research in this field: First, it focuses on analyzing the manifestation, specificity, and stability of atypical facial expression characteristics in children with ASD; second, it traces the developmental trajectory from manual evaluation to computer-automated recognition technology, deeply exploring the applicability, advantages, and limitations of each method; finally, it examines the application of ASD early screening based on these facial expression characteristics, with particular emphasis on the introduction of artificial intelligence technology. This technology not only improves the ecological validity of screening (no direct contact with participants required) but also enhances screening efficiency (capable of processing diverse data types and increasing processing speed) and demonstrates potential for large-scale sample screening, making it highly representative and practical.

2.1 Literature Search Strategy

The literature search was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009). Studies on facial expressions in children with ASD were retrieved from PubMed, EMBASE, Web of Science, AMS-journals, China National Knowledge Infrastructure (CNKI), and Wanfang databases from inception to September 2024. The search combined subject headings with free-text terms. English search terms included Autism Spectrum Disorder, measuring Autism Risk Behaviors, Facial Emotions, Facial Expression, and Emotion Automatic. Chinese search terms included 孤独症谱系障碍 (autism spectrum disorder), 情绪表达 (emotion expression), 共情 (empathy), 孤独症早期筛查 (autism early screening), and 儿童面部表情 (children's facial expression).

2.2.1 Inclusion Criteria

(1) Study participants: Children with ASD and TD children, where ASD children met diagnostic criteria for ASD and were diagnosed by professional physicians, with no gender restrictions.

(2) Study content: Included measurement of facial expressions in ASD with clear measurement indicators, using TD children or other non-ASD children as control groups.

2.2.2 Exclusion Criteria

(1) Study participants: TD children only, and primarily adolescents and adults (age $>$ 12 years).

(2) Study content: No clear measurement indicators for facial expressions.

(3) Duplicate publications.

2.2.3 Literature Review Method

Based on the above criteria, six eligible studies were identified. The screening process is shown in Figure 1 [Figure 1: see original paper].

Figure 1 Literature screening process and results

2.2.4 Basic Information of Included Studies

The results of the included studies show that with the rapid development of artificial intelligence technology, researchers have used methods such as viewing emotional face pictures, videos, cartoons, and human interaction videos to elicit children's facial emotional expressions, recorded these performances with 摄像 devices, and applied computer-automated recognition technology to identify and evaluate facial expressions in children with ASD. This approach effectively explores the potential of facial expressions as stable and effective markers of risk behaviors, clearly distinguishing children with ASD from TD children, and demonstrating that atypical facial expression characteristics have broad application prospects in ASD early screening.

This review systematically included six studies on atypical facial expression characteristics in children with ASD. Table 1 summarizes the research designs and outcome indicators related to atypical facial expression characteristics in these studies. The methods and results of the six studies are analyzed and summarized below.

Table 1 Summary of sample characteristics, induction paradigms, and outcome indicators of included studies

Measurement Method	Induction Paradigm	Stimulus Material Emotion	Facial Expression Indicators
Hashemi et al., 2021 (16-31 months)	Computer recognition	Watching videos	Bubbles, jumping rabbits, and toys
廖梦怡等, 2020 (3-6 years)	Computer recognition	Watching videos	Positive and negative emotion cartoons
唐传高等, 2020 (8-18 months)	Computer recognition	Real-world interaction	Still-face paradigm
廖梦怡等, 2021 (3-6 years)	Computer recognition	Watching videos	Funny videos of mother feeding baby
Carpenter et al., 2021 (16-31 months)	Computer recognition	Watching videos	Jumping rabbits, puppets, singing
Egger et al., 2018 (12-72 months)	Computer recognition	Watching videos	Videos of women and toys

Note: Computer recognition: Camera records children's faces, computer automatically recognizes facial expressions. Appropriateness: Facial expression emotion matches the current situation. Automatic mimicry accuracy and frequency: Children's spontaneous imitation accuracy and frequency of facial expressions without prompting. Frequency and duration: Frequency and duration of different emotional facial expressions over a period. Reaction time: Time difference between emotion induction and facial expression appearance.

3.1.1 Prevalence of Neutral Facial Expressions and Reduction of Positive Expressions

Facial expressions are typically categorized as positive, negative, and neutral. Generally, positive and negative expressions are triggered by specific emotional stimuli, while neutral expressions often appear in situations lacking clear emotional stimuli (Briot et al., 2021). Research indicates that children with ASD show significantly different facial expression characteristics compared to TD children or non-ASD children (Yeung, 2022). A meta-analysis by Trevisan et al. (2018) revealed that children with ASD typically express emotions less frequently through facial expressions, showing lower expression frequency and, when expressions do occur, relatively shorter duration (Trevisan et al., 2018). This characteristic makes a predominance of neutral expressions one of the early features of ASD, particularly in social contexts where children with ASD more frequently display neutral or emotionally flat facial expressions (Clifford & Dissanayake, 2008). Related studies have further validated this characteristic. In simulated daily interaction contexts, children with ASD showed significantly longer durations of neutral expressions during mutual gaze with their mothers compared to non-ASD children (唐传高等, 2020). In laboratory settings, when viewing positive amusing videos (such as bubbles and jumping rabbits), children with ASD still showed significantly prolonged neutral expression durations while positive expression durations were markedly shortened (Egger et al., 2018; Hashemi et al., 2021). Cross-sectional studies have also found that with increasing age (1-5 years), the characteristic of neutral expressions predominating remains stable in children with ASD. Although positive expressions increase with age, their proportion remains significantly lower than that of neutral expressions (Egger et al., 2018).

In summary, the characteristic of children with ASD showing predominantly neutral facial expressions with reduced positive expressions may reflect significant difficulties in emotion perception, social context understanding, and self-emotion regulation. This feature is particularly prominent in social contexts and remains stable with age. Therefore, the frequency and duration of facial expressions can serve as early screening indicators for ASD risk behaviors.

3.1.2 Low Frequency of Social Smiling

In child development, smiling is one of the most common social behaviors. Social smiling refers to children smiling while looking at others, a behavior that typically emerges in TD children at 2-3 months of age and increases in frequency with age (Ahn et al., 2024; Pezzotti et al., 2024). However, research indicates that children with ASD show significant deficits in both the frequency and attentional focus of social smiling. Compared to TD children, children with ASD display social smiling less frequently in social contexts, a characteristic considered one of the important early indicators for ASD identification (Ahn et al., 2024). A retrospective study by Alvari et al. (2021) used home videos combined with OpenFace AI-based software to analyze facial expression behaviors and micro-movements in children aged 12-16 months. Results showed that compared to TD children, children with ASD had significantly reduced frequency and duration of social smiling (Alvari et al., 2021). This difference was particularly evident in interactions with close family members; even when facing their parents, children with ASD showed less initiative in displaying smiles. Similarly, a study by Nichols et al. (2014) recruiting children aged 12-23 months showed that high-risk ASD children had lower social smiling, non-social smiling, and eye contact during smiling compared to lower-risk children (Nichols et al., 2014). Additionally, Filliter et al. (2015) found that high-risk ASD children already showed significantly lower levels and durations of social smiling at 6 months, a characteristic that remained consistent in follow-up age groups at 12 and 18 months (Filliter et al., 2015). These results indicate that delays in social smiling and emotional interaction in children with ASD are evident in early developmental stages and remain relatively stable in subsequent development. In summary, the frequency, duration, and eye contact during smiling can all serve as reliable markers for identifying potential ASD risk.

3.1.3 Insufficient Automatic Facial Expression Imitation Ability

In social interactions, people typically imitate others' facial expressions—for example, unconsciously smiling when seeing a smiling face or frowning when seeing an angry expression. This behavior is called "facial mimicry" and forms the basis of multiple key social-cognitive functions (Liu et al., 2023). Clinical research indicates that abnormalities in facial expression imitation ability are closely related to severe social dysfunction (Korb et al., 2010).

Assessment of automatic facial expression imitation is primarily based on contact-based facial EMG and non-contact video expression recognition methods. Assessment indicators include multiple dimensions such as imitation accuracy, automaticity, intensity, and reaction time. Through EMG analysis, different expressions correspond to specific facial muscle activities: the zygomaticus major (located on both sides of the face, connecting the cheekbone and mouth corner) is typically associated with smiling and happy expressions; the corrugator supercilii (located above the eyebrows) is responsible for pulling the eyebrows down and inward, commonly seen in angry expressions; and the medial frontalis (located in the forehead region) is responsible for raising the eyebrows, typically associated with surprise or confusion expressions. Based on these muscle activity patterns, researchers can precisely analyze children's imitation abilities for different emotional expressions. Accordingly, Deschamps et al. (2015) used EMG to study automatic imitation performance in 20 children with ASD and 27 TD children (aged 6-7 years) when viewing pictures of angry, fearful, sad, and happy expressions. Results showed no significant difference in imitation accuracy between the two groups, but social response impairments in children with ASD were significantly associated with reduced frequency of imitation for fearful faces (Deschamps et al., 2015). In contrast, a study by Beall et al. (2008) on children with ASD aged 8-13 years showed that EMG responses to different emotional expression pictures in children with ASD lacked stability and discriminability, suggesting that their facial imitation ability may be deficient compared to TD children. However, the imitation ability for happy expressions in children with ASD improved with age (Beall et al., 2008). On the other hand, studies using non-contact video expression recognition methods have reached similar conclusions. For example, Liu et al. (2023) had children view static colored facial expression pictures (such as happy, sad, and fearful) and used automatic facial coding software to analyze video recordings. Results showed no significant difference in expression imitation accuracy between children with ASD and TD children, but the imitation intensity in children with ASD was significantly lower than that in TD children (Liu et al., 2023).

Overall, studies based on both contact-based facial EMG and non-contact facial expression video recognition technologies consistently indicate that children with ASD exhibit certain abnormalities in automatic facial expression imitation ability. Although differences in expression imitation accuracy between children with ASD and TD children are not significant, children with ASD show lower imitation intensity, particularly with more ambiguous responses and weaker expression discrimination when facing negative emotions such as fear and anger. Notably, with increasing age, the imitation ability for positive emotional expressions (such as happiness) in children with ASD improves. These studies suggest that social response impairments in children with ASD may be closely related to deficits in automatic facial expression imitation ability, particularly in recognizing and imitating complex expressions. Future research could combine larger sample sizes and multi-dimensional physiological response indicators to further explore the developmental mechanisms of facial expression imitation ability and its underlying neural basis, which would help develop more precise early screening tools for ASD.

3.2.1 Manual Assessment

Manual assessment primarily relies on behavioral observation and evaluators' subjective judgment to achieve early screening of children with ASD (Dawson et al., 2005). This method mainly includes two approaches: First, evaluators assess children with ASD based on standardized diagnostic tools, such as using infant autism screening scales to collect data on children's daily behaviors and cognitive abilities, with professional doctors conducting evaluations through observation to screen for ASD (Guthrie et al., 2019; Thabtah & Peebles, 2019). Second, evaluators conduct frame-by-frame analysis of facial expression changes in children with ASD based on videos of their overt behaviors recorded by parents, according to standardized tools (Clifford & Dissanayake, 2008). However, whether based on standardized tools for professional evaluation or manual coding through frame-by-frame analysis of home videos, these traditional screening methods have the following limitations: (1) **Dependence on professional resources**: Professional doctor screening requires long-term training, but shortages of medical resources lead to extended screening times, potentially missing critical intervention periods. (2) **Subjectivity limitations**: The evaluation process is susceptible to evaluators' subjective factors, reducing the objectivity of diagnostic results. (3) **Difficulty in quantification**: Direct observation of children's facial expressions is difficult to quantify precisely, while frame-by-frame video analysis is extremely time-consuming and labor-intensive. (4) **Insufficient scalability**: Manual observation methods are difficult to support large-scale screening, limiting their application scope.

In summary, traditional ASD early screening methods have significant deficiencies in human resource costs, objectivity, and efficiency. To address these challenges, there is an urgent need to develop a new, efficient, objective, and economical screening technology pathway to compensate for existing method limitations and promote the popularization and scientific advancement of ASD early screening.

3.2.2 EMG Sensors

Facial expression changes are complex and fleeting, making direct observation and recording difficult. However, EMG sensor technology provides an important objective tool for capturing and quantifying facial expressions in children with ASD by detecting bioelectrical activity of facial muscles. Compared to traditional manual assessment methods, EMG technology has the following advantages: (1) **Non-invasive**: EMG sensors only need to attach electrodes to the skin surface to measure muscle electrical activity, causing no harm to children. (2) **High sensitivity**: EMG sensors can detect weak muscle electrical signals, accurately reflecting muscle contraction and relaxation. (3) **High temporal resolution**: EMG sensors can collect muscle electrical signals in real-time with millisecond-level temporal resolution, suitable for analyzing dynamic processes of rapid facial expression changes. (4) **High spatial resolution**: EMG sensors can be placed on different facial muscle sites, such as the frontalis, zygomaticus, and corrugator supercilii, to study regional differences and coordination of muscle activities. (5) **Objectivity**: By quantitatively recording muscle electrical signals, EMG technology can precisely present facial expression characteristics of children with ASD in data form, avoiding subjective bias.

Nevertheless, EMG technology still faces some limitations when applied to children's facial expression detection. First, sensors are typically concentrated in the cheek and eyebrow regions, which may be insufficient to comprehensively capture complex facial expression activities, thereby limiting judgment of the severity of facial expression abnormalities in ASD (Pellicano & Burr, 2012). Second, facial attachment of sensors may inhibit children's natural expressions, affecting the ecological validity of results. Additionally, EMG measurement requires a certain degree of cooperation from children, thus limiting its applicability for early screening of younger children.

3.2.3 Computer Automatic Recognition

In recent years, the rapid development in computer artificial intelligence, particularly the maturation of machine learning and deep learning technologies, has brought revolutionary advances to the application of computer vision in ASD early screening (Leroy et al., 2024). ASD screening based on computer automatic recognition technology demonstrates numerous advantages: (1) **Precise, objective, and quantitative description of children's facial expression patterns**: Computer automatic recognition technology can accurately capture subtle changes in children's facial expressions, enabling quantitative description of facial expression patterns. This method avoids subjectivity in manual evaluation and provides more reliable data support for facial expression research. (2) **Saving labor and time, supporting large-scale promotion**: Automatic recognition technology eliminates the need for manual frame-by-frame analysis, greatly reducing analysis costs and time investment, and substantially improving screening efficiency. Its high scalability makes it suitable for large-scale population screening, potentially alleviating medical resource shortages in traditional screening methods. (3) **Simple equipment, wide applicability**: Facial expression recognition only requires an ordinary camera to complete data collection. Its non-contact characteristic not only reduces operational difficulty but also avoids interference with children's natural expressions from equipment, making it more suitable for screening in daily family or educational environments. (4) **Multi-modal combined classification**: Computer recognition technology can combine facial expression data with other biological-behavioral indicators (such as eye movement trajectories and attention measurements) to construct more comprehensive ASD screening models through multi-modal data analysis, thereby improving screening accuracy and reliability.

3.3 Application: Early Screening of Atypical Facial Expression Characteristics in Children with ASD—Computer-Based Automatic Recognition

As noted above, atypical facial expression characteristics in children with ASD include a predominance of neutral facial expressions, reduced positive facial expressions, low frequency of social smiling, and insufficient facial expression imitation ability. These features remain stable from infancy through childhood and serve as important markers for ASD risk assessment. Currently, with the development of computer vision technology and artificial intelligence, automated risk assessment tools based on these atypical facial expression characteristics are gradually being refined, demonstrating high practicality: strong ecological validity (no direct contact with participants, reducing human interference), outstanding efficiency (rapid processing of diverse data types), and applicability to large-scale screening with strong representativeness. The following explores the specific applications of computer technology in early screening of atypical facial expression characteristics in children with ASD from these three aspects.

3.3.1 Application of Non-Contact Facial Expression Recognition

This section explores how non-contact screening can be achieved based on facial expression characteristics, demonstrating the ecological advantages of this method. Tang et al. (2020) proposed an early automatic screening method for ASD based on children's facial expressions. The study included 30 children aged 8-18 months (10 children with ASD and 20 TD children), who engaged in simulated daily playful interactions and still-face states with their mothers while their facial information was recorded using concealed 摄像 devices (such as ordinary cameras). Researchers combined manual annotation with computer automatic recognition methods to identify children's facial expressions. Results showed that in the still-face state, children with ASD had significantly longer durations of neutral facial expressions than TD children, and the automated classification accuracy based on facial expressions reached 83.3% (唐传高等, 2020). Similarly, Hammal et al. (2017) studied facial expressions in children aged 16-31 months (42 children with ASD and 82 TD children) while they watched simple video stimuli (such as bubbles, jumping rabbits, and puppet toys, with video durations of 30 seconds, 66 seconds, and 68 seconds, respectively). The study found that these videos could effectively elicit positive expressions in TD children, while children with ASD showed fewer positive expressions, again validating the effectiveness of non-contact facial expression recognition for ASD screening (Hammal et al., 2017). Additionally, domestic scholars used cartoons of interest to children as stimulus materials, extracting 5 positive emotion videos and 5 negative emotion videos from the animated TV series "Home with Kids," each 12 seconds long. Researchers recruited 3-6-year-old children (14 children with ASD, 14 TD children) to watch the cartoons while simultaneously recording their facial videos. Results found that when watching positive emotion videos, children with ASD were less likely to be elicited to show positive facial expressions compared to TD children; when watching negative emotion videos, there was no significant difference in negative expressions between ASD and TD children (廖梦怡等, 2020). This study demonstrated the quantitative analysis capability of computer real-time facial expression recognition, and its generated recognition indicators have reference value for screening children with ASD.

In summary, researchers using cameras for non-contact facial expression recognition technology have shown significant application potential in ASD screening. First, this method relies on 摄像 devices for data collection, eliminating the need for unfamiliar researchers to record on-site or for participants to wear contact devices (such as EMG electrodes), effectively avoiding the possibility of inhibiting natural expressions due to contact, thereby significantly improving the convenience of data collection and the ecological validity of screening. Second, by designing experimental methods that simulate daily life situations (such as recording natural interactions between children and their mothers, watching simple stimulus videos, or emotionally engaging cartoons), researchers can capture more authentic facial expression characteristics of participants in more relaxed environments. This data collection approach that approximates natural states not only optimizes the ecological validity of screening but also enhances data representativeness, providing more reliable technical support for ASD early screening and risk assessment.

3.3.2 Efficient Data Processing Application of Facial Expression Fusion with Multi-Modal Data

This section focuses on improving the accuracy and efficiency of ASD screening by combining facial expressions with other data types (such as head movement, eye movement, physiological signals, language, and behavior). Multi-modal data can reveal multi-level abnormal patterns in children with ASD, providing more comprehensive information support for early diagnosis. Carpenter et al. (2021) collected facial videos of 22 children with ASD (mean age 26 months) and 74 TD children (mean age 21.7 months) while they voluntarily watched simple stimulus videos (such as bubbles, jumping rabbit toys, puppet toys) to elicit spontaneous facial expressions. Consistent with previous research, computer vision and machine learning analysis results showed that children with ASD displayed more neutral expressions, while TD children showed richer facial expressions (Carpenter et al., 2021). Based on this, researchers further introduced competitive visual stimuli (people and toys appearing simultaneously), using cameras and computer recognition technology to track children's facial orientation to determine their attentional bias toward people or toys. Results showed that multi-modal analysis combining facial expressions and orientation information significantly improved screening accuracy, helping to distinguish between ASD and TD children (Carpenter et al., 2021). Similarly, 廖梦怡 et al. (2021) recorded facial expression videos, eye movement data, and cognitive question response scores and reaction times in 3-6-year-old children (74 children with ASD, 70 TD children) while they watched short videos ("mother feeding baby"). By fusing multi-modal data and using a random forest classifier to identify ASD and TD children, results showed that the classification accuracy of fused multi-modal data reached 85%, significantly higher than the accuracy based on single facial expression data (廖梦怡等, 2021). Finally, a study by 马伟娜 and 朱蓓蓓 (2014) further integrated physiological signal data (skin conductance, skin temperature, and finger pulse) of children with ASD while they viewed different emotional pictures. Results showed that changes in skin conductance, skin temperature, and finger pulse in children with ASD when viewing emotional pictures were significantly lower than in TD children, suggesting that emotional stimuli have difficulty eliciting emotional responses in children with ASD (马伟娜, 朱蓓蓓, 2014). This finding further indicates that the characteristic of children with ASD showing more neutral expressions and fewer positive expressions may stem from their emotion perception impairments.

In summary, integrating multi-modal data for ASD screening not only achieves high classification accuracy but also, in some contexts, outperforms traditional methods relying on single indicators or manual evaluation. Therefore, multi-modal data fusion is a highly promising early screening technology for ASD, providing important evidence and application value for precise diagnosis.

3.3.3 Large-Scale Screening Technology Application Based on Facial Expression Recognition

Existing research on early screening methods based on atypical facial expression characteristics in children with ASD has mostly focused on small sample sizes. However, with the growing demand for early screening and intervention for children with ASD, how to achieve large-scale screening has become a key challenge. In this context, the introduction of mobile technology provides an important solution. Egger et al. (2018) developed a smartphone-based mobile application that used the phone to present video stimulus materials (such as bubbles, rabbits, mirrors) to elicit children's social and emotional responses, while using the phone camera to record children's facial expressions in real-time. This method breaks through the spatial and temporal limitations of traditional screening, allowing parents to complete screening flexibly at home, which is convenient and fast, greatly expanding application scenarios. In the study, researchers used computer vision and machine learning technology to analyze mobile-recorded facial videos of children to automatically detect and classify their emotional expressions and behavior patterns. The study covered 1,756 families (children aged 12-72 months), collecting 5,618 caregiver reports and 4,441 videos recorded in natural environments. Analysis results showed that compared to low-risk ASD children, high-risk ASD children showed significantly increased neutral expressions and significantly reduced positive expressions when viewing bubble, rabbit, and mirror stimuli (Egger et al., 2018). Therefore, these characteristics can serve as effective indicators for early screening, and analyzing these facial expression features can identify high-risk ASD children earlier. Similarly, Thabtah and Peebles (2019) developed a machine learning-based mobile screening tool called ASD Tests. This application simplified traditional screening scales by designing exclusive tests for different age groups (infancy, childhood, adolescence, and adulthood), with each group only needing to complete 10 test questions within 3-5 minutes. Non-professionals can easily operate it, and it can be widely applied in homes, schools, or medical institutions. The study found that this tool achieved sensitivity, specificity, and accuracy rates of over 95% for ASD screening, representing an efficient and highly accessible screening solution (Thabtah & Peebles, 2019).

Previous ASD screening was mostly conducted in laboratory or hospital environments, while the mobile apps developed by Egger et al. (2018) and Thabtah and Peebles (2019) enable parents to use smartphones to collect data in children's natural environments, thereby capturing their natural state behaviors. Computer-based large-scale screening using mobile applications is not limited by time or space, expanding screening application scenarios to various settings such as homes and schools. This method can record and recognize facial expressions of children with ASD in both laboratory and natural contexts, improving ecological validity and providing practical technical support for large-scale early screening of ASD.

4 Summary and Outlook

This article discusses atypical facial expression characteristics in children with ASD, first outlining the main features: predominance of neutral facial expressions, reduction of positive facial expressions, low frequency of social smiling, and insufficient spontaneous facial expression imitation ability. Second, it systematically reviews existing assessment tools and analyzes the evolutionary process of three major assessment methods—manual evaluation, facial EMG evaluation, and computer-automated facial expression recognition—clarifying their respective advantages and disadvantages. Specifically, manual evaluation relies on expert subjective judgment, which, despite being professional, is inefficient and has subjective bias; facial EMG evaluation provides precise facial muscle activity data but is operationally complex and may affect natural expressions; while computer-automated recognition achieves more efficient and objective emotion expression recognition through artificial intelligence technology, showing broad application potential. Finally, this article focuses on exploring the application potential of facial expression recognition based on computer artificial intelligence technology in early screening of children with ASD, noting that this technology helps improve screening efficiency and accuracy, providing important support for early intervention. Future research could also strengthen the following aspects:

Designing induction paradigms that more closely approximate natural scenarios for children's facial expressions to improve experimental ecological validity. Researchers continuously attempt to explore more attractive experimental designs for children through various experimental materials ranging from static pictures to simple geometric stimulus animations, to human interaction videos with social attributes and cartoons favored by children, to elicit more authentic facial expressions. Additionally, by manipulating the valence of stimulus materials (positive, neutral, and negative), experiments can guide children to display different facial expressions. However, three aspects of this approach can be further optimized: First, **selection and age-appropriateness of video materials**—whether videos align with the preferences and comprehension abilities of the target age group directly affects their attention and emotional expressions. Therefore, video materials should undergo age-appropriateness evaluation before experiments to ensure they match target children's interests. After experiments, children's interest in and comprehension of videos can also be measured to further confirm material validity and applicability. Second, **presentation duration of video materials**—common video durations range from 12 to 68 seconds. If too short, children may not fully immerse in the animation context, affecting situational comprehension and thus authentic facial expressions. Therefore, appropriately extending video duration to allow children to fully enter the context helps capture more authentic emotional expressions. Third, **valence design of video materials**—current research mostly uses single-valence video materials (positive, neutral, or negative) for classification analysis. However, having children switch from watching a positive clip to a negative one easily causes emotional fragmentation, which still carries laboratory design characteristics and lacks natural contextual coherence. Future research could consider using single long clips containing positive, neutral, and negative plot fluctuations to ensure story integrity. Subsequent analysis can then isolate facial expression features elicited by different valence segments while maintaining children's attention, achieving more natural and ecological experimental design.

Exploring diverse facial expression characteristics in children with ASD. Currently, consistent results on atypical facial expression characteristics in children with ASD mainly focus on reduced positive expressions and increased neutral expressions. However, some studies have explored facial expression characteristics in children with ASD when viewing negative stimulus materials, but results remain controversial. Generally, children with ASD tend to maintain more neutral expressions when facing negative stimuli (Brewer et al., 2016), with fewer negative emotional expressions or showing delays, which may reflect difficulties in recognizing negative emotions in children with ASD (Ashwin et al., 2006), or may indicate that although they can perceive negative emotions, their facial expressions remain relatively rigid (Pelphrey et al., 2002). Additionally, other studies found that children and adolescents with ASD showed no significant difference in neural responses compared to non-ASD children when facing angry and fearful stimuli, showing no specific facial expressions (Malaia et al., 2019). However, some research indicates that children with ASD show more intense emotional expressions when facing negative stimuli (Magnée et al., 2007), or display incongruent facial expressions such as angry frowning accompanied by raised eyebrows (Beall et al., 2008). These atypical responses suggest that children with ASD have more complex and diverse expression patterns for negative expressions. Therefore, future research should continue to deeply explore atypical facial expression characteristics in children with ASD when facing negative stimuli, including potentially incongruent or odd facial expressions they may display. This research direction will help reveal unique manifestations of emotion expression recognition and expression in children with ASD, providing more evidence for ASD screening and intervention.

Improving the accuracy and sensitivity of computer-automated facial expression recognition models. Since children are in developmental stages with facial features significantly different from adults (Hammal et al., 2017), future research can improve facial expression recognition model accuracy by constructing age-group-specific emotional facial expression databases for different age groups (such as infancy and childhood). Meanwhile, establishing norms for atypical facial expression characteristics in children with ASD through large-sample data can also significantly enhance recognition effectiveness. Additionally, computer-automated recognition technology helps monitor temporal dynamic changes in children's facial expressions, deriving quantitative indicators such as expression elicitation intensity, elicitation time, and maintenance duration. These temporal dynamic features help deepen understanding of facial expressions in children with ASD. Furthermore, computer technology can combine multiple characteristic indicators such as scales, cognitive tests, and eye-tracking, integrating multi-dimensional data to enhance assessment capabilities for atypical facial expressions in children with ASD.

References

唐传高, 郑文明, 宗源, 仇娜娜, 闫思蒙, 翟梦瑶, 柯晓燕. (2020). 深度空时婴幼儿表情识别模型下的 ASD 自动筛查. 中国图象图形学报, 25(11), 11.

廖梦怡, 陈靓影, 张坤, 王广帅. (2020). 自闭症谱系障碍儿童共情过程中能力缺陷量化研究. 中国特殊教育, (1), 51-59.

廖梦怡, 陈靓影, 王广帅, 彭世新. (2021). 融合多模态数据的自闭症谱系障碍儿童智能化识别及其有效性. 科学通报, 66(20), 11.

马伟娜, 朱蓓蓓. (2014). 孤独症儿童的情绪共情能力及情绪表情注意方式. 心理学报, 46(4), 528–539.

Adrien, J. L., Lenoir, P., Martineau, J., Perrot, A., Hameury, L., Larmande, C., & Sauvage, D. (1993). Blind ratings of early symptoms of autism based upon family home movies. *Journal of the American Academy of Child and Adolescent Psychiatry, 32*(3), 617–626. https://doi.org/10.1097/00004583-199305000-00019

Ahn, Y. A., Moffitt, J. M., Tao, Y., Custode, S., Parlade, M., Beaumont, A., Cardona, S., Hale, M., Durocher, J., Alessandri, M., Shyu, M. L., Perry, L. K., & Messinger, D. S. (2024). Objective measurement of social gaze and smile behaviors in children with suspected autism spectrum disorder during administration of the autism diagnostic observation schedule, 2nd edition. *Journal of Autism and Developmental Disorders, 54*(6), 2124–2137. https://doi.org/10.1007/s10803-023-05990-z

Alvari, G., Furlanello, C., & Venuti, P. (2021). Is smiling the key? Machine learning analytics detect subtle patterns in micro-expressions of infants with ASD. *Journal of Clinical Medicine, 10*, 1776. https://doi.org/10.3390/jcm10081776

Ashwin, C., Chapman, E., Colle, L., & Baron-Cohen, S. (2006). Impaired recognition of negative basic emotions in autism: A test of the amygdala theory. *Social Neuroscience, 1*(3–4), 349–363. https://doi.org/10.1080/17470910601040772

Beall, P. M., Moody, E. J., McIntosh, D. N., Hepburn, S. L., & Reed, C. L. (2008). Rapid facial reactions to emotional facial expressions in typically developing children and children with autism spectrum disorder. *Journal of Experimental Child Psychology, 101*(3), 206–223. https://doi.org/10.1016/j.jecp.2008.04.004

Brewer, R., Biotti, F., Catmur, C., Press, C., Happé, F., Cook, R., & Bird, G.

(2016). Can neurotypical individuals read autistic facial expressions? Atypical production of emotional facial expressions in autism spectrum disorders. *Autism Research, 9*(2), 262–271. https://doi.org/10.1002/aur.1508

Briot, K., Pizano, A., Bouvard, M., & Amestoy, A. (2021). New technologies as promising tools for assessing facial emotion expressions impairments in ASD: A systematic review. *Frontiers in Psychiatry, 12*, 634756. https://doi.org/10.3389/fpsyt.2021.634756

Carpenter, K. L. H., Hahemi, J., Campbell, K., Lippmann, S. J., Baker, J. P., Egger, H. L., Espinosa, S., Vermeer, S., Sapiro, G., & Dawson, G. (2021). Digital behavioral phenotyping detects atypical pattern of facial expression in toddlers with autism. *Autism Research, 14*(3), 488–499. https://doi.org/10.1002/aur.2391

Clifford, S. M., & Dissanayake, C. (2008). The early development of joint attention in infants with autistic disorder using home video observations and parental interview. *Journal of Autism and Developmental Disorders, 38*(5), 791–805. https://doi.org/10.1007/s10803-007-0444-7

Dawson, G., Webb, S. J., & McPartland, J. (2005). Understanding the nature of face processing impairment in autism: Insights from behavioral and electrophysiological studies. *Developmental Neuropsychology, 27*(3), 403–424. https://doi.org/10.1207/s15326942dn2703_6

Deschamps, P. K. H., Coppes, L., Kenemans, J. L., Schutter, D. J. L. G., & Matthys, W. (2015). Electromyographic responses to emotional facial expressions in 6–7 year olds with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 45*(2), 354–362. https://doi.org/10.1007/s10803-013-1890-z

Egger, H. L., Dawson, G., Hashemi, J., Carpenter, K. L. H., Espinosa, S., Campbell, K., Brotkin, S., Schaich-Borg, J., Qiu, Q., Tepper, M., Baker, J. P., Bloomfield, R. A., & Sapiro, G. (2018). Automatic emotion and attention analysis of young children at home: A researchKit autism feasibility study. *Npj Digital Medicine, 1*, 20. https://doi.org/10.1038/s41746-018-0024-6

Filliter, J. H., Longard, J., Lawrence, M. A., Zwaigenbaum, L., Brian, J., Garon, N., Smith, I. M., Roncadin, C., Roberts, W., & Bryson, S. E. (2015). Positive affect in infant siblings of children diagnosed with autism spectrum disorder. *Journal of Abnormal Child Psychology, 43*(3), 567–575. https://doi.org/10.1007/s10802-014-9938-5

First, M. B. (2013). Diagnostic and statistical manual of mental disorders, 5th edition, and clinical utility. *The Journal of Nervous and Mental Disease, 201*(9), 727–729. https://doi.org/10.1097/NMD.0b013e3182a2168a

Grazzani, I., Ornaghi, V., Conte, E., Pepe, A., & Caprin, C. (2018). The relation between emotion understanding and theory of mind in children aged 3 to 8: The key role of language. *Frontiers in Psychology, 9*, 724. https://doi.org/10.3389/fpsyg.2018.00724

Guthrie, W., Wallis, K., Bennett, A., Brooks, E., Dudley, J., Gerdes, M., Pandey, J., Levy, S. E., Schultz, R. T., & Miller, J. S. (2019). Accuracy of autism screening in a large pediatric network. *Pediatrics, 144*(4), e20183963. https://doi.org/10.1542/peds.2018-3963

Hammal, Z., Chu, W. S., Cohn, J. F., Heike, C., & Speltz, M. L. (2017). Automatic action unit detection in infants using convolutional neural network. *2017 Seventh International Conference on Affective Computing and Intelligent Interaction (ACII)*, San Antonio, TX, USA, 216–221. https://doi.org/10.1109/ACII.2017.8273603

Hashemi, J., Dawson, G., Carpenter, K. L. H., Campbell, K., Qiu, Q., Espinosa, S., Marsan, S., Baker, J. P., Egger, H. L., & Sapiro, G. (2021). Computer vision analysis for quantification of autism risk behaviors. *IEEE Transactions on Affective Computing, 12*(1), 215–226. https://doi.org/10.1109/TAFFC.2018.2868196

Keating, C. T., & Cook, J. L. (2021). Facial expression production and recognition in autism spectrum disorders: A shifting landscape. *Psychiatric Clinics of North America, 44*(1), 125–139. https://doi.org/10.1016/j.psc.2020.11.010

Korb, S., Grandjean, D., & Scherer, K. R. (2010). Timing and voluntary suppression of facial mimicry to smiling faces in a Go/NoGo task-An EMG study. *Biological Psychology, 85*(2), 347–349. https://doi.org/10.1016/j.biopsycho.2010.07.012

Leroy, G., Andrews, J. G., Kealohi-Preece, M., Jaswani, A., Song, H., Galindo, M. K., & Rice, S. A. (2024). Transparent deep learning to identify autism spectrum disorders (ASD) in EHR using clinical notes. *Journal of the American Medical Informatics Association, 31*(6), 1313–1321. https://doi.org/10.1093/jamia/ocae080

Liu, S., Wang, Y., & Song, Y. (2023). Atypical facial mimicry for basic emotions in children with autism spectrum disorder. *Autism Research, 16*(7), 1375–1388. https://doi.org/10.1002/aur.2957

Magnée, M. J. C. M., De Gelder, B., Van Engeland, H., & Kemner, C. (2007). Facial electromyographic responses to emotional information from faces and voices in individuals with pervasive developmental disorder. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 48*(11), 1122–1130. https://doi.org/10.1111/j.1469-7610.2007.01779.x

Malaia, E., Cockerham, D., & Rublein, K. (2019). Visual integration of fear and anger emotional cues by children on the autism spectrum and neurotypical peers: An EEG study. *Neuropsychologia, 126*, 138–146. https://doi.org/10.1016/j.neuropsychologia.2017.06.014

Manfredonia, J., Bangerter, A., Manyakov, N. V., Ness, S., Lewin, D., Skalkin, A., Boice, M., Goodwin, M. S., Dawson, G., Hendren, R., Leventhal, B., Shic, F., & Pandina, G. (2019). Automatic recognition of posed facial expression of emotion in individuals with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 49*(1), 279–293. https://doi.org/10.1007/s10803-018-3757-9

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., Antes, G., Atkins, D., Barbour, V., Barrowman, N., Berlin, J. A., Clark, J., Clarke, M., Cook, D., D'Amico, R., Deeks, J. J., Devereaux, P. J., Dickersin, K., Egger, M., Ernst, E., Gøtzsche, P. C., … Tugwell, P. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine, 6*(7), e1000097. https://doi.org/10.1371/journal.pmed.1000097

Nichols, C. M. M., Ibañez, L. V., Foss-Feig, J. H., & Stone, W. L. (2014). Social smiling and its components in high-risk infant siblings without later ASD symptomatology. *Journal of Autism and Developmental Disorders, 44*(4), 894–902. https://doi.org/10.1007/s10803-013-1944-2

Pellicano, E., & Burr, D. (2012). When the world becomes "too real": A bayesian explanation of autistic perception. *Trends in Cognitive Sciences, 16*(10), 504–510. https://doi.org/10.1016/j.tics.2012.08.009

Pelphrey, K. A., Sasson, N. J., Reznick, J. S., Paul, G., Goldman, B. D., & Piven, J. (2002). Visual scanning of faces in autism. *Journal of Autism and Developmental Disorders, 32*(4), 249–261. https://doi.org/10.1023/A:1016374617369

Pezzotti, E., Provenzi, L., Naboni, C., Capelli, E., Ghirardello, S., Borgatti, R., & Orcesi, S. (2024). Masked or not, I smile to you: Exploring full-term and preterm infants' social smiles to adults wearing a protective facemask. *Infant Behavior and Development, 75*(10), 101947. https://doi.org/10.1016/j.infbeh.2024.101947

Saral, D., Olcay, S., & Ozturk, H. (2023). Autism spectrum disorder: when there is no cure, there are countless of treatments. *Journal of Autism and Developmental Disorders, 53*(12), 4901–4916. https://doi.org/10.1007/s10803-022-05745-2

Thabtah, F., & Peebles, D. (2019). Early autism screening: A comprehensive review. *International Journal of Environmental Research and Public Health, 16*(18), 3502. https://doi.org/10.3390/ijerph16183502

Trevisan, D. A., Hoskyn, M., & Birmingham, E. (2018). Facial expression production in autism: A meta-analysis. *Autism Research, 11*(12), 1586–1601. https://doi.org/10.1002/aur.2037

Wieckowski, A. T., Hamner, T., Nanovic, S., Porto, K. S., Coulter, K. L., Eldeeb, S. Y., Chen, C. M. A., Fein, D. A., Barton, M. L., Adamson, L. B., & Robins, D. L. (2021). Early and repeated screening detects autism spectrum disorder. *Journal of Pediatrics, 234*, 227–235. https://doi.org/10.1016/j.jpeds.2021.03.009

Yeung, M. K. (2022). A systematic review and meta-analysis of facial emotion recognition in autism spectrum disorder: The specificity of deficits and the role of task characteristics. *Neuroscience and Biobehavioral Reviews, 133*, 104518. https://doi.org/10.1016/j.neubiorev.2021.104518

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