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The early development of emotion recognition in autistic children: Decoding basic emotions from facial expressions and from emotion-provoking situations

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Abstract

Autism is associated with challenges in emotion recognition. Yet, little is known about how emotion recognition develops over time in autistic children. This four-wave longitudinal study followed the development of three emotion-recognition abilities regarding four basic emotions in children with and without autism aged 2.5 to 6 years over three years. Behavioral tasks were used to examine whether children could differentiate facial expressions (emotion differentiation), identify facial expressions with verbal labels (emotion identification), and attribute emotions to emotion-provoking situations (emotion attribution). We confirmed previous findings that autistic children experienced more difficulties in emotion recognition than non-autistic children and the group differences were present already from the preschool age. However, the group differences were observed only when children processed emotional information from facial expressions. When emotional information could be deduced from situational cues, most group differences disappeared. Furthermore, this study provided novel longitudinal evidence that emotion recognition improved with age in autistic children: compared to non-autistic children, autistic children showed similar learning curves in emotion discrimination and emotion attribution, and they showed greater improvements in emotion identification. We suggest that inclusion and respect in an environment free of stereotyping are likely to foster the development of emotion recognition among autistic children.

Keywords: autistic preschooler; emotion recognition; facial expression; emotion-provoking situation; longitudinal study

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Introduction

Emotion expression communicates to others what one wants to achieve. A happy face signals that one likes the situation and welcomes further interaction, whereas an angry face shows one's discontent and determination for reinstating his or her goal (Nikitin & Freund, 2019; Taylor & Barton, 2015). Social communication and social interaction constitute one of the most challenging areas for people with autism (American Psychiatric Association, 2013). The predicament is partly related to their difficulties in recognizing others' emotions (Bölte & Poustka, 2003; Kuuskikko et al., 2009). Plenty of research has investigated emotion recognition in autistic individuals (for reviews, see Harms et al., 2010; Lozier et al., 2014; Uljarevic & Hamilton, 2013). These studies contributed to our knowledge of the between-group differences. However, due to their cross-sectional designs, little is known about how emotion-recognition abilities develop within autistic individuals over time. To address this gap and to start from an early life stage, this four-wave longitudinal study followed the development of emotion recognition in autistic children aged 2.5 to 6 years, in comparison to their non-autistic peers.

In typical development, emotion recognition begins with perceiving and discriminating facial emotion expressions (i.e., emotion discrimination). Few-month-old infants already show awareness that happy faces look differently from angry faces (Grossmann, 2010; Kobiella et al., 2007). Around the first birthday, children are not only aware of the differences in the physical features of facial expressions, but they have also acquired some understanding of the semantics associated with different facial expressions (Camras & Shutter, 2010; Hertenstein & Campos, 2004). For example, one-year-olds used their mothers' facial expressions as social references to guide their behaviors in the classic visual cliff experiment (Sorce et al., 1985). Later, along with language development, children become capable of naming facial emotion expressions (i.e., emotion identification) (Dunn et al., 1987; Ridgeway et al., 1985). Associating facial expressions with their verbal labels enables children to categorize emotions and to acquire the scripted knowledge of emotions, which includes not only facial expressions but also the action tendencies triggered by emotions and the antecedent events that provoke emotions (Widen & Russell, 2004). Understanding that every emotion is

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provoked by a specific situation and being able to predict others' emotions based on situational information (i.e., emotion attribution) marks another progress towards matured emotion recognition (Rieffe & Wiefferink, 2017). While toddlers and preschoolers rely primarily on facial expressions for processing emotional information, school-aged children utilize more often situational cues (Herba & Phillips, 2004).

The above-mentioned abilities develop through the process of emotional socialization. That is, young children learn about emotions by observing how others (especially parents) respond in social interactions, by having emotional conversations with others, and by interacting with others and learning from trial and error (Castro et al., 2015; Mathieson & Banerjee, 2011). Compared to non-autistic children, autistic children miss out more often on these spontaneous learning opportunities, which could exacerbate their difficulties in understanding others' mental states such as emotions and hinder them from developing perspective-taking abilities (Gray et al., 2016; Li et al., 2022).

Indeed, research showed that autistic children aged between 4 and 17 years encountered more difficulties than non-autistic children in discriminating facial expressions (e.g., Tardif et al., 2007; Wieckowski et al., 2019), identifying facial expressions (e.g., Griffiths et al., 2019; Xavier et al., 2015), and attributing emotions to emotion-provoking situations (Da Fonseca et al., 2009; Fridenson-Hayo et al., 2016; Tell et al., 2014). It is especially challenging for autistic children when emotions have negative valence such as sad and disgust (Balconi et al., 2012; Evers et al., 2015), with a complex nature such as shame and guilt (Heerey et al., 2003; Kotroni et al., 2019), presented in a low intensity (Song & Hakoda, 2018), or presented for a shorter duration (Nagy et al., 2021).

A few studies did not find between-group differences in emotion recognition. Some of them matched the autistic and non-autistic groups on cognitive abilities such as verbal and global IQ (Castelli, 2005; Lacroix et al., 2014). However, as pointed out by Harms et al. (2010), an uneven IQ profile is phenotypically linked with autism. Removing the effect of IQ might remove some essential attributes linked with autism (Dennis et al., 2009). Other studies examined the recognition of basic emotions in prototypical situations among middle-school-aged youths with and without autism and found similar performances in the two groups (e.g., Jones et al., 2011; Tracy et al., 2011). Possibly, autistic children's emotion-recognition abilities develop over time and their ability to recognize basic emotions reach the same level as non-autistic peers at older ages.

To find out whether emotion recognition indeed develops in autistic children and whether their development follows the same trajectory as non-autistic children, longitudinal investigations are needed. Yet, in contrast to the abundant research on between-group comparisons, there is a dearth of developmental data, preventing us from delineating the developmental course of emotion recognition in autistic children. To the best of our knowledge, only one study used a longitudinal design. Rosen and Lerner (2016) found that the ability to identify facial expressions of basic emotions in 11- to 17-year-old autistic youths improved over a period of 18 weeks. Their finding is consistent with the findings of correlational studies, which reported a positive relation between age and emotion recognition in autistic children aged between 4 to 13 years (e.g., Fridenson-Hayo et al., 2016; Lacroix et al., 2014; Tell et al., 2014). Furthermore, two meta-analyses, each amalgamating more than 40 cross-sectional studies on emotion recognition in autistic individuals of various ages, found that autistic people's difficulties in emotion recognition did not diminish or disappear with age (Uljarevic & Hamilton, 2013); rather, the differences between autistic and non-autistic people in emotion recognition became larger from childhood to adolescence and adulthood (Lozier et al., 2014). These findings indicate that emotion recognition might develop either at the same pace in autistic and non-autistic people or at a slower rate in autistic people.

Present study

The present study followed the development of three emotion-recognition abilities (i.e., emotion discrimination, emotion identification, and emotion attribution) in 2.5- to 6-year-old children with and without autism over a time course of three years. Based on the literature, we expected that autistic children had more difficulties than non-autistic children in differentiating, identifying, and attributing emotions (e.g., Da Fonseca et al., 2009; Wieckowski et al., 2019; Xavier et al., 2015). We assumed that all three abilities improved with age in non-autistic children (Herba & Phillips, 2004; Widen & Russell, 2008). Due to the scarcity of longitudinal data on autistic children, our hypotheses regarding their development were exploratory. We expected that autistic children's emotion-recognition abilities improved over time (Rosen & Lerner, 2016), and that their abilities developed either at the same pace or at a slower rate compared to the development of non-autistic children (Lozier et al., 2014; Uljarevic & Hamilton, 2013).

In addition to the effect of age, we examined the extent to which the level of autistic traits contributed to the development of emotion recognition in autistic children. Previous correlational studies on autistic children found that a higher level of autistic traits was related to more difficulties in emotion recognition (e.g., Brosnan et al., 2015; Evers et al., 2015; Tell et al., 2014; Xavier et al., 2015). We explored whether such associations were also present longitudinally.

Methods

Participants and procedure

This study was part of a larger-scaled longitudinal research conducted in the Netherlands, on the social and emotional development of preschool children with communication challenges, including children with hearing loss, developmental language disorder, and autism (Li et al., 2022; Rieffe & Wiefferink, 2017; Tsou et al., 2021). The total sample of the larger-scaled research included 73 Dutch children with autism (65 boys) and 418 typically developing Dutch children (226 boys). Autistic children met the following inclusion criteria: (1) the child received an autism diagnosis according to the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.) (American Psychiatric Association, 2000) based on the *Autism Diagnostic Interview-Revised* (Lord et al., 1994) set by a qualified child psychologist or psychiatrist at Time 1, (2) parents confirmed three years later that the child retained the autism diagnosis, and (3) the child had IQ scores above 70 and no additional clinical diagnoses. Inclusion criteria for non-autistic children were (1) IQ scores above 70, and (2) no clinical diagnoses or disabilities.

Autistic children were recruited via a specialized institution for diagnosis and intervention of autism, Center for Autism, Leiden. Non-autistic children were recruited from daycare centers and mainstream primary schools in the same region. The IQ profiles of autistic children were either retrieved from school or collected by

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the institution, and thus the information came from various intelligence tests, including those measuring nonverbal IQ (i.e., the Snijders-Oomen Nonverbal Intelligence Tests [SON-R] [Snijders et al., 1989] and Wechsler Nonverbal Scale of Ability [Wechsler & Naglieri, 2006]) and those measuring both verbal and nonverbal IQ (i.e., Wechsler Intelligence Scale for Children [Wechsler, 1974] and Wechsler Preschool and Primary Scale of Intelligence [Wechsler, 1990]). As for non-autistic children, only nonverbal IQ was measured by the SON-R.

The Ethics Committee of Leiden University and Center for Autism granted permission for the larger-scaled research project (P08.140/SH/sh). All parents provided written informed consent. Children and their parents participated in the research once a year and the tasks and questionnaires were administered in total four times. The mean duration between Time 1 and Time 2 was 13.20 months ($SD = 3.47$ months), between Time 2 and Time 3 was 12.15 months ($SD = 1.58$ months), and between Time 4 and Time 3 was 12.23 months ($SD = 1.05$ months). Children were visited either at school or at the specialized institution (for autistic children only), where they finished a series of tasks under the guidance of a trained psychologist. Parents filled out a group of questionnaires to report on their child's development. The Social Responsive Scale (SRS; Constantino & Gruber, 2005) was filled out at Time 1, Time 3, and Time 4, where parents reported on the level of their children's autistic traits. SRS was not administered to the parents at Time 2. This questionnaire consists of 65 items with responses on a 4-point scale, where higher scores indicate more accentuated autistic traits. The raw total scores were calculated, based on which the T-scores were generated using the Dutch SRS manual (Roeyers et al., 2011). Since the Dutch norms apply to children aged between four and 17 years, no T-scores were generated for children who were younger than four. To present the level of autistic traits of participants, T-scores were reported in Table 1. For analyzing the longitudinal associations between autistic traits and emotion recognition in autistic children, the raw total scores of SRS were entered for multilevel analyses, so that data of autistic children who were younger than four could be included in the analyses.

Due to time constraints, not all children were administered the full test battery. Besides, as often observed in longitudinal studies, there were participant dropouts over the time. The dropout rates were especially high from Time 1 to Time 2 (47% in the total sample, 26% in the autistic sample, and 57% in the non-autistic sample), whereas the dropout rates from Time 2 to Time 4 were much lower (see Supplementary Tables 1, 2, and 3 for the available data and the descriptive statistics of the study variables at each time point). We used Little's MCAR tests to examine the patterns of missing data at each time point. The results indicated that the missing patterns were completely random ($422.98 < \chi^2\text{s} < 2570.48$, $ps > .05$). Furthermore, we checked if the participants who had missing data of the outcome variables at Time 2 differed from those who did not have missing data at Time 2 in the background and outcome variables measured at Time 1. The results showed no group difference (see Supplementary Table 4), indicating that the subsample who dropped out from the study might not differ in characteristics from the subsample who stayed in the study (Sterne et al., 2009).

Participants of the larger research project were included in this study if they had data on the emotion-recognition variables at one-time point at least (for the justification of including participants with single observations, see Hox et al. (2017) and Pandis et al. (2017)). The final sample examined in the current study included 61 autistic children (7 girls) and 121 non-autistic children (11 girls), aged 32 to 72 months (mean age = 55.74 months). For sample size justification, see Supplementary Table 5.

Table 1. Demographic characteristics of participants: the ranges and means (standard deviations (SD)) of background variables

	Autistic			Non-autistic		
	Range	Mean (*SD*)	*N*	Range	Mean (*SD*)	*N*
Age in months						
Time 1	32–72	56.31 (10.27)	61	32–72	55.45 (11.37)	121
Time 2	45–85	69.18 (10.57)	44	45–88	70.16 (11.01)	51
Time 3	57–97	82.45 (9.45)	42	57–97	81.16 (10.69)	49
Time 4	72–109	95.05 (9.07)	37	69–107	93.21 (10.25)	43
Male%		88.50	61		90.91	121
IQ**	71–132	99.92 (16.45)	51	71–149	110.29 (15.07)	62
SRS T score						
Time 1**	53–98	75.24 (10.86)	41	39–55	46.07 (4.18)	14
Time 3**	55–111	78.79 (13.27)	38	39–61	47.28 (5.27)	36
Time 4**	60–98	77.91 (11.30)	23	38–56	45.70 (5.11)	27
Education mother[a*]	1–5	3.80 (1.14)	54	1–5	4.42 (.90)	48
Education father[a]	1–5	3.67 (1.38)	55	1–5	4.02 (.96)	41
Net annual income[b**]	1–5	2.92 (1.13)	39	1–5	3.85 (1.10)	67

[a]Parent education level: one = no/primary education; two = lower general secondary education; three = middle general secondary education; four = higher general secondary education; five = college/university.
[b]Net household income: 1one = less than €15,000; two = €15,000–€30,000; three = €30,000–€45,000; four = €45,000–€60,000; five = more than €60,000.
*$p < .05$ ** $p < .001$.

Table 1 shows the descriptive characteristics of the participants. The autistic and non-autistic participants did not differ in age: $-.44 < ts < .85$, $ps > .05$, or in gender distribution: $\chi^2\,(1) = .26$, $p = .611$. Autistic children had on average a lower IQ than non-autistic children: $t(111) = 3.49$, $p < .001$. They had higher SRS T-scores at Time 1: $t(52.71) = 14.49$, $p < .001$, Time 3: $t(48.92) = 13.55$, $p < .001$, and Time 4: $t(29.57) = 12.61$, $p < .001$. Mothers of autistic children had on average a lower education level than mothers of non-autistic children: $t(98.58) = 3.07$, $p = .003$. The average education levels of fathers did not differ between groups: $t(93.68) = 1.47$, $p = .144$. Families of autistic children had lower average income than families of non-autistic children: $t(104) = 4.13$, $p < .001$.

This study's design, hypotheses, and analysis plan were preregistered at https://doi.org/10.17605/OSF.IO/QGR58. Dataset and associated information of this manuscript will be stored and shared publicly at the Leiden University archiving platform DataverseNL.

Measures

Three behavioral tasks were administered to the participants to measure their abilities to discriminate and identify facial expressions and their ability to attribute emotions to emotion-provoking situations. Considering the young age of the participants, these tasks were designed to place minimal verbal demands on children and involved only four basic emotions, i.e., happiness, anger, sadness, and fear. These tasks were used previously for examining emotion recognition in toddlers and preschoolers with hearing loss (Wiefferink et al., 2013) and with developmental language disorder (Rieffe & Wiefferink, 2017). These tasks showed good concurrent validity and satisfying reliabilities when used to measure emotion-recognition abilities in the current sample (see Supplementary Tables 6 and 7 for the information on the psychometric properties of the behavioral tasks).

Emotion discrimination task

First, children did two practice tasks, where they were asked to sort out cards of cars and flowers, and next cards of faces with a hat and of faces with glasses. A sheet was placed in front of them, where the drawing of one category (e.g., a car) was printed on the top left corner, and the drawing of another category (e.g., a bundle of flowers) was printed on the top right corner. Then the experimenter demonstrated how to place two cards with drawings of the two different categories onto the sheet, accompanied by a simple oral explanation: "Look, this one should be put here, and this one should be put here." The two practice tasks were used to help children understand the intention of the discrimination task and to familiarize them with the task procedure.

Next, children sorted out facial expressions. Again, the experimenter first demonstrated how to place two cards with drawings of two different facial expressions onto the sheet, accompanied by a simple oral explanation: "Look, this one should be put here, and this one should be put here." Following that, children were given six cards (e.g., three drawings of happy faces and three drawings of sad faces) to do the sorting. In condition one, they needed to sort out emotions of different valences (e.g., happy faces versus sad faces). In condition two, they needed to sort out emotions of the same emotional valence (e.g., angry faces versus sad faces). Condition one was supposed to be easier than condition two because the differences between facial expressions of different valences are more prominent than the differences between facial expressions of the same valence. Children scored "one" when placing one card under the correct category and scored maximally "three" for each category. A mean score of condition one and a mean score of condition two were calculated, respectively.

Emotion identification task

The experimenter showed children eight drawings of facial emotion expressions for happiness, anger, sadness, and fear (two drawings for each emotion) and asked: "Who looks happy?" Children had to point to the drawing of a happy face. Next, the researcher asked: "Is there anyone else who looks happy?" Children had to point to another drawing of a happy face. The same procedure was repeated for anger, sadness, and fear. Children scored "one" for each correctly identified facial emotion expressions and scored maximally "two" for each emotion. A mean score for identifying positive facial expressions (i.e., happy faces) and a mean score for identifying negative facial expressions (i.e., angry, sad, and fearful faces) were calculated, respectively.

Emotion attribution task

Children were shown drawings of eight vignettes, depicting two prototypical emotion-provoking situations for happiness, anger, sadness, and fear, respectively. Meanwhile, the experimenter gave a simple oral explanation (e.g., "Look, the boy sees a dog" while pointing at a drawing that depicted a frightening dog) (see Supplementary Table 8 for the descriptions of the eight vignettes). Then the experimenter asked: "How does the boy feel?" This required a verbal answer from children (i.e., the verbal condition). Considering that some children might not know the word for the emotion, next, the experimenter showed children a sheet with drawings of a happy, angry, sad, and fearful face and asked: "How does the boy look?" This required the child to point to the corresponding facial expression (i.e., the visual condition).

In both conditions, children scored "two" when assigning the emotion that was intended by the study, for example, answering "happy" and/or pointing to a happy face when the presented situation was prototypical for triggering happiness. Children scored "one" when assigning an emotion that was not the intended emotion but of the intended valence, for example, answering "good" or "fine" when the situation was prototypical for triggering happiness, or answering "sad" and/or pointing to a sad face when the situation was prototypical for triggering fear. Children scored "zero" when not answering the question, saying "I don't know", or assigning an emotion of the opposite valence, for example, answering "sad" and/or pointing to a sad face when the situation was prototypical for triggering happiness. This scoring system took into consideration that a prototypical situation could provoke different emotions within the same valence. For example, a child may feel scared when seeing a frightening dog, but it is also possible that the child feels sad. Furthermore, children younger than three tend to mix emotions within the same valence, for example, referring to all the negative emotions as "anger" or "sad" (Widen, 2013). For each condition, a mean score of attributing positive emotions to happy-provoking situations and a mean score of attributing negative emotions to anger-, sadness-, and fear-provoking situations were calculated, respectively.

The drawings used in the above-mentioned tasks were computer generated and printed out in black and white. The facial emotion expressions were drawn based on photos of four- and five-year-old boys, which were randomly chosen from a large database with photos of various facial emotion expressions (Wiefferink et al., 2013). Examples of the drawings can be found in Supplementary Figure 1.

Statistical analyses

R (version 3.3.3; R Core Team 2019) was used to make figures (with the package "ggplot2"; Wickham, 2009). IBM SPSS Statistics for Macintosh (version 27.0; Armonk, NY: IBM Corp.) were used to conduct Linear Mixed Model (LMM) analyses for examining the developmental trajectories of emotion recognition abilities and their associations with symptom severity. LMM can account for the dependency within the longitudinal data (Hox et al., 2017) and is robust in handling missing data when they miss (completely) at random (Twisk et al., 2013).

We followed a formal model-fitting procedure, i.e., fitting increasingly more complex models to the data step by step. Simpler models with a better model fit were selected over the more complex model. To evaluate model fit, for nested models, the preferred model showed significantly less deviance, i.e., lower values of −2 Log Likelihood (−2LL). For non-nested models, the preferred model showed lower Akaike Information Criterion and Bayesian Information Criterion values.

To examine the developmental trajectories of emotion-recognition abilities, we started with a null model which included only a fixed and random intercept. Then, age (centered around 32 months, the youngest age of all participants) was added to the model. We examined two models of change: linear and quadratic, respectively. Next, group (zero = non-autistic, one = autistic) was added to examine if the levels of emotion recognition differed

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between the two groups across time. Fourth, we added the interactions of age and group to the model to examine whether the two groups differed in developmental trajectories.

To investigate the role of autistic traits in predicting the development of emotion recognition abilities in autistic children, first, we filtered out the data of non-autistic children from the dataset. Next, we calculated the mean SRS scores by averaging autistic children's SRS raw total scores at Time 1, Time 3, and Time 4. Third, we added the SRS mean scores as the predicting variable to the best age models for predicting emotion recognition of autistic children.

Results

Development of emotion discrimination

Table 2 shows the estimates of the fixed and random effects of the best-fitting models for emotion discrimination. Figure 1 depicts the developmental trajectories of emotion discrimination in autistic and non-autistic children. For model fit indices of the null models, the best fitting models, and the model fit comparisons, see Supplementary Table 9.

The best fitting model for discriminating between positive and negative facial emotion expressions was with the fixed effects of linear age: $t(133.86) = 8.79$, $p < .001$, and group: $t(142.30) = -3.62$, $p < .001$. There was also a random age effect: $p = .048$, indicating that there was a large individual variability in the age slopes. The best fitting model for discriminating between negative facial emotion expressions was with the fixed effect of linear age: $t(446.85) = 10.09$, $p < .001$, and group: $t(128.95) = -3.22$, $p = .002$. These results show that the ability to discriminate between facial emotion expressions improved with age in all children, but autistic children performed overall less well than non-autistic children.

Development of emotion identification

Table 3 provides the estimates of the best-fitting models for emotion identification (see also Supplementary Table 9). Figure 2 depicts the developmental trajectories of emotion identification in autistic and non-autistic children.

The best fitting model for identifying positive emotions was with the fixed effect of linear age: $t(120.84) = 3.26$, $p = .001$, group: $t(175.73) = -3.41$, $p < .001$, and their interaction: $t(119.40) = 2.64$, $p = .009$. Besides, there was a random age effect ($p < .001$), indicating that there was a large individual variability in the age slopes. While both groups showed improvement with age, the improvement in autistic children ($b = .01$, $t(48.67) = 4.80$, $p < .001$) was greater than that in non-autistic children ($b = .006$, $t(67.15) = 3.60$, $p < .001$).

The best fitting model for identifying negative emotions was with the fixed effect of linear age: $t(119.39) = 7.25$, $p < .001$, group: $t(169.50) = -3.40$, $p < .001$, and their interaction: $t(119.57) = 2.32$, $p = .022$. While both groups showed improvement with age, the improvement in autistic children ($b = .02$, $t(50.90) = 7.62$, $p < .001$) was greater than that in non-autistic children ($b = .01$, $t(112.96) = 8.31$, $p < .001$).

Developmental trajectories of emotion attribution

Table 4 provides the estimates of the best-fitting models for emotion attribution (see also Supplementary Table 9). Figure 3 depicts the developmental trajectories of emotion attribution in autistic and non-autistic children.

The best fitting model for attributing positive emotions in the verbal condition was only with the fixed effect of linear age: $t(370{,}74) = 3.55$, $p < .001$, showing that autistic children did not differ from non-autistic children in the level nor in the developmental trajectory and this ability improved over time in all children. The best fitting model for attributing positive emotions in the visual condition was with the fixed effect of linear age: $t(124.04) = 5.41$, $p < .001$, and group: $t(132.50) = -3.58$, $p < .001$, showing that this ability increased in both groups, and autistic children scored overall lower in the visual condition than non-autistic children. Besides, there was a random effect of linear age: $p < .001$, indicating that there was a great individual variability in the age slopes.

The best-fitting model for attributing negative emotions in the verbal condition was only with the fixed effect of linear age: $t(358.36) = 3.15$, $p = .002$, showing that this ability increased with age in all children, and autistic children did not differ from non-autistic children in the level nor in the developmental trajectory. The best age model for the visual condition was with the fixed ($t(103.89) = 6.02$, $p < .001$) and random effect ($p = .015$) of linear age. The results showed that this ability improved in both groups, and autistic children did not differ from non-autistic children in the level nor in the developmental trajectory. Besides, there was a great variability in the age slopes.

Autistic traits and the development of emotion recognition in autistic children

Adding the SRS mean as a predictor to the best age models improved model fits for all predicting models (see Supplementary Table 10 for information on model fits and model comparisons). However, there was only one significant effect of the SRS mean, that is, a higher mean level of SRS contributed to predicting a lower level of emotion discrimination between positive and negative emotions for autistic children: $b = -.008$, *CI* [−.01, −.003], $t(61.47) = -2.99$, $p = .004$. For the development of other emotion-recognition abilities, no significant effect of the SRS mean was found. See Table 5 for the coefficients of the SRS mean in the predicting models.

Discussion

To accurately recognize others' emotions is a prerequisite for smooth social communication and social interaction, and yet autistic people can experience difficulties in reading others' emotions. This study is among the first to examine the early development of emotion recognition in autistic children aged 2.5 to 6 years, in comparison to the development of non-autistic peers. First, our study confirmed previous findings that autistic children experienced more difficulties in emotion recognition than non-autistic children and these difficulties were present already from the preschool age. Noteworthy, the difficulties were observed only when autistic children needed to process emotional information from facial expressions. When emotional information could be deduced from situational cues, most group differences disappeared. Second, this study provided novel longitudinal evidence that emotion-recognition abilities grew with age in autistic children: compared to non-autistic children, autistic children showed similar improvements over time in emotion discrimination and in emotion attribution, and they showed greater improvements in emotion identification. Below we discuss these findings in detail.

Table 2. Fixed and random effects of the best fitting models for *emotional discrimination*

	Positive vs. Negative				*Negative vs. Negative*			
Fixed effects	Estimates	*SE*	*CI* [low, high]		Estimates	*SE*	*CI* [low, high]	
Intercept	1.82**	.10	[1.62, 2.03]		1.36**	.10	[1.16, 1.55]	
Age	.02**	.002	[.01, .02]		.02**	.002	[.02, .03]	
Group	−.30**	.08	[-.47, −−.14]		−−−.33*	.10	[−.53, −.12]	
Random effects	Estimates	*SE*	*CI* [low, high]	Wald's *Z*	Estimates	*SE*	*CI* [low, high]	Wald's *Z*
Residual	.41**	.04	[.34, .49]	10.36	.55**	.05	[.46, .65]	11.49
Intercept	.66*	.19	[.37, 1.16]	3.44	.18*	.05	[.10, .31]	3.44
Age	.0002*	.00008	[.00006, 0004]	1.97	–	–	–	–

*$p < .05$; **$p < .001$.

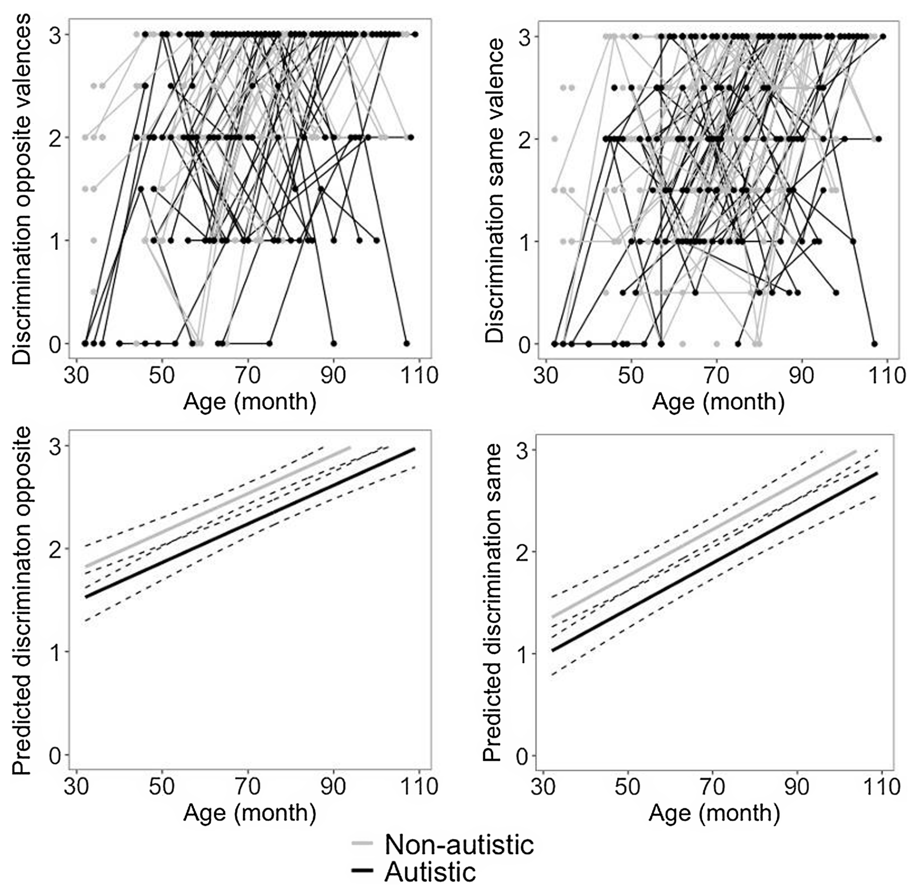

Figure 1. Upper left and right: graphic representations of the levels of discrimination between emotions of opposite valences and emotions of the same valence at four time points. Each dot represents the data of one participant at one time point. The dots were connected in lines, each line representing the development of one participant. Participants had data at one time point are presented by dots. Lower left and right: regression lines depicting the predicted levels of discrimination between emotions of opposite valences and emotions of the same valence with 95% CI's based on the best fitting models.

First, in line with the literature (e.g., Da Fonseca et al., 2009; Wieckowski et al., 2019; Xavier et al., 2015), we found that autistic children experienced more difficulties than non-autistic children in discriminating and identifying facial expressions. However, unexpectedly, when asked to attribute emotions based on situational cues, autistic children performed similarly to their non-autistic peers except for in one condition (i.e., attributing positive emotions in the visual condition). This raises the question: is it possible that autistic children's emotional recognition was disrupted by their difficulty processing facial information?

There is substantial evidence showing that autistic people face a general challenge in processing facial information, which is not confined to recognizing facial emotion expressions but is also present in recognizing emotionally neutral faces (Behrmann et al., 2006; Joseph & Tanaka, 2003). Some researchers postulate that face processing in autistic people is disrupted because they avoid looking at the eye region. Eyes carry the most revealing information about a person's identity and inner mental states such as emotions and intentions. However, eyes are perceived by many autistic people as socially intimidating and can cause them overarousal (Tanaka & Sung, 2016). This "eye-avoidance" hypothesis has received support from eye-tracking and neuro-physiological studies, which showed that when asked to scan face stimuli spontaneously, autistic people had shorter fixation durations at the eye region than non-autistic people (Nuske et al., 2014; White et al., 2015) and showed reduced activations in

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Table 3. Fixed and random effects of the best-fitting models for *emotional identification*

	Positive emotions				Negative emotions			
Fixed effects	Estimates	*SE*	*CI* [low, high]		Estimates	*SE*	*CI* [low, high]	
Intercept	1.67**	.09	[1.49, 1.84]		1.26**	.08	[1.09, 1.42]	
Age	.006*	.002	[.002, .009]		.01**	.002	[.009, .015]	
Group	−.51*	.15	[−.81, −.22]		−.48*	.14	[−.76, −.20]	
Age × group	.008*	.003	[.002, .01]		.006*	.003	[.001, .01]	
Random effects	Estimates	*SE*	*CI* [low, high]	Wald's *Z*	Estimates	*SE*	*CI* [low, high]	Wald's *Z*
Residual	.11**	.01	[.09, .14]	9.52	.11**	.01	[.07, .10]	9.31
Intercept	.46**	.09	[.32, .67]	6.25	.46**	.09	[.53, .93]	5.29
Slope	.0002**	.00004	[.0001, .0003]	4.09	.0001*	.00004	[.0001, .0002]	3.05

*$p < .05$; **$p < .001$.

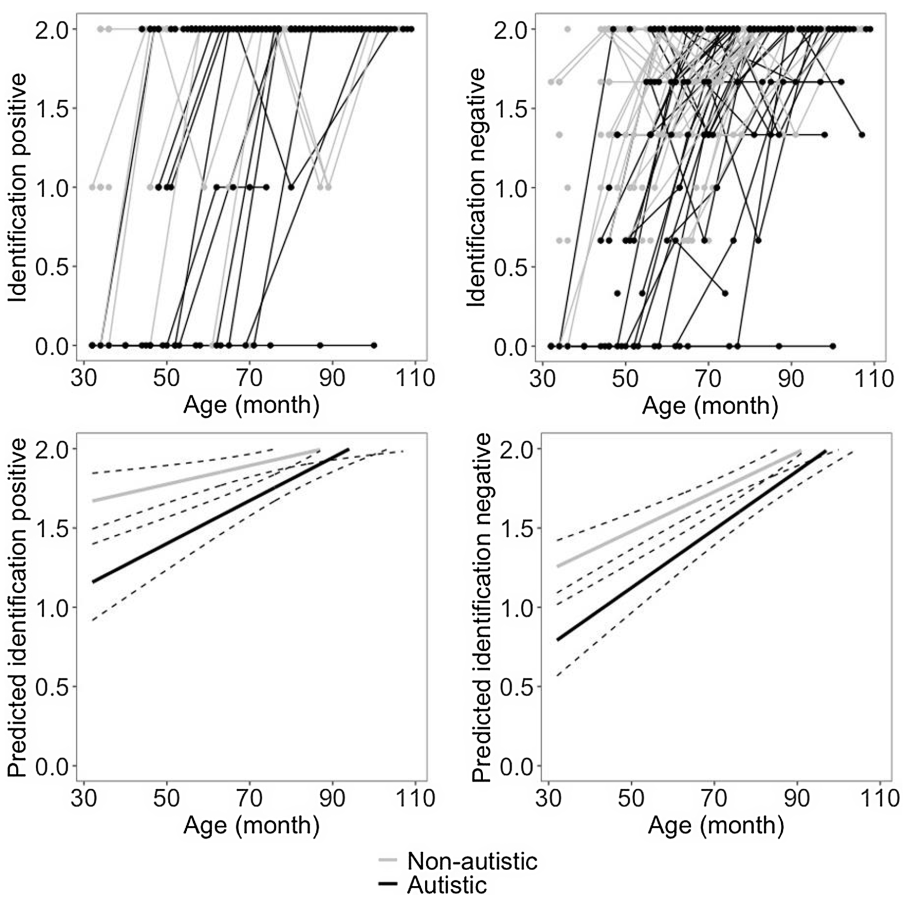

Figure 2. Upper left and right: graphic representations of the levels of identifying positive and negative facial expressions at four time points. Each dot represents the data of one participant at one time point. The dots were connected in lines, each line representing the development of one participant. Participants had data at one time point are presented by dots. Lower left and right: regression lines depicting the predicted levels of identifying positive and negative facial expressions with 95% CI's based on the best fitting models.

the brain network related to face processing (e.g., O'Connor et al., 2005; de Jong et al., 2008). However, when autistic people were guided to attend to the eye region, they had stronger skin conductance reactions and amygdala activations than non-autistic people (Bradley et al., 2001; Dalton et al., 2005), indicating the experience of overarousal.

It should be noted that before examining children's abilities to discriminate between emotional facial expressions, we asked children to sort out objects (cars versus flowers) and emotionally neutral faces (faces with a hat versus faces with glasses) in the practice tasks. Post hoc analyses comparing the group performances showed that autistic children performed also less well than non-autistic children in the practice tasks where face stimuli were not involved (see Supplementary Table 11). This suggests that autistic children's performances might be affected by other factors besides their challenges in processing facial information. For example, the testing environment could be stressful for autistic children, as they had to do tasks with an adult stranger. Besides, autistic children might not feel motivated to participate and they might not pay full attention to the tasks. Previous studies found

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Table 4. Fixed and random effects of the best-fitting models for *emotional attribution*

Positive emotions	Verbal condition				Visual condition			
Fixed effects	Estimates	*SE*	*CI* [low, high]		Estimates	*SE*	*CI* [low, high]	
Intercept	1.34**	.07	[1.21, 1.47]		1.35**	.09	[1.17, 1.52]	
Age	.005**	.001	[.002, .008]		.01**	.002	[.006, .013]	
Group	–	–	–		−.26**	.07	[−.40, −.11]	
Random effects	Estimates	*SE*	*CI* [low, high]	Wald's *Z*	Estimates	*SE*	*CI* [low, high]	Wald's *Z*
Residual	.17**	.02	[.14, .21]	10.64	.18**	.02	[.15, .23]	9.38
Intercept	.26**	.04	[.18, .36]	5.88	.71**	.14	[.49, 1.04]	5.17
Slope	–	–	–	–	.0002**	.00006	[.0001, .0004]	3.61
Negative emotions	*Verbal condition*				*Visual condition*			
Fixed effects	Estimates	*SE*	*CI* [low, high]		Estimates	*SE*	*CI* [low, high]	
Intercept	1.05**	.05	[.94, .1.15]		.90**	.07	[.77, 1.03]	
Age	.003*	.001	[.001, .006]		.009**	.001	[.006, .01]	
Random effects	Estimates	*SE*	*CI* [low, high]	Wald's *Z*	Estimates	*SE*	*CI* [low, high]	Wald's *Z*
Residual	.10**	.009	[.08, .11]	11.06	.14**	.02	[.12, .18]	9.32
Intercept	.19**	.03	[.14, .25]	6.69	.29**	.07	[.17, .48]	3.82
Slope	–	–	–	–	.0001*	.00004	[.00005, .0002]	2.43

*$p < .05$; **$p < .001$.

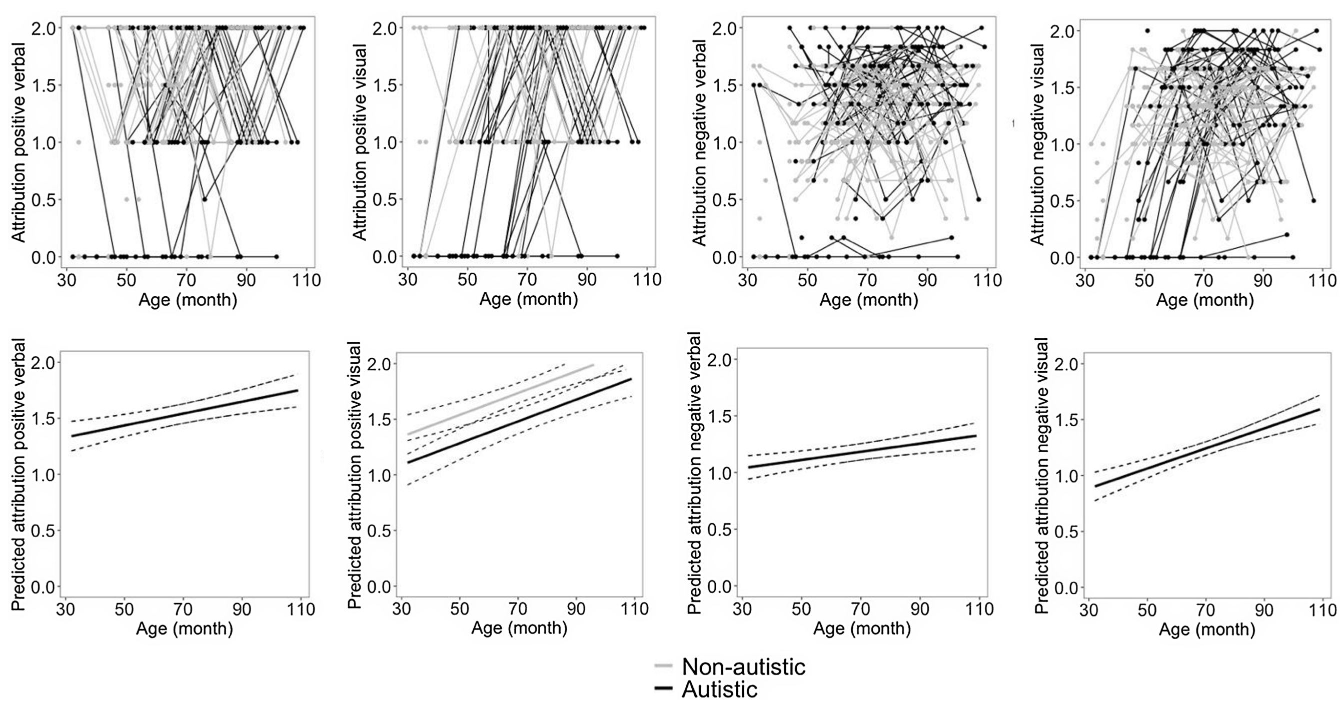

Figure 3. Upper left and right: graphic representations of the levels of attributing positive and negative emotions in the verbal and visual conditions of all participants at four time points. Each dot represents the data of one participant at one time point. The dots were connected in lines, each line representing the development of one participant. Participants had data at one time point are presented by dots. Lower left and right: regression lines depicting the predicted levels of attributing positive and negative emotions in the verbal and visual conditions with 95% CI's based on the best fitting models.

that when autistic children were motivated to engage in tasks, they performed similarly to non-autistic children in emotion recognition and Theory of Mind tasks (Begeer et al., 2006; Peterson et al., 2013).

While autistic children performed less well than non-autistic children in recognizing emotions from facial expressions, they performed similarly to non-autistic children in recognizing emotions from the depictions of emotion-provoking situations.

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Table 5. Coefficients SRS mean for predicting emotion-recognition abilities of autistic children

	SRS mean coefficient	Standard error	*CI* [low, high]	*p*-value
Emotion discrimination				
Positive vs. negative	−.008	.003	[−.01, −.003]	.004
Negative vs. negative	−.006	.003	[−.013, .001]	.079
Emotion identification				
Positive emotion	.0004	.002	[−.004, .005]	.179
Negative emotion	−.001	.003	[−.006, .004]	.674
Emotion attribution				
Positive emotion verbal	.003	.003	[−.003, .01]	.315
Positive emotion visual	.002	.003	[−.004, .008]	.441
Negative emotion verbal	−.0006	.003	[−.007, .005]	.836
Negative emotion visual	−.002	.003	[−.007, .003]	.401

On the one hand, it is possible that, compared to extracting information from a face stimulus, it was more relaxing for autistic children to process information from a story narration. In addition, presenting autistic children with the depiction of an emotion-provoking situation might give them sufficient time and information to analyze the emotion by using explicit cognitive and language-mediated strategies (Nagy et al., 2021). Harms et al. (2010) pointed out that although many autistic people have trouble processing facial emotion expressions in an automatic and spontaneous manner, they can overcome the difficulties by using compensating cognitive strategies.

On the other hand, the similar performances of the two groups could be because emotion attribution was more complex than emotion discrimination and identification, and non-autistic children were not yet proficient at performing the task, either. As mentioned before, young children start emotion recognition first by interpreting facial expressions. Deducing another's emotional state from situational cues is a more advanced perspective-taking ability and occurs at older ages (Langdon et al., 2006). Indeed, when looking at their performances in the three emotion-recognition tasks, non-autistic children showed ceiling effects at Times 3 and 4 for emotion discrimination and emotion identification. However, their performances in the emotion-attribution tasks, especially in the tasks for attributing negative emotions, showed that there was still space for improvement (see Supplementary Tables 1, 2, and 3). Note that we did find one group difference in emotion attribution: autistic children performed less well than non-autistic children in attributing positive emotions in the visual condition. In this condition, children needed to designate the positive emotion by pointing to the corresponding facial expression. This group difference might be related to autistic children's difficulty processing facial information. It could also be because non-autistic children performed better in this condition than in the other conditions, and thus the group difference was visible. Future research using a more nuanced experimental design and following children's development for a longer period can help pinpoint the unique challenges that autistic children face in their development of emotion recognition.

In line with Rosen and Lerner (2016), we found that autistic children's emotion recognition grew with age. Although findings from meta-analysis research suggest the development of emotion recognition could be slower in autistic people than in non-autistic people (Lozier et al., 2014), our longitudinal data did not confirm this. We found that, for emotion discrimination and emotion attribution, autistic children developed at similar rates as non-autistic children, and for emotion identification autistic children showed greater increases over time than non-autistic children. Note that our study only examined basic abilities of emotion recognition. As children grow older, they need to develop more sophisticated abilities, such as recognizing emotions that are expressed subtly and dynamically, and analyzing emotional information which requires advanced perspective-taking abilities. The increasing complexity of the developmental task for emotion recognition may widen the differences between autistic children and their non-autistic peers. Furthermore, being marginalized in social circles can have long-term negative impacts on autistic children: their difficulty understanding others' emotions and mental states may elicit misunderstanding and hostility from the environment (Williams & Gray, 2013), resulting in fewer opportunities for autistic children to participate in the social learning process. This, in turn, will exacerbate autistic children's difficulties in emotion recognition.

In addition to age, we expected that the level of autistic traits could have an influence on the development of emotion recognition among autistic children. Although adding the mean levels of autistic traits as a predictor contributed to explaining the variability of the predicting models, only one longitudinal association - the association between the mean levels of autistic traits and children's ability to discriminate between positive and negative facial emotion expressions – reached the significant level. We have also run post hoc analyses to check if the baseline levels of autistic traits (i.e., using the SRS scores at Time 1 as the predictor) would contribute to predicting the development of emotion recognition in autistic children. Similarly, only the association with children's ability to discriminate between positive and negative facial emotion expressions reached the significant level (see Supplementary Table 12). The lack of strong associations between autistic traits and the development of emotion recognition in autistic children might be partly due to the measurement chosen in the study. The SRS is most appropriate for use with children aged between four and 18 years (Constantino & Gruber, 2005). However, 18% of our autistic participants were younger than four at Time 1, and there were still 7% of autistic participants younger than four at Time 2. The SRS might not be sensitive enough to detect autistic traits in such a young sample. Another possibility is that the quantity and intensity of autistic traits might have a greater influence on more advanced and more sophisticated emotional abilities than on the basic abilities examined in this study.

It should also be noted that other factors than the levels of autistic traits might influence children's development of emotion recognition. One such factor could be children's language abilities. Children acquire an in-depth and nuanced understanding of emotions through discussing emotional events with others and through communicating with others how they feel (Cutting & Dunn, 1999; Harris, 2005). A rich body of research has shown that having conversations with family members, friends, and peers about emotions and mental states fosters the development of

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emotional understanding in children (e.g., Jenkins et al., 2003; Taumoepeau & Ruffman, 2008). This social learning process is facilitated by children's language abilities. Yet, autistic children often lag behind non-autistic children in language development (Barbaro & Dissanayake, 2012; Reindal et al., 2023), which might hinder them from participating in the social learning process and in turn hinder their development of emotion recognition.

In our original study design, we did not examine the influence of children's language abilities because we did not have formal measurements for language abilities. While revising this manuscript and following the suggestion of a reviewer, we conducted post hoc analyses, where we added three language indices (i.e., emotion vocabulary, language expression, and language comprehension) to the predicting models to explore whether and how children's language abilities could influence their development of emotion recognition. The post hoc analyses showed that autistic children scored indeed lower on the three language indices (see Supplementary Table 13). Furthermore, the language indices (especially emotion vocabulary and language expression) had stronger effects than the diagnosis of autism on predicting children's development of emotion recognition (see Supplementary Tables 14, 15, and 16). This indicates that having autism might not directly entail a delayed development of emotion recognition. Experiencing language barriers and restricted social learning might mediate the association between having autism and delayed development of emotion-recognition abilities in these children.

This study has the advantage of using a longitudinal approach to unravel the development of emotion recognition in autistic children from a relatively young age. However, some caveats should be noted. First, the testing materials consisted of drawings of faces with pronounced emotional expressions. Face looking can be overstimulating for autistic children (e.g., Lassalle et al., 2017; Wagner et al., 2016). Compared to the photos of human faces, we expected that the drawings of faces might be less arousing for autistic children, thus using drawings instead of photos might help diminish the overstimulation in autistic children and interfere less with their task performances. Nonetheless, such drawings of facial expressions are easier to detect than facial expressions encountered in daily life, where the emotions are expressed often more subtly, with various intensities, and in a dynamic way. Despite the relatively low ecological validity of the testing materials, autistic children were still outperformed by non-autistic peers, indicating that recognizing emotions from facial expressions could be a real challenge for them. Second, this study included only one positive emotion (i.e., happiness), whereas positive affect could encompass a range of diverse positive emotional states. Our study design reflects a general bias in emotion research, where positive affect is usually studied as one category, but more nuanced distinctions are made when it comes to negative affect (Sauter, 2010). Future research should investigate how autistic children could recognize different types of positive emotions, providing us with a more comprehensive understanding of their emotion-recognition abilities. Third, the autistic sample included in this study had an IQ score above 70, showing no developmental delay at the time of data collection. In addition, the autistic participants and their parents were involved in supporting programs for autistic children. The increasing trends observed in autistic children for emotion recognition could at least partly result from the support that the participants and their parents received. Caution is warranted when generalizing our findings to other autistic groups. Fourth, autistic girls were underrepresented in this study, so as in the general population with autism. Although fewer girls are diagnosed with autism, it does not mean that the predicament is of a lesser extent for autistic girls than for autistic boys. Future research should make efforts to understand the unique challenges that autistic girls face and provide them with gender-tailored support. Last but not the least, our findings only reflected the average performances and abilities of autistic children. As indicated by the random effects of age found in most models, the developmental trends differed greatly among children. Autistic children are as heterogeneous and diverse as non-autistic children, and the findings of this study should not be used to label them.

To conclude, this study confirmed previous findings that autistic children faced challenges in emotion recognition, especially in recognizing facial emotion expressions. These challenges were present already from young ages and were persistent over time. Despite the challenges, autistic children showed similar improvements over time to non-autistic children. Understanding the challenges that autistic children face and acknowledging their potential can make a positive step toward supporting them in the right way. Future research should investigate factors that facilitate and promote emotional development in autistic children, such as creating an inclusive and respectful social environment, where autistic children can participate in social interactions at ease and can receive equal social learning opportunities as their non-autistic peers.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0954579423000913.

Data availability statement. This study's design, hypotheses, and analysis plan were preregistered at https://doi.org/10.17605/OSF.IO/QGR58. After this study is published, the dataset and associated information of this manuscript will be stored and shared publicly at the Leiden University archiving platform DataverseNL.

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Competing interests. The authors report there are no competing interests to declare.

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