Understanding, expressing, and interacting: the development of emotional functioning in young children with autism

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Appendices.

Supplementary materials

Acknowledgements

Curriculum Vitae

Supplementary Materials Chapter 2

Table S2.1. Means and standard deviations (SD) of emotion discrimination at four waves.

	Autistic			*Non-autistic*		
	Mean	**SD**	**N**	**Mean**	**SD**	**N**
Positive vs. Negative (0-3)						
Time 1	1.91	1.08	61	2.19	.84	121
Time 2	2.30	.96	45	2.63	.74	51
Time 3	2.49	.83	43	2.86	.41	49
Time 4	2.59	.81	41	2.89	.31	47
Sad vs. Angry (0-3)						
Time 1	1.57	1.06	61	1.87	.91	121
Time 2	1.97	.95	45	2.17	.94	52
Time 3	2.17	.94	43	2.56	.75	49
Time 4	2.33	.90	40	2.73	.52	47

Table S2.2. Means and standard deviations (SD) of emotion identification at four waves.

	Autistic			*Non-autistic*		
	Mean	**SD**	**N**	**Mean**	**SD**	**N**
Happy (0-2)						
Time 1	1.39	.88	62	1.75	.60	121
Time 2	1.67	.74	45	1.98	.14	52
Time 3	1.88	.45	43	1.94	.24	49
Time 4	1.93	.35	41	2.00	.00	47
Angry (0-2)						
Time 1	1.29	.91	62	1.77	.60	121
Time 2	1.60	.75	45	2.00	.00	52
Time 3	1.84	.53	43	2.00	.00	49
Time 4	1.83	.54	41	2.00	.00	47
Sad (0-2)						
Time 1	1.03	.94	62	1.37	.83	121
Time 2	1.38	.81	45	1.77	.47	52
Time 3	1.70	.64	43	1.92	.28	49
Time 4	1.83	.50	41	1.96	.20	47
Fear (0-2)						
Time 1	1.10	.95	62	1.36	.84	121
Time 2	1.42	.87	45	1.79	.50	52
Time 3	1.74	.62	43	1.94	.24	49
Time 4	1.88	.46	41	1.94	.32	47

Table S2.3. Means and standard deviations (SD) of emotion attribution at four waves.

	Autistic						*Non-autistic*					
	Verbal			***Visual***			***Verbal***			***Visual***		
	Mean	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**
Positive emotions (0-2)												
Wave 1	1.10	.89	62	1.11	.89	62	1.58	.69	121	1.59	.68	121
Wave 2	1.58	.78	45	1.58	.78	45	1.88	.32	52	1.88	.32	52
Wave 3	1.53	.74	47	1.60	.69	43	1.79	.45	53	1.78	.47	49
Wave 4	1.61	.61	47	1.63	.58	41	1.87	.34	53	1.86	.35	43
Negative emotions (0-2)												
Wave 1	1.18	.66	62	.94	.73	62	1.11	.52	121	1.13	.49	121
Wave 2	1.30	.61	45	1.34	.62	45	1.29	.31	52	1.33	.30	52
Wave 3	1.45	.55	43	1.47	.57	43	1.28	.38	49	1.27	.39	49
Wave 4	1.33	.55	41	1.34	.53	41	1.30	.45	47	1.34	.45	45

Table S2.4. Eight vignettes depicting emotion-provoking situations in the emotion attribution task.

Vignette content
1. The boy is building a tower; someone knocks it down.
2. The boy receives an ice cream.
3. Someone is pulling at the boy's shirt.
4. The boy falls off from the bicycle.
5. The boy receives a present.
6. The Boya sees a frightening dog.
7. The spade of the boy is broken.
8. The boy sees a crocodile.

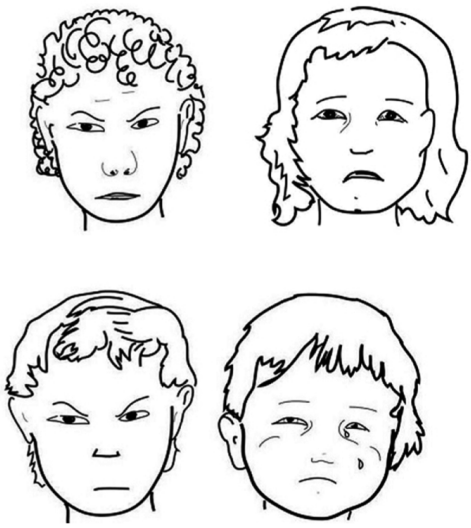

Figure S2.1. Examples of facial emotion expressions used in this study. From left to right: angry facial expressions and sad facial expressions.

Table S2.5. Model fit indices of the best age models for emotion recognition.

	Emotion discrimination			
	Positive vs. negative			
	AIC	BIC	-2LL	X^2 statistics
Null model	1143.21	1155.59	1137.21	-
Best age model**:** age (linear; fixed), group	1033.77	1054.28	1023.77	X^2 (2)=113.44, p<.001
	Sad vs. Anger			
	AIC	BIC	-2LL	X^2 statistics
Null model	1241.63	1254.01	1235.63	-
Best age model: age (linear; fixed), group	1118.13	1138.65	1108.13	X^2 (2)=127.50, p<.001

				Emotion identification
	Happy			
	AIC	BIC	-2LL	X^2 statistics
Null model	712.53	724.93	706.53	
Best age model: age (linear; fixed & random), group, age x group	552.65	585.50	536.65	X^2 (5)=169.88, p<.001
	Angry			
	AIC	BIC	-2LL	X^2 statistics
Null model	743.92	756.32	737.92	
Best age model: age (linear; fixed & random), group, age x group	561.89	594.73	545.89	X^2 (5)=192.04, p<.001
	Sad			
	AIC	BIC	-2LL	X^2 statistics
Null model	1003.97	1016.37	997.97	
Best age model: age (linear; fixed & random), group	857.09	885.84	843.09	X^2 (4)=154.89, p<.001
	Fear			
	AIC	BIC	-2LL	X^2 statistics
Null model	1017.72	1030.11	1011.72	
Best age model: age (linear; fixed & random), group	850.26	879.01	836.26	X^2 (4)=161.71, p<.001
				Emotion attribution
	Positive emotions (Verbal)			
	AIC	BIC	-2LL	X^2 statistics
Null model	963.13	975.52	957.13	
Best age model: age (linear; fixed & random), group	832.06	860.80	818.06	X^2 (4) = 139.07, p < .001

	Positive emotions (Visual)			
	AIC	BIC	-2LL	X^2 statistics
Null model	892.08	904.45	886.08	
Best age model: age (linear; fixed & random), group, age x group	782.54	815.32	766.54	X^2 (5) = 119.54, $p < .001$
	Negative emotions (Verbal)			
	AIC	BIC	-2LL	X^2 statistics
Null model	541.32	553.71	535.32	
Best age model: age (linear; fixed)	524.59	541.02	516.59	X^2 (1) = 18.73, $p < .001$
	Negative emotions (Visual)			
	AIC	BIC	-2LL	X^2 statistics
Null model	692.32	794.71	686.32	
Best age model: age (linear; fixed & random)	622.05	646.67	610.05	X^2 (3) = 76.27, $p < .001$

NOTE. Models removed during the formal model-fitting procedures were not presented here. The χ^2 statistics present the comparisons of the -2LL values between the best fitting models and the null models.

Table S2.6. Model fit indices of the predicting models with the means score of SRS as the predictor on emotion recognition abilities in autistic children.

				Emotion discrimination
	AIC	BIC	-2LL	X^2 statistics
Age-only model	425.04	437.92	417.04	-
Model with SRS mean	338.55	353.71	328.55	X^2 (1) = 88.49, p < .001
				Emotion identification
	AIC	BIC	-2LL	X^2 statistics
Age-only model	283.88	296.76	275.88	-
Model with SRS mean	230.16	245.31	220.16	X^2 (1) = 55.72, p < .001
				Emotion attribution verbal condition
	AIC	BIC	-2LL	X^2 statistics
Age-only model	301.82	314.71	293.82	-
Model with SRS mean	243.82	258.98	233.82	X^2 (1) = 60, p < .001
				Emotion attribution visual condition
	AIC	BIC	-2LL	X^2 statistics
Age-only model	310.73	323.59	302.73	-
Model with SRS mean	251.71	266.83	241.71	X^2 (1) = 61.02, p < .001

NOTE. The χ^2 statistics present the comparisons of the -2LL values of the age-only models and the models with SRS mean and change scores as predictors.

Supplementary Materials Chapter 3

Table S3.1. Sample size justification.

Analysis	Explanation
Power analysis for the larger project	An a priori power analysis was conducted for the larger research project that embedded this study. It showed that to observe a medium-sized effect (effect size = .35, power = .80, alpha = .05), a total sample size of 216 children would be needed for analyses with four repeated measures and two groups. Note that this analysis was done for the larger project and based on a repeated measure ANOVA design. We opted for mixed models for the current study because it better accounts for the dependency within the data and can handle missing or unbalanced data.
Power analysis for the present study	We did not conduct an a priori power analysis specifically for this study because the study was based on the data already collected. Yet, to understand the sample size needed for detecting the effect of diagnosis group in multilevel models, a simulation analysis was conducted via the Optimal Design program (Version 3.01; Raudenbush et al., 2011). It showed that in the case where each participant has two waves of data, an effect of group can be detected with a power ≥ .80 when the total number of participants is ≥ 150; in the case where each participant has three waves of data, a total sample size of ≥ 100 is needed (alpha = .05; effect size = .35). Given that 80% of our participants had three waves of data, we assumed that the power for conducting the analyses is adequate.

Table S3.2. Internal consistency of measures at three times points.

	Cronbach's α		
	Autistic	**Non-autistic**	**Total**
Time 1			
Shame/guilt	0.97	0.79	0.96
Pride	0.88	0.78	0.83
EU	0.91	0.74	0.91
Time 2			
Shame/guilt	0.71	0.82	0.81
Pride	0.83	0.78	0.80
EU	0.92	0.76	0.92
Time 3			
Shame/guilt	0.81	0.83	0.86
Pride	0.79	0.81	0.82
EU	0.88	0.79	0.89

NOTE. EU: emotion understanding.

Table S3.3. Correlation matrix of the predicting variables and moral emotions at three time points.

		Pride			Age			FB[a]			EU[b]		
		T1	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
Shame	**T1**	.29**			.06			.45**/.16			-.25/.15		
	T2		.09			-.21*			.03			.10	
	T3			.42**			.12			.30**			.36**
Pride	**T1**				.36*/.05			.40**/-.07			-.03		
	T2					.15			.45**/-.002			.15	
	T3						-.10			.39*/-.01			.13
Age	**T1**							.45**/.66**			.02		
	T2								.39**			-.01	
	T3									.23*			.22
FB[a]	**T1**										.16		
	T2											.45**/.13	
	T3												.34**

Note. [a.] false belief; [b.] emotion understanding. *$p < .05$; **$p < .001$.

First, the correlation analyses were conducted for children with and without ASD separately. Next, Fisher *r*-to-*z* transformations were used to compare the correlations of the two groups. Correlations that did not differ between groups were recalculated by collapsing groups. Correlations that differed between groups were both reported in the table, with the correlation of the ASD group on the left and the correlation of the non-ASD group on the right separated by slash.

Supplementary Materials Chapter 4

Table S4.1. Mean scores, standard deviations (SD) and reliabilities of parent-reported empathy of autistic and non-autistic group at four time points.

	Autistic				*Non-autistic*			
	Mean	**SD**	**ω_t**	**N**	**Mean**	**SD**	**ω_t**	**N**
Affective (0-2)								
Time 1	0.32	0.34	0.85	54	0.30	0.32	0.89	118
Time 2	0.34	0.38	0.86	50	0.30	0.31	0.88	49
Time 3	0.38	0.42	0.91	45	0.26	0.29	0.80	41
Time 4	0.38	0.36	0.83	31	0.22	0.30	0.91	33
Attention (0-2)								
Time 1	0.93	0.49	0.88	54	1.38	0.35	0.82	118
Time 2	0.97	0.49	0.89	50	1.40	0.36	0.81	49
Time 3	0.96	0.47	0.87	45	1.41	0.31	0.73	41
Time 4	1.02	0.48	0.87	31	1.36	0.42	0.88	33
Prosocial (0-2)								
Time 1	0.39	0.38	0.86	54	0.98	0.39	0.89	118
Time 2	0.41	0.42	0.91	50	1.12	0.36	0.89	49
Time 3	0.47	0.45	0.88	45	1.19	0.33	0.86	41
Time 4	0.58	0.40	0.90	31	1.26	0.42	0.94	33
Cognitive (0-5)								
Time 1	2.90	0.92	0.93	55	3.87	0.54	0.84	121
Time 2	2.94	0.91	0.94	50	4.13	0.81	0.89	49
Time 3	2.97	0.96	0.95	45	4.15	0.53	0.90	41
Time 4	3.14	0.98	0.94	31	4.04	0.55	0.90	33

Table S4.2. Mean scores, standard deviations (SD) and reliabilities of observed empathy of autistic and non-autistic group at four time points.

	Autistic				*Non-autistic*			
	Mean	**SD**	**ω_t**	**N**	**Mean**	**SD**	**ω_t**	**N**
Affective (0-2)								
Time 1	0.64	0.48	0.90	61	0.83	0.47	0.84	145
Time 2	0,63	0.53	0.83	50	0.89	0.53	0.80	51
Time 3	0.68	0.39	0.78	47	0.73	0.44	0.70	48
Time 4	0.59	0.46	0.83	43	1.13	0.43	0.74	44
Attention (0-2)								
Time 1	0.99	0.62	0.93	61	1.50	0.48	0.88	145
Time 2	1.36	0.57	0.89	50	1.83	0.28	0.75	51
Time 3	1.02	0.29	0.78	47	1.25	0.25	0.72	48
Time 4	0.95	0.38	0.85	43	1.21	0.24	0.80	44
Prosocial (0-2)								
Time 1	0.22	0.28	0.87	60	0.31	0.35	0.82	144
Time 2	0.40	0.40	0.71	50	0.54	0.41	0.84	51
Time 3	0.64	0.36	0.66	47	0.41	0.33	0.55	48
Time 4	0.49	0.29	0.64	42	0.57	0.40	0.64	43

Table S4.3. Mean scores, standard deviations (SD) and reliabilities of psychosocial functioning of autistic and non-autistic group at four time points.

	Autistic				*Non-autistic*			
	Mean	**SD**	**ω_t**	**N**	**Mean**	**SD**	**ω_t**	**N**
Externalizing (0-3)								
Time 1	0.94	0.49	0.95	55	0.43	0.25	0.89	112
Time 2	0.50	0.34	0.94	49	0.32	0.26	0.93	45
Time 3	0.50	0.33	0.94	45	0.30	0.24	0.94	34
Time 4	0.43	0.38	0.94	30	0.22	0.22	0.93	28
Cooperation (0-2)								
Time 1	1.33	0.62	0.96	60	1.74	0.35	0.92	145
Time 2	1.44	0.46	0.95	50	1.85	0.23	0.91	52
Time 3	1.56	0.40	0.94	47	1.77	0.34	0.93	47
Time 4	1.53	0.52	0.96	44	1.85	0.16	0.82	44

Table S4.4. Model fit indices of the best age models for empathy.

Parent reports				
	Affective			
	AIC	BIC	-2LL	X^2 statistics
Null model	165.69	177.81	159.69	-
***Best age model*:** age (linear)	155.43	171.37	147.43	X^2 (1)=9.26, p<.001
	Attention			
	AIC	BIC	-2LL	X^2 statistics
Null model	331.38	343.51	325.38	-
Best age model: age (linear), group	292.52	312.44	282.52	X^2 (2)=51.21, p<.001
	Prosocial			
	AIC	BIC	-2LL	X^2 statistics
Null model	386.91	399.03	380.91	
Best age model: age (linear), group	264.66	284.58	254.66	X^2 (2)=126.25, p<.001
	Cognitive			
	AIC	BIC	-2LL	X^2 statistics
Null model	1116.12	1124.23	1112.12	
Best age model: age (linear), group, age*group	881.75	901.72	871.75	X^2 (2)=240.37, p<.001
Observation				
	Affective			
	AIC	BIC	-2LL	X^2 statistics
Null model	662.43	675	656.43	
Best age model: age (linear), group	636.06	656.91	626.06	X^2 (2)=30.37, p<.001
	Attention			
	AIC	BIC	-2LL	X^2 statistics
Null model	705.34	717.92	699.34	

Best age model: age (linear), group, age*group	625.30	646.16	615.30	X^2 (3)=41.43, p<.001
	Prosocial			
	AIC	BIC	-2LL	X^2 statistics
Null model	423.79	436.34	417.79	
Best age model: age(linear), group, age*group	379.49	404.47	367.49	X^2 (3)=50.30, p<.001

Table S4.5. Model fit indices of the best fitting models for psychosocial functioning with empathy as the predictor.

	Externalizing problems			
	AIC	BIC	-2LL	X^2 statistics
Null model	210.06	229.75	200.06	-
Best predicting model with parent-reported empathy without cognitive empathy: age, group, mean, change	201.77	229.10	187.77	X^2 (2) = 12.29, p = .002
Best predicting model with parent-reported empathy including cognitive empathy: age, group, mean, change	201.46	228.87	187.46	X^2 (2) = 12.54, p = .002
Best predicting model with observed empathy: age, group, mean, change	206.74	232.26	190.74	X^2 (2) = 9.32, p = .009
	Social competence			
	AIC	BIC	-2LL	X^2 statistics
Null model	384.92	405.78	374.92	-
Best predicting model with parent-reported empathy without cognitive	261.03	292.62	245.03	X^2 (3) = 129.89, p < .001

empathy: age, group, mean, change, mean*group				
Best predicting model with parent-reported empathy including cognitive empathy: age, group, mean, change, mean*group	300.09	268.34	252.34	X^2 (3) = 122.58, $p < .001$
Best predicting model with observed empathy: age, group, mean, change, mean*group, change*group	299.23	336.74	281.23	X^2 (4) = 92.69, $p < .001$

Notes Supplementary Table 4 and 5. Models removed during the formal model-fitting procedures were not presented here. The χ^2 statistics present the comparisons of the -2LL values between the best fitting models and the null models.

Supplementary Materials Chapter 5

Table S5.1. Available data per group per time-point (TP).

	TD	ASD	TOTAL
Internalizing	n	n	N
1 TP	33	11	44
2 TP	22	8	30
3 TP	42	40	82
Externalizing			
1 TP	33	11	44
2 TP	23	8	31
3 TP	41	40	81
Negative Emotion expression			
1 TP	29	11	40
2 TP	21	7	28
3 TP	47	41	88
Emotion recognition			
1 TP	29	11	40
2 TP	20	7	27
3 TP	48	41	59
Emotion vocabulary basic			
1 TP	29	11	40
2 TP	21	7	28
3 TP	47	41	89
Emotion vocabulary mental states			
1 TP	29	11	40
2 TP	21	7	28
3 TP	47	41	89

Table S5.2. Internal consistency of measures per time point per group.

		Cronbach's α	
		TD	ASD
Time 1			
Internalizing		0.874	0.639
Externalizing		0.868	0.962
Negative emotion expression		0.787	0.633
Positive emotion expression		0.655	0.673
Emotion recognition		0.758	0.878
Emotion vocabulary			
	Basic	0.865	0.748
	Mental states	0.697	0.752
Time 2			
Internalizing		0.874	0.882
Externalizing		0.889	0.895
Negative emotion expression		0.802	0.817
Positive emotion expression		0.398	0.705
Emotion recognition		0.764	0.908
Emotion vocabulary			
	Basic	0.749	0.831
	Mental states	0.827	0.824
Time 3			
Internalizing		0.869	0.894
Externalizing		0.887	0.919
Negative emoiton expression		0.679	0.825
Positive emotion expression		0.600	0.780
Emotion recognition		0.798	0.908
Emotion vocabulary			
	Basic	-0.360	0.792
	Mental states	0.134	0.811

Table S5.3. Model fit indices per model.

	Internalizing			Externalizing		
Best fitting age-model	AIC	BIC	X^2 statistic	AIC	BIC	X^2 statistic
Null Model	2055	2062	-	2391	2399	-
Linear Age-model	1976	1983	$X^2(1) = -79$, $p < .001$	2315	2323	$X^2(1) = -67$, $p < .001$
Quadratic Age-model	1985	1993	$X^2(1) = 10$, $p > .20$	2324	2332	$X^2(1) = 9$, $p > .20$
Cubic Age-model	1995	2003	$X^2(1) = 10$, $p > .20$	2333	2340	$X^2(1) = 8$, $p > .20$
Linear Age x Group	**1966**	**1974**	$X^2(2) = 29$, $p < .001$	**2291**	**2299**	$X^2(2) = -41$, $p < .001$
Best fitting model including all predictors						
Full model	**1878**	**1885**	$X^2(5) = 89$, $p < .001$	2203	2211	$X^2(5) = -88$, $p < .001$
Full model including interactions with Group	1868	1875	$X^2(5) = 10$, $p > .10$	**2179**	**2186**	$X^2(5) = -25$, $p < .001$

With χ^2 analyses we tested whether adding extra variables to the model improved model fit. We used the difference between the BIC values of the most parsimonious model with the next model, so null model – linear age-model (i.e., BIC (linear age-model) 1983 - BIC (null model) 2062 = 79). For the full model including all variables of emotion functioning (i.e., emotion expression, emotion recognition, and emotion vocabulary), we compared with the best age-model. We report the χ^2 statistic of model comparison of the BIC values, given that BIC values take the number of added variables into account. Note that BIC and AIC indices resulted in the same selection of best fitting models.

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CURRICULUM VITAE

Boya Li was born on 27 April 1978, in Yichang, China. From 1996 to 2000, she did her Bachelor study at Beijing Language and Culture University, majoring in teaching Chinese as a foreign language. In 2000, she started her Master program at Peking University, specializing in Chinese linguistics. After one year, she moved to the Netherlands to do her doctoral research on Chinese sentence final particles, under the supervision of prof. dr. Rint Sybesma and prof. dr. Lisa Cheng at Leiden University Center for Linguistics. She obtained her PhD degree in linguistics in 2006. After finishing her PhD project, Boya moved to Warsaw, Poland, to live with her husband. During her stay in Warsaw, she grew a strong interest in psychology. From 2010 to 2013, she did her Bachelor study in psychology at the Faculty of Psychology, the University of Warsaw. She moved back to the Netherlands in 2013 and was admitted to the Research Master program in developmental psychology at Leiden University. After obtaining her Research Master degree in 2015, Boya received the opportunity to work as a researcher and teacher in the unit of Developmental and Educational Psychology at Leiden University. She started her second PhD project in December 2019, under the supervision of prof. Carolien Rieffe, dr. Kirstin Greaves-Lord, and dr. Els Blijd-Hoogewys, to investigate the development of emotional functioning in young children with autism. From January 2021, she joined a new research project as a postdoc researcher, working together with prof. Carolien Rieffe and dr. Els Blijd-Hoogewys, to investigate how to create a more inclusive social environment for pupils with autism.