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4 **Clinical, socio-demographic, and parental correlates of early autism traits in a
5 community cohort**

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33 Abstract

34 **Background:** Autism traits emerge between the ages of 1 and 2. It is not known if experiences which
35 increase the likelihood of childhood autism are related to early trait emergence, or if other exposures
36 are more important. Identifying factors linked to toddler autism traits in the general population may
37 improve our understanding of the mechanisms underlying atypical neurodevelopment.

38 **Methods:** Clinical, socio-demographic, and parental information was collected at birth from 536
39 toddlers in London, UK (gestational age at birth, sex, maternal body mass index, age, parental
40 education level, parental first language, parental history of neurodevelopmental disorders) and at 18
41 months (parent cohabiting status, two measures of social deprivation, three measures of maternal
42 parenting style, and a measure of maternal postnatal depression). General neurodevelopment was
43 assessed with the Bayley Scales of Infant and Toddler Development, 3rd Edition (BSID-III), and autism
44 traits were assessed using the Quantitative Checklist for Autism in Toddlers (Q-CHAT). Multivariable
45 models were used to identify associations between variables and Q-CHAT. A model including BSID-III
46 was used to identify factors associated with Q-CHAT independent of general neurodevelopment.
47 Models were also evaluated addressing variable collinearity with principal component analysis (PCA).

48 **Results:** A multivariable model explained 20% of Q-CHAT variance, with four individually significant
49 variables (two measures of parenting style and two measures of socio-economic deprivation). After
50 adding general neurodevelopment into the model 36% of Q-CHAT variance was explained, with three
51 individually significant variables (two measures of parenting style and one measure of language
52 development). After addressing variable collinearity with PCA, parenting style and social deprivation
53 were positively correlated with Q-CHAT score via a single principal component, independently of
54 general neurodevelopment. Neither sex nor family history of autism were associated with Q-CHAT
55 score.

56 **Limitations:** The Q-CHAT is parent rated and is therefore a subjective opinion rather than a clinical
57 assessment. We measured Q-CHAT at a single timepoint, and to date no participant has been followed
58 up in later childhood, so we are focused purely on emerging traits rather than clinical autism
59 diagnoses.

60 **Conclusions:** Autism traits are common at age 18 months, and greater emergence is specifically
61 related to exposure to early life adversity.

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63 **Keywords**

64 Autism; Screening; Perinatal

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76 **Background**

77 Autism spectrum disorders (ASD) are typically diagnosed between 4 and 7 years of age (1, 2). The age
78 at symptom onset however is often lower than this, with neurodivergence first being suspected by
79 parents in most instances between 1 and 2 years of age (3). Screening tools aiming to quantify autism
80 traits in this age group are well established and cut-off points with high sensitivity (albeit at the cost
81 of low specificity (4)) for predicting a future clinical autism diagnosis have been demonstrated (5, 6),
82 although results in some real-world cohorts are less promising (7). One such tool is the Qualitative
83 Checklist for Autism in Toddlers (Q-CHAT) (8). The Q-CHAT is a 25-item questionnaire with each item
84 rated by the parents from 0-4. It has been validated for use in multiple countries (9-13), and has a
85 positive predictive value of 28% for a future ASD diagnosis (using screening at two timepoints) (14).
86 Autistic traits exist in the population as a continuum (15), and most individuals screened, typically
87 developing or otherwise, will display at least some autism traits at age 18 months (16).
88 The likelihood of receiving an autism diagnosis is associated with both genetic and environmental
89 factors (17, 18), and the same may be true of early autism traits. Some factors are known to correlate
90 with autism traits at age 18 months – for example, sex (with males scoring higher than females) (7, 8,
91 19, 20) or preterm birth (10, 21). However, beyond these factors there is a relative lack of research
92 into what else may influence the emergence of autism traits in early life, although single studies have
93 linked maternal nausea and vomiting during pregnancy (22), neonatal illness (23), maternal
94 depression and anxiety (24, 25), immigrant mothers (26) and lower levels of parental education (24)
95 with higher scores on 18 month autism screening tools. Q-CHAT score at 18 months has also been
96 shown to be negatively correlated with general language development (10). The broader
97 developmental phenotype is known to be influenced by a wide range of exposures, including preterm
98 birth (27), neonatal illness (28), and multiple psychosocial factors (29-32). Given that Q-CHAT is known
99 to correlate with general language development, it is reasonable to hypothesise that Q-CHAT scores
100 may themselves be influenced by these same exposures.

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102 As well as research using structured tools there are previous studies which examine exposures
103 associated with single features of social communication development in toddlerhood. Multiple factors
104 including less responsive or less effective maternal parenting styles (33, 34), greater maternal
105 depression and experience of trauma (35) and a lower quality home environment (36) have been
106 correlated with less favourable social communication development in toddlerhood.

107 Because greater autism trait emergence at age 18 months is associated with a greater likelihood of
108 childhood autism (14) understanding correlates of the Q-CHAT score at 18 months may help us to
109 understand what early life experiences are associated with an increased likelihood of a future autism
110 diagnosis in some individuals. The developing Human Connectome Project (dHCP) has collected Q-
111 CHAT scores, other neurodevelopmental measures and demographic information from a large cohort
112 of 18-month-old toddlers in London, UK. Using this dataset, we aimed to characterise correlates of Q-
113 CHAT score. We hypothesised that, in keeping with the known associations between early life
114 adversity and other measures of neurodevelopment, we would observe a pattern of psychosocial
115 adversity being associated with higher Q-CHAT scores. Relationships between variables and Q-CHAT
116 score are presented in both univariable (in part to inform future studies which may only have some of
117 our variables available) and multivariable models, with scores from the Bayley Scales of Infant and
118 Toddler Development, 3rd Edition (BSID-III) (37) additionally included as a covariate to understand
119 whether any relationships between these early life experiences and autism traits are influenced by
120 general neurodevelopment.

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125 **Methods**

126 **Sample**

127 This study is based on a sample of neonates participating in the Developing Human Connectome
128 Project (dHCP, <http://www.developingconnectome.org/>). Participants were all recruited at St
129 Thomas' Hospital, London, UK. There were no specific inclusion or exclusion criteria for enrolment in
130 this study, and recruitment was primarily from the antenatal clinic with no specific stratification.

131 Toddlers were invited for neurodevelopmental assessment at 18 months post-expected delivery date;
132 appointments were made according to family availability as close as possible to this time-point. The
133 only inclusion criteria for this manuscript from the overall cohort was completion of the
134 neurodevelopmental assessment. There were no exclusion criteria.

135 This project has received UK NHS research ethics committee approval (14/LO/1169, IRAS 138070), and
136 conducted in accordance with the World Medical Association's Code of Ethics (Declaration of Helsinki).
137 Written informed consent was obtained from parents at recruitment into the study.

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139 **Data Collection**

140 Data collection took place either at St Thomas' Hospital, London, UK, or via questionnaires distributed
141 to the participants' parents. At the time of birth, clinical variables, gestational age at birth and sex
142 were extracted from the medical records of participants in the study; and maternal age, maternal pre-
143 pregnancy BMI, and parent ASD/attention deficit hyperactivity disorder (ADHD) history were also
144 collected via a maternal questionnaire. The last of these was asked in the format "Have you or your
145 child's biological father ever been diagnosed with Attention Deficit Hyperactivity Disorder (ADHD) or
146 Autism?" This was a yes/no question.

147 At the time of birth, the socio-demographic status of participant families was recorded as measured
148 by the Index of Multiple Deprivation Rank (IMD), a postcode-based score assigned to every address in
149 the UK which gives a composite measure of socio-economic disadvantage, based on the mother's
150 address at the time of birth. A lower score corresponds to greater geographical deprivation, with 1
151 being the lowest score possible and 32,844 being the highest score possible.

152 Further socio-demographic information was collected by questionnaire: maternal age at leaving
153 education ("At what age were you last in full time education?"), maternal 1st language ("Is English your
154 first language?"), and parent cohabiting status. The Cognitively Stimulating Parenting Scale (CSPS), a
155 questionnaire assessing the availability of resources to support cognitively stimulation parenting,
156 associated to both parenting style and socio-economic deprivation was also collected (38, 39). The
157 CSPS was updated to include items relating to access to mobile phones and apps. A higher score is
158 indicative of a more stimulating home environment, with a minimum possible score of 0 and a
159 maximum possible score of 40. The Q-CHAT score (a parent reported questionnaire) was collected at
160 the time of 18-month follow-up. This gives a score between 0 and 100, with higher scores indicative
161 of more autism traits. The Bayley Scales of Infant and Toddler Development, 3rd edition (BSID-III) (37),
162 was administered by either a Chartered Psychologist or Paediatrician when the children were 18-
163 months of age. The composite scores (Cognitive, Motor and Language) are used for analysis in this
164 study. Two measures of parenting style were also collected at this time. The first of these, the
165 Parenting Scale (40), is a self-reported tool that measures three different dimensions of parenting:
166 Laxness, the tendency to behave passively and give in to misbehaviour; Over-reactivity, which
167 measures anger, meanness and irritability in parenting; and Verbosity, a measure of parental
168 dependence on talking even when ineffective as a discipline style. The dimensions have a minimum
169 score of 1, and a maximum of 7. The Edinburgh Postnatal Depression Scale (EPDS) was also completed
170 at follow-up. This is a well-established self-reported tool for quantifying postnatal depressive
171 symptoms, with a minimum score of 0 and a maximum of 30. Higher scores are indicative of more
172 depressive symptoms (41).

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174 **Statistical Analysis**

175 Univariable associations between variables and Q-CHAT score were tested by Pearson's correlation or
176 t-test as appropriate. Associations between variables of interest and Q-CHAT score were assessed by
177 generalized linear model (GLM). Statistical significance was tested with random permutation tests,
178 using 10,000 permutations. P-values are reported uncorrected, with those surviving multiple
179 comparisons via false discovery rate (FDR) indicated (42). Principal component analysis was used to
180 characterize the latent structure of independent variables, and to address collinearity between linear
181 variables. The “elbow method” (43) was used to determine the optimal number of principal
182 components (PCs) to use in later analyses. Associations between PC scores and the original input
183 variables was determined by Pearson's correlation, with $p < 0.05$ after FDR correction considered
184 significant.

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186 Analyses were performed and figures made using Rstudio v4.0.2 (Rstudio, MA, U.S.A). The
187 “FDRestimation”, and “corrplot” packages were additionally used (44, 45). PCA was performed using
188 the “prcomp” function from base R rather than a dedicated package. Our code to implement random
189 permutation tests for GLMs in R can be downloaded from <https://github.com/CoDe-Neuro/ptestR>.

190 **Data availability**

191 The dHCP is an open-access project. Data from the project can be downloaded by registering at
192 <https://data.developingconnectome.org>. Analyses presented here include data to be included in
193 future releases.

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197 **Results**

198 **Population**

199 At the time of the study commencing, 644 individuals in the dHCP dataset had a Q-CHAT score
200 available. Of these 536 had a complete set of demographic data and were included in the study. A
201 comparison between individuals included and excluded is shown in Supplementary Table S1. There
202 were some differences between those included and excluded – individuals included in the study
203 experienced on average lower geographical deprivation (IMD Rank), lower maternal depression, and
204 less extreme parenting styles. The characteristics of the sample used, and the univariate relationships
205 of each variable to Q-CHAT score are shown in Table 1. A frequency distribution of Q-CHAT scores is
206 in Supplementary Figure S1.

207

208 *--Table 1 approximately here--*

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210 Nine variables were significantly associated with Q-CHAT score. BMI ($r=0.093$, $p=0.030$), EPDS
211 ($r=0.127$, $p<0.001$), and three measures of maternal parenting style; laxness ($r=0.286$, $p<0.001$), over-
212 reactivity ($r=0.180$, $p<0.001$) and verbosity ($r=0.300$, $p<0.001$) were positively correlated with Q-CHAT
213 score, and mother's age ($r=-0.105$, $p=0.014$), IMD rank ($r=-0.190$, $p<0.001$) and CSPS score ($r=-0.219$,
214 $p<0.001$) were negatively correlated with Q-CHAT score. Total Q-CHAT scores were significantly higher
215 in individuals whose mother's spoke a language other than English as their 1st language ($t=4.52$,
216 $p<0.001$).

217 All BSID-III composite scores were negatively associated with Q-CHAT score. The strongest association
218 was with Language Composite Score ($r=-0.528$, $p<0.001$).

219 **Multivariable models of Q-CHAT score**

220 We assessed the association of all variables with Q-CHAT score in two separate multivariable models,
221 with or without the addition of BSID-III composite scores to control for the effect of general
222 neurodevelopment and identify specific relationships between demographic variables and Q-CHAT
223 score.

224

225 *---Table 2 approximately here---*

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227 A multivariable model without BSID-III explained 20% of Q-CHAT variance. After FDR correction four
228 variables were individually associated with Q-CHAT score: IMD Rank ($t=-2.56, p=0.010$) and CSPS ($t=-$
229 $3.38, p<0.001$) were negatively associated and Mother Laxness ($t=3.79, p<0.001$) and Mother Verbosity
230 ($t=3.29, p=0.001$) were positively associated. After adding BSID-III composite scores to the model two
231 of these (Mother Laxness and Mother Verbosity) remained significantly associated with Total Q-CHAT
232 score ($t=2.68, p=0.007$ and $t=3.39, p<0.001$ respectively), in addition to BSID-III language composite
233 score ($t=-8.32, p<0.001$), which was negatively associated with Total Q-CHAT score. Notably sex and
234 parent ASD/ADHD diagnosis status did not correlate individually with Q-CHAT score in either model.

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236 *--- Figure 1 approximately here ---*

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238 A limitation of interpreting these models is the collinearity between demographic variables (Figure
239 1A). In order to address this without removing variables from the model, we performed a PCA of the
240 linear variables to obtain orthogonal components, which we then used in a general linear model in
241 place of the original linear variables (46). We selected the first 3 principal components (PCs) to
242 represent our data (Figure 1B). The multivariable models associating demographic variables and BSID-
243 III composite scores with Q-CHAT score (Table 2) were subsequently repeated, with linear variables

244 being replaced by PCA components 1-3 (Table 3). Details of variable correlations with each PC are
245 shown in Figure 1D. PC1 captures variable associations which are associated with positive parenting
246 styles and low socio-economic deprivation, PC2 is associated with socio-economic deprivation and a
247 less stimulating home environment, and PC3 is associated with low clinical adversity.

248 17% of Q-CHAT variance was explained by a model including 3 PCs and the categorical variables only,
249 with only PC1 remaining statistically significant in the model after FDR correction ($t=-8.17$, $p<0.001$,
250 Table 3). 36% of Q-CHAT variance was explained by the model including BSID-III scores to account for
251 general neurodevelopment, with PC1 and BSID-III language composite scores statistically significant
252 ($t=-6.59$ and $t=-8.96$ respectively, $p<0.001$, Table 3).

253

254 ---Table 3 approximately here---

255

256 PC1 (positive parenting styles and low socio-economic deprivation) is negatively correlated with Q-
257 CHAT score ($t=-8.17$, $p<0.001$) - ie, individuals with more adversity have lower Q-CHAT scores. Via this
258 PC we can see that maternal age at last full-time education, three measures of parenting style and
259 EPDS are positively associated with Q-CHAT score; whereas maternal age at leaving education and
260 IMD rank are negatively associated with Q-CHAT score. Once again it is worth noting that sex and
261 parent ASD/ADHD diagnosis status did not correlate with Q-CHAT score in either model.

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267 Discussion

268 We observed correlations of Q-CHAT score with measures of parenting style and measures of socio-
269 demographic adversity, with the former category demonstrating the strongest associations.
270 Conversely, some variables known to increase the likelihood of an autism diagnosis in later childhood,
271 such as male sex (47), a family history of autism (48) and gestational age at birth (49) were not
272 associated with Q-CHAT scores.

273 A multivariable model of demographic variables explained 20% of Q-CHAT variance. In this model four
274 variables (two measures of social deprivation and two measures of parenting style) were individually
275 significantly associated with Q-CHAT score. Adding measures of general neurodevelopment to this
276 model increased the explained variance to 36%, however this also resulted in two variables, IMD Rank
277 and CSPS (measures of social deprivation) no longer being individually significantly associated with Q-
278 CHAT score. Taken together this suggests that maternal parenting style is specifically associated with
279 Q-CHAT score, whereas that the association of social deprivation with Q-CHAT is partially explained
280 by general neurodevelopment.

281 Maternal verbosity had the strongest association with Q-CHAT score of any variable tested, remaining
282 significantly associated with Q-CHAT score in multivariable models with and without general
283 neurodevelopment. The mechanism via which this association occurs is unknown, but several
284 pathways are plausible. Parenting and affection display styles are heritable traits, and it may be that
285 the genetic and environmental factors contributing to adverse parenting styles also contribute to
286 autism trait emergence in toddlerhood (50, 51). Previous studies have suggested that parenting styles
287 directly influence childhood behaviour, as children learn by repetition (52, 53). Parent-child
288 relationships of children with childhood autism diagnoses are also more likely to be discordant than
289 those of neurotypical offspring (54). This discordance is thought to be both a cause and consequence
290 of difficulties in social understanding (55, 56), and it is possible that even at 18 months toddlers

291 displaying more autism traits have greater difficulty relating to their parents, leading to greater
292 discordance (57, 58). In support of this hypothesis a recent randomised controlled trial demonstrated
293 that a 10-session therapist delivered parenting skills intervention, which promoted concordant
294 interaction, led to a roughly 3 fold reduction in autism diagnoses 2 years later (59). However, parenting
295 styles are at least partly heritable (60), hence it is also possible that the offspring of parents who
296 naturally display more verbose and less collaborative parenting styles experience more difficulties
297 developing social relationship abilities, and thus score more highly on the Q-CHAT. A final possibility
298 is that maternal verbosity is in part a proxy measure of other forms of adversity: Verbosity has been
299 previously shown to correlate with multiple measures of maternal stress (61), which in turn has
300 previously been reported to correlate with a higher likelihood of offspring autism (62). All dimensions
301 of parenting style are correlated with IMD rank in our data (Figure 1), and this is in keeping with a
302 body of literature demonstrating associations between parenting style and socio-economic status
303 (63). A more deeply phenotyped sample would be required to investigate how and if these different
304 factors influence the relationship between maternal verbosity and Q-CHAT score. We do not seek to
305 suggest that the emergence of autism traits is something parents can control, and a final possible
306 interpretation of the correlation between maternal parenting style and autism trait emergence is
307 reporting bias. Given that both the Q-CHAT and the parenting style questionnaire are self-reported
308 tools individual patterns of response could relate to a wide number of factors, including mental state,
309 intellectual ability and neurodevelopmental profile. Future studies could consider clinician
310 administered measures to address this issue. There is another limitation to our findings here – we did
311 not ask any questions about family composition or care arrangements beyond parent cohabiting
312 status – we therefore do not know if the mother was the primary caregiver for each child included.

313 Based on previous literature, some of our results are expected, while others are unexpected. For
314 instance, we showed that multiple measures of psychosocial disadvantage correlate with higher Q-
315 CHAT scores. There is a significant body of evidence demonstrating that early life adversity affects
316 several domains of early childhood behaviour, including cognitive (29), motor (30), and language (64)

317 development, as well as emerging psychopathologies (25, 65). It is known that lower socio-economic
318 status correlates with higher scores on the precursor to the Q-CHAT, the M-CHAT (32). Also, one
319 previous study has specifically reported higher Q-CHAT scores in the offspring of depressed mothers
320 (24). Therefore, our finding that maternal depressive symptom burden, measured using EPDS,
321 correlates with offspring Q-CHAT score is not unexpected. In keeping with existing knowledge about
322 neurodevelopment is our finding that two measures of social adversity correlate with higher Q-CHAT
323 score. Our finding of a univariable association between maternal first language and Q-CHAT score is
324 also in keeping with a body of previous literature which demonstrates a higher rate of autism
325 diagnoses in children from immigrant backgrounds. It is likely that parent first language not being
326 English represents an increased risk of experiencing other adversities (66), rather than inferring that
327 being raised in a bilingual environment has an effect on autism trait emergence, which is not thought
328 to be the case (67).

329 We unexpectedly found no association between sex and Q-CHAT score in any analysis performed. A
330 handful of previous studies have demonstrated higher Q-CHAT scores in male toddlers compared to
331 female toddlers, with small but significant average score differences (3.1 (68), 3.1 (69) and 1.9 (8))
332 reported. It is not immediately obvious why we do not see the same difference in our data, although
333 it may be that in a larger sample this difference would have been apparent. Males in our cohort did in
334 fact score 1.4 Q-CHAT points higher than females on average (Cohen's $d = 0.16$), but the difference is
335 not statistically significant. Similarly in a multivariable model the individual correlation between sex
336 and Q-CHAT score is apparent ($t=-2.32$, $p=0.020$, Table 2) but did not survive FDR correction. It would
337 be more appropriate to say that there is a trend towards males having higher Q-CHAT scores in our
338 data than that there is no association at all.

339 We also found no significant association between parental history of ASD and Q-CHAT score in any
340 analysis performed. A difference may reasonably have been expected based on the known familial
341 increased likelihood of autism and ADHD diagnoses (48, 70). To date, one study has directly reported

342 on the association between parental history of ASD and Q-CHAT score and found a large group
343 difference, with the familial ASD history group having higher Q-CHAT scores at age 16-30 months (71).
344 One other study has specifically examined the difference between Q-CHAT scores in individuals with
345 and without an older sibling with autism, and also found significant group differences (72). It is not
346 clear why we do not see the same effect here, although it is possible that the method in which we
347 recorded family history (the mother was asked only if she or her partner had ever been diagnosed
348 with autism) was too narrow a definition (a more broad dimensional assessment would have been
349 preferable), or alternatively it may be the case that we lacked sufficient positive cases (28 parents
350 reported an ASD or ADHD diagnosis compared to 506 with no diagnosis) to have determinative power.
351 Parents were also asked if the child participating in the study had an older sibling with an autism or
352 ADHD diagnosis – as only 206 individuals had older siblings we have not included this variable in the
353 main analysis. There was similarly no difference ($t=-0.51$, $p=0.62$) in mean Q-CHAT score between
354 those with ($n=23$, mean Q-CHAT = 31.4) and without ($n=183$, mean Q-CHAT = 30.1) an older sibling
355 with a neurodevelopmental diagnosis. This may again be due to an insufficient number of positive
356 cases for determinant power.

357 It has been previously reported that preterm birth confers an increasing likelihood of both childhood
358 autism diagnosis and greater early autism trait emergence (73, 74). One previous study reports Q-
359 CHAT scores in a cohort of toddlers born before 30 weeks of gestation, who scored a mean of 33.7
360 (10), although to our knowledge no direct comparison of Q-CHAT scores in individuals born term and
361 preterm has yet been presented. In our cohort we find no association between gestational age at birth
362 and Q-CHAT score directly through univariable or multivariable associations, or indirectly via PCA
363 latent components. One possibility is that early life autism trait emergence is less readily detected by
364 screening tools in some preterm children (75, 76). Although we have used gestational age as a linear
365 variable if we consider preterm birth as a binary variable there is also no difference between groups.
366 The mean Q-CHAT of individuals born preterm is 30.1, and the mean Q-CHAT of individuals born at
367 term is 30.1. The mean Q-CHAT scores in individuals born before 30 weeks gestation in our sample

368 (n=36) is however 34.6, which is in keeping with the 33.7 average score reported by Wong et al. (2014)
369 using the same criteria. Further research is needed to understand how the degree of prematurity
370 effects early life autism trait emergence.

371 A finding of particular interest is how associations between demographic variables and Q-CHAT score
372 were influenced by general neurodevelopment, which in our study is represented by BSID-III. All BSID-
373 III composite scores correlated individually to the Q-CHAT score (Table 1). In a multivariable model
374 without BSID-III scores four variables (two socio-demographic measures, and two measures of
375 parenting style) were significantly associated with Q-CHAT score (Table 2). With BSID-III composite
376 scores added to the model the two socio-demographic associations were no longer significant,
377 although the BSID-III language composite score association was. This is possibly in part due to co-
378 linearity of the input variables (Figure 1A). After transforming linear variables into latent orthogonal
379 components with PCA, PC1 (associated with positive parenting styles and low socio-economic
380 deprivation), was significantly negatively associated with Q-CHAT score with or without BSID-III scores
381 as a confounder – i.e., more early life adversity was associated with more autism traits (Table 3). PC1
382 was significantly associated with Q-CHAT score in both models, suggesting that socio-demographic
383 and parental factors are specifically influencing autism trait development as opposed to solely having
384 a general effect on neurodevelopment. Using PC1, we can see how our original variables contribute
385 to Q-CHAT score (Figure 1D). Some of the variables contributing to PC1 are expected based on our
386 univariable results and previous literature; via PC1, early life adversity is associated with more autism
387 traits, and maternal depression and more extreme parenting style is associated with more autism
388 traits. Two variables however correlate in a less intuitive fashion. Firstly, maternal age is positively
389 contributing to the association with Q-CHAT score (Figure 1D). This is not in keeping with a significant
390 body of literature that suggests that the offspring of older parents have a higher likelihood of autism
391 (77). One possible explanation is that there are aspects of social deprivation that we are not capturing
392 with our variables, for example income or wider availability of family support, which may be related
393 to both parental age and autism trait development. Secondly, maternal age at leaving full time

394 education is positively contributing to the association with Q-CHAT score via the PC1. Given that
395 greater social deprivation in our sample is in general associated with higher Q-CHAT scores this is
396 somewhat counter-intuitive and is not in keeping with the one previous exploratory study to report
397 on this association (24). There is a larger body of work regarding associations of parental education
398 and childhood autism diagnoses, with at least some research suggesting that autism is more
399 commonly diagnosed in the offspring of highly educated parents (78), so the same may be true of
400 early life autism trait development. The reasons behind this difference are potentially complex,
401 including greater access to medical professionals in more affluent families (79), diagnostic
402 overshadowing (80) and more stigmatising views towards autism sometimes held by less educated
403 parents (81).

404 Our findings suggest some possible avenues for future research. Deeply phenotyped and well powered
405 prospective cohort studies of childhood autism are needed, but given the prevalence of the condition
406 sample sizes would need to be extremely large to allow for firm conclusions to be drawn. A more
407 logically favourable approach to further examining some of the antecedents of autism trait
408 development we (and other authors) have proposed would be to focus on groups hypothesised to be
409 more likely to develop a high level of traits. This study design is well established when examining the
410 sequelae of a family history of autism (82), and has also been used to study the effects of parental
411 immigration (66) and depression (83). We suggest that a cohort experiencing severe psycho-social
412 deprivation is a potential avenue in the study of early life autism traits.

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418 Limitations

419 There are some further limitations to our findings in addition to those discussed above. The cohort
420 used is from a single study centre, and therefore may not be representative of the wider population.
421 The sub-sample included in this study also differs from those excluded, in general experiencing less
422 psycho-social adversity, with differences observed in IMD Rank, maternal parenting style and EPDS
423 score. The nature of the scale is itself also a limitation: the Q-CHAT is parent rated, and therefore is
424 indicative of the parent's subjective assessment of their child, rather than an objective test (23); it is
425 thus possible that reporting bias with common method variance could have altered our results.
426 A general linear model of all socio-demographic factors studied explained 20% of the variance of Q-
427 CHAT score. Whilst this is a promising finding there are clearly a number of non-studied factors which
428 may contribute to individual patterns of autism trait emergence, including genetics and medical
429 comorbidities. Although emerging traits at age 18 months increase the likelihood of a future diagnosis
430 of autism, the positive predictive value of a high Q-CHAT score (or indeed a high score on any early
431 autism screening tool) is low (84). The prevalence of childhood autism in the UK is approximately 1.8%
432 (85). If this prevalence is seen in our cohort then approximately 10 individuals may be expected to
433 receive an autism diagnosis, meaning that what we are largely studying here are variations in the
434 spectrum of typical development, which may (86) or may not (87) be of any real world relevance.
435 Some of our more unexpected findings (for example the lack of a robust association between Q-CHAT
436 score and sex) may in part be explained by a difference between the underlying nature of a clinical
437 autism diagnoses and the expression of autism traits in the wider population. We hope in future to
438 follow-up this cohort in childhood, which will allow us to re-analyse if the same factors we find here
439 to be predictive of autism trait emergence are also predictive of diagnostic status.

440

441 **Conclusions**

442 Autism traits at age 18 months in a typical population are associated with several prior exposures,
443 most significantly parenting styles. In multivariable models 20% of variance of Q-CHAT score can be
444 explained by socio-economic and parental factors, with the universal finding being that a less
445 favourable environment results in a higher Q-CHAT score (more autism traits). Our results are of
446 potential interest from two perspectives. Firstly, future authors investigating the Q-CHAT score and
447 other measures of early autism traits should be aware of our findings as potential confounders or
448 limiting factors in their work. Secondly, from our data it would be reasonable to expect a greater rate
449 of diagnoses in more socio-economically deprived children, which does not currently occur. Are
450 potential autism diagnoses being missed in more socially deprived groups?

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459 **Declarations**

460 **Ethical Approval**

461 This project has received UK NHS research ethics committee approval (14/LO/1169, IRAS 138070), and
462 conducted in accordance with the World Medical Association's Code of Ethics (Declaration of Helsinki).
463 Written informed consent was obtained from parents at recruitment into the study.

464 **Competing Interests**

465 No author has a competing interest to declare.

466 **Data availability**

467 The dHCP is an open-access project. Data from the project can be downloaded by registering at
468 <https://data.developingconnectome.org> . Analyses presented here include data to be included in
469 future releases.

470 **Author Contributions**

471 All authors met ICJME criteria for authorship. **OGG** – conception, analysis, interpretation, writing
472 original draft, final approval, accountability, **AC** – data collection, writing, review and editing, final
473 approval, accountability, **SF** - data collection, writing, review and editing, final approval,
474 accountability, **LF** – software, analysis, writing, review and editing, final approval, accountability,
475 **SFM** – interpretation, writing, review and editing, final approval, accountability, **LH** – interpretation,
476 writing, review and editing, final approval, accountability, **NH** – data curation, interpretation,
477 writing, review and editing, final approval, accountability, **TC** – interpretation, writing, review and
478 editing, final approval, accountability, **DM** – interpretation, analysis, writing, review and editing, final
479 approval, accountability, **TA** – data collection, interpretation, writing, review and editing, final
480 approval, accountability, **GM** – interpretation, analysis, writing, review and editing, final approval,
481 accountability, **CN** – interpretation, analysis, writing, review and editing, final approval,

482 accountability, **DE** – interpretation, analysis, final approval, accountability, **DB** – conception, analysis,
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752 **Figures**

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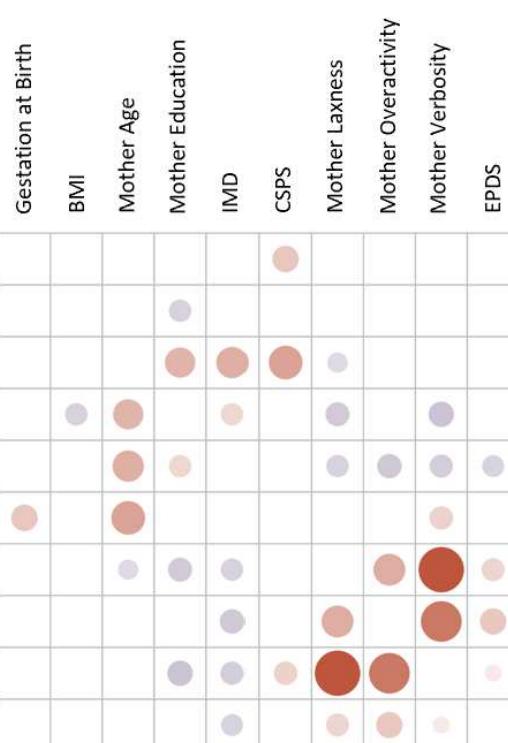
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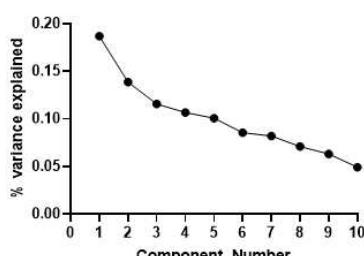
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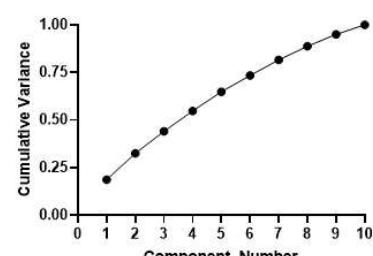
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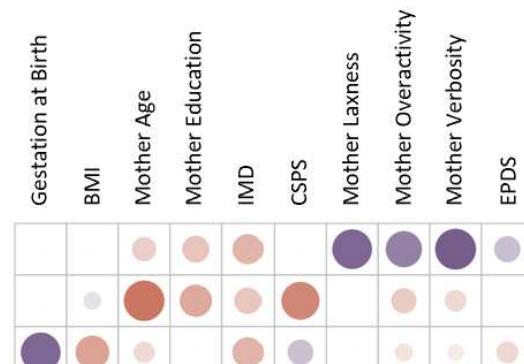
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766 **Figure 1** – Principal Component Analysis of linear variables. **A** Correlogram of associations between
767 linear variables. Pearson's r indicated for correlations with $p < 0.05$. **B** Scree plot of PCA components **C**
768 Cumulative variance plot of PCA components **D** Correlations of original linear variables to principal
769 components. Correlation indicated by size and colour of circle. Only correlations remaining significant
770 ($p < 0.05$) after FDR correction are shown. Values of each correlation are shown in Supplementary
771 Table S2.

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783 **Tables**

784 **Table 1. Sample Characteristics.** Mean, standard deviation, and range displayed for linear variables.

785 Frequency displayed for categorical variables. Correlations to QCHAT calculated by Pearson's r or t-
786 test as appropriate. Significant univariable correlations are shown in bold, those remaining significant
787 after FDR correction indicated by *.

Outcome variable		
Total Q-CHAT Score, <i>Mean (SD), Range</i>	30.1 (5.9), 8-70	-
Clinical variables		r (p)
Age at follow-up [months], <i>Mean (SD), Range</i>	18.8 (1.6), 16-26	0.010 (0.535)
Gestational Age at Birth [weeks], <i>Mean (SD), Range</i>	38.1 (3.9), 23.0-43.0	-0.067 (0.120)
BMI [kg/m ²], <i>Mean (SD), Range</i>	24.2 (4.4), 15.3-43.4	0.093 (0.030)
Mother Age [years], <i>Mean (SD), Range</i>	34.3 (4.7), 17-52	-0.105 (0.014)
		t (p)
Sex [Male (0), Female (1)], <i>N (%)</i>	278 (52%), 258 (48%)	1.820 (0.068)
Parent ASD/ADHD Diagnosis [Yes (1), No (0)], <i>N (%)</i>	28 (5%), 508 (95%)	-0.4246 (0.674)
Socio-demographic variables		r (p)
IMD Rank, <i>Mean (SD), Range</i>	14626.2 (7409.2), 2410-32726	-0.190 (<0.001)*
CSPS, <i>Mean (SD), Range</i>	20.5 (3.5), 7-28	-0.219 (<0.001)*
Mother Education [years], <i>Mean (SD), Range</i>	23.6 (4.5), 12-43	0.001 (0.957)
		t (p)
Mother 1 st Language [English (1), Other (0)], <i>N (%)</i>	338 (63%), 198 (37%)	4.518 (<0.001)*
Parents Cohabiting [Yes (0), No (1)], <i>N (%)</i>	520 (97%), 16 (3%)	-1.650 (0.119)
Parental-psychological variables		r (p)
Mother Laxness, <i>Mean (SD), Range</i>	2.9 (0.8), 1-5.6	0.286 (<0.001)*
Mother Over-reactivity, <i>Mean (SD), Range</i>	2.2 (0.7), 1-5.1	0.180 (<0.001)*
Mother Verbosity, <i>Mean (SD), Range</i>	3.4 (0.8), 1-6.4	0.300 (<0.001)*
Mother EPDS, <i>Mean (SD), Range</i>	4.5 (4.2), 0-28	0.127 (<0.001)*
BSID-III Cognitive Composite, <i>Mean (SD), Range</i>	101.0 (11.1), 55-130	-0.358 (<0.001)*
BSID-III Language Composite, <i>Mean (SD), Range</i>	98.2 (15.4), 47-153	-0.528 (<0.001)*
BSID-III Motor Composite, <i>Mean (SD), Range</i>	101.5 (10.2), 52-130	-0.267 (<0.001)*

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791 **Table 2.** General linear model of the association between clinical, socio-demographic, and parental
792 variables and Q-CHAT with or without the addition of BSID-III Cognitive, Motor and Language
793 Composite Scores to the model. Non-reference categories are as follows: Sex – Male, Parent
794 ASD/ADHD Diagnosis – Yes, Mother 1st Language – Not English.

	Without BSID-III		With BSID-III	
	t	p	t	p
Gestational Age at Birth	-1.94	0.052	-0.45	0.646
BMI	0.57	0.567	0.95	0.341
Mother Age	-0.73	0.461	-1.17	0.239
Sex	-2.32	0.020	-0.83	0.407
Parent ASD/ADHD Diagnosis	0.57	0.567	-0.23	0.813
IMD Rank	-2.56	0.010*	-2.06	0.039
CSPS	-3.38	<0.001*	-1.17	0.238
Mother Education	-0.08	0.929	0.35	0.719
Mother 1 st Language English	-1.58	0.113	-0.01	0.994
Parents Cohabiting	1.74	0.082	1.49	0.135
Mother Laxness	3.79	<0.001*	2.68	0.007*
Mother Over-reactivity	1.11	0.269	1.04	0.297
Mother Verbosity	3.29	0.001*	3.39	<0.001*
Mother EPDS	1.72	0.08	1.26	0.206
Cognitive Composite	NA	NA	-0.28	0.779
Language Composite	NA	NA	-8.32	<0.001*
Motor Composite	NA	NA	-0.41	0.677

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796 *Bold indicates p<0.05, * indicates significance after FDR multiple comparison correction (a<0.05)*

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804 **Table 3.** General linear model of the association between demographic variables, BSID-III composite
805 scores and Q-CHAT. Linear variables were first transformed into orthogonal components via PCA. PC1
806 captures variable associations which are associated with positive parenting styles and low socio-
807 economic deprivation, PC2 is associated with low socio-economic deprivation and expressive
808 parenting styles, and PC3 is associated with variables describing clinical adversity.

	Without BSID-III		With BSID-III	
	r^2 (Adj. r^2) = 0.17(0.16), p<0.001		r^2 (Adj. r^2) = 0.35(0.33), p<0.001	
	t	p	t	p
PC1	-8.17	<0.001*	-6.59	<0.001*
PC2	-1.86	0.062	-0.70	0.480
PC3	1.29	0.194	0.10	0.913
Sex	-2.02	0.043	-0.48	0.630
Parent ASD/ADHD Diagnosis	0.59	0.550	-0.26	0.790
Mother 1 st Language English	-1.86	0.063	-0.06	0.948
Parents Cohabiting	2.04	0.041	1.51	0.129
Cognitive Composite	NA	NA	-0.55	0.577
Language Composite	NA	NA	-8.96	<0.001*
Motor Composite	NA	NA	-0.15	0.880

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810 *Bold indicates p<0.05, * indicates significance after FDR multiple comparison correction (a<0.05)*

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