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ORIGINAL PAPER

A Relationship Between Early Language Skills and Adult Autistic-Like Traits: Evidence from a Longitudinal Population-Based Study

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Abstract The current study examined the relationship between early language ability and autistic-like traits in adulthood, utilising data from 644 participants from a longitudinal study of the general population. Language performance at 2 years was measured with the Language Development Survey (LDS), and at 20 years the participants completed the Autism-Spectrum Quotient (AQ). Vocabulary size at 2 years was negatively associated with Total AQ score, as well as scores on the Communication, and Social Skills subscales. Adults who had been late talkers were also more likely to have 'high' scores on the Communication subscale. This is the first study to show an association between early language ability and autistic-like traits in adulthood.

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Introduction

Expressive language delay is a very common phenomenon experienced by between 9 and 20% of 2-year olds (Fenson 2007; Rescorla 1989; Zubrick et al. 2007). Early expressive language delays are often identified based on parent report when a child is between 18 and 30 months of age, with the first indicators being a small vocabulary size, slow vocabulary growth, and/or the absence of word combinations. The cause of these early language delays, and the subsequent outcomes for the children who exhibit them, vary widely (Paul and Roth 2011; Rescorla 2011). Some children present with early language delays which occur in the absence of any other underlying cognitive, neurological, socio-emotional or sensory conditions, and these children are commonly referred to as 'late talkers' (Hawa and Spanoudis 2014; Whitehouse et al. 2011; Zubrick et al. 2007). Whereas for other children, these early delays in expressive language can be one of the first behavioural symptoms of an underlying condition such as autism spectrum disorder (ASD) (Buschmann et al. 2008; Rescorla 2011). It was this association between delayed language acquisition and ASD that provided the motivation for the current study.

ASD is a neurodevelopmental condition which is characterized by impairments in social interaction and communication, and restricted, repetitive behaviours (American Psychiatric Association 2013). Expressive language is often the first reported parental concern for children later diagnosed with ASD (De Giacomo and Fombonne 1998; Herlihy et al. 2015), and thus previous work has comprehensively explored the possible link between language and

ASD (see Boucher 2012, for a review). This previous work highlights that a range of language ability exists in the ASD population, in that there is a subset of children who present with intact structural language abilities (Grzadzinski et al. 2013); however, there is also a substantial number of individuals with ASD who also present with concomitant language difficulties (Buschmann et al. 2008; Luyster et al. 2007a, b; Rescorla 2011; Rescorla and Safyer 2013).

More recently, research has documented the presence of ASD-like features across large community samples, providing support for a continuum of autistic-like traits across the general population, with clinical ASD representing the extreme end of the distribution (Palmer et al. 2015; Ruzich et al. 2015). Given the prevalence of autistic-like traits in the general population, a growing body of research has attempted to identify early predictors of increased autistic symptomology in the wider population. This focus on identifying developmental factors associated with autistic-like traits has gained increasing traction in the literature as it may provide important insights into the mechanisms that underpin the clinical condition.

To date, studies have investigated the association between autistic-like traits and a number of factors known to be associated with ASD. This body of research has included, for example, the study of prenatal factors [such as low maternal vitamin D levels (Whitehouse et al. 2013); exposure to ultrasound scans; (Stoch et al. 2012)], perinatal factors [e.g. low birthweight (Pyhälä et al. 2014); testosterone exposure; (Whitehouse et al. 2012); androgen and estrogen composites; (Jamnadass et al. 2015)] as well as gastrointestinal problems in childhood (Whitehouse et al. 2011). From these studies very low birthweight and lower maternal vitamin D levels were found to be associated with autistic-like traits in the general population. Further, some of this previous work also provides evidence that males tend to score higher than females on measures of autistic-like traits (e.g. Jamnadass et al. 2015; Whitehouse et al. 2012).

The relationship that exists between early language delays and ASD has led to the consideration of early language ability as a predictor of autistic-like traits in population-based samples. Bolton et al. (2012), for example, used data collected as part of the Avon Longitudinal Study of Parents and Children (ALSPAC) to investigate the association between early factors measured over the first 30 months of the child's life and their level of autistic traits by age 9 years. The measure of autistic traits utilised by Bolton et al. (2012) was based on an earlier ALSPAC study (see Steer et al. 2010) and comprised one single autistic traits score which was derived from seven principle factors, gathered between 6 months and 9 years of age and that had been found to be strongly associated with ASD outcome in the ALSPAC cohort. Bolton et al. (2012) found that communicative skills (vocabulary and word combinations), measured over the first 30 months, was one of the factors which predicted the presence of autistic traits by age 9 years. Whilst these results provide preliminary evidence towards a potential association, the authors state that their findings must be interpreted with caution due to possible confounding as the measure of early communicative ability was also one of the seven principle factors used to derive the overall autistic traits score (Bolton et al. 2012, p. 255).

In a study using a different longitudinal dataset, Dworzynski et al. (2007) investigated whether language performance and autistic-like traits were related in a sample of 6087 twin pairs. These data were collected as part of the Twins Early Development Study (TEDS), a population-based study of twins born between 1994 and 1996 in the United Kingdom (UK). When their children were 2, 3 and 4 years of age, parents completed the UK adaptation of the MacArthur Communicative Development Inventory (Fenson 1993) as a measure of expressive vocabulary and grammar. Parents were also asked to complete the Childhood Asperger's Syndrome Test (CAST; Scott et al. 2002) when the twins were between 7 and 9 years of age. The CAST has been designed as a screening instrument for ASD and is intended to be used in non-clinical samples. It consists of 31 items, and in addition to a total CAST score, three subscales were also derived to assess the following core features of ASD: (1) social impairment, (2) communication abnormalities, and (3) repetitive, restrictive behaviours/interests. Results indicated a modest correlation between lower language performance (at 2–4 years) and the presence of higher levels of autistic-like traits (at 8 years). Most noteworthy was that this relationship was only found across the social and communication domains.

The results of Dworzynski et al. (2007) are intriguing as they provide further evidence towards a relationship between language and ASD-like traits in the general population. More specifically, it appears that this relationship is guided by the social communication component of the ASD phenotype. However, Dworzynski et al. (2007) did not exclude participants on the basis of an ASD diagnosis and therefore it is unclear how the inclusion of such children may have influenced the identified associations. Furthermore, the sample included only twins and so it is of interest to explore whether the same relationship is also present in singleton births. Given that previous work in this area (Bolton et al. 2012; Dworzynski et al. 2007) only examined this association into middle childhood, it is also not yet known whether this relationship between language and autistic-like traits remains into adulthood. Clearly, further research in this area is warranted.

Therefore the current study aimed to expand on previous work by investigating the association between early expressive language ability measured in childhood and the

presence of autistic-like traits in adulthood. The current study focused on early language ability at 2 years, as this is when early language delays, and more specifically 'late talkers', are most commonly identified. A high demand placed on early intervention services, coupled with the continuum of ability that exists in language across both typical and atypical populations has led to an increased focus on understanding the long-term prognosis for late talkers (Rescorla 2011). Studies to date have investigated the long-term outcomes across childhood and into adolescence for late talkers across a range of domains including, but not limited to, language, literacy, behaviour, and social skills (e.g. Desmarais et al. 2008; Rescorla 2011). However, no studies have explored these long-term outcomes beyond the adolescent period and thus; an opportunity exists to understand more about the longitudinal associations between early language ability and later autistic traits in a general population-based sample extending into the adult years.

In addressing this gap, the current study investigated the following two research questions: (1) is there an association between vocabulary size at 2 years and the level of autistic-like traits in adulthood? and (2) is there an association between late talking status and high levels of autistic-like traits in adulthood? Given the known relationship between language and ASD, we hypothesised that the participants with a history of early language delay would present with higher levels of autistic-like traits compared to participants with typical language histories (Buschmann et al. 2008; Wheelwright et al. 2010). Following on from the work by Dworzynski et al. (2007), we also hypothesised that this relationship would be most evident for the subscales assessing the social communication aspects of the disorder (i.e. the Communication, and Social Skills subscales), rather than the restricted and repetitive behaviours (i.e. the Attention Switching, Attention to Detail and Imagination subscales).

Method

Participants

Participants were part of the Western Australian Pregnancy Cohort (Raine) Study which is an ongoing longitudinal study of mothers and their offspring consecutively recruited from the King Edward Memorial Hospital or surrounding private clinics in Perth (Australia) between May 1989 and November 1991 (n = 2900). The inclusionary criteria for pregnant mothers included a gestational age between 16 and 20 weeks, English language skills sufficient to understand the study demands, an expectation to deliver at King Edward Memorial Hospital, and an intention to remain in Western Australia to enable future follow-up of their child (Newnham et al. 1993). From the 2900 pregnant women recruited, 2868 offspring were available for follow-up at birth. Since their birth, the Raine cohort of children has been followed-up at 1, 2, 3, 5, 8, 10, 14, 17, 18, 20 and 22 years of age. Participant recruitment and all follow-ups were approved by the Human Ethics committee at the King Edward Memorial Hospital and/or the Princess Margaret Hospital for Children in Perth. At the 20 and 22 year follow-ups, ethical approval was obtained from the Human Research Ethics Committee at the University of Western Australia. Parents provided written informed consent to participate at each time-point, with the offspring themselves providing written informed consent after the age of 18.

To avoid confounds relating to English as a second language and the presence of additional disabilities, participants were excluded from the analysis if their mother reported speaking a language other than English at home at the first clinic visit (n = 160), or if the child was reported to have a diagnosis of an additional disability (hearing impairment, intellectual disability) at the 16-year follow-up (n = 32). Further, as described in more detail below, we restricted our analysis to only include participants who had both the Language Development Survey (LDS; Rescorla 1989) and Autism-Spectrum Quotient (AQ; Baron-Cohen et al. 2001) data available. Participants in the Raine cohort who had reported a diagnosis of ASD at any of the previous follow ups were not asked to complete the AQ, and thus were not included in the analyses. A total of 644 participants (22.4% of the original Raine cohort) met the inclusionary criteria and completed both the LDS and AQ, and hence were the focus of this study (see Fig. 1).

Behavioural Measures

Language Development Survey (LDS)

At the 2-year follow-up (mean = 2.14; SD 0.15; range 1.75–3.30) caregivers of 1623 children completed the LDS as a measure of their child's expressive language skills. The LDS contains 310 words arranged into 14 semantic categories (Rescorla and Achenbach 2002). The caregiver is asked to identify which of the 310 words the child says spontaneously (with only minor pronunciation variations) and any examples of word combinations the child uses. The LDS has been shown to have high test–retest reliability (0.97–0.99), and high Cronbach's internal consistency (0.99) (Rescorla 1989). The criteria for late talking varies across studies (e.g. see Desmarais et al. 2008 for a review), however, the current study employed the classification recommended by Rescorla (1989) as part of the LDS. Thus, late talkers were defined as children who produced fewer than 50 words and/or no word combinations at 2 years of

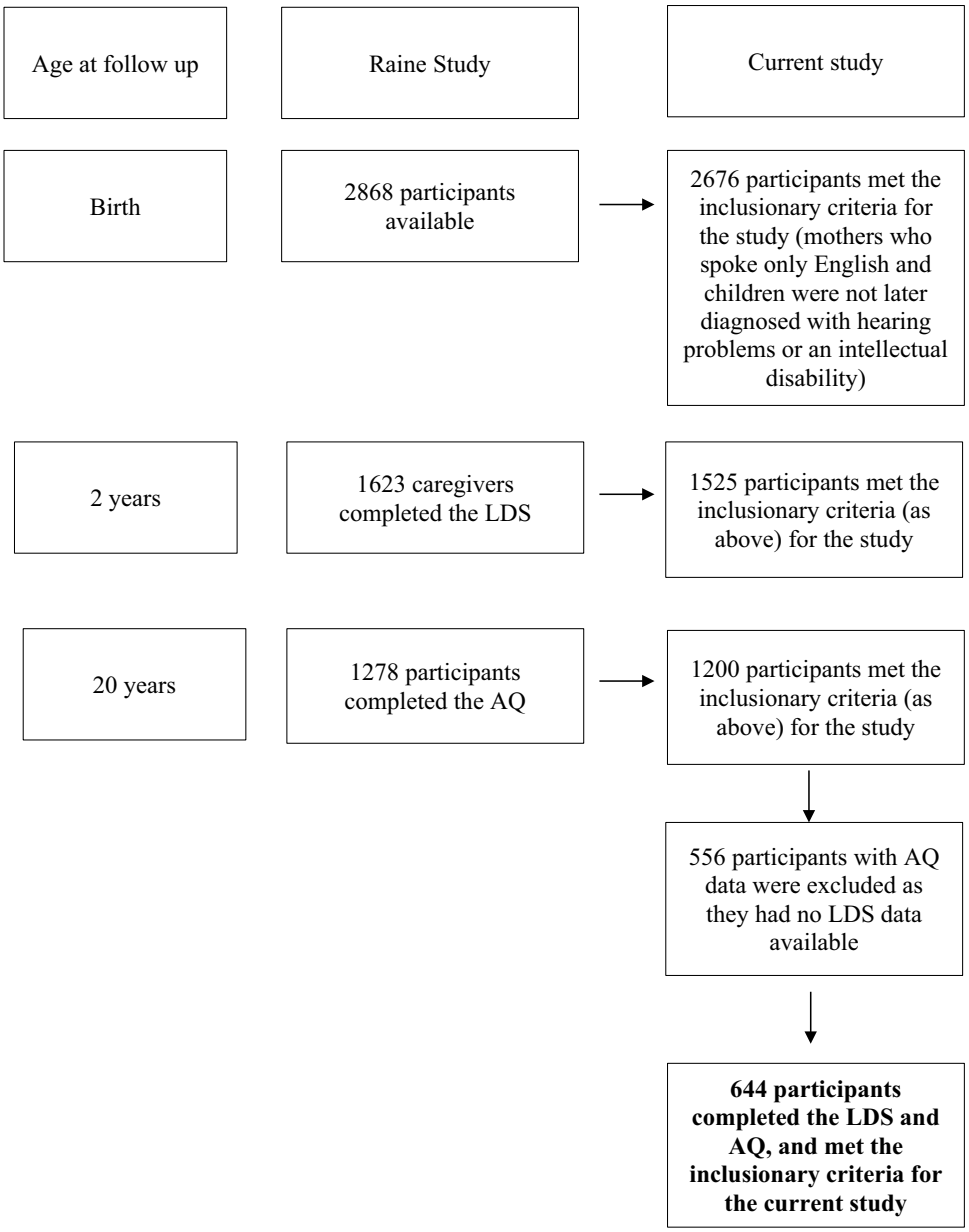

Fig. 1 Flow diagram which demonstrates the follow-up of participants included in the Raine Study as well as those retained for the current study

age (Rescorla 1989). All other children were categorised as having typical expressive language skills.

Autism-Spectrum Quotient (AQ)

The AQ was collected on 1278 participants at 20 years of age (mean = 19.70; SD 0.72; range 17.28–22.07), however only 644 of these participants met the inclusionary criteria and also had LDS data available. The AQ is a self-report questionnaire that provides a quantitative measure of autistic-like traits in the general population. The tool consists of 50 statements and individuals are asked to rate on a 4-point scale how well each statement applies to them (definitely agree, slightly agree, slightly disagree, or definitely disagree). Half of the questions are worded to elicit an 'agree' response and the other half, a 'disagree' response. The questionnaire is designed to assess five areas associated with autism and the extended phenotype: Attention to Detail, Attention Switching, Communication, Imagination and Social Skills. The AQ has been shown to have acceptably high sensitivity and specificity (sensitivity 0.95, specificity 0.52, positive predictive value 0.84, and negative predictive value 0.78) (Baron-Cohen et al. 2001).

Scoring

The original scoring procedure outlined by Baron-Cohen et al. (2001) allocates a score of 1 to a response indicating

the presence of an autistic-like trait, and 0 to a response which does not indicate the presence of an autistic-like trait. A total AQ score is calculated by tallying the scores from the five subscales (maximum possible score is 50). Since the initial study by Baron-Cohen et al. (2001), researchers have also employed an alternate, 4-point scoring method to identify autistic-like traits in the general population as it is purported to retain a greater amount of detail regarding the participant's response in comparison to the 0/1 scoring (Austin 2005; Russell-Smith et al. 2011; Stewart and Austin 2010). Using the alternate scoring method, participants respond as per the original AQ format, however, responses are scored on a continuous Likert scale ranging from 1 (no/minimal presence of autistic-like traits) to 4 (strong presence of autistic-like traits). Similarly to the original scoring procedure, a total AQ score can be calculated by tallying each item, however, using this alternate method, the maximum possible score is 200 (Austin 2005). This form of scoring has been reported to have satisfactory internal reliability (Austin 2005), and has been shown to maximise the reliable range of measurement of traits identified using the scale compared to the dichotomous scoring approach (Murray et al. 2015). The alternate scoring system was used in the current study.

Performance on the AQ was also categorised to determine 'high' levels of autistic-like traits in the current sample. As per previous studies by Stoch et al. (2012), Whitehouse et al. (2012), and Jamnadass et al. (2015), participants whose scores were within the upper decile (90th percentile) of the sample's scores were categorised as exhibiting 'higher' levels of autistic-like traits in each domain, with all other participants forming the 'lower' AQ group. Thus, high AQ scores were classified as ≥119 for the Total AQ score, ≥31 for the Attention to Detail subscale, ≥28 for the Attention Switching subscale, ≥24 for the Communication subscale, ≥24 for the Imagination subscale, and ≥23 for the Social Skills subscale.

Confounders

From the available measures within the dataset, sociodemographic variables present at the birth of the child that are known to influence language development, as well as additional factors known to influence AQ scores, were controlled for in the current study. Parental factors which are known to influence early language ability as well as language outcomes (Harrison and McLeod 2010; Taylor et al. 2013) were considered. This included parental educational attainment and age, as well as maternal race. Maternal and paternal educational level were dichotomized as incomplete secondary education (<12 years) and complete secondary education (12 years). Maternal and paternal age were treated as continuous variables, and maternal race classified mothers as Caucasian or non-Caucasian. Maternal smoking during pregnancy has been found to be associated with many childhood outcomes, including language, cognition and school performance (Clifford et al. 2012; Lambe et al. 2006), and therefore exposure to tobacco in utero was categorised into three levels including: none, 1–10 cigarettes daily or more than 10 cigarettes daily. Family income is strongly associated with child language outcomes (Dale et al. 2003; McKean et al. 2015; Reilly et al. 2010). The level of income reported at the time of recruitment into the study was categorised according to whether minimum household income was under or over the 'poverty line' as defined by the Australian Government cut-off at the time (i.e. $24,000 AUD) (Whitehouse et al. 2013). Child factors included gestational age which was dichotomized between those born before 37 weeks and those born at or after 37 weeks, and birthweight which was categorized as low if less than 2500 g or normal if greater than or equal to 2500 g. Sex of the offspring was also included as a possible confounder due to the known association between sex and both language (e.g. Harrison and McLeod 2010) and AQ performance (e.g. Ruzich et al. 2015). Finally, given the possible association between depression and anxiety levels and scores on the AQ (Ashwood et al. 2016), depression and anxiety were also included in the analysis as continuous variables. Depression and anxiety were measured using the short form of the Depression, Anxiety and Stress Scale (DASS 21) (Henry and Crawford 2005; Lovibond and Lovibond 1995) at the 20 year follow-up.

Statistical Analyses

To examine the influence of participant attrition, Chi square analyses compared sociodemographic variables present at birth between the participants included in the current study (those with both LDS and AQ data available), and the remainder of the Raine cohort. In addition, independent sample *t* tests (two-tailed) compared the AQ scores of the current study sample and those from the wider cohort who had completed the AQ but had no LDS data available. Further comparisons of the current study sample and sex differences on the AQ were also made using one-sided independent sample *t* tests.

Pearson's correlations were then used to investigate the association between vocabulary size at 2 years and the scores on the AQ, including the Total AQ score and the five individual subscales. Significant correlations were further examined with multivariable linear regression. Firstly, any possible confounding variables which were correlated with the outcome variable of interest (score on the relevant AQ scale) at the significance level of $p < 0.1$ (Hilbe 2009) were entered into the model. Then the number of words spoken at 2 years was added to the model.

Table 1 Scores on the Autism-Spectrum Quotient (AQ) and its subscales for the Raine cohort participants, according to those who did and did not have Language Development Survey (LDS) data available

	Available (n = 644)	Not available (n = 556)	*p*
	M (*SD*)	*M* (*SD*)	
Total AQ	102.06 (12.33)	104.39 (12.89)	**0.001**
Attention to detail	25.05 (4.58)	25.23 (4.46)	0.489
Attention switching	22.32 (3.81)	22.88 (3.89)	**0.011**
Communication	18.22 (3.93)	18.74 (4.05)	**0.025**
Imagination	18.89 (3.96)	19.41 (4.17)	**0.028**
Social skills	17.57 (3.91)	18.12 (4.20)	**0.018**

p-values are for two-tailed independent-sample *t*-tests; bold values indicate statistical significance ($p < 0.05$)

Sample restricted to participants who met the inclusionary criteria for the study

Table 2 Means (SD) for Autism-Spectrum Quotient (AQ) scores based on sex

	Female n = 336	Male n = 308	*p*	Cohen's d
	Mean (SD)	Mean (SD)		
Total AQ	100.62 (11.75)	103.62 (12.78)	0.001	0.24
Attention to detail	24.96 (4.62)	25.16 (4.54)	0.295	0.04
Attention switching	22.07 (3.86)	22.59 (3.75)	0.040	0.13
Communication	17.95 (3.80)	18.52 (4.06)	0.030	0.14
Imagination	18.30 (3.50)	19.54 (4.32)	<0.001	0.31
Social skills	17.35 (3.92)	17.80 (3.89)	0.069	0.11

p-values are for one-sided independent *t* tests

Sample restricted to participants who met the inclusionary criteria for the study and had both Language Development Survey and AQ data available

Next the data were expressed categorically to examine the association between late talking versus typical language status at 2 years and high (upper decile) versus all other scores on the AQ and its subscales. Chi square analyses were conducted, with significant differences on the overall AQ or subscales being followed up with multivariable logistic regression using the same two-step procedure as the multivariable linear regression model described above. The alpha levels for both the linear and logistic regression models were set at $p < 0.05$. All statistical analyses were completed using Stata version 13 (StataCorp 2013).

Results

Attrition analyses revealed participants included in the study, compared to those from the wider Raine cohort, were more likely to have mothers who were older at the child's birth, who had completed secondary school, and who did not smoke during pregnancy. Similarly, participants included in the current study had fathers who were more likely to have completed secondary education, were older at the birth of the child and to have been born into families with higher income, compared to those individuals not included (see online supplementary material file 1).

Table 1 describes the difference in AQ scores for participants who completed the AQ and LDS ($n = 644$) and those who completed the AQ but did not have LDS data available ($n = 556$). Participants with no LDS data available, and hence not included in the current study, had significantly higher scores on the AQ and all the subtests except Attention to Detail, as compared to those participants included in the current study.

The mean LDS score for the current sample (n = 644) was 190.65 words (SD 82.05), with a range of 2–310 words. The mean AQ score was 102.06 points (SD 12.33), and a range of 66–151. In light of previous work showing that males often perform higher on the AQ than females (Ruzich et al. 2015), independent one-sided *t* tests were conducted to explore this association in the current cohort. As shown in Table 2 below, males had significantly higher scores than females on the Total AQ score, as well as on the Attention Switching, Communication, and Imagination subscales.

Early Vocabulary Size and AQ Scores

Results from the Pearson's correlation analyses revealed modest but statistically significant negative correlations were found between vocabulary size and the Total AQ score ($r = -0.16$, $p = <0.001$), as well as scores on the Attention Switching ($r = -0.08$, $p = 0.014$), Social Skills ($r = -0.12$, $p = <0.001$), Communication ($r = -0.15$, $p = <0.001$), and Imagination ($r = -0.14$, $p = <0.001$) subscales. There was no correlation between number of words spoken at 2 years and responses on the Attention to Detail subscale ($r = -0.00$, $p = 0.987$). Table 3 shows the results of the adjusted multivariable linear regression model. The results of the fully adjusted models showed small but statistically significant effects remained for the association between number of spoken words and Total AQ score, as well as the Communication and Social Skills subscales. More specifically, for every extra word spoken at 2 years, there was a 0.012 point decrease in Total AQ score in adulthood. Similarly, there was a 0.004

Table 3 Adjusted linear regression models showing the association between number of words at 2 years and scores on the Autism-Spectrum Quotient (AQ) in adulthood

	β	SE	95% CI	*p*
Total AQ score	−0.012[a]	0.006	−0.024, 0.000	**0.045**
Attention switching	−0.002[b]	0.002	−0.006, 0.001	0.245
Communication	−0.004[c]	0.002	−0.008, −0.001	**0.019**
Imagination	−0.004[d]	0.002	−0.007, 0.000	0.056
Social skills	−0.004[e]	0.002	−0.008, −0.001	**0.022**

Bold values indicate statistical significance ($p < 0.05$)

SE standard error, *CI* confidence interval, *AQ* Autism-Spectrum Quotient

[a]Regression model adjusted for maternal education, maternal smoking during pregnancy, paternal education, paternal age, family income, sex, depression and anxiety

[b]Regression model adjusted for maternal race, family income, sex, depression and anxiety

[c]Regression model adjusted for maternal education, maternal age, paternal age, family income, sex, depression and anxiety

[d]Regression model adjusted for maternal education, maternal age, maternal smoking during pregnancy, paternal education, family income and sex

[e]Regression model adjusted for maternal education, family income, depression and anxiet

Table 4 The number of individuals with a high score on the Autism-Spectrum Quotient (AQ) according to their language status at 2 years

	Typical n = 578 n (%)	Late talker n = 66 n (%)	$\chi^2(1)$	*p*
Total AQ score				
Lower scores	534 (92.4%)	56 (84.8%)		
High scores	44 (7.6%)	10 (15.2%)	4.38	**0.036**
Attention to detail				
Lower scores	513 (88.7%)	55 (83.3%)		
High scores	65 (11.3%)	11 (16.7%)	1.67	0.196
Attention Switching				
Lower scores	527 (91.2%)	62 (93.9%)		
High scores	51 (8.8%)	4 (6.1%)	0.58	0.447
Communication				
Lower scores	537 (92.9%)	54 (81.8%)		
High scores	41 (7.1%)	12 (18.2%)	9.64	**0.002**
Imagination				
Lower scores	517 (89.4%)	53 (80.3%)		
High scores	61 (10.6%)	13 (19.7%)	4.87	**0.027**
Social skills				
Lower scores	517 (89.4%)	58 (87.9%)		
High scores	61 (10.6%)	8 (12.1%)	0.15	0.696

Bold values indicate statistical significance ($p < 0.05$)

point decrease in both Communication and Social Skills subscale scores for every extra word spoken at 2 years.

Late Talking Status and High AQ Scores

10.2% of the current sample met the criteria for late talking at 2 years of age. Chi square analyses revealed late talkers were more likely to be male and to have fathers who did not complete secondary education compared to children with typical early language. Late talkers were comparable to typically developing children on all other sociodemographic and child-related factors (see online supplemental file 2).

Chi square analyses, presented in Table 4, revealed that individuals with a history of late talking were more likely to have a high score on the Total AQ, Communication subscale, and Imagination subscale. Comparisons on all other AQ scales did not reach statistical significance. Table 5 presents the findings from the multivariable logistic regression analyses. The final models revealed that late talking status remained associated with higher scores on the Communication subscale after controlling for maternal educational attainment, maternal smoking during pregnancy, gestational age, birthweight, sex, depression and anxiety.

Table 5 Adjusted logistic regression models showing the association between late talking status at 2 years and high scores on the Autism-Spectrum Quotient (AQ) in adulthood

	Adjusted OR (95% CI)	*p*
Total AQ score		
Lower scores	Reference	
High scores	1.85 (0.76–4.51)[a]	0.175
Communication		
Lower scores	Reference	
High scores	3.32 (1.48–7.45)[b]	**0.004**
Imagination		
Lower scores	Reference	
High scores	1.75 (0.89–3.44)[c]	0.103

Bold values indicate statistical significance ($p < 0.05$)

OR odds ratio, *CI* confidence interval

[a]Regression model adjusted for family income, maternal age, sex, anxiety and depression

[b]Regression model adjusted for maternal education, maternal smoking during pregnancy, gestational age, birthweight, sex, anxiety and depression

[c]Regression model adjusted for sex

Discussion

This prospective study is the first to examine the relationship between language ability in early childhood and the presence of autistic-like traits in adulthood. Expressive vocabulary size at age 2 years was found to be inversely associated with higher levels of autistic-like traits at age 20 years. Furthermore results indicated that when data were expressed categorically, there was a significant association between late talking status at age 2 and 'high' levels of autistic-like traits in adulthood. Thus, the results of the current study provide further evidence towards a relationship between early communication skills and later levels of autistic-like traits in a general population-based sample.

Early vocabulary size was negatively associated with AQ scores in adulthood. More specifically, the greater the number of words spoken by participants at 2 years the lower the level of autistic-like traits in adulthood. Whilst associations were weak in magnitude, they remained statistically significant for total AQ score, as well as performance on the Communication and Social Skills subscales, even after adjusting for other confounding factors. The identified associations between vocabulary size and the Social Skills and Communication subscales of the AQ extends the work by Dworzynski et al. (2007), who also found a link between early language skills and the social communication aspects of the autistic phenotype in middle childhood. What is more, that a similar association was found, demonstrating that this relationship is present into adulthood.

The Social Skills and Communication subscales of the AQ, tap into the pragmatic components of language, including how individuals use language to relate to people (e.g. Question 26-"I frequently find that I don't know how to keep a conversation going"), as well as their preferences and habits for social situations (e.g. Question 1—"I would rather go to a library than a party"). Thus, the findings of the current study are consistent with other studies investigating early language ability and pragmatic outcomes in children. Irwin et al. (2002), for example, found that late talkers were more likely to present with low social competence than typically developing peers. It is also argued that reduced expressive vocabularies in early childhood may lead to less motivation for socialisation and interaction with other children which, in turn, results in fewer opportunities to continue building language skills (Desmarais et al. 2008). Thus, the present results provide further evidence that early vocabulary skills provide an important foundation for the development of social communication skills in the general population, and most importantly, this remains into the adult years.

The current study also looked more closely at autistic-like traits in young adults who were classified as late talkers based on their earlier language development. Focusing on the prognosis of late talkers is important due to the variability that exists in language across development. There is substantial evidence showing that a significant proportion of late talkers resolve their initial language delays (e.g. Rice et al. 2008), which means that early intervention specialists are often faced with the difficult decision of whether direct intervention is required or whether a 'wait and see' approach is more appropriate (Paul and Roth 2011). Given the high demand on early intervention services and the pivotal role that language has for laying the foundation for many other skills, there is a continued need to understand more about the long-term outcomes for late talkers. Thus, the current study adds to this knowledge base by demonstrating that late talkers may have autistic-like social communication difficulties in adulthood.

Most noteworthy was the finding that late talkers were three times more likely to obtain higher scores on the Communication subscale of the AQ than adults with a typical language history at 2 years, even after adjusting for other sociodemographic variables. The majority of studies investigating the outcomes of late talkers focus on structural language (and literacy) abilities. A review by Rescorla (2011) in this domain highlighted that when followed up in childhood and adolescence, whilst the majority of late talkers perform within normal limits on standardised assessments of language and literacy their scores remain somewhat lower than their peers who followed a more typical course of early language development. This pattern has been shown up to 17 years of age (Rescorla 2009).

It is hypothesised that the identified association between late talking and high Communication subscale scores may be explained by two key pathways. Firstly, similar to the findings identified by Rescorla (2011), the late talkers in the current study may have resolved their language delays to within normal limits on standardised assessments but as indicated by their 'higher' scores on the Communication subscale they may continue to exhibit subtle difficulties in their preferences for using language for communication in adulthood compared to peers with typical language histories. Alternatively, it could be that adults with a history of late talking continued to present with persisting language difficulties which impacted their endorsement of questions relating to conversation skills and hence, it was continued atypical language contributing to higher scores on the Communication subscale. Further research is needed which compares how an individual's structural language abilities, and pragmatic skills, may be influencing their performance on the AQ. This is an important consideration as Bishop et al. (2004) found that compared to parents of typically developing children, parents of children with autism had higher scores on the Communication and Social Skills subscales of the AQ. Interestingly, however, the two groups did not differ on their performance on the short form of

the Wechsler Adult Intelligence Scale (Bishop et al. 2004). Exploring whether this disassociation also exists between structural language functioning and perceived use of language for communication and socialisation in the late talking population is warranted. Furthermore, research which explores the functional implications of high AQ scores, given earlier language ability, on other long-term outcomes (including educational, vocational, and social domains) may provide important insights into the role early intervention practices need to play for promoting and fostering social communication in the early years, as well as intervening for structural language deficits.

The results of the current study also lend support to previous work showing an association between sex and higher levels of autistic-like traits in the general population (Austin 2005; Baron-Cohen et al. 2001; Ruzich et al. 2015). As per these previous studies, the current study found males scored significantly higher than females on the overall AQ score (Baron-Cohen et al. 2001; Ruzich et al. 2015). Whilst this trend exists in terms of total AQ score, the distinct differences on subscales appear to differ across studies. For example, the current study found males scored significantly higher than females on the Attention Switching, Communication, and Imagination subscales, whereas Austin (2005) found a similar profile for the Communication and Imagination subscales, but also detected sex differences for the Social Skills subscale, but no differences between males and females on the Attention Switching subscale. Further, in the current study the association between sex and the Imagination subscale was most noticeable, in that when sex was entered into the model first, the association between language and higher Imagination scores was no longer significant (see Table 5). Taken together, the current results and those of previous studies, highlight the importance of considering the influence of sex when investigating autistic-like traits, particularly in population-based samples.

Whilst the current study provides preliminary evidence of an association between early expressive language ability and autistic-like traits in adulthood, there are some limitations of the study which must be acknowledged. Unfortunately a combination of sample attrition, along with funding constraints at the 2-year follow-up, meant only 22.4% of the original cohort were included in the current study. As evidenced in Table 1, those without LDS data available did have higher levels of autistic traits thus suggesting this may be underrepresented in the study. Secondly, whilst the AQ has been shown to have strong reliability and validity (Baron-Cohen et al. 2001), and has been widely used in both research and clinical settings (e.g. Ruzich et al. 2015), some considerations in using the AQ as an outcome measure must be acknowledged. Recent studies have emerged suggesting caution in using the AQ in isolation to screen for ASD-related difficulties in both clinical and population samples (Ashwood et al. 2016; Bishop and Seltzer 2012). Bishop and Seltzer (2012) found that individuals with ASD scored significantly lower than those individuals reported in the original validation of the AQ (by Baron-Cohen et al. 2001) and therefore the authors questioned whether higher scores may indeed reflect other factors that are not associated with ASD in adulthood. This is supported by recent evidence suggesting that performance on the AQ is highly correlated with anxiety, personality traits, cognition and psychological distress (e.g. Ashwood et al. 2016; Kitazoe et al. 2015). Thus, whilst the use of a birth cohort allowed for the controlling of extensive sociodemographic factors, as well as the level of depression and anxiety reported by participants at the 20 year follow-up, we acknowledge that the identified associations may reflect other non-autism confounds not controlled for in the current study. Future work which includes additional factors such as concurrent language ability, and cognition, as well as possible mediating factors that occur between the two assessment points, including identified language impairment, will provide important extensions on the current study.

The current study adds to the growing body of evidence which shows that individuals in the general population, whilst not presenting with symptoms severe enough to warrant an ASD diagnosis, do have traits that fall on a continuum with autism (Ruzich et al. 2015). More pertinently, this study provides evidence that, in the general population, language ability in early childhood is associated with the levels of autistic-like traits in adulthood. Of particular interest, was that young adults who had presented with compromised language endowment in the early foundational years reported distinct differences in their preferences for using language for social purposes, compared to young people with early typical language histories. Hence, this study provides important preliminary evidence towards understanding the long-term prognosis for early language delays in terms of the levels of autistic-like traits experienced in early adulthood.

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Authors' Contributions RA: This study forms part of RA's PhD. RA assisted with conceptualizing and designing the study, performed

the statistical analysis, drafted the manuscript, and approved the final manuscript as submitted. WA, AW, DC, and KM conceived the study and participated in its design, interpretation and discussion of the results, reviewed and revised the manuscript, and approved the final manuscript as submitted. JS participated in its design, interpretation and discussion of the results, reviewed and revised the manuscript, and approved the final manuscript as submitted. SF participated in the design of the study, helped to draft the manuscript and reviewed and revised the manuscript, and approved the final manuscript as submitted. All authors read and approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Informed Consent Informed consent was obtained from all individual participants included in the study. Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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