**Sources of variability in the prospective relation of language to social, emotional, and
behaviour problem symptoms: implications for Developmental Language Disorder**

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Abstract

Children with developmental language disorder (DLD) are at risk for social, emotional and behavioural (SEB) maladjustment throughout development, though it is unclear if poor language proficiency per se can account for this risk, as associations between language and SEB appear more variable among typical language children. This study investigates whether the relationship between language and SEB problems is stronger at very low levels of language, and considers confounders including socio-economic status, sex and non-verbal intelligence. These are examined using a population-based survey design, including children with a wide range of language and cognitive profiles, and assessed using the Strengths and Difficulties Questionnaire and six standardised language measures ($n = 363$, weighted $n = 6,451$). Structural equation models adjusted for prior levels of SEB reveal that the relationship of language at age 5-6 years to SEB at 7-9 years was non-linear. Language more strongly predicted all clusters of SEB at disordered language levels relative to typical language levels; with standardised betas of -0.25 versus 0.03 for behavioural, -0.31 versus -0.04 for peer, and 0.27 versus 0.03 for prosocial, problems. Wald tests between these pairs of betas yielded p -values from .049 to .014. Sex moderated the nonlinear association between language and emotional symptoms. These findings indicate a clinical need to support language development in order to mitigate against problems of SEB, and to carefully monitor the mental health needs of children with DLD, particularly in the context of multiple, and potentially sex-specific, risks.

Keywords : Language Disorder, Emotional Problems, Behavioural Problems, Peer Problems, Prospective cohort

General Scientific Summary: Children with a marked deficit in language have higher rates of behavioural and emotional disorders in later life. However, studies among typically developing children do not always find a link between language and symptoms of emotional behavioural disorders. This study supports the notion of unequal risk, where the risk is amplified for children with very low levels of language.

Children with developmental language disorder (DLD) are consistently reported to be at elevated risk for social, emotional and behavioural (SEB) maladjustment (Curtis, Frey, Watson, Hampton, & Roberts, 2018; Goh & O'Kearney, 2013). DLD is the consensus term for a condition characterised by deficits in vocabulary, grammar and/or discourse skills and incorporates the condition previously known as 'specific language impairment' (Bishop, Snowling, Thompson, Greenhalgh, & Consortium, 2017). DLD affects approximately 7% of the school-aged population (Norbury et al., 2016; Tomblin et al., 1997) and persists into adulthood (Johnson, Beitchman, & Brownlie, 2010). It is critical to understand the mechanisms underpinning the association between DLD and SEB maladjustment in order to inform intervention approaches.

Meta-analyses of prospective longitudinal (Goh & O'Kearney, 2013) and cross-sectional studies (Curtis et al., 2018) comparing children with DLD to children with typical language have found moderate increases in SEB symptoms in children with DLD. This is the case for both internalising (anxiety, depression) and externalising (conduct problems, attention deficits) problems. It has been estimated that between 32.7% and 42.8% of children with DLD meet clinical cut-offs for SEB concern by adolescence (Beitchman et al., 2001; Snowling, Bishop, Stothard, Chipchase, & Kaplan, 2006). However, it is unclear whether it is language deficits per se that are driving this relationship, or whether the relationship reflects the presence of other variables that associate with both SEB and DLD, such as lower non-verbal cognitive ability, socio-economic disadvantage, and male sex. Furthermore, few prospective studies have taken prior levels of SEB into account, limiting conclusions about the direction of the relationship between DLD and SEB maladjustment. If language alone was driving the relationship between DLD and SEB we would expect a prospective relationship between language measures and SEB symptoms across the spectrum of language ability. Studies of typically developing children provide evidence of an association, but the effect

size is typically modest (Chow & Wehby, 2018). For example, Petersen et al. (2013) reported a small but significant ($B = 0.01$ to 0.02) prediction from language to behaviour, which maintained after inclusion of covariates such as socio-economics status (SES), academic achievement, sex, and prior levels of behavioural and inattention-hyperactivity problems. The developmental relationship was in one direction only – language predicted behaviour, but behaviour was not longitudinally predictive of later language, consistent with the hypothesis that language deficits have a causal role in SEB maladjustment. However, the small effect size raises questions about the mechanistic role of language in developing SEB competence (Curtis et al., 2018; Goh & O'Kearney, 2013)

One possible explanation for the smaller effect sizes observed in population cohorts, relative to studies comparing children with and without DLD, is that the relationship between language and SEB may be non-linear. Stronger relationships at the tail of the language distribution may indicate that limited language competence prevents the development of skills that promote SEB adjustment, for example, using language to regulate emotion or develop supportive peer relationships. However, once a sufficient level of language is reached to allow development of such skills, greater language competence may not provide additional SEB benefit. Comparison of correlations at different points on the language continuum support this view. For example, Plomin, Price, Eley, Dale, Stevenson (2002) reported that correlations between language and SEB in pre-schoolers (aged 2-4 years) were larger for children scoring below the 10th centile on language, relative to the rest of the population (total sample $r = .05$ to $.18$, 10th percentile = $.09$ to $.32$). Similarly, Conway et al. (2017) found that the relationship between language and behaviour in 2-4-year-olds was strongest at below average levels of language proficiency, and not evident at average or above average levels. These findings suggest a 'threshold' account, in which the risk for poor

outcome is greatest at extreme levels of language deficit, may better characterise language risk for adverse SEB.

Support for a threshold account is currently inconclusive and limited by focus on under-fives; we lack data on the relationship between language and SEB in older children with more persistent language disorder. A second limitation concerns sampling; larger population studies tend to focus on cohorts with average or above-average language skills, whereas studies of children with DLD focus predominantly on clinical referrals which are subject to Berkson's bias (1946), where children with co-occurring conditions are more likely to be referred for clinical services, even if the two conditions are unrelated in the population. In addition, few studies have taken prior levels of SEB into account, which may inflate estimates of a language-behaviour relationship. Hence, whether a threshold account would be supported in a population-derived sample of older children with DLD remains an empirical question.

Alternatively, the stronger association between language and SEB in clinical samples could reflect the presence of other variables that associate with both SEB and DLD, such as lower non-verbal cognitive ability, socio-economic disadvantage, and male sex. Non-verbal cognitive skills are thought to function as a general protective factor for mental health, through either reduced exposure to or the buffering of negative life stressors (Caspi et al., 2014). Notably, all meta-analyses and many primary studies have used diagnostic criteria for 'specific language impairment' that exclude children with co-morbidities or lower non-verbal ability scores. Consequently, there is little data regarding the potential moderating effect of non-verbal IQ on language-SEB relationships, and existing evidence is inconsistent. In one longitudinal study of 12,099 five-year-old children, only those with co-occurring language and cognitive deficits were at elevated risk of poor mental health in adulthood; language deficit in the context of adequate non-verbal cognitive ability did not elevate risk (Law, Rush,

Schoon, & Parsons, 2009; see also Snowling et al. 2006). In contrast, results from a large epidemiological sample found that children with language impairment experienced similar levels of SEB outcome, regardless of cognitive ability (Tomblin & Nippold, 2014). Hence, the role of non-verbal cognitive ability on SEB outcome remains unclear.

Socio-economic disadvantage is consistently associated with both language (Noble, McCandliss, & Farah, 2007) and SEB outcomes (Kalff et al., 2001). Thus, their co-occurrence may be particularly potent for SEB outcomes in children with DLD. For example, SES amplified the association between vocabulary and SEB in a community sample (Goh & O’Kearney, 2015; Yew & O’Kearney, 2015) and warrants further investigation as a moderator.

Numerous studies have highlighted sex differences in DLD and SEB problems, with boys overrepresented in clinical samples of DLD, and externalising and ADHD types of SEB (Ford, Goodman, & Meltzer, 2003; Mouridsen & Hauschild, 2010; Polanczyk, Salum, Sugaya, Caye, & Rohde, 2015; Whitehouse, 2010). Far less is known about how sex moderates the relationship between language and SEB. For instance, girls with DLD have been found to be at elevated risk of emotional symptoms in middle childhood (Beitchman et al., 2001), adolescent boys with DLD have reported greater symptoms of depression (Conti-Ramsden & Botting, 2008), while in studies with larger samples, no sex differences have been evident (Goh & O’Kearney, 2015; Yew & O’Kearney, 2015). Taken together, these studies suggest the possibility of symptom moderation by sex in later childhood, though no previous study has investigated whether sex moderates the longitudinal relationship between early language and later SEB.

The multitude of methods used to measure language and SEB makes it difficult to compare studies, especially when there is an attempt to relate specific aspects of language (receptive or expressive) to different types of SEB outcome (internalising versus

externalising problems). Two meta-analyses (Chow, Ekholm, & Coleman, 2018; Chow & Wehby, 2018) reported generally stronger associations between receptive language and any SEB outcome, relative to associations with expressive language, though individual studies have varied considerably in the strength and specificity of sub-type analyses. In the current study we employ latent variables, which permit comparison of underlying constructs over time, undiluted by the measurement error associated with specific assessments, yielding more precise estimates (Putnick & Bornstein, 2016)

The current study investigates the prospective association of language to SEB utilising an intensively profiled cohort of children with and without language disorder. To guard against Berkson's bias, all children were recruited from community schools using a population-based survey design. This longitudinal sample represents children starting mainstream education in Surrey in Southeast England in Reception year (ages 4-5), and includes a wide range of language and cognitive profiles. Children were identified as having language disorder on the basis of standardised tests of language and functional impact on education performance (e.g. Norbury et al., 2016), however, the study was designed to examine the role of language in SEB development across the full spectrum of ability, and therefore our analyses employ language as a continuous variable.

To our knowledge this is the first study to empirically and systematically evaluate three sources of variability influencing prospective associations between language and SEB. First, we considered language modality by testing a measurement model which included six standardised measures of language. Second, we examined the threshold account by modelling the prospective association of language at Year 1 (age 5;1 to 6;10) to SEB problem outcomes at Year 3 (age 7;1 to 9;3) at different levels of language, adjusting for prior SEB symptoms. Finally, we considered potential moderators of this association, including nonverbal cognition, socio-economic status and male sex.

Method

Participants

<Figure 1 here>

Participants were drawn from the Surrey Communication and Language in Education Study (SCALES; Figure 1), a longitudinal cohort study of language development and disorder (see Norbury et al., 2016 for details). Data from Reception, Year 1 and Year 3 are included in the current study. In the first phase, teacher-rated language and SEB questionnaires were available for 7267 children (59% of children enrolled in state-funded reception classes in Surrey during 2011/12) aged between 4;9 and 5;10 and predominately of white ethnicity (n = 5,979, 82.3%). Socio-economic status was estimated using the Income Deprivation Affecting Children Index (IDACI) rank score, ranging from 1 for the most deprived area in the UK to 32,482 for the least deprived, and in SCALES, had a mean rank of 21,364.35 (SD = 7755.31), relative to the national average of 16,241. There were no differences between participating schools and remaining schools in terms of neighbourhood deprivation, the numbers of children on role with special educational needs, or provision of free school meals (Norbury et al. 2016).

Monolingual children were selected for in-depth assessment (Year 1) using stratified random sampling accounting for language proficiency at screen, sex, and season of birth. We invited all children reported to have ‘no phrase speech’ (defined as producing only single words or two combinations, n = 48), 40% of children with teacher-rated low language proficiency (scores <14th centile for season of birth on teacher-rated Children’s Communication Checklist-Short) and 4% of all remaining children. We oversampled girls to ensure equal numbers of both sex. Our weighting procedures take account of this sampling design (i.e. boy scores carry greater ‘weight’) and therefore weighted estimates reflect the screened population (See Supplement S1 for weighted histograms).

Of the 636 children invited, 529 monolingual children (83% of those invited) were profiled using multiple assessments of language, behaviour, and cognition (50.2% Male; Norbury et al. 2016). Children were aged between 5;1 – 6;10, predominantly of white ethnicity ($n = 476$; 90.2%; Supplemental Materials S1 for breakdown), and had a mean rank IDACI score of 21,366.39 ($SD = 7763.54$). Assessments were conducted at the child's school and lasted approximately two hours (with breaks). Children met the criteria for language disorder if they scored $-1.5SD$ or below on two out of five language composites (vocabulary, grammar, narrative, receptive language and expressive language; Norbury et al. 2016). One hundred and thirty-six children (25.8% total sample) met research criteria for language disorder in Year 1 (age 5-6 years). Of these, 45 had an existing known diagnosis associated with language disorder while the remaining 91 children were classified as having DLD (Bishop et al., 2017). Fourteen children had an autism diagnosis and 15 children had a rare biomedical condition reported by parents or teachers (e.g. Down syndrome, neurofibromatosis). An additional 16 children were identified as having Intellectual Disability based on receiving scores of less than $-2SD$ below the mean on standardised non-verbal IQ tests. All other children were deemed to have typical language development ($n = 392$).

In Year 3, 95% ($n = 499$) of the cohort were reassessed (Norbury et al. 2017), with teacher reports of social, emotional and behavioural symptoms using the SDQ (Goodman, 1997) available for 363/499 children (73% of reassessed cohort, 68.6% of children profiled at Year 1). They were aged between 7;1 and 9;3, were predominantly of White ethnicity ($n = 324$, 89.3%), and a mean IDACI rank score of 21,372 ($SD = 7783.12$).

Sampling weights and missing data

Inverse probability weighting is often utilised in large longitudinal studies to yield population representative samples, by calculating weights which account for selective

participation, and adjusting them for inevitable non-response in subsequent waves. Likewise, inverse probability weighting is utilised in SCALES as detailed elsewhere (Gooch, Sears, Maydew, Vamvakas & Norbury, 2019; Vamvakas et al., 2019). In brief, weights were constructed as the inverse of the probability of inclusion in the study from a logistic regression model fit to the entire screened population of 6,459 monolingual children attending mainstream schools; this model estimated the probability of inclusion for in-depth assessment at Year 1, with predictor variables including sex, season of birth, and scores on the CCC-S. These weights were further adjusted for differential non-response/missing data at Year 3 by estimating a second logistic regression model fit to 529 children selected for in-depth assessment at Year 1. This model utilised predictors of missingness on the SDQ data (n = 125) including: IDACI rank score, SDQ total difficulties score, pupils on school role, percentage of children in school with special educational needs, and percentage receiving free school meals. The final sampling weights were the multiplication of the inverse of the probabilities from both logistic models (Vamvakas et al., 2019). There were no differences between children with (n=363) and without (n=125) teacher-rated SDQ on age, sex, non-verbal cognition, DLD-status, SDQ scores at Reception, or SES (IDACI rank scores) (Supplemental Materials S2). Hence, the weighted models are representative of the monolingual cohort from which this sample is drawn.

Consent Procedures

Consent procedures and study protocol were developed in consultation with Surrey County Council and approved by the Research Ethics Committee at Royal Holloway, University of London, where this study, The Surrey Communication and Language in Education Study, originated. Ethical approval for continued data storage and analysis is provided by the UCL Research Ethics Committee (9733/002). For the screening phase, opt-out consent was employed as data could be provided anonymously; 20 families opted-out. In

the second phase, written, informed consent for two episodes of direct assessment, including teacher report of child language and behaviour, was obtained from parents or legal guardians of participants. Prior to assessment in Year 3, families received an additional information sheet and the option to withdraw from the study; 18 families withdrew, five moved abroad, three could not be contacted and three provided insufficient data at test for diagnostic classification. Of the 29 children (19 males) not included in follow-up, 22 had been classified as ‘typically developing’ in Year 1 and had no evidence of language, learning or behavioural difficulties.

In-depth Assessment

Social, Emotional and Behavioural problems. Teachers completed the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997) at Reception and in Year 1. The SDQ is a well-validated questionnaire rating 25 items tapping social, emotional and behavioural strengths and weakness across five subscales (Peer Problems, Emotional Symptoms, Conduct Problems Inattention/Hyperactivity, and Pro-social), each rated on a 3-point scale (e.g. '0' = Not True, '1' = Somewhat True, '2' = Certainly True, possible score range 0-10). Internal consistency for teacher ratings is variable, with Cronbach’s alpha for this sample ranging from .67 (Peer Problems) to .87 (Hyperactivity). This is consistent with pooled reliability estimates (Stone et al., 2015) .63 (Peer Problems) to .83 (Hyperactivity), and pooled test-retest reliability, .72 (Emotional Problems) to .85 (Hyperactivity). SDQ scores at Reception (age 4-5) and Year 3 (ages 7-8) were utilised in this study.

Receptive/Expressive One word Picture Vocabulary Tests. (R/EOWPVT-4; Martin & Brownell, 2011). ROWPVT and EOWPVT require word-to-picture matching and picture naming tests respectively, with possible scores ranging from 0-190. Test–retest reliability is 0.97 for both measures and internal consistency for ages 5- to 8-years is excellent (Cronbach’s α = .94–.97).

Test of Reception of Grammar – Short Form. (TROG-S; Bishop, 2003). Forty of the original 80 test items were included in which children heard a sentence such as “the ball that is red is on the pencil” and were asked to select the corresponding picture out of a choice of four. If a child answered incorrectly on six consecutive items then the test was discontinued. Scores for this task range from 0 to 40, with excellent agreement between short and long forms in pilot testing, $r(17) = .88$.

School Age Sentence Repetition Imitation Test- English. (SASIT-E32; Marinis, Chiat, Armon-Lotem, Piper, & Roy, 2011). The SASIT-E32 asks the child to repeat pre-recorded sentences of increasing length and grammatical complexity, played over headphones (possible score 0-32). Inter-rater reliability for scoring is excellent, 0.98 (Chiat & Roy, 2013).

Assessment of Comprehension and Expression 6-11. (ACE 6-11; Adams, Cooke, Crutchley, Hesketh, & Reeves, 2001). In Narrative Recall, the child was asked to listen to a pre-recorded story with accompanying pictures displayed on a laptop computer. After listening to the story, the child was asked to tell the story in their own words with the pictures displayed. The child was awarded one point for a maximum of 35 propositions accurately re-told. Internal consistency is adequate (Cronbach’s $\alpha = .73$) for children aged 6- to 11-years.

A bespoke measure of narrative comprehension was constructed in which the child was asked to answer 12 (6 literal and 6 inference) questions about the story. Answers were scored on a three point scale (0 for an incorrect/no response, 1 for a partially correct response and 2 points for a complete and accurate response) with a total possible score of 24. All scoring was done by consensus to ensure rater consistency. For all aforementioned language measures, test scores at Year 1 (ages 5-6) were utilised in this study.

Non-verbal ability. Non-verbal ability (NVIQ) was measured in Year 1 (ages 5-6) using block design and matrix reasoning subtests from the Wechsler Preschool and Primary Scales of Intelligence (WPPSI-3rd UK edition; Wechsler, 2003) in Year 1 (ages 5–6) and the

Wechsler Intelligence Scales for Children (WISC 4th UK edition; Wechsler, 2004) in Year 3 (ages 7–9).

Socio-economic status. The Income Deprivation Affecting Children Index (IDACI) scores were derived from household post-codes and provide an estimate of socio-economic deprivation (McLennan, Barnes, Davies, Garratt, & Dibben, 2011). Deprivation is defined as households receiving income support, jobseeker's allowance, working or disabled person's tax credits or national asylum support whose equalised income is 60% below national median before housing costs.

Analytic Strategy

Three sets of latent variable models, examining (1) language, (2) SEB, and (3) language and SEB, were run in Mplus version 7.4 with the WEIGHT command, in-order to incorporate inverse probability weights, yielding weighted estimates (model $n = 363$, weighted $n = 6,451$). First, to address measurement issues, we conducted confirmatory factor analysis of scores on the six language measures using the maximum likelihood robust estimator. We asked whether receptive and expressive language factors could be modelled separately to ascertain modality specific relationships with SEB outcomes (cf. Snowling et al. 2006). In fact, the initial two-factor model was inadmissible due to correlations between the two factors exceeding 1. Instead, a single language factor provided the best fit to the data ($\chi^2 = 7.37$, $df = 8$, $p = .497$, $CFI = 1.00$, $TLI = 1.00$, $RMSEA = .00$ (.00 to .058), with factor loadings ranging from 0.60 to 0.81 across all six measures. The one-factor model had a high reliability of omega of 0.90, while its factor scores also had a high reliability of 0.90 (Supplemental Materials S3), hence minimising the possibility of attenuation of associations due to measurement error (Rdz-Navarro, 2019).

Second, longitudinal SEB models were then tested for measurement invariance, using the weighted least squares mean and variance (WLSMV) adjusted estimator to account for the ordered-categorical outcomes of the SDQ (Liu et al., 2017). Robust testing of measurement invariance ensures that the underlying construct of SEB is being measured or interpreted in the same way by different respondents at different testing points (Putnick & Bornstein, 2016). The level of strong measurement invariance with thresholds and factor loadings of like items constrained to equality is recommended for unbiased path regression results (Guenole & Brown, 2014). Measurement invariance was sufficient for four of the five sub-scales of interest (Supplemental Materials S4). It was inadequate for the Hyperactivity sub-scale, which could not be examined for configural invariance, as this model failed to converge. Mean scores on this sub-scale are reported for information, but we did not model longitudinal relationships between language and hyperactivity, as parameter estimates are invalid due to failure to converge, and neither fit indices nor modification indices are available for use to guide post-hoc modifications.

Third, language, sex, socio-economic status, and NVIQ were successively added as predictors of the longitudinal SEB factor models. Language was first entered as the sole predictor to examine its prospective association with SEB, after accounting for earlier SEB scores. Next, a non-linear term (Language level x language level) was added to examine the ‘threshold’ account. Finally, sex, SES, and NVIQ were included as potential moderators. As interactions with *latent* variables cannot be specified in the WLSMV estimator (Muthen & Muthen, 2012), the observed variable factor scores from the latent model of language were used instead. All lower order predictors were mean centered to allow interpretation as main effects. To clarify the nature of significant interactions, they were decomposed through plots of their simple slopes at levels of -1.5SD and 0SD. Models which were uniformly above cut-offs for good fitting models (Hu & Bentler, 1999) of $TLI > 0.95$, $CFI > 0.95$, $RMSEA < .06$

were considered as ‘close’ fit. As it is also important to consider the chi-square test of model fit, models which passed this test in addition to aforementioned cut-off were considered to be of ‘good fit’. Models which passed two out of three fit criteria, with the offending index not below less stringent cut-offs of TLI >0.90, CFI > 0.90 and RMSEA < .08 (Bentler & Bonett, 1980; Browne & Cudeck, 1992) were considered as ‘acceptable fit’.

Results

<Table 1 here>

Table 1 presents descriptive statistics weighted from the longitudinal cohort of 529 children at Year 1 and of 363 children subsequently reassessed at Year 3. In Year 1, children with DLD obtained lower scores on a non-verbal ability composite, had a higher proportion of boys, and experienced higher levels of socio-economic deprivation relative to peers with typical language development. DLD children also had persistently elevated symptoms on hyperactivity-inattention, peer and prosocial subscales, with approximately 50% of DLD children scoring at or above the borderline-abnormal range at Year 3. Aforementioned findings also appear applicable to children with language disorder associated with a Known Diagnosis (KD; autism, intellectual disability or other biomedical condition), but were not tested for statistical significance in keeping with the DLD focus of this paper. According to the SDQ manual (Youthinmind, 2016), 20% of children aged 4-17 are expected to have borderline to abnormal range SEB concerns. In SCALES, the percentages of DLD and typical language children scoring in the borderline range appear lower than 20% across SDQ subscales of emotional and conduct problems at Years 1 and 3 (Table 1).

Longitudinal relationships between language and SEB

<Figure 2 here>

For SDQ sub-scales in which measurement invariance was established, two-wave lagged path models were constructed (SEB at intake to SEB in Year 3). Year 1 language

significantly improved prediction of Year 3 Emotional problems, but not Conduct or Peer problems, or Pro-social behaviour (Emotional problems $\beta = -0.17$ (0.07), $p = .009$; Conduct problems $\beta = 0.00$ (0.06), $p = .941$; Peer problems $\beta = -0.06$ (0.06), $p = .332$; Prosocial $\beta = 0.05$ (0.06), $p = .402$); where β refers the standardised beta followed by its standard errors in parentheses. Path diagrams for these models are provided in Supplement Material S6.

A non-linear quadratic term language proficiency was then added as a predictor (Figure 2). This quadratic term predicted Year 3 Conduct, Peer and Prosocial problems (Conduct problems: Language² $\beta = 0.14$ (0.06), $p = .018$; Peer problems: Language² $\beta = 0.13$ (0.06), $p = .023$; Prosocial problems : Language² $\beta = -0.12$ (0.06), $p = .040$). The quadratic term also showed a marginal relationship with emotional problems (Emotional problems: Language² $\beta = 0.11$ (0.06), $p = .07$).

This non-linear relationship was decomposed in Figure 2; in line with our diagnostic cut-offs, we examined the slope at a language score of -1.5 SD relative to the slope at the normative language mean of 0 SD. Slopes differed for Conduct problems (Wald test = 6.06, 1, $p = .014$), Peer problems (Wald test = 4.48, 1, $p = .034$) and Prosocial (Wald test = 3.87, 1, $p = .049$). Slopes at -1.5 SD were of moderate effect size (Conduct problem $\beta = -0.25$ (0.10), $p = .010$; Peer problems $\beta = -0.31$ (0.12), $p = .012$; Prosocial $\beta = 0.27$ (0.12), $p = .026$) whilst those at 0 SD were of small effect (Conduct problem $\beta = 0.03$ (0.07), $p = .638$; Peer Problems $\beta = -0.04$ (0.07), $p = .604$; Prosocial $\beta = 0.03$ (0.06), $p = .635$). Hence, stronger relationships between language and conduct, peer problems, and pro-social behaviour was observed at lower levels of language. For Emotional problems, there was a moderate slope of language proficiency at -1.5 SD ($\beta = -0.39$ (0.12), $p = .002$) which was only marginally different to the slope at 0 SD ($\beta = -0.15$ (0.08), $p = .046$, Wald test = 3.19, 1, $p = .074$). All chi-square tests were significant, but models were uniformly above recommended cut-offs for all other fit indices (Hu & Bentler, 1999).

Further non-linearity was not supported as the addition of a higher order L^3 cubic term was not predictive of any form of SEB (Conduct problems: $p = .888$; Peer problems: $p = .433$; Emotional problems: $p = .697$; Prosocial: $p = .852$).

Is the longitudinal relationship between language and SEB moderated by sex, NVIQ, or SES?

<Figure 3 here>

In the final step, sex, non-verbal ability and SES were entered as an additional block of moderators to the path models (Figure 3). Multicollinearity was observed as non-verbal ability and SES were highly correlated with language (e.g. $r = 0.70$ between Language² and Language x NVIQ; $r = -0.78$ between SES x Language and SES x Language²), and model results showed standard errors which were unusually large (see Supplement Material S6 for complete models). We therefore pruned the models to only include the main effects of SES and non-verbal ability, while retaining sex as a moderator (Figure 3).

In these adjusted models in Figure 3, the non-linear relationship of language to Conduct problems was maintained, with a significant slope at -1.5 SD but not at 0 SD of language (-1.5 SD $\beta = -0.22$ (0.10), $p = .030$; 0 SD $\beta = 0.05$ (0.08), $p = .590$). The relationship of language² to Emotional problems was moderated by sex. For boys, language at -1.5SD but not 0 SD was related to Emotional problems (-1.5 SD $\beta = -0.55$ (0.19), $p = .003$; 0 SD $\beta = -0.04$ (0.12), $p = .120$). For girls, the reverse pattern was found, in which language at 0 SD but not -1.5 SD was related to Emotional problems (0 SD $\beta = -0.22$ (0.11), $p = .040$; -1.5 SD $\beta = -0.17$ (0.19), $p = .380$). Finally, the non-linear relationship of language² to Peer problems maintained whilst the relationship to Prosocial behaviour attenuated. Further slope tests indicated a stronger association of language at lower levels of language, but were not statistically significant for either Peer (0 SD $\beta = 0.06$ (0.08), $p = .480$; -1.5 SD $\beta = -0.19$ (0.13), $p = .140$) or Prosocial outcomes (0 SD $\beta = 0.02$ (0.09), $p = .849$; -1.5 SD $\beta = 0.26$

(0.15), $p = .079$). Main effects of SES and non-verbal ability were not statistically significant and are reported in full in Supplemental Materials S6. With the exception of the TLI, all other models were uniformly above cut-offs for fit indices (Hu & Bentler, 1999) and were all of at least adequate fit.

Discussion

We examined three possible sources of variation in the prospective association of language at Year 1 to social, emotional and behavioural problem (SEB) at Year 3 in a longitudinal, population-derived cohort of children with and without language disorders (SCALES; sample $n = 363$; weighted $n = 6,451$). First, we considered language *modality* as a source of variability by testing a measurement model which included six standard measures of expressive and receptive language. Second, we examined a *threshold account*, in which stronger associations with SEB were expected at the tail of the language distribution, with negligible relationships as language approaches the normative mean. Finally, we considered if non-verbal cognition, socio-economic status and male sex *moderated* the relationship between language and SEB. However, collinearity meant only sex could be fully tested as a moderator. To our knowledge this is the first attempt to empirically verify conditions under which prospective associations may be robustly found between language and SEB.

A single factor language model was the most parsimonious, had good fit, and was superior to the two factor expressive-receptive model. This is consistent with a growing literature unable to parse language into distinct domains (Bornstein, Hahn, & Putnick, 2016; Lonigan & Milburn, 2017; Tomblin & Zhang, 2006). We then observed a non-linear relationship in which SEB did not associate uniformly across the language continuum. Instead, language at the level consistent with diagnosis of DLD (-1.5 SD) had a significant and strong association with conduct, emotional (boys only), peer and pro-social problems, while the association with language at an average level (0 SD) was not significant. This

finding aligns with the larger literature reporting moderately sized increases in levels of SEB among children with DLD (Yew & O’Kearney, 2013), but more variable and much smaller effect sizes among unselected samples with a higher mean level of language (Bornstein, Hahn, & Suwalsky, 2013; Chow & Wehby, 2018). Thus, variation in initial language levels may account for differences between studies. While our data indicate that language levels in early primary school are important indicators of concurrent and future SEB concern, rate of language growth may also improve prediction of SEB (Westrupp et al., 2019).

Our models (Figures 2 and 3) are suggestive of a U-shaped relationship between language and SEB, in which the contribution of language is amplified at either extreme of the distribution. However, that SEB may be amplified in children with highest language competence is unexpected and we note the very small numbers of children with exceptional language skills in our sample, yielding correspondingly wide confidence intervals. Given this finding was not predicted, and that exceptional verbal skills are not a recognised risk factor for SEB problems, we did not test slope differences at $+1.5SD$. These findings suggest that better than average language skills are not protective of SEB risk, though replication is needed.

It is possible that thresholds reflect the insensitivity of the SDQ to measure ‘above-average’ SEB competence. The SDQ was designed to characterise abnormal SEB, rather than the full range of social, emotional, and behavioural skill (see Supplemental Material S5 for information curves). In this case, the upper-right end of the U-shape curve, where children with exceptional language cluster, may be ‘pulled’ down to a L-shape, or even further down to a continuous linear descending line, when the full SEB spectrum is considered. Thus possible linear relationships may be obscured by poor measurement of above-average SEB outcome (Cole, Armstrong, & Pemberton, 2010).

1 Instead, at the tail of the language distribution children are at amplified risk of social,
2 emotional and behavioural problems. However, in terms of *absolute* risk, even at the most
3 extreme levels of language deficit, the 95% CIs did not uniformly cross cut-offs for
4 ‘borderline’ concern of SEB. This differs from meta-analytic findings (e.g. Curtis 2018, Yew
5 & O’Kearney, 2013) and may reflect the fact that this sample is relatively more affluent and
6 had a lower prevalence of SEB than predicted from existing normative data on the SDQ (e.g.
7 11.6% and 6.2% of entire sample met 80th percentile borderline cut-off for conduct and
8 emotional problems).

9 In addition, the relationship between language and SEB was estimated in
10 autoregressive models; prior SEB accounts for between 0.01 to 50.4 % of variation in SEB
11 outcomes, likely attenuating the predictive effect of language (Adachi & Willoughby, 2015).
12 Our findings are consistent with previous research showing that children with DLD present
13 with elevated symptom profiles that are often below clinical thresholds (St Clair, Pickles,
14 Durkin, & Conti-Ramsden, 2011). The one exception is hyperactivity-inattention, with half of
15 the DLD group receiving teacher ratings within the clinical range at Year 3.

16 Further examination of the longitudinal relationship between language and
17 hyperactivity-inattention was hampered by a lack of measurement invariance, indicating that
18 the construct of hyperactivity-inattention was not consistent over time (Putnick & Bornstein,
19 2016). The fact that our study relied on teacher ratings, which by necessity resulted in
20 different respondents at different points in time, may have exacerbated this issue.

21 Our final question asked if known correlates of language disorder, namely lower non-
22 verbal ability, male sex and neighbourhood disadvantage, moderated the association between
23 language and SEB. Sex significantly influenced the relationship between language and SEB,
24 such that lower levels of language yielded more stark emotional problems for boys, but not
25 girls. One earlier study reported that while teen-aged girls were more susceptible to emotion

problems within the total population, there were no sex-differences in the cohort with language disorder (Conti-Ramsden & Botting, 2008). It is therefore possible that sex differences may change with age in this population. Few prior studies have tested sex differences in cohorts that include DLD, thus these findings require replication. We were not able to directly test non-verbal ability and neighbourhood disadvantage as moderators due to multicollinearity. It remains challenging to disentangle unique effects of language on SEB from the effects of these highly correlated variables. Nevertheless, language is arguably more malleable than socio-economic status or non-verbal cognition, and therefore intervention studies that target language could elucidate causal mechanisms.

For emotional and conduct problems, elevated risk for children with language disorder was evident even after adjustment for non-verbal ability and neighbourhood disadvantage. However, relationships with prosocial and peer problems attenuated when covariates were included, and the contribution of any single predictor fell below statistical significance. This highlights the heterogeneous developmental pathways for individuals with language disorder, in which co-occurring SEB deficits are common, but not inevitable (Conti-Ramsden et al., 2019). Variable outcome is likely influenced by additional biological and environmental risk factors, and perhaps differences brought about by age (Curtis et al., 2018) not measured here.

In sum, the current study provides strong evidence that the relationship between language and SEB is not linear and risk of adverse SEB outcome is greatest for those with clinically significant levels of language deficit. Children with typically developing language show fewer SEB symptoms, though good language does not appear to confer additional advantage. DLD is associated with non-verbal deficits and socio-economic disadvantage, but the specific influence of language maintains even when these additional risks are taken into account. Finally, risks are broadly similar for boys and girls, though the development of

emotional symptoms may be sex specific. These findings are consistent with the view that in DLD, children fail to develop the oral language skills necessary for positive SEB adjustment. Such skills may include the ability to identify emotional states of self and others (Griffiths, Goh, Norbury, & SCALES, 2020), use verbal strategies to regulate their own emotions and behaviour, and use language to build positive social networks (Cole et al., 2010; Durkin & Conti-Ramsden, 2010) Positive outcomes of language-based interventions for SEB (e.g. Curtis, Kaiser, Estabrook & Roberts, 2019) support this hypothesis, though whether such interventions would have positive impacts on children with clinical levels of language disorder remains to be seen.

Strengths and Limitations

The strengths of this study include the relatively large sample size, the wide variety of language and cognitive abilities within the sample, and multiple measures of language, which has not been possible in other large cohort studies. Measures of language and SEB were obtained independently, reducing single-rater bias, and all models take account of prior levels of SEB. Our study is limited by including few children experiencing pronounced socio-economic disadvantage, and a lower than expected prevalence of SEB. Moreover, the Strengths & Difficulties Questionnaire is not a diagnostic instrument. We chose the SDQ because its psychometric properties are well-described and it is consistently used in other population studies, allowing direct comparison of our findings with previous research.

Sensitivity analyses suggest that 0 to 10.2% of cases can be flagged as highly influential. Flagged cases cluster at points along the regression line where datapoints are sparse, such as at the ends of language continuum or at high SDQ values. The impact of these cases was minimal (Supplemental Materials S7). These results were based on observed manifest (as opposed to latent) variables without adjustment for measurement error. Sample size may be considered as a limitation of the present examination of a threshold account,

despite the use of the largest cohort (weighted $n=6,451$) to date with multiple measures of language among children with and without language disorder.

Finally, although we were able to consider three key moderators, we were unable to include extensive measures of biological and environmental risk which may have enhanced identification of children most at-risk. We are therefore unable to elucidate possible mechanisms linking language disorder and SEB, including whether this represents shared biological causal mechanisms (e.g. overlapping genetic risk, Newbury et al. (2019), family history of poor mental health (Conti-Ramsden et al. 2019), or a confluence of developmental cascades in which poor language predisposes children to academic underachievement and associated loss of self-esteem (Tomblin, Zhang, Buckwalter, & Catts, 2000; Westrupp et al., 2019).

Conclusion

In conclusion, the relationship between language and social, emotional and behavioural outcomes is not linear, but amplified at clinical levels of language disorder. This may explain seemingly discrepant findings reporting larger associations in DLD samples and more variable associations between language and SEB from unselected community samples. Intervention studies are needed to test causal theories which posit limited oral language as an early barrier to robust development of regulatory processes that foster good mental health. In addition, future cohort studies should investigate multiple risk models that combine biological and environmental factors to yield a more comprehensive picture of developmental pathways to good SEB for children with DLD.

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Table 1. Weighted means, percentages and standard errors of omnibus and planned comparisons across children with DLD, Typical Language and language disorder associated with a Known diagnosis

	Mean/% (SE)			Omnibus Test	Planned comparison		
	DLD	Typical language	Known diagnosis	Overall F (df)	Overall P	F (df) between DLD and TL	P between DLD and TL
N raw, Weighted n, %	91,487.76,7.6%	392,5803.32, 90.1%	45,151.27,2.3%	NA	NA	NA	NA
Age (Months)	71.52 (0.68)	71.77 (0.32)	73.08 (0.67)	1.80 (2,526)	.166	0.11 (1,527)	.745
Male	54.3% (9.0%)	49.2% (3.3%)	76.8% (7.7%)	113.84(1.98,113.84)	.000	199.82 (1,527)	.000
NVIQ	-0.77 (0.11)	0.11 (0.06)	-1.82 (0.21)	57.49 (2,526)	.000	50.07 (1,527)	.000
SES deprivation	0.19 (0.02)	0.09 (0.05)	0.15 (0.02)	9.98 (2,526)	.000	15.67 (1,527)	.000
<i>Reception Year (4-5 years)</i>							
SDQ CP	0.91 (0.20)	0.73 (0.08)	1.97 (0.41)	4.64 (2,526)	.010	0.70 (1,527)	.402
SDQ EP	1.07 (0.23)	1.19 (0.11)	2.14 (0.45)	2.33 (2,526)	.099	0.22 (1,527)	.637
SDQ HI	4.04 (0.40)	2.20 (0.18)	6.64 (1.20)	14.70 (2,526)	.000	17.74 (1,527)	.000
SDQ PP	1.26 (0.23)	1.12 (0.11)	3.45 (0.58)	7.88 (2,526)	.000	0.29 (1,527)	.588
SDQ PS	7.25 (0.42)	7.81 (0.16)	4.72 (0.77)	8.17 (2,526)	.000	1.57 (1,527)	.211
SDQ CP % Borderline+	11.8% (3.2%)	10.2% (1.9%)	43.5% (13.4%)	9.21 (1.80,950.53)	.000	0.19 (1,527)	.666
SDQ EP % Borderline+	5.3% (1.9%)	6.4% (1.5%)	11.7% (5.2%)	1.93 (1.93, 1018.07)	.421	0.22 (1,527)	.637
SDQ HI % Borderline+	23.0% (5.0%)	13.8% (2.1%)	67.8% (12.6%)	17.32 (1.94, 1023.32)	.000	3.62 (1,527)	.058
SDQ PP % Borderline+	26.3% (6.2%)	21.3% (2.6%)	63.2% (12.6%)	7.02 (2.00,1049.62)	.001	0.60 (1,527)	.438
SDQ PS % Borderline+	26.3% (6.2%)	21.3% (2.6%)	63.2% (12.2%)	7.02 (2.00, 10049.62)	.001	0.60 (1,527)	.438
<i>Year 3 (7-8 years)</i>							
^a SDQ CP	1.28 (0.33)	0.64 (0.10)	1.19 (0.47)	2.31 (2,361)	.100	3.52 (1,362)	.061
^a SDQ EP	2.06 (0.39)	1.34 (0.15)	2.93 (0.38)	8.42 (2,361)	.000	2.97 (1,362)	.086
^a SDQ HI	4.51 (0.62)	2.47 (0.22)	6.77 (0.91)	14.29 (2,361)	.000	9.78 (1,362)	.002
^a SDQ PP	1.85 (0.30)	0.97 (0.12)	3.29 (0.43)	15.90 (2,361)	.000	7.50 (1,362)	.006
^a SDQ PS	6.74 (0.57)	8.07 (0.16)	5.55 (0.33)	24.60 (2,361)	.000	5.18 (1,362)	.023
^a SDQ CP % Borderline+	16.1% (6.6%)	8.4% (2.1%)	19.9% (8.3%)	2.04 (1.70, 615.69)	.139	1.81 (1,331)	.179
^a SDQ EP % Borderline+	13.9% (6.4%)	9.9% (2.3%)	18.4% (8.0%)	0.69 (1.68, 609.55)	.476	0.42 (1,331)	.518
^a SDQ HI % Borderline+	49.4% (12.3%)	15.4% (2.8%)	63.4% (16.8%)	10.75 (1.90, 688.35)	.000	11.67 (1,331)	.001
^a SDQ PP % Borderline+	15.4% (6.5%)	10.6% (2.4%)	54.4% (14.8%)	8.25 (1.96,711.72)	.000	0.58 (1,331)	.446
^a SDQ PS % Borderline+	29.3% (9.2%)	13.9% (2.6%)	68.6% (11.3%)	12.10 (1.75, 634.99)	.000	3.88 (1,331)	.050

Note : Age = age in months at Year 1 Language Assessment; CP=Conduct Problems; CP Borderline+ = score>3; EP=Emotional Problems; EP Borderline+ = score>4; HI=Hyperactivity-Inattention; HI Borderline+ = score>6; PP=Peer Problems; PP Borderline score+ = >3; PS = Prosocial; PS Borderline+ = score>5; ^aWeighted from n= 363 with complete data at Year 3

Figure 1. Recruitment flow chart of the Surrey Communication and Language in Education (SCALES) study.

Note. One of the 529 children seen for the first in-depth assessment did not provide sufficient data to be included in the analysis. Therefore data is available for 528 children. EAL = English as an additional Language; SDQ = Strengths Difficulties Questionnaire

Figure 2. Structural equation diagrams of the contribution of language to A) Conduct B) Emotional C) Peer and D) Prosocial problems adjusted for prior levels with accompanying decompositions.

Note. Dotted red lines denote borderline highest 20% cut-offs. Models $n = 363$, weighted $n = 6,451$. Fit indices of models are A) $\chi^2 = 94.59$ (52), $p = .000$, CFI = .97, TLI = .96, RMSEA =

.05 [.03, .06]. B) $\chi^2 = 66.18$ (53), $p = .106$, CFI = .99, TLI = .99, RMSEA = .03 [.00, .04]. C) $\chi^2 = 93.02$ (44), $p = .000$, CFI = .96, TLI = .95, RMSEA = .06 [.04, .07]. D) $\chi^2 = 94.95$ (52), $p = .00$ CFI = .99, TLI = .98, RMSEA = .05 [.03, .06].

A Conduct problems ; Close fit

B Emotional problems ; Adequate fit

C Peer Problems; Adequate fit

D Prosocial ; Close fit

Figure 3. Structural equation diagrams truncated to only show significant main effects or interactions of SES, NVIQ, Sex with language to A) Conduct B) Emotional C) Peer and D) Prosocial problems at Year 3 adjusted for prior levels with accompanying decompositions.

Note. Dotted red lines denote borderline highest 20% cut-offs. Models n = 363, weighted n= 6.451. See Supplement S6 for non-truncated structural equation diagram with significant and non-significant factor loadings and paths of SES, NVIQ and Sex. Fit indices of models are A) $\chi^2= 131.39$ (92), p = .004, CFI = .97, TLI = .96, RMSEA = .04 [.02, .05]. B) $\chi^2= 146.18$ (93), p = .000, CFI = .96, TLI = .94, RMSEA = .04 [.03, .05]. C) $\chi^2= 149.66$ (92), p = .000, CFI = .96, TLI = .94, RMSEA = .04 [.03, .05] D) $\chi^2= 141.83$ (93), p = .000, CFI = .98, TLI = .98, RMSEA = .04 [.03, .05].

Online Supplements S1 to S7

Online Supplement S1: Weighted histograms and correlations of study variables and supplemental ethnicity information

Online Supplement S2: Missing Group Analysis

Online Supplement S3: Confirmatory factor analysis of six language measures

Online Supplement S4: Longitudinal Measurement invariance of Strengths Difficulties Questionnaire

Online Supplement S5: Information Curves of Strengths Difficulties Questionnaire

Online Supplement S6: Path diagram and parameter estimates of full and pruned structural equation models

Online Supplement S7: Examination of cases flagged as influential

Online Supplement S1: Weighted histograms and correlations of study variables

Figure 1. Weighted histograms of six standardised language measures. EOWPVT = Expressive one word picture vocabulary test

Note: ROWPVT = Receptive one word picture vocabulary test; SENTREP = Sentence repetition; TROG = Test of Reception of Grammar; SENTREP = School Age Sentence Repetition Imitation Test; NARCOMP = Narrative Comprehension from the Assessment of Comprehension and Expression ; NARRECALL = Narrative Recall from the Assessment of Comprehension and Expression

Figure 2. Weighted Histograms of proposed moderators of NVIQ, SES (IDACI Score) and Sex. NVIQ = Non-verbal

Note: SES (IDACI Score) = Socio-economic status (Income Deprivation Affecting Children Index Score)

Figure 3. Weighted histograms of Strengths Difficulties Questionnaire for subscales of Emotional, Conduct, Peer and Prosocial Problems

Table 1. Weighted correlation matrix of language, NVIQ, Sex and SES and conduct problem (CP) subscale items at Reception and Year 3 (weighted n = 6,451)

	Language Factor Score	Sex	SES	NVIQ	CP1 Reception	CP2 Reception	CP3 Reception	CP4 Reception	CP5 Reception	CP1 Y3	CP2 Y3	CP3 Y3	CP4 Y3	CP5 Y3
Language Factor Score	1.00													
Sex	-0.07	1.00												
SES	-0.35	0.03	1.00											
NVIQ	0.57	0.07	-0.21	1.00										
CP1 Reception	-0.03	0.16	0.02	0.01	1.00									
CP2 Reception	-0.13	0.19	0.16	-0.14	0.43	1.00								
CP3 Reception	-0.02	0.17	0.03	-0.04	0.38	0.49	1.00							
CP4 Reception	-0.06	0.20	0.03	0.00	0.46	0.44	0.40	1.00						
CP5 Reception	-0.02	0.11	0.07	-0.06	0.19	0.36	0.28	0.48	1.00					
CP1_Y3	0.00	0.03	0.13	0.05	0.31	0.19	0.24	0.28	0.13	1.00				
CP2_Y3	-0.10	0.16	0.17	-0.10	0.30	0.41	0.30	0.30	0.21	0.30	1.00			
CP3_Y3	0.00	0.11	0.01	-0.01	0.19	0.32	0.26	0.21	0.17	0.46	0.45	1.00		
CP4_Y3	-0.03	0.17	0.12	-0.04	0.18	0.34	0.20	0.33	0.43	0.33	0.30	0.50	1.00	
CP5_Y3	-0.01	0.09	0.04	0.00	-0.01	0.21	0.01	0.04	0.07	0.05	0.04	0.02	0.40	1.00

Table 2. Weighted correlation matrix of language, NVIQ, Sex and SES and emotional symptoms (ES) subscale items at Reception and Year 3 (weighted n = 6,451)

	Language Factor Score	Sex	SES	NVI Q	ES1 Recept ion	ES2 Recept ion	ES3 Recepti on	ES4 Recepti on	ES5 Recepti on	ES1 Y3	ES2 Y3	ES3 Y3	ES4 Y3	ES5 Y3
Language Factor Score	1													
Sex	-0.07	1												
SES	-0.35	0.03	1											
NVIQ	0.57	0.07	-0.21	1										
ES1 Reception	0.11	-0.16	-0.03	0.15	1									
ES2 Reception	0.01	0.00	-0.05	-0.01	0.3	1								
ES3 Reception	-0.05	0.1	0.07	0.04	0.32	0.39	1							
ES4 Reception	-0.11	0.01	0.09	-0.15	0.33	0.55	0.43	1						
ES5 Reception	0.04	-0.01	-0.02	0.01	0.35	0.58	0.38	0.55	1					
ES1_Y3	-0.09	-0.05	0.15	0.02	0.1	0.02	0.05	0.03	-0.03	1				
ES2_Y3	0.01	0.04	-0.02	0.05	0.05	0.07	0.11	0.15	0.15	0.41	1			
ES3_Y3	0.00	0.08	0.04	0.04	-0.01	0.05	0.03	0.10	0.05	0.32	0.48	1		
ES4_Y3	-0.23	0.02	0.17	-0.09	-0.03	0.01	0.05	0.08	0.10	0.39	0.55	0.38	1	
ES5_Y3	-0.17	0.08	0.10	-0.15	0.05	0.05	0.04	0.08	0.16	0.35	0.54	0.41	0.62	1

Table 3. Weighted correlation matrix of language, NVIQ, Sex and SES and peer problems (PP) subscale items at Reception and Year 3 (weighted n = 6,451)

	Language Factor Score	Sex	SES	NVIQ	PP1 Reception	PP2 Reception	PP3 Reception	PP4 Reception	PP5 Reception	PP1 Y3	PP2 Y3	PP3 Y3	PP4 Y3	PP5 Y3
Language Factor Score	1.00													
Sex	-0.07	1.00												
SES	-0.35	0.03	1.00											
NVIQ	0.57	0.07	-0.21	1.00										
PP1 Reception	-0.07	0.21	0.04	-0.06	1.00									
PP2 Reception	-0.08	0.20	0.08	-0.06	0.68	1.00								
PP3 Reception	0.00	0.12	0.04	-0.02	0.44	0.51	1.00							
PP4 Reception	-0.01	0.15	0.00	-0.03	0.15	0.11	0.19	1.00						
PP5 Reception	0.17	0.09	-0.04	0.16	0.49	0.39	0.20	0.08	1.00					
PP1_Y3	-0.04	0.03	0.21	-0.04	0.26	0.15	0.06	-0.01	0.02	1.00				
PP2_Y3	-0.14	0.13	0.09	-0.14	0.31	0.29	0.24	0.11	0.07	0.32	1.00			
PP3_Y3	-0.10	0.12	0.10	-0.11	0.30	0.22	0.25	0.21	0.05	0.21	0.64	1.00		
PP4_Y3	0.05	0.08	-0.02	0.00	0.12	0.01	0.14	0.23	0.06	0.36	0.19	0.10	1.00	
PP5_Y3	0.12	0.14	0.11	0.12	0.24	0.20	0.18	0.17	0.16	0.35	0.32	0.33	0.09	1.00

Table 4. Weighted correlation matrix of language, NVIQ, Sex and SES and prosocial subscale (PS) items at Reception and Year 3 (weighted n = 6,451)

	Language Factor Score	Sex	SES	NVIQ	PS1 Reception	PS2 Reception	PS3 Reception	PS4 Reception	PS5 Reception	PS1 Y3	PS2 Y3	PS3 Y3	PS4_ Y3	PS5 Y3
Language Factor Score	1.00													
Sex	-0.07	1.00												
SES	-0.35	0.03	1.00											
NVIQ	0.57	0.07	-0.21	1.00										
PS1 Reception	0.09	-0.21	0.00	0.05	1.00									
PS2 Reception	0.11	-0.15	-0.07	0.14	0.71	1.00								
PS3 Reception	0.09	-0.29	0.00	0.11	0.63	0.58	1.00							
PS4 Reception	0.17	-0.19	0.00	0.10	0.59	0.52	0.61	1.00						
PS5 Reception	0.22	-0.24	-0.09	0.15	0.60	0.52	0.67	0.59	1.00					
PS1_Y3	0.10	-0.15	-0.16	0.11	0.31	0.24	0.34	0.24	0.25	1.00				
PS2_Y3	0.07	-0.12	-0.18	0.01	0.34	0.27	0.30	0.23	0.35	0.61	1.00			
PS3_Y3	0.08	-0.19	0.02	0.04	0.33	0.22	0.33	0.18	0.33	0.58	0.44	1.00		
PS4_Y3	0.09	-0.10	0.00	0.05	0.20	0.12	0.22	0.14	0.15	0.45	0.44	0.61	1.00	
PS5_Y3	0.17	-0.24	-0.04	0.14	0.29	0.15	0.30	0.21	0.29	0.35	0.31	0.54	0.38	1.00

Table 5. Unweighted ethnicity of the longitudinal cohort of SCALES children at Year I

Ethnicity	n
White	476
Asian or Asian British	12
Mixed/Dual Background	24
Any other Ethnic Group (including Black or Black British)	16

Online Supplement S2 : Missing group analysis

Table 1 presents weighted comparisons between these 363 children and the 165 that were not analysed due to missing data. In Year 3, 95% (n = 499) of the in-depth cohort were reassessed (Norbury et al. 2017). Teacher reports of social, emotional and behavioural symptoms using the SDQ (Goodman et al., 1997) were available for 363/499 children (73% of reassessed cohort). These 363 children with SDQ data at Year 3 were analysed in this study and constitute 68.6% of the 528 children profiled at Year 1.

Table 1. Missing group analyses between children with data to be analysed and those who did not

	Included in analysis (n = 363)	Not analysed (n= 165)	Overall F (df)	Overall p
Language Group Status	7.0% (1.6%) DLD 87.8% (2.1%) TL 5.3% (1.4%) KD	7.2% (2.2%) DLD 89.2% (2.6%) TL 3.6% (1.4%) KD	.305 (1.98, 1043.95)	.735
Age	71.69 (0.35)	71.98 (0.53)	0.21 (1,527)	.646
Male	50.1% (3.7%)	49.2% (5.7%)	0.02 (1, 527)	.895
NVIQ	0.02 (0.07)	-0.04 (0.11)	0.17 (1,527)	.679
SES	0.99 (0.01)	0.10 (0.01)	0.03 (1, 527)	.856
<i>Reception Year SDQ</i>				
SDQ CP	0.75 (0.09)	0.82 (0.14)	0.19 (1,527)	.666
SDQ EP	1.16 (0.12)	1.31 (0.21)	0.39 (1,527)	.534
SDQ HI	2.44 (0.21)	2.47 (0.29)	0.01 (1,527)	.932
SDQ PP	1.20 (0.12)	1.16 (0.19)	0.04 (1,527)	.845
SDQ PS	7.81 (0.17)	7.44 (0.30)	1.23 (1,527)	.268
SDQ CP % Borderline or above	11.6% (2.1%)	10.1% (3.0%)	0.17 (1,527)	.682
SDQ EP % Borderline or above	6.2% (1.6%)	7.1% (2.5%)	0.11 (1,527)	.744
SDQ HI % Borderline or above	16.3% (2.4%)	14.4% (3.3%)	0.21 (1,527)	.644

SDQ PP % Borderline or above	22.3% (2.9%)	23.5% (4.5%)	0.06 (1,527)	.815
SDQ PS % Borderline or above	22.3% (2.9%)	23.5% (4.5%)	0.06 (1,527)	.815

Note : CP=Conduct Problems; DLD= Developmental Language Disorder; EP=Emotional Problems; HI=Hyperactivity-Inattention; KD = Known Diagnosis; PP=Peer Problems; TL = Typical Language

Table 1 weighted results show no difference across study variables. There were no differences between children with or without teacher ratings on age, sex, non-verbal cognition, prevalence of DLD at Year 1, teacher ratings of social, emotional, and behavioural competence at Reception, or socio-economic status as measured by IDACI rank scores, which index neighbourhood deprivation.

Table 2 provides further information on missingness of study variables, by reporting the percentage of missing data.

Table 2. Percentage of missing data on study variables

Study variable	Missing (n / % of Year 1 cohort)
EOWPVT	0.0
ROWPVT	0.0
SENTREP	0.0
TROG	0.0
NARCOMP	0.0
NARRECALL	0.0
Sex	0.0
NVIQ	0.0
IDACI	0.0
Reception SDQ	0.0
Year 3 SDQ	165/31.3%

References

Goodman, R. (1997). The Strengths and Difficulties Questionnaire: a research note. *Journal of Child Psychology and Psychiatry*, 38(5), 581-586.

Online Supplement S3 : Confirmatory factor analysis of six language measures

Figure 1. One factor and two factor confirmatory Factor Analysis models of six measures of language.

Note: All factor loadings and correlations are standardised betas that are significantly different from 0 ($p < .001$). EOWT = Expressive One Word Picture Vocabulary Test; ROWT = Receptive One Word Picture Vocabulary Test; TROG = Test of Reception of Grammar; SENT = School Age Sentence Repetition Imitation Test; NARC = Assessment of Comprehension and Expression Comprehension; NARR = Assessment of Comprehension and Expression Recall; SL = Structural Language; R = Receptive Language, E = Expressive Language.

Figure 1 presents (a) one factor ‘structural language’ ($\chi^2=7.37$, $df = 8$, $p = .497$, $CFI = 1.00$, $TLI = 1.00$, $RMSEA = .00$ [.00,.058], $SRMR = 0.02$) and (b) two factor ‘expressive-receptive’ confirmatory factor ($\chi^2=7.30$, $df = 7$, $p = .399$, $CFI = 1.00$, $TLI = 1.00$, $RMSEA = .01$ [.00,.066], $SRMR = 0.02$) models across the six measures of language used in this study. An a priori correlation was specified between narrative recall and comprehension measures as these scores were derived from the same measure (ACE 6 -11; Adams et al., 2001) and thus expected to be more highly related to each other than all other measures of language. Both models showed good fit with non-significant chi-square tests of model fit, though the two factor model contained an inadmissible correlation of 1.01.

The one factor model was named ‘structural language’ consistent with observed factor loadings ranging from 0.60 to 0.81 across all six measures. The two factors in the expressive-receptive model were found to correlate at 1.01. As correlations cannot exceed 1.00, this is an inadmissible parameter, indicating that this model should be dropped. Even if this correlation was to be considered at an admissible number of 1.00, this perfect correlation indicates that these two factors are essentially identical, further supporting the one factor model. For these reasons, the one factor ‘structural language’ model was retained. This latent factor and its factor scores showed high reliability. Here, omega was 0.90, appropriate here as the factor loadings were not all equal, an assumption required for an accurate calculation of Cronbach’s alpha. Moreover, factor score reliability based on Classical Test Theory (Raju, et al., 2007) was also high at 0.90, calculated as the variance of the latent factor of language, divided by the variance of the latent factor of language + standard error of language squared.

Reference

Raju, N. S., Price, L. R., Oshima, T. C., & Nering, M. L. (2007). Standardized conditional SEM: A case for conditional reliability. *Applied Psychological Measurement*, 31(3), 169-180.

Online Supplement S4 : Longitudinal measurement invariance of Strengths Difficulties Questionnaire

Figure 1. Structural Equation Diagrams of models (1a)Configural invariance (1b)Weak Invariance (1c)Strong Invariance

Figure 1 depicts the three types of structural equation models used to test measurement invariance of socio-emotional behavioural outcomes across two waves of Reception and Year 3. Consistent with the factor structure of the SDQ (Goodman, 1997), a model where all five items were specified to load onto a single factor in each wave was tested.

Table 1. Results of tests of longitudinal measurement invariance of socio-emotional behavioural outcomes across two waves

Models	Conduct Problems (CD)	Emotional Problems (EP)	Hyperactivity inattention (HI)	Prosocial (PS)	Peer Problems (PP)	Chi-square comparison to previous model (χ^2 ,df,p)
1a: Configural Invariance	Met. $\chi^2 = 73.84$, 29, $p = .000$ CFI = .97, TLI = .95, RMSEA = 0.07 [0.05, 0.08]	Met $\chi^2 = 23.87$, 29, $p = .735$ CFI = 1.00, TLI = 1.00, RMSEA = 0.00 [0.00, 0.03]	Not met. No convergence.	Met. $\chi^2 = 68.88$, 29, $p = .000$ CFI = .99, TLI = .98, RMSEA = 0.06 [0.04, 0.08]	Met $\chi^2 = 61.93$, 29, $p = .000$ CFI = .98, TLI = .96, RMSEA = .06 [.04, .08]	NA
1b: Weak Invariance : Factor loadings	Partially met ^a $\chi^2 = 75.52$, 32, $p = .000$ CFI = .97, TLI = .95,	Met $\chi^2 = 30.46$, 33, $p = .594$ CFI = 1.00, TLI = 1.00, RMSEA = 0.00 [0.00, 0.03]	NA	Partially met. ^a $\chi^2 = 73.08$, 32, $p = .000$ CFI = .99, TLI = .98,	Partially met ^a $\chi^2 = 67.02$, 32, $p = .000$ CFI = .97, TLI = .96,	Model fit does not significantly worsen CD ^a = 0.65, 3, $p = .885$ EP = 7.12, 4, $p = .130$ PP ^a = 6.66, 3, $p = .083$ PS ^a = 5.69, 3, $p = .128$

	RMSEA = .06 [.04, .08]			RMSEA = 0.06 [0.04, 0.08]	RMSEA = .06 [.04, .07]	
1c: Strong Invariance : Factor loadings and thresholds	Met ^a $\chi^2 = 78.33, 36,$ $p = .000$ CFI = 0.97, TLI = 0.96, RMSEA = .06 [.04, .07]	Met $\chi^2 = 33.65, 37, p =$.627. CFI = 1.00, TLI = 1.00, RMSEA = 0.00 [0.00, 0.03]	NA	Met ^a $\chi^2 = 77.24, 36,$ $p = .000$ CFI = 0.99, TLI = 0.98, RMSEA = .06 [.04, .07].	Met ^a $\chi^2 = 68.85,$ 36, $p = .001$ CFI = 0.98, TLI = 0.97, RMSEA = .05 [.03, .07]	Model fit does not significantly worsen CD = 5.51, 4, $p = .239$ EP = 3.06, 4, $p = .548$ PP = 2.18, 4, $p = .702$ PS = 2.68, 4, $p = .613$

Note: ^aPartial invariance was met as factor loading for 1 of 5 items was freed.

As shown in Table 1, for the first type of model '1a', configural invariance, four out of five SEB domains showed configural invariance. The hyperactivity-inattention model failed to converge, suggesting a very poor fit to the data. With the exception of the RMSEA for conduct problems which was 0.01 away from accepted cut-offs for good fit, all other fit indices were within cut-offs for SEB domains of conduct, emotional and peer problems. These three domains were thus judged to be of adequate or very close to adequate fit and retained for further testing. In model 1b weak invariance, these four SEB domains were subsequently found to meet criteria for weak or partial weak invariance. Items here were constrained to the same factor loading across waves (e.g. loading of item1 Reception = loading of item1 Yr3; loading of item 2

Reception = loading of item 2 Yr3, see ‘a1 to a5’ in Figure 1). Emotional problems showed weak invariance, as constraining the factor loadings did not worsen model fit, as shown by a non-significant chi-square model comparison test. Conduct, prosocial and peer problems showed partial weak invariance, as model fit did not worsen when one of five items was allowed to vary across waves.

Finally, as shown in Model 1c Table 1 all four SEB domains met criteria for strong or partial strong invariance (Model 1c). Items here were constrained to the same threshold (see ‘b1 to b5’ in Figure 1) across waves. Emotional problems showed strong invariance, as constraining the intercepts did not worsen model fit. Although constraining the intercepts of conduct, prosocial and peer problems did not worsen model fit, the result from the partial weak invariance is ‘carried forward’ with previously freed factor loading continuing to be freed. Model 1c Emotional problems showed good fit as indicated by a non-significant chi-square test of model fit. Conduct, prosocial and peer problems showed adequate fit, as chi-square tests of model fit were significant while fit indices were above accepted cut-offs (Hu & Bentler, 1999).

Table 2. Parameters constrained to equality across Reception and Year 3 as per model 1c which meets strong or partial strong longitudinal measurement invariance

	Conduct	Emotional	Peer	Prosocial
Factor loadings				
Item 1	X	X	X	X
Item 2	X	X	X	X

Item 3 ^a	X	X		
Item 4	X	X	X	X
Item 5 ^b		X	X	X
Thresholds				
Item 1	X	X	X	X
Item 2	X	X	X	X
Item 3	X	X	X	X
Item 4	X	X	X	X
Item 5	X	X	X	X

Note : X Constrained to equality across Reception and Year 3. ^aUnconstrained items 3 for Peer and Prosocial were questions 14 and 9 on the SDQ respectively. ^bUnconstrained item 5 Conduct was question 22 on the SDQ.

Online Supplement S5 : Information curves of Strengths Difficulties Questionnaire

Figure 1. Test information curves for Conduct Problems, Emotional Problems, Peer Problems and Prosocial at Year 3.

Derived from item response theory, the amount of information per each latent construct of conduct, emotional, peer and prosocial are calculated. As shown in Figure 1, tests are informative from 0 to 3 standard deviation levels of the latent construct being estimated. For example, an information of 5, corresponding to a cronbach's alpha of 0.80 (Demars, 2010), is reached at approximately 0.5 SDs of conduct problems. As the level of conduct problems rises beyond 0.5 SD, the level of information continues to exceed 5 and its corresponding reliability of 0.80. This truncated range of sensitivity, only in the 0 to 3 standard deviation range, is in keeping with the designation of the 5 items of the SDQ conduct scale as a problem subscale (Goodman, 1997). This same pattern is seen for other problem subscales of emotional and peer problems.

For the prosocial scale, the information curve indicates it is sensitive in the range of 'problems' of prosociality. Here, an information of 5, corresponding to a cronbach's alpha of 0.80 (DeMars, 2010), is reached at approximately -2.5 SDs of prosociality. This level of information continues or exceeds 5 and its corresponding reliability of 0.80 until a prosocial

level of approximately 0.5 SD. Hence, this scale is not informative at highly skilled or proficient levels of prosociality, but instead measures the ‘problem’ range of prosociality.

References

DeMars, C. (2010). *Item response theory*. Oxford University Press.

Goodman, R. (1997). The Strengths and Difficulties Questionnaire: a research note. *Journal of child psychology and psychiatry*, 38(5), 581-586.

Online Supplement S6 : Path diagram and parameter estimates of pruned and non-pruned structural equation models

Legend : L = Language factor score Year 1, L^2 = Language factor score squared, SES = Socioeconomic status, Sex = Sex, NVIQ = Nonverbal Intelligence, F-R = SDQ subscale factor reception, F-Y3 = SDQ subscale factor Year 3.

Figure 1. Structural equation diagram displaying both significant and non-significant main effects and interactions with language to socio-emotional behavioural outcomes at Year 3 adjusted for prior levels. The truncated version of this is displayed in Figure 3 of the main manuscript. See Table 1 below for parameter estimates. Covariance between indicators, predictors and F-R not shown for clarity.

Table 1. Unstandardised and standardised betas of Figure 1 of the contribution of language, SES, gender and NVIQ across SEB outcomes of Conduct Problems, Emotional problems and Peer Problems

	Conduct Problems (CP) ^a		Emotional Problems (EP) ^b		Peer Problems (PP) ^c		Prosocial (PS) ^d	
Path	Unstandardised Beta (SE)	Standardised Beta (SE)	Unstandardised Beta (SE)	Standardised Beta (SE)	Unstandardised Beta (SE)	Standardised Beta (SE)	Unstandardised Beta (SE)	Standardised Beta (SE)
<i>Paths (P1 to P8)</i>								
1 L	0.08 (0.14)	0.05 (0.09)	-0.16 (0.11)	-0.13 (0.09)	0.16 (0.23)	0.06 (0.09)	0.05 (0.27)	0.02 (0.09)
2 L ²	0.21 (0.09)*	0.13 (0.06)*	0.13 (0.08)	0.11 (0.07)	0.32 (0.16) ^e	0.12 (0.06)*	-0.33 (0.18) ^f	-0.12 (0.06) ^g
3 SES	1.00 (1.09)	0.08 (0.08)	0.72 (0.92)	0.08 (0.10)	2.95 (1.90)	0.14 (0.09)	-0.87 (2.17)	-0.04 (0.09)
4 Sex	0.20 (0.23)	0.08 (0.08)	-0.08 (0.19)	-0.05 (0.11)	0.27 (0.40)	0.07 (0.10)	-0.72 (0.44)	-0.16 (0.10)
5 NVIQ	0.02 (0.11)	0.02 (0.09)	0.01 (0.07)	0.02 (0.08)	-0.16 (0.14)	-0.08 (0.07)	0.00 (0.18)	0.00 (0.08)
6 L x Sex	0.22 (0.21)	0.06 (0.06)	0.23 (0.17)	0.09 (0.07)	-0.30 (0.35)	-0.06 (0.06)	0.27 (0.38)	0.04 (0.06)
7 L ² x Sex	-0.21 (0.18)	-0.08 (0.06)	0.31 (0.15)*	0.16 (0.07)*	0.13 (0.29)	0.03 (0.07)	0.45 (0.32)	0.10 (0.07)
8 F-R	0.73 (0.15)***	0.70 (0.08)***	0.13 (0.10)	0.13 (0.09)	0.42 (0.11)***	0.47 (0.09)***	0.42 (0.09)***	0.45 (0.08)***
<i>Factor Loading (FL 1 to FL 10)</i>								
1 R-1	1.00 (0.00)	0.77 (0.05)***	1.00 (0.00)	0.66 (0.06)***	1.00 (0.00)	0.91 (0.03)***	1.00 (0.00)	0.92 (0.02)***
2 R-2	1.27 (0.29)***	0.83 (0.04)***	2.22 (0.60)***	0.89 (0.04)***	1.08 (0.41)**	0.92 (0.04)***	0.68 (0.15)***	0.85 (0.03)***
3 R-3	1.02 (0.20)***	0.77 (0.04)***	1.21 (0.28)***	0.73 (0.06)***	0.49 (0.10)***	0.73 (0.04)***	0.89 (0.17)***	0.91 (0.02)***
4 R-4	1.78 (0.42)***	0.90 (0.03)***	1.70 (0.31)***	0.83 (0.04)***	0.31 (0.09)***	0.56 (0.08)***	0.65 (0.14)***	0.84 (0.03)***
5 R-5	1.49 (0.34)***	0.87 (0.04)***	2.01 (0.41)***	0.87 (0.04)***	0.31 (0.08)***	0.57 (0.08)***	0.75 (0.16)***	0.88 (0.03)***
6 Y3-1	1.00 (0.00)	0.77 (0.06)***	1.00 (0.00)	0.62 (0.07)***	1.00 (0.00)	0.67 (0.07)***	1.00 (0.00)	0.88 (0.03)***
7 Y3-2	1.27 (0.29)***	0.79 (0.06)***	2.22 (0.60)***	0.83 (0.03)***	1.08 (0.41)**	0.94 (0.05)***	0.68 (0.15)***	0.82 (0.04)***
8 Y3-3	1.02 (0.20)***	0.83 (0.04)***	1.21 (0.28)***	0.75 (0.05)***	0.72 (0.18)***	0.87 (0.05)***	1.11 (0.24)***	0.92 (0.03)***
9 Y3-4	1.78 (0.42)***	0.85 (0.06)***	1.70 (0.31)***	0.90 (0.03)***	0.31 (0.09)***	0.42 (0.06)***	0.65 (0.14)***	0.73 (0.04)***
10 Y3-5	0.62 (0.23)***	0.39 (0.08)***	2.01 (0.41)***	0.94 (0.04)***	0.31 (0.08)***	0.65 (0.07)***	0.75 (0.16)***	0.68 (0.05)***

Note: ^aPartial strong invariance constrains applied to CP reception and Yr 3. ^bStrong invariance constrains applied to EP reception and Yr 3. ^cPartial strong invariance constrains applied to PP reception and Yr 3. ^dPartial strong invariance constrains applied to PS reception and Yr 3. ^ep = .053. ^fp = .063, ^gp = .054.

Legend : L = Language factor score Year 1, L^2 = Language factor score squared, SES = Socioeconomic status, Sex = Sex, NVIQ = Nonverbal Intelligence, F-R = SDQ subscale factor reception, F-Y3 = SDQ subscale factor Year 3.

Figure 2. Non-pruned multicollinear structural equation diagram of both significant and non-significant main effects and interactions with language to socio-emotional behavioural outcomes at Year 3 adjusted for prior levels. See Table 2 below for parameter estimates. Covariance between indicators, predictors and F-R not shown for clarity.

Table 2. Unstandardised and standardised betas from Figure 2 of the contribution of language, SES, gender and NVIQ across outcomes of Conduct Problems, Emotional problems and Peer Problems

	Conduct Problems (CP) ^a		Emotional Problems (EP) ^b		Peer Problems (PP) ^c		Prosocial (PS) ^d	
Path	Unstandardised Beta (SE)	Standardised Beta (SE)	Unstandardised Beta (SE)	Standardised Beta (SE)	Unstandardised Beta (SE)	Standardised Beta (SE)	Unstandardised Beta (SE)	Standardised Beta (SE)
<i>Paths (P1 to P12)</i>								
1 L	0.19 (0.16)	0.11 (0.09)	-0.18 (0.14)	-0.15 (0.11)	0.16 (0.29)	0.06 (0.11)	0.01 (0.32)	0.00 (0.11)
2 L ²	0.71 (0.18)***	0.43 (0.09)***	0.23 (0.12)	0.21 (0.10)*	0.47 (0.28)	0.19 (0.11)	-0.49 (0.31)	-0.17 (0.11)
3 SES	1.54 (1.44)	0.12 (0.11)	1.81 (1.19)	0.20 (0.12)	3.05 (2.12)	0.16 (0.11)	-2.55 (2.64)	-0.11 (0.12)
4 Sex	0.18 (0.24)	0.07 (0.10)	-0.06 (0.19)	-0.03 (0.11)	0.26 (0.37)	0.07 (0.10)	-0.79 (0.43)	-0.18 (0.09)
5 NVIQ	0.04 (0.12)	0.03 (0.10)	0.03 (0.08)	0.03 (0.10)	-0.14 (0.14)	-0.07 (0.07)	-0.03 (0.19)	-0.01 (0.09)
6 L x Sex	0.54 (0.25)*	0.16 (0.07)*	0.30 (0.19)	0.20 (0.23)	-0.15 (0.33)	-0.03 (0.06)	0.15 (0.42)	0.02 (0.07)
7 L ² x Sex	-0.02 (0.18)	-0.01 (0.07)	0.21 (0.16)	-0.10 (0.25)	0.18 (0.29)	0.05 (0.07)	0.57 (0.37)	0.12 (0.08)
8 F-R	0.74 (0.15)***	0.72 (0.07)***	0.13 (0.10)	0.13 (0.09)	0.40 (0.11)***	0.46 (0.10)	0.40 (0.09)***	0.43 (0.08)***
9 L x SES	3.92 (2.87)	0.27 (0.19)	2.04 (2.34)	0.20 (0.23)	0.30 (5.33)	0.01 (0.24)	-5.78 (5.40)	-0.23 (0.21)
10 L² x SES	1.28 (2.04)	0.14 (0.22)	-0.62 (1.59)	-0.10 (0.25)	-0.28 (2.85)	-0.02 (0.21)	-0.55 (3.03)	-0.04 (0.19)
11 L x NVIQ	-0.47 (0.16)**	-0.33 (0.09)***	0.03 (0.07)	0.03 (0.07)	-0.20 (0.22)	-0.09 (0.10)	-0.14 (0.26)	-0.05 (0.10)
12 L² x NVIQ	-0.04 (0.07)	-0.05 (0.09)	-0.01 (0.05)	-0.02 (0.09)	-0.03 (0.10)	-0.03 (0.08)	0.02 (0.12)	0.01 (0.09)
<i>Factor Loading (FL 1 to FL 10)</i>								
1 R-1	1.00 (0.00)	0.77 (0.05)***	1.00 (0.00)	0.65 (0.06)***	1.00 (0.00)	0.91 (0.03)***	1.00 (0.00)	0.92 (0.02)***
2 R-2	1.24 (0.24)***	0.83 (0.04)***	2.24 (0.59)***	0.89 (0.04)***	1.10 (0.42)**	0.92 (0.04)***	0.69 (0.15)***	0.85 (0.03)***
3 R-3	1.00 (0.19)***	0.77 (0.04)***	1.20 (0.27)***	0.72 (0.06)***	0.48 (0.10)***	0.72 (0.05)***	0.90 (0.17)***	0.90 (0.02)***
4 R-4	1.76 (0.41)***	0.91 (0.03)***	1.79 (0.34)***	0.84 (0.04)***	0.29 (0.09)**	0.53 (0.08)***	0.66 (0.14)***	0.84 (0.03)***
5 R-5	1.43 (0.32)***	0.87 (0.04)***	2.06 (0.43)***	0.87 (0.04)***	0.39 (0.10)***	0.64 (0.07)***	0.78 (0.16)***	0.88 (0.03)***
6 Y3-1	1.00 (0.00)	0.77 (0.06)***	1.00 (0.00)	0.60 (0.07)***	1.00 (0.00)	0.66 (0.07)***	1.00 (0.00)	0.88 (0.04)***
7 Y3-2	1.24 (0.24)***	0.80 (0.06)***	2.24 (0.59)***	0.82 (0.03)***	1.10 (0.42)**	0.93 (0.05)***	0.69 (0.15)***	0.82 (0.04)***
8 Y3-3	1.00 (0.19)***	0.83 (0.04)***	1.20 (0.27)***	0.73 (0.05)***	0.77 (0.19)***	0.89 (0.05)***	1.12 (0.23)***	0.91 (0.03)***
9 Y3-4	1.76 (0.41)***	0.85 (0.06)***	1.79 (0.34)***	0.92 (0.03)***	0.29 (0.09)**	0.39 (0.06)***	0.66 (0.14)***	0.73 (0.04)***
10 Y3-5	0.60 (0.22)**	0.39 (0.08)***	2.06 (0.43)***	0.93 (0.04)***	0.39 (0.10)***	0.67 (0.07)***	0.78 (0.16)***	0.70 (0.05)***

Note : Pruned paths bolded. Note: ^aPartial strong invariance constraints applied to CP reception and Yr 3. ^bStrong invariance constraints applied to EP reception and Yr 3. ^cPartial strong invariance constraints applied to PP reception and Yr 3. ^dPartial strong invariance constraints applied to PS reception and Yr 3.

Figure 3. Path models of Year 1 language predicting two-wave lagged socio-emotional behavioural problems

Online Supplement S7 : Examination of cases flagged as influential

Analytic Strategy

In addition to existing model fit indices available in the main manuscript, further examination of cases flagged as influential was conducted here. An observed variable approach was utilised here as the WLSMV latent variable approach in the main manuscript is unable to quantify data points of undue influence or large regression residuals. In keeping with the latent variable models in the main manuscript, two sets of regression models were run. This includes (i) the relationship of language to SEB, adjusting for prior SEB and (ii) the relationship of language to SEB with known predictors of sex, NVIQ and SES, adjusting for prior SEB.

Influential case analysis for weighted data can be considered to be an area of ongoing research, with implementation in the R package ‘svydiagnostics’ which we utilise here. Standardised residuals and Cooks D taking into account weights calculated, where values of >3 and >2 respectively (Li & Valliant, 2015; Valliant & Valliant, 2018) were flagged as possible outliers. Linear regressions were calculated in the R package ‘survey’, with weights which adjust for design features and missing data incorporated with the ‘svydesign’ command.

Results

Question 1 : Do influential cases impact the relationship of language to SEB adjusting for prior SEB : Weighted Regression models 1a to 1d

To assist in visualisation of influential cases, Figure 1 plots naïve unweighted scatterplots of Models 1a, 1b, 1c and 1d. These do not account for weights or the additional covariate of prior SDQ score at Reception, which simply cannot be incorporated into a single plot.

Points coloured red have a standardised residual >3 and can be observed to be far away from the naïve quadratic curve plot. This is consistent with high standardised residuals which indicate a large difference between the predicted and observed point.

Points coloured blue have a Cooks $D > 2$, which suggests that these data points when removed will have a particularly strong influence on regression beta estimates. It appears that these points appear in regions where there are a relatively low density of points. This is adjusted for in the main analysis by sample weights, which assign a larger weight to these points. Recall that these naïve plots do not represent these weighted estimates.

Figure 1. Plots of naïve unweighted scatterplots of a) conduct problems, b) emotional problems, c) peer problems and d) prosocial.

Further sensitivity analysis was conducted to consider the impact of removing these flagged cases. As shown in Table 1, flagged cases made up 1.4 to 6.8% of all cases depending on SDQ outcome. After flagged cases were removed, re-estimated emotional and prosocial models were generally free of flagged cases, but these continued to be present in conduct and peer problem models. The significance of the betaweights across all four models were similar (i.e. significant remained significant) before and after the removal of these flagged cases. Change in p-values was minimal as 1 of 9 parameters changed, with the language squared term for the peer problems dropping to a marginal level of $p = .064$.

Table 1. Sensitivity analysis of regression models utilising observed variables with and without influential cases

		Model 1a: Conduct Problems	Model 1b: Emotional Problems	Model 1c: Peer Problems	Model 1d: Prosocial
<i>Multiple regression models</i>					
Predictors (Unstd b, SE, p-value)					
Language composite		-0.13 (0.09) P = .142	-0.40 (0.15) P = .008	-0.26 (0.11) P = .024	0.41 (0.14) P = .004
Language composite squared		0.11 (0.05) P = .037	0.16 (0.10) P = .108	0.20 (0.07) P = .003	-0.21 (0.07) P = .004
Reception Year SDQ		0.45 (0.09) P = .000	0.12 (0.08) P = .105	0.29 (0.08) P = .000	-0.34 (0.06) P = .000
Model (sample sizes)					
model n; weighted n		363; 6489	363; 6489	363; 6489	363; 6489
n. Cooks d >2		14	3	4	4
n. Standardised residuals >+/-3		7	3	4	1

Total n. influential cases		21 (5.8%)	6 (1.7%)	8 (2.2%)	5 (1.4%)
<i>Multiple regression models with influential cases removed</i>					
Predictors (Unstd b, SE, p-value)					
Language composite		-0.10 (0.09) P = .271	-0.36 (0.14) P = .010	-0.22 (0.11) P = .036	0.41(0.14) P = .003
Language composite squared		0.10 (0.05) P = .049	0.12 (0.11) P = .258	0.13 (0.07) P = .064	-0.22 (0.09) P = .014
Reception Year SDQ		0.44 (0.09) P = .000	0.12 (0.08) P = .100	0.28 (0.08) P = .000	-0.34 (0.06) P = .000
Model (Sample sizes)					
Sample n; weighted n		342 ;6196	357; 6333	355; 6327	358 ;6340
n. Cooks d >2		14	0	6	1
n. Standardised residuals >+/-3		5	1	1	0
Total n. influential cases		19 (5.6%)	1 (0.3%)	7 (2.0%)	1 (0.3%)

p = .064

Question 2 : Do influential cases impact the relationship of language to SEB with known predictors of sex, NVIQ and SES, adjusting for prior SEB : Weighted Regression models 2a to 2d

A visual scatterplot such as Figure 1 depicting the unweighted relationship between two variables of language and SDQ outcome could not be provided here, as it is more likely to deviate from the actual regression models due to the substantial increase in number of predictors from 3 to 8.

Table 2 shows sensitivity analysis before and after removal of flagged cases 1.3 to 9.9 % of the sample. The significance of the betaweights across all four models were largely similar (i.e. significant remained significant). 3 out of 9 parameters changed in significance. In the

peer problems model, the (i) language composite squared term dropped to marginal and (ii) the Sex * language squared term became significant. In the prosocial model, the sex term dropped to non-significance. No changes in significance were observed in conduct and emotional problem models.

Table 2. Sensitivity analysis of regression models utilising observed variables with and without influential cases

		Model 2a: Conduct Problems	Model 2b: Emotional Problems	Model 2c: Peer Problems	Model 2d: Prosocial
<i>Multiple regression models</i>					
Unstd b, SE, p-value					
Language composite		-0.07 (0.10) P = .485	-0.38 (0.17) P = .030	-0.09 (0.14) P = .511	0.37 (0.19) P = .059
Language composite squared		0.10 (0.05) P = .055	0.15 (0.08) P = .060	0.18 (0.06) P = .005	-0.20 (0.07) P = .004
Reception Year SDQ		0.43 (0.09) P = .000	0.11 (0.14) P = .140	0.25 (0.07) P = .001	-0.32 (0.06) P = .000
SES		1.36 (0.76) P = .074	1.73 (1.67) P = .302	2.62 (1.26) P = .039	-0.65 (1.71) P = .702
Sex		0.17 (0.18) P = .352	-0.23 (0.33) P = .482	0.15 (0.23) P = .524	-0.71 (0.34) P = .038
NVIQ		0.00 (0.08) P = .982	0.08 (0.13) P = .554	-0.11 (0.11) P = .320	0.01 (0.14) P = .907
Sex * Language		0.20 (0.17) P = .230	-0.13 (0.28) P = .647	-0.30 (0.22) P = .180	-0.07 (0.28) P = .868
Sex * Language sq		-0.10 (0.10) P = .316	0.30 (0.16) P = .061	0.23 (0.13) P = .083	0.15 (0.14) P = .276
Sample sizes					
model n; weighted n		363; 6489	363; 6489	363; 6489	363; 6489

n. Cooks d >2		28	2	6	2
n. Standardised residuals >+/-3		8	3	5	2
Total n. influential cases		36 (9.9%)	5 (1.3%)	11 (3.0%)	4 (1.1%)
<i>Multiple regression models with influential cases removed</i>					
Unstd b, SE, p-value					
Language composite		-0.07 (0.12) P = .546	-0.38 (0.17) P = .036	-0.12 (0.14) P = .371	0.37 (0.19) P = .056
Language composite squared		0.06 (0.06) P = .284	0.17 (0.09) P = .056	0.11 (0.06) P = .060	-0.18 (0.07) P = .014
Reception Year SDQ		0.42 (0.10) P = .000	0.12 (0.08) P = .139	0.23 (0.07) P = .001	-0.31(0.06) P = .000
SES		1.49 (0.77) P = .055	1.70 (1.69) P = .314	2.57 (1.26) P = .042	-0.67 (1.72) P = .696
Sex		0.05 (0.18) P = .781	-0.22 (0.34) P = .510	0.10 (0.22) P = .645	-0.66 (0.35) P = .059
NVIQ		0.0 (0.09) P = .979	0.07 (0.13) P = .567	-0.07 (0.11) P = .543	-0.01 (0.15) P = .960
Sex * Language		0.20 (0.19) P = .279	-0.14 (0.30) P = .639	-0.36 (0.22) P = .103	-0.02 (0.29) P = .939
Sex * Language sq		0.01 (0.10) P = .950	0.29 (0.18) P = .109	0.28 (0.11) P = .014	0.10 (0.14) P = .503
Sample sizes					
Sample n; weighted n		342 ;6196	355 ;6313	355; 6327	358 ;6340
n. Cooks d >2		29	1	9	1
n. Standardised residuals >+/-3		8	3	5	1
Total n. influential cases		35 (10.2%)	4 (1.1%)	14 (3.9%)	2 (0.6%)

Discussion

None of the cases flagged as influential are due to 'implausible' values, as all had valid responses within the boundaries of their measures. SDQ subscale scores were within scores of 0 to 10 while standardised language composite scores were within -3.5 to 2.9 SD. Instead, these 0.6 to 10.2 % of flagged cases represent natural variation which are not well explained by the specified regression model.

The impact of flagged cases was found to be minimal. The significance of language and language interaction terms did not change when flagged cases were removed across SDQ outcomes of conduct, emotional and prosociality. The language x language term was no longer significant when flagged cases were removed in peer problems models. This indicates that the non-linear relationship for observed (as opposed to latent) peer problems is dependent on influential cases, though the significance of these terms remained marginal ($p=.064$; $.060$).

The presence of these flagged cases is consistent with limitations which we discuss in the main manuscript. Language, NVIQ, sex and SES are a limited subset of all predictors of SEB, which are known to be predicted by multiple biological, environmental and psychosocial factors. It is expectable that for some children, these factors may have nothing to do with their poor SEB, flagged as high residuals, which are datapoints very far from that predicted by current regression models. Regression models of observed (as opposed to latent) peer and conduct problems continued to exhibit influential cases, and thus may be less likely to replicate. Flagged as having a Cook's $d > 2$, these influential cases appear in areas of the curve where datapoints are sparse, such as at the ends of the language continuum. This limitation is present despite utilising the largest and most representative cohort of children with multiple language measures to date (weighted $n = 6451$).

Finally, regression models utilised here assume zero measurement error, which in reality can arise from inadvertent errors from participant fatigue, inattention. questionnaire wording. They also assume that SDQ composites have the same ability to measure the construct of SEB, even as children in this cohort undergo developmental changes from Reception to Year 3. These multiple sources of measurement error attenuate regression beta estimates (Muthen, Muthen & Asparouhov, 2016; Gunole et al., 2014), from which residuals and Cooks Ds are based on. In this way, these observed variable regression results are less valid and less reliable than latent variable results of the relationship between language and SEB.

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