Conway L, Levickis P, Smith K, McKean C, Mensah F, Reilly S.

Associations between expressive and receptive language and internalizing and externalizing behaviours in a community-based prospective study of slow-to-talk toddlers.

International Journal of Language and Communication Disorders (2017)
DOI: https://doi.org/10.1111/1460-6984.12320

Associations between expressive and receptive language and internalising and externalising behaviours in a community-based prospective study of slow-to-talk toddlers

Laura J Conway[1,2] BA, Penny A Levickis[1] PhD, Fiona Mensah[1,2,3] PhD , Cristina McKean[5] PhD, Kylie Smith[1,2] BSpPath & Sheena Reilly[1,2,4] PhD

Affiliations

[1]Murdoch Childrens Research Institute, Flemington Road, Parkville, Victoria 3052, Australia

[2]The Department of Paediatrics, University of Melbourne, Parkville, Victoria 3052, Australia

[3]Royal Children's Hospital, Flemington Road, Parkville, Victoria 3052, Australia

[4]Health Executive, Griffith University, Gold Coast, Queensland 4222, Australia

[5]School of Education, Communication and Language Sciences, Newcastle University, King George VI Building, Queen Victoria Road, Newcastle upon Tyne NE1 7RU, UK

Running head: Language and behaviour in slow-to-talk toddlers

Keywords: language, externalising behaviour, internalising behaviour

Author contact details:

Laura Conway: T: +61 3 9936 6041 | F: +61 3 9348 1391| E: laura.conway@mcri.edu.au

Penny Levickis: T: +61 3 8341 6454| F: +61 3 9348 1391| E: penny.levickis@mcri.edu.au

Fiona Mensah: T: +61 3 9345 4741 | F: +61 3 9348 1391| E: fiona.mensah@mcri.edu.au

Cristina McKean: T: 0191 208 6528 |F: 0191 208 6546 | E: cristina.mckean@ncl.ac.uk

Kylie Smith: T: +61 3 8341 6324 | F: +61 3 9348 1391| E: kylie.smith@mcri.edu.au

Sheena Reilly: T: +61 7 5678 0711 | E: s.reilly@griffith.edu.au

Declaration of Interest: The authors declare that there is no conflict of interest.

Abstract

Background: Evidence suggests that language, and social, emotional and behavioural (SEB) difficulties are associated in children and adolescents. When these associations emerge and whether they differ by language or SEB difficulty profile is unclear. This knowledge is crucial to guide prevention and intervention programs for children with language and SEB difficulties.

Aims: This study aims to determine whether receptive and expressive language skills are associated with internalising and externalising behaviours in slow-to-talk toddlers.

Methods & Procedures: In a community-based prospective study of 200 slow-to-talk children, language was measured at 24- and 36-months using *Preschool Language Scale 4th Edition* and at 48-months using *Clinical Evaluation of Language Fundamentals - Preschool 2nd Edition*. Internalising and externalising behaviours were measured by parent-report at each age. Longitudinal data were analysed using repeated measures regression, with up to three observations per child. Robust standard errors were used to account for non-independence of measures within participants. The shape of the associations were examined by fitting quadratic and cubic terms. The effects of confounders on the associations were examined.

Outcomes & Results: Receptive language had a negative *linear* association with internalising behaviours after adjusting for confounders (β = -0.16, 95% [CI -0.26, -0.07], p=.001); and a negative *curved* association with externalising behaviours after adjusting for biological confounders ($\beta_{quadratic}$ = 0.08 [0.01, 0.15], p=.03, β_{cubic} = -0.04 [-0.07, -0.02], p=.001), attenuating after adjusting for environmental confounders ($\beta_{quadratic}$ = 0.06 [-0.01, 0.13], p=.09, β_{cubic} = -0.03 [-0.06, -0.003], p=.03). The curvature suggests that the negative association with externalising behaviours only existed for children with either very low or very high receptive language scores. After controlling for confounders, there was no evidence that expressive language scores were associated with internalising (β = -0.08, 95% [CI -0.17, 0.01], p=.10) or externalising behaviours (β = 0.03, 95% [CI -0.09, 0.18], p=.61). Tests of interaction revealed no evidence of a differential association by age.

Conclusions & Implications: In 24- to 48-months-old slow-to-talk children, lower receptive language scores were associated with higher internalising behaviours. The magnitude of the association was small. For children with very poor receptive language scores, lower receptive language skills were associated with higher externalising behaviours. Young children with low receptive language abilities may be at risk of internalising difficulties; those with very low receptive language skills may be at particular risk of externalising difficulties. This has clinical implications for interventions for young children with receptive language difficulties.

What this paper adds
What is already known on this subject? Language and SEB difficulties are associated in childhood. When the association emerges, whether it differs by language domain or SEB profile, and whether it exists across the language-skills distribution or only at the extremes is unclear.
What this study adds? The association between language and SEB difficulties emerges from 24-months, is stable to 48-months, and differs by profiles. Receptive, not expressive, language skills are independently associated with SEB adjustment. Whilst receptive language is negatively associated with internalising behaviours across its whole distribution of abilities, only receptive language skills at the extremes are associated with externalising behaviours: very poor receptive language skills may be a risk factor for externalising difficulties, while very good skills may be protective.
Clinical implications of this study Clinicians need to be aware that children with low receptive language skills between 2 and 4 years of age and a history of being slow-to-talk may be at risk of SEB difficulties from as young as 2 years. Those with the lowest language skills are of greatest concern for being at risk of externalising difficulties and should be monitored for externalising difficulties. However, low language skills should be considered in the context of other biological and environmental risk factors.

Introduction

Language and social, emotional, and behavioural (SEB) difficulties affect approximately one in five children (Bayer et al., 2012; Reilly et al. 2010), restricting their long-term prospects across academic, employment and interpersonal domains. Language and SEB difficulties have high levels of co-morbidity in samples of clinically-referred children (e.g., St Clair, Pickles, Durkin, & Conti-Ramsden, 2011). Clinical studies however are not ideal to quantify the language-behaviour association in the community: they typically commence after a child has been diagnosed with the difficulty, may over-represent participants with severe impairment, and subsequently may inflate co-morbidity estimates (Plomin, Price, Eley, Dale, & Stevenson, 2002). Prospective population-based studies that commence in infancy or early childhood have the advantage of starting before difficulties emerge, contain the full spectrum of language difficulties from mild to severe, and often collect concurrent information on co-morbidities and confounders (e.g., Whitehouse, Robinson, & Zubrick, 2011; Zubrick, Taylor, Rice, & Slegers, 2007).

There is some evidence that the association between language and SEB difficulties does exist in population samples, evident at school entry and persisting until at least age 11-years (Yew & O'Kearney, 2015a). However, the nature of the association, when it emerges, if it holds across the distribution of language and SEB adjustment scores or only at the extremes, and whether it differs by language and SEB adjustment profiles remains unclear. This is critical information if preventative interventions are to be appropriately targeted in terms of content, timing, and identification of children at risk.

A number of hypotheses attempt to explain the nature of the association between language and behaviour. For example, language and SEB difficulties may co-occur due to common biological (e.g., low birthweight) or environmental risks (e.g., low socio-economic status) that create broad developmental vulnerabilities. Alternatively, because language is a social behaviour, language difficulties may impede positive interactions and lead to withdrawal, frustration or aggression (Cole, Armstrong, & Pemberton, 2010). Alternatively, behaviour difficulties may interfere with language development (Carpenter & Drabick, 2011) by limiting the frequency and quality of interactions, decreasing exposure to rich linguistic input. Finally, the association may be indirect: poor early language development leads to poor academic achievement, which may lead to disengagement with school and subsequent development of social and mental health problems (Beitchman, Brownlie & Wilson, 1996). These hypotheses are not necessarily mutually exclusive, and may differ depending on the language domain or SEB profile. It has been difficult to test these hypotheses within studies to date due to different sample ages, different components of language and SEB adjustment measured, and different confounders examined. Understanding the nature of the association will be helpful for clinicians, parents and teachers in their attempts to help those children effected by both language and SEB difficulties reach their potential.

Regarding when the association between language and SEB difficulties begins, population-based studies that commence early in life offer the best opportunity to detect emerging relations. The age at which language is first measured and analysed in existing population-based studies varies from infancy to primary-school age. The age at which SEB adjustment is measured also varies, with some studies measuring it concurrently with language skills (Rescorla & Achenbach, 2002; Zubrick et al., 2007), others measuring it longitudinally (Clegg, Law, Rush, Peters, & Roulstone, 2015), and a smaller number doing both (Bretherton et al., 2014; Whitehouse et al., 2011). Whilst some studies report no or limited evidence for an association between language and behaviour (Rescorla & Achenbach, 2002; Zubrick et al., 2007), many others report a cross-sectional (Bretherton et al., 2014; Whitehouse et al., 2011) or longitudinal association (Silva et al., 1987; Clegg et al., 2015). A more precise estimate of the age at which the association emerges, and whether it persists longitudinally, would facilitate the timing of intervention strategies.

Most population-based studies, with a few exceptions (e.g., Clegg et al., 2015; Plomin et al., 2002), have defined language or behaviour, or both, as categorical rather than dimensional (e.g., Whitehouse et al., 2011). This has clinical implications because it reduces our ability to determine whether the association holds across the whole distribution of abilities or whether it exists only at the extremes. This knowledge would support the identification of empirically derived cut-points for defining children ‘at risk’ or in contrast, suggest that a gradient model of risk be adopted, whereby decreasing scores are associated with increasing difficulties.

‘Low’ and ‘typical’ language groups have historically been defined at baseline based on scores from one measure, often expressive vocabulary (e.g., Zubrick et al., 2007). SEB scores or the proportion of participants scoring within the clinical range for SEB difficulties, are then typically compared between groups. When groups are predefined in this way, the potential for monitoring associations is reduced. Firstly, grouping based on a single language domain may not accurately represent abilities in other domains. Secondly, since early language skills develop rapidly and fluctuate (Ukoumunne et al., 2012), between-group analysis may conceal heterogeneity in skills within the groups over time, reducing the likelihood of identifying emerging associations.

Finally, in order to target interventions appropriately, clinicians need to know which components of language are associated with which aspects of SEB adjustment. A crucial gap in the literature concerns receptive language which may be a stronger predictor of later language skills than expressive language (e.g. Watt, Wetherby, & Shumway, 2006). Receptive language delays are a clinical indicator for referral (Reilly, McKean, Morgan, & Wake, 2015), and may be indicative of broader underlying cognitive difficulties likely to be related to SEB adjustment (Toppelberg & Shapiro, 2000). Recent population-study findings support this (Bretherton et al., 2014; Clegg, et al., 2015; Girard, Pingault, Doyle, Falissard, & Tremblay, 2016), but differences in sample ages, design (cross-sectional or longitudinal), language and SEB measures, and how language is conceptualised (categorical versus dimensional) limit conclusions for clinical guidelines being drawn.

Similarly, there is a lack of information about whether internalising and externalising behaviours are differentially associated with language. Evidence suggests early internalising and externalising behaviour development follow different pathways (Bayer et al., 2012). Feasibly, different aspects of language and SEB adjustment may be associated (Beitchman et al., 1996), and these associations may change throughout development (St Clair et al., 2011). This is difficult to establish since studies differ in how they measure SEB adjustment. Some use summary scores (e.g., Clegg et al., 2015), whilst others measure specific behaviours such as conduct problems (e.g., Girard et al., 2016).

To address these issues, population-based studies that measure both early receptive and expressive language abilities alongside SEB adjustment at multiple times are needed. This will strengthen the evidence from which to derive clinical recommendations for children with language difficulties.

Aims

This study examines to what extent language skills and SEB adjustment are associated in a population-based prospective study of slow-to-talk toddlers. Specifically, we aim to:

1. Examine (a) whether receptive and expressive language and internalising and externalising behaviours are associated at 24-, 36- and 48-months, and (b) the form of these associations (i.e. linear vs. non-linear);
2. Examine whether these associations vary across the different ages;
3. Examine whether the associations may be explained by biological or environmental confounders.

Methods

Study context

Let's Learn Language is a cluster randomized-controlled trial (NHMRC ##384491) within a population-based language survey (Wake et al., 2011). As there were no outcome differences between intervention and comparison groups, participants are analysed here as a single cohort. Parents of 12-month-olds attending their well-child check-up in three of

Melbourne's local government areas were invited to participate. 1,217 completed the baseline questionnaire. Exclusion criteria included: known developmental delay, major medical condition, suspected autism spectrum disorder, and parents with insufficient English to complete written questionnaires. At 18-months, 93.5% (n=1,138) completed a low-expressive vocabulary screen. Children scoring ≤ 20th percentile based on population norms for the screen (Roy, Kersley & Law, 2005) (n=301, 26.4%) were eligible for the trial. At 48-months, participants were recruited into a subsequent trial, *Language for Learning* (NHMRC #607407) (Wake et al., 2015). Ethical approval was from the Royal Children's Hospital Human Research Ethics Committee (#26028). 202 families gave informed consent to this study. Four children subsequently diagnosed with autism at 3-4 years were excluded from analysis. The magnitude of language-behaviour associations found in previous population-based studies are small. This sample offers a greater opportunity to detect an association in children who might be at the lower end of a language ability 'spectrum' (Roos & Weismer, 2008), and hence be at greater risk of SEB difficulties.

Measures

Primary language measures were standardised continuous receptive and expressive language scores (M=100, SD=15) from face-to-face home assessments using *Preschool Language Scale (PLS-4)* (Zimmerman, Steiner, & Pond, 2002) at 24- and 36-months, and *Clinical Evaluation of Language Fundamentals Preschool Edition (CELF-P2)* (Semel, Wiig, & Secord, 2006) at 48-months. Primary SEB adjustment measures were continuous internalising and externalising behaviour raw scores from parent-completed measures: *Child Behaviour Checklist/1.5-5 (CBCL)* at 24- and 36-months (Achenbach & Rescorla, 2000) and *Strengths and*

Difficulties Questionnaire 2-4 years (SDQ) (Goodman, 2001) at 48-months. The change in measures occurred when participants joined the subsequent trial, Study Name, when they were 48-months old, primarily to harmonise measures between studies. A second study joining *Language for Learning*, *Let's Read* (Goldfeld et al., 2012), was using the SDQ as its outcome measure at age 48-months. Hence the decision was made for *Let's Learn Language* to also use the SDQ at 48-months and at subsequent data collection points as part of *Language for Learning*.

The CBCL comprises 99 statements which the parent rates on a three-point scale. Summed ratings yield an internalising behaviour score (possible range: 0-72) and externalising behaviour score (possible range: 0-48). CBCL raw scores were used rather than T-scores because the wide age-range of the norming sample (1-5 years) might reduce sensitivity to variation in yearly age-bands **(**Bayer, Hiscock, Ukoumunne, Price, & Wake, 2008).

The SDQ comprises 25 statements which the parent rates on a three-point scale, yielding scores on four problem domains: Hyperactivity/Inattention, Conduct Problems, Peer Problems, and Emotional Symptoms. The Hyperactivity/Inattention and Conduct Problem subscales are summed to give an Externalising Behaviour score (possible range 0-20), and the Peer Problems and Emotional Symptoms subscales are summed to give an Internalising Behaviour score (possible range 0-20). Higher scores indicate more problem behaviours. Unlike the CBCL, there are no T-scores for the SDQ. Rather, parent ratings are summed across items to yield domain and summary scores. The summary scores for internalising and externalising behaviours were used in this analyses, modelled as continuous variables. For detailed scoring information see http://www.sdqinfo.com.

Ideally the CBCL would have been used at 48-months because of the larger number of items per composite scale compared to the SDQ. However, because of the harmonisation previously mentioned, the SDQ was used. A collateral benefit of this was the shorter length of the SDQ may have reduced the burden on families participating in this longitudinal study which comprised a large battery of measures. Both CBCL and SDQ yield an internalising and externalising summary score which are used in the analyses here.

Biological and environmental covariates were collected in the baseline questionnaire, identified *a priori* as potential confounders of language and/or SEB difficulties based on theoretical argument (e.g., see Morgan, Farkas, Hillemeier, Hammer & Maczuga, 2015) and previous findings (Clegg et al., 2015; Zubrick et al., 2007). Biological covariates were: gender, gestational age, birthweight (proxy measure of biological risk) and birth-order (first or later born); environmental covariates were: parental education, maternal age at child's birth, household employment (at least one parent employed), non-English-speaking background (NESB), and socioeconomic status measured by the Socioeconomic Indices For Area (SEIFA) disadvantage score (Australian Bureau of Statistics, 2001).

Analyses

To describe the prevalence of language difficulties, low and typical receptive and expressive language groups at 24-, 36- and 48-months were defined using the cut-off $\geq$ 1.25 standard deviations below the mean for standard scores (Reilly et al., 2010). The SDQ borderline cut-point norms were applied to Hyperactivity/Inattention (6-10), Conduct Problems (3-10), Emotional Symptoms (4-10) and Peer Problems (3-10) subscales.

We applied regression models to explore whether language and SEB scores were associated between 24-and 48-months (aim 1a). As noted earlier, various theories explain the language-behaviour association. In order to fit regression models, it was necessary to specify an explanatory and an outcome variable. Given our sample was defined by language skill, we defined language scores as the explanatory variables. However, we acknowledge that the associations described do not imply a directionality whereby language is determining SEB adjustment or vice versa.

Language and SEB scores were examined as continuous variables, standardised to z-scores (mean 0, standard deviation (SD) 1) to facilitate comparability. Regression coefficients therefore represent effect sizes, Cohen's *d*, reflecting the standardised difference between two means (Cohen, 1992). Longitudinal data were analysed using repeated measures regression, with up to three repeated observations per participant (one per wave) (see Vittinghoff, Glidden, Shiboski & McCulloch, 2011). This reduced the number of statistical comparisons and increased the precision of estimates compared to those that would be attained by analysing the data at each wave. We accounted for the within-participant clustering, and subsequent non-independence of the repeated measures within participants, by using robust standard errors. Receptive language and expressive language scores were analysed separately from each other to avoid the collinearity that would be introduced by including them together in a model.

There were a small number of internalising behaviour values which were high (n=3) and indicative of children experiencing a high level of difficulties, as would be expected within a community sample of children. However, to check that these values were not unduly influencing the associations, the analyses were conducted with and without these cases. When the cases were excluded from the analyses, the magnitude of the association between receptive language and internalising behaviour scores was largely unchanged (all cases: β= -0.19 [-0.31, -0.08], $p<.001$; high values excluded: β = -0.15 [-0.23, -0.06], $p=.001$), as was the association between expressive language and internalising behaviour scores (all cases: β = -0.11 [-0.22, -0.01], $p=.034$; high values excluded: β = -0.08 [-0.17, 0.001], $p=.053$). We concluded that the associations between internalising difficulties and language abilities were not driven by the small number of extreme values.

To explore the form (shape) of the associations (aim 1b), a range of models were fitted to the data. This was to determine whether the associations uniformly existed across the full range of language scores (in which case evidence of linear effects would be found), or differentially at the extremes (in which case evidence of curvature would be found). First we examined evidence for linear effects of language, such that a one unit higher language score would be associated with an estimated mean change in SEB score of uniform magnitude across the full range of language scores. Regression models in which language scores were fitted as continuous (assuming a linear effect) were compared to ones where language scores were included as categorical (assuming a non-linear effect) using Wald tests. Non-statistically significant differences between the models were interpreted as there being no evidence supporting a non-linear effect of language on SEB adjustment. Next we examined evidence for specific non-linear effects of language, by fitting quadratic and cubic terms to the regression models alongside the linear term. Statistically significant associations were accepted as evidence for the relevant form of the association (i.e., linear, quadratic or cubic).

To investigate whether the associations between language and SEB adjustment scores varied between 24- and 48-months (aim 2), tests of interaction were conducted. An indicator variable for wave of data collection (1=24-months, 2=36-months, 3=48-months) multiplied by the language explanatory variable was entered to specify the interaction terms. Wald tests compared the regression models containing the interaction terms to models without these terms. Non-statistically significant differences between the models were interpreted as there being no evidence for differences in the associations by wave.

Regarding aim 3, confounders were grouped into biological and environmental exposures. The biological group was added to the best fitting models identified in aim 1, followed by the environmental group to determine whether the associations existed independently of these exposures. A change in beta coefficient, confidence interval, and R-squared was interpreted as evidence of some of the variation in SEB adjustment being explained by the confounders.

Given the multiple comparisons considered, all models were interpreted with caution and by looking for consistent patterns. Analyses were conducted with Stata 13.0 (StataCorp LP, 2013).

Results

Participant characteristics

Sample demographics are presented in table 1. The mean SEIFA score (*M*=1026) indicates the sample was marginally more advantaged than the average Australian population (*M*=1000).

[TABLE 1]

Language and SEB adjustment scores are presented in table 2. At 24-months, 14.7% and 32.8% had low expressive and receptive language respectively, compared to 8.9% and 12.5% at 36-months and 14.4% and 17.4% at 48-months. Histograms revealed that although the sample was selected as being slow-to-talk at 18-months, by 36- and 48-months the spread of language scores included a diversity of abilities expected in a typical population sample, where the mean is 100, SD 15 (figure 1).

[FIGURE 1]

It was not possible to determine the number of participants at 24- and 36-months scoring within the borderline/clinical range for SEB difficulties due to the lack of age-specific cut-points in the CBCL. However, the mean internalising (normal range: 0-72; 24-months *M* 5.4, *SD* 4.6; 36-months *M* 6.3, *SD* 4.9) and externalising scores (normal range: 0-48; 24-months *M* 12.2, *SD* 7.6; 36-months *M* 11.1, *SD* 7.3) were at the lower end of the possible range, indicating very few problem behaviours. It was also not possible to determine the number of participants scoring above the cut-points for internalising and externalising problems at 48-months-old because those cut points were not available for the SDQ (2-4). However, to provide descriptive data regarding the nature of SEB functioning in the sample for the reader, we applied the cut-offs for the SDQ domains at 48-months: 13.0% and 24.6% scored within the borderline/clinical range for

Hyperactivity/Inattention and Conduct Problems respectively, and 23.7% and 17.2% scored within the borderline/clinical range for Emotional Symptoms and Peer Problems. The mean scores for three domains were within the normal range: Emotional Symptoms (normal range: 0-3; *M* 1.6, *SD* 1.6), Hyperactivity/Inattention (normal range: 0-5; *M* 3.2, *SD* 2.2), Peer Problems (normal range: 0-2; *M* 1.2, *SD* 1.4). The mean score for Conduct Problems was slightly elevated (normal range: 0-2; *M* 2.3, *SD* 1.8).

[TABLE 2]

Correlations amongst language and SEB measures are presented in table 3. Receptive language measures were positively correlated over time (r = .59 to .71) as were expressive language measures (r = .40 to .75). Cross-time correlations between internalising behaviour measures (r = .27 to .68) and externalising behaviours (r = .42 to .70) were also positively correlated. Receptive and expressive language measures were correlated (r =.40 to .62), supporting our decision to separate our analyses of receptive and expressive language.

[TABLE 3]

Associations between language domains and SEB adjustment

Aim 1 examined whether receptive and expressive language and internalising and externalising behaviours were associated. In the unadjusted models there was evidence that higher language scores, meaning better skills, were associated with lower SEB adjustment scores, meaning better SEB adjustment with the exception of expressive language skills and externalising behaviour scores (see table 4, model 1). For example, for each standard deviation higher expressive language score, there was an estimated 0.11 standard deviations lower internalising behaviour score; this means better expressive language skills were associated with lower internalising problems (mean difference, β = -0.11, 95% CI [-0.22, -0.01], p = .03). A similar finding occurred between receptive language and internalising behaviours (β = -0.19 [-0.31, -0.08], p =.001), and between receptive language and externalising behaviours ($\beta_{quadratic}$ = 0.07 [0.002, 0.14], p=.04, $_{cubic}$ = -0.04 [-0.07, -0.02], p=.002). No evidence was found for an association between expressive language and externalising behaviour (β = -0.02 [-0.14, 0.10], p = .74).

Shape of the associations between language domains and SEB adjustment

Regarding the form of the associations (aim 1b), Wald tests revealed no evidence of non-linearity when language scores were modelled as categorical in addition to the continuous linear term for any of the associations (e.g., receptive language: internalising behaviours, F (3, 199) = 0.07, p=.98, and externalising behaviours, F (3, 199) = 1.75, p=.16). However, examination of the shape of the associations through fitting cubic and quadratic terms of the language variables in addition to the linear term revealed more nuanced findings. Figure 2 illustrates the form and strength of the best fitting model of each combination of the language-behaviour associations.

The model of receptive language and externalising behaviours supported the use of both a quadratic (β_{linear} = -0.13 [-0.24, -0.02], p = .02, $\beta_{quadratic}$ = 0.09 [0.01, 0.17], p = .03, R^2 = .035) and a cubic term (β_{linear} = -0.01 [-0.16, 0.14], p = .90, β_{cubic} = -0.05 [-0.09, -0.01], p = .02, R^2 = .033) (see supplementary table 4). The final best-fitting (unadjusted) model supported the quadratic and cubic terms together ($\beta_{quadratic}$ = 0.07 [0.002, 0.14], p = .04, β_{cubic} = -0.04 [-0.07, -0.02], p = .002, R^2 = .042). The linear term did not contribute independently to this model.

Figure 2 illustrates the reverse 'S' shape of this association, showing evidence that the strength of the association between receptive language and externalising behaviours varied across receptive language ability. After adjusting for biological confounders this association remained evident ($\beta_{quadratic}$ = 0.08 [0.01, 0.15], p=.03, β_{cubic} = -0.04 [-0.07, -0.02], p=.001), whilst controlling for environmental confounders lead to an attenuation of the quadratic term ($\beta_{quadratic}$ = 0.06 [-0.01, 0.13], p=.09, β_{cubic} = -0.03 [-0.06, -0.003], p=.03) (see table 4, models 2 and 3).

There was no evidence that quadratic or cubic terms were supported by the regression models for the other associations. See supplementary tables 1-4 for details of all forms tested.

[FIGURE 2]

Variability in the language and SEB associations by child age

There was no evidence that the associations between language and SEB adjustment varied across the age range 24- to 48-months (aim 2), evidenced by the statistically non-significant terms for interaction by age that were found for both internalising and externalising behaviours, with receptive and expressive language (see supplementary table 5). This supports the presentation of constant estimates of associations across the ages 24-, 36- and 48-months. For example, there was no significant difference between the associations estimated for mean internalising behaviours and receptive language at wave 3 compared with those at wave 2, or for those at wave 4 compared with those at wave 2 (F (2, 199) = 0.19, p= .83).

Contribution of biological and environmental exposures to the associations

Our third aim examined whether the associations between language and SEB adjustment may be explained by biological or environmental confounders (see models 2 and 3, table 4).

Regarding expressive language and internalising behaviours, the addition of biological exposures to the model (child age, sex, gestation, birthweight, birth order) increased the variance explained from 1.2% to 6.4%, whilst leaving the beta coefficient confidence intervals largely unchanged ($\beta_{unadjusted}$ = -0.11 [-0.22, -0.01], p=.03, R^2 = 1.2; β_{model2} = -0.12 [-0.22, -0.02], p=.02, R^2 = 6.4). Addition of the environmental exposures (treatment group, SEIFA, NESB, parental education, maternal age, parental employment) resulted in the variance explained increasing to 9.2%, and the evidence for the contribution of language scores to the model diminishing (β_{model3} = -0.08 [-0.17, 0.01], p=.10, R^2 = 9.2). This suggests that once environmental confounders were added, expressive language explained little variation in internalising behaviour scores.

In contrast, evidence of the association between receptive language and internalising behaviours remained even after biological (β_{model2} = -0.21 [-0.33, -0.10], p<.001, R^2 = 9.0) and environmental exposures (β_{model3} = -0.16 [-0.26, -0.07], p=.001, R^2 = 11.0) were included in the models. The variance explained in internalising behaviour scores increased from 3.6% in the unadjusted model, to 9.0% in model 2, and 11.0% in model 3.

Finally, evidence for the association between receptive language and externalising behaviours remained after controlling for biological exposures ($\beta_{model2\_quadratic}$ = 0.08 [-0.01, 0.13], p=.03, β_{model2_cubic} = -0.04 [-0.07, -0.02], p=.001, R^2 = 5.7). The associations attenuated slightly after the environmental exposures were also included, although the cubic term remained statistically significant ($\beta_{model3\_quadratic}$ = 0.06 [-0.01, 0.13], p=.09, β_{model3_cubic} = -0.03 [-0.06, -0.003], p=.03, R^2 = 8.8). The variance in externalising behaviour scores explained by receptive language scores was 4.2%, increasing to 5.7% in model 2, and 8.8% in model 3.

Discussion

This paper describes the range of associations between early receptive and expressive language and internalising and externalising behaviours in a prospective population-based sample of slow-to-talk children. Children's receptive language abilities across the distribution were negatively associated with their internalising behaviour scores, meaning poorer receptive language skills were associated with poorer internalising behaviours. On the contrary, receptive language and externalising behaviours were negatively associated only in children with either very good or very poor receptive language scores. However, consistent with previous reports in this area, a very modest amount of variability in internalising and externalising difficulties could be attributed to variability in young children's receptive language abilities. There was no evidence that children's expressive skills were related to their externalising behaviours, nor to internalising behaviours once biological and environmental confounders were considered (aim 1). These patterns were evident from 24-months, and were stable up to 48-months (aim 2).

Our findings suggest that receptive language skills may be integral to the emerging language-behaviour association in the early years in slow-to-talk children. The curved association with externalising behaviours is interesting and, to our knowledge, this is the first study to report the non-linear nature of the association at this age. A negative association with externalising behaviour only existed for children with either very low or very high receptive language scores. Compared to children with mid-range receptive language skills for whom there was little evidence of an association with externalising behaviours, children with the poorest receptive language skills experienced the poorest externalising behaviours and children with the highest receptive language skills seemed to be protected from externalising difficulties.

Very good receptive language skills may protect a child from experiencing the frustration, isolation and confusion related to misunderstanding interactions, whereas very poor receptive language skills may place the child at risk of these experiences. Children with mid-range comprehension may display age-appropriate externalising behaviours. On the graph there appears to be an inflection around 1.5 standard deviations below the mean. We postulate this might approximate to a "comprehension threshold" below which interactions are increasingly problematic for children, leading to problems understanding and predicting their world and triggering externalising behaviours. Alternatively, children scoring below this threshold may be unable to use language for 'self-talk' or to be verbally scaffolded by their parents to regulate their behaviour (Vallotton & Ayoub, 2011). A final interpretation is that assessing receptive language skills in very young children is difficult, and those with externalizing behaviour problems may be particularly challenging to assess. Hence it is not possible to rule out the possibility that the low receptive language scores may reflect measurement difficulty rather than poor receptive language skills per se. The linear association with internalising difficulties warrants a different interpretation. There may be no comprehension threshold below which internalising problems become apparent. Instead, there is a steady worsening of internalising behaviours as receptive language skills decline.

It is important to note that only a small amount of variability in SEB scores was explained by the participants' receptive language abilities in our regression models. An issue we did not consider but which warrants investigation is whether the associations represent a direct contribution of receptive language difficulties to the development of SEB difficulties, or whether, as some have recently speculated (Conti-Ramsden & Durkin, 2015; Yew & O'Kearney, 2015b), they represent an indirect contribution. Yew and O'Kearney (2015b) have argued that language difficulties interact with the predictors of SEB difficulties during development, intensifying the influence of certain risk factors (e.g. hostile parenting, low SES) and neutralising the influence of some protective factors (e.g. child sociability). In this way, language difficulties might *indirectly* contribute to the development of SEB difficulties. This hypothesis may help explain the small amount of variability in SEB outcomes in the current study. The socially and educationally advantaged nature of our sample means that more vulnerable families were under-represented. The absence of vulnerable families, and risk factors associated with SEB difficulties (e.g. low SES, hostile parenting), may have restricted our ability to observe indirect contributions of language difficulties to SEB difficulties. It is equally feasible that the advantaged sample benefited from protective factors that offset the risk posed by language difficulties.

In seeking to understand the nature of the language-behaviour association, we investigated the associations with and without inclusion of biological and environmental confounders to determine whether they might be explained by common risk factors or whether they exist independently (aim 3). Receptive and expressive language skills explained a small amount of variation in SEB scores in the unadjusted models (between 1.2% and 4.2%). They continued to make a unique contribution after controlling for biological confounders (i.e., gender, birthweight, parity). However, once environmental confounders (e.g., SEIFA, parental education and employment) were controlled for, there was no longer evidence that *expressive* language independently predicted internalising behaviours. This suggests the association was explained by environmental factors that present a risk for both poor expressive language and poor internalising behaviours. Children with a history of being slow-to-talk who present clinically with low expressive language between 24- and 48-months may be at risk of internalising difficulties only in the presence of environmental risks. Future research examining whether expressive language difficulties may interact with these biological and environmental risk factors to contribute to the development of SEB difficulties is necessary.

In contrast, receptive language contributed to internalising and externalising behaviours independent of environmental factors, suggesting a more direct association than is the case for expressive language. Nevertheless, the small amount of variation explained supports conclusions from other studies suggesting that a range of biological and environmental factors contribute to SEB difficulties beyond poor language skills (Clegg et al., 2015; Morgan et al., 2015). It may be more appropriate to consider poor language skills at 24- to 48-months as one of many factors which increase the risk of SEB difficulties, rather than a standalone risk. The possibility that there are complex interactions between language difficulties and risk and protective factors for SEB difficulties is a particularly promising area for future research (Conti-Ramsden & Durkin, 2015; Yew & O'Kearney, 2015b). From a clinical perspective this supports the importance of taking histories that capture a range of biological (e.g., birthweight, parity) and environmental risk and protective factors (e.g., maternal age at birth, parental education and employment).

The different patterns between receptive and expressive language scores and internalising and externalising behaviour scores suggest there may be multiple pathways to the associations between language and behaviour. It also highlights the importance of investigating different components of language and behaviour, as they are differentially associated, as previous researchers have hypothesised (e.g., Beitchman et al., 1996; Tomblin, Zhang, Buckwalter, & Catts, 2000). An association between receptive language and behaviour was apparent from 24-months old, much earlier than the school-age association which some have hypothesised is mediated through poor academic achievement (Beitchman et al., 1996). Future research should examine whether emerging literacy changes this association. The early association between expressive language and internalising difficulties identified in the unadjusted but not adjusted model may exist at this age by virtue of common environmental risks. Perhaps low expressive language becomes increasingly problematic as children's environments broaden to include meaningful interactions outside the family. Children's difficulties expressing themselves to peers and teachers may lead to greater frustration, anger and aggression. Or, the association may be more intricate than this, with language difficulties contributing indirectly to SEB difficulties by modifying the effect of risk or protective factors on the development of internalising or externalising behaviour problems. So, whilst we found a stable pattern of associations between 24- and 48-months, the associations may change after starting school, and follow different trajectories. Future research should follow pre-schoolers into their school years to investigate these trajectories, and consider both direct and indirect contributions of language difficulties to SEB difficulties.

This study is not without limitations. The sample only comprised children who were slow-to-talk, defined by their expressive vocabulary scores at 18-months of age. This means that children who scored above the expressive vocabulary cut-point but who may have had other language difficulties, for example, with receptive language, or who developed language difficulties later, and those who had expressive vocabulary skills within normal limits were not included. It would be valuable to compare our findings to those from a sample of children from a typical population not screened for delayed expressive vocabulary. This would also enable examination of the language profiles of children who did not meet the 18-months low expressive vocabulary criteria. Potentially the associations we found in our sample that was representative of 24-month-olds who were slow-to-talk at 18-months may be different in a sample of 24-month olds representative of all language abilities at 18-months. For example, the association between receptive language and SEB adjustment might be greater than we found since children who had receptive but not expressive difficulties at 18-months were not included in our sample. Furthermore, the associations may differ in children with later emerging language difficulties.

However, it is reassuring that only 17.4% and 14.4% of our slow-to-talk sample had low receptive and expressive language respectively at 48-months, similar to the proportion of 48-month-old children in the general population with low language (Reilly et al., 2010). This resolution of early difficulties also echoes a previous study that found nearly 70% of children categorised as ‘late talkers’ at 24-months had typical language skills by 48-months (Reilly et al., 2010). The spread of our sample’s language scores at follow-up suggests the 18-month delays had levelled out, and by 48-months included a diversity that allowed analysis across the entire distribution of abilities expected in a general population of pre-schoolers. Categorising children based on delayed language emergence in the absence of other developmental delays may well be arbitrary. Likewise, the proportion of children meeting borderline/clinical levels on the SDQ subscales at 48-months were similar to what would be expected in a general population (i.e., 80% within normal limits, 10% borderline, 10% clinical).

An additional sample limitation is that families with low SES, who reportedly have a higher incidence of language and SEB difficulties (Kiernan & Mensah, 2009), were under-represented. This means our findings might underestimate the figures that would be seen in a sample that fully represents families experiencing socio-economic disadvantage.

A further limitation is that we did not control for non-verbal IQ in our analyses. Non-verbal IQ has been shown to be associated with SEB difficulties (e.g. Bretherton et al., 2014) and language development (e.g. Botting, 2005). Non-verbal IQ was only measured during the 48-month-old assessment, using the matrices subtest of the Kaufman Brief Intelligence Test (Kaufman & Kaufman, 2004). Participants' mean score was 103.2 (SD 13.0). However, we did not include the 48-month old KBIT scores in our long-form analyses because we felt it was not appropriate to infer that these scores reflected the participants' nonverbal abilities at 24- and 36-months.

However, we were able to examine whether their 48-month-old non-verbal IQ scores contributed to the cross-sectional associations between receptive language and SEB scores. Adjusting for non-verbal IQ made almost no difference to the association between receptive language and externalising behaviour scores ($\beta_{unadjusted}$= -0.48 [-0.98, 0.01], p=.053; compared to $\beta_{adjusted}$ = -0.52 [-1.05, -0.16], p=.057). It did however attenuate the findings between receptive language and internalising behaviours ($\beta_{unadjusted}$ = -0.40 [-0.76, -0.05], p=.027; $\beta_{adjusted}$ = -0.27 [-0.67, 0.10], p=.142.). This indicates that at 48-months-old, nonverbal abilities may contribute to internalising behaviour problems over and above the contribution made by receptive language skills. Whilst it is not possible to generalise these findings to the earlier ages, they do highlight the need for future research to investigate the role played by nonverbal IQ in the emergence of the association between language and SEB difficulties.

At 48-months the language and behaviour measures changed. This was because participants from the original study, Study Name, were invited into a subsequent study when they were 48-months-old, Study Name, which used different measures. Whilst the tools purport to measure the same constructs, we acknowledge the potential for non-equivalence. Changing measures is not without precedent in longitudinal studies (e.g., Clegg et al., 2015; St Clair et al., 2011), particularly when following a cohort from a young age. The cross-time correlations between language measures and between behaviour measures did vary, perhaps as a consequence of instability in the constructs themselves, or due to the equivalence of the measures administered, or perhaps because some problem behaviours, e.g., emotional symptoms, may be more difficult to observe in toddlers than in pre-schoolers.

Despite these limitations, our results provide novel insights into the varied but stable nature of the associations between different language domains and SEB profiles from 24- to 48-months old in children with a history of being slow-to-talk. The particular language and behaviour profiles measured in studies matter. This is important to guide comparisons of existing studies, to inform the design of future studies, and to inform the clinicians and educators who care for children at risk of these difficulties.

This cohort offers the opportunity to monitor whether the associations change as the participants attend school. Future research must monitor the developmental trajectory of the association between receptive language and SEB adjustment into later childhood and adolescence, as well as monitor whether an independent association between expressive language and SEB adjustment emerges. Furthermore, research should model language as one risk factor among many and examine its direct and indirect contribution to SEB difficulties, to inform clinical referral pathways. In addition, understanding whether the associations differ between children whose language difficulties persist and those whose resolve is important for clinical decisions. Finally, it is important to determine whether our findings can be generalised beyond the slow-to-talk population by using a sample representative of the general population.

Summary & Conclusions

Our findings show that young children with very low receptive language scores are at risk of experiencing SEB difficulties, and this risk becomes apparent from as early as 24-months old. Although the direct clinical implications of these findings relate to children whose expressive language was slow to develop at 18-months-old, they should be interpreted cautiously in relation to children in general until replication within a sample representative of the general population is possible. The findings are perhaps most critical for children whose receptive language abilities fall below a certain threshold, beyond which the risk of externalising behaviour difficulties is greatest. For these children it is important that clinicians are aware of the possible need for input from psychologists to address their SEB adjustment.

Acknowledgements

The *Let's Learn Language* Trial and the *Language for Learning* Study were funded by the Australian National Health and Medical Research Council (LLL: NHMRC Strategic Award 384491; L4L: Project Grant 607407). Preparation of this paper was supported by the NHMRC-funded Centre of Research Excellence in Child Language (1023493), an Australian Postgraduate Award (APA) for LC, an NHMRC Practitioner Fellowship for SR (1041892), and an NHMRC Career Development Fellowship for FM. We are indebted to Professor Melissa Wake for her central role as Chief Investigator on both studies. We thank Professor Margot Prior, Dr Emma Sciberras, and Dr Elizabeth Westrupp for their advice. We sincerely thank the participating children and parents, and research assistants for data collection.

Correspondence to: Laura Conway, Murdoch Childrens Research Institute, Parkville, 3052. Email: laura.conway@mcri.edu.au

References

Achenbach, T. M., & Rescorla, L. A. (2000). *Manual for the ASEBA Preschool Forms & Profiles*. Burlington, VT: University of Vermont, Research Center for Children, Youth, & Families.

Australian Bureau of Statistics. (2001). *Socio-economic Indexes for Areas.* Canberra, Australia: Australian Bureau of Statistics.

Bayer, J. K., Ukoumunne, O. C., Mathers, M., Wake, M., Abdi, N., & Hiscock, H. (2012). Development of children's internalising and externalising problems from infancy to five years of age. *Australian and New Zealand Journal of Psychiatry, 46* (7), 659-668. doi:10.1177/0004867412450076

Bayer, J. K., Hiscock, H., Ukoumunne, O. C., Price, A., & Wake, M. (2008). Early childhood aetiology of mental health problems: a longitudinal population-based study. *Journal of Child Psychology and Psychiatry, 49* (11), 1166-1174. doi:10.1111/j.1469-7610.2008.01943.x

Beitchman, J. H., Wilson, B., Brownlie, E. B., Walters, H., Inglis, A., & Lancee, W. (1996). Long-term consistency in speech/language profiles .2. Behavioral, emotional, and social outcomes. *Journal of the American Academy of Child and Adolescent Psychiatry, 35* (6), 815-825. doi:10.1097/00004583-199606000-00022

Botting, N. (2005). Non-verbal cognitive development and language impairment. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 46* (3), 317-326.

Bretherton, L., Prior, M., Bavin, E., Cini, E., Eadie, P., & Reilly, S. (2014). Developing relationships between language and behaviour in preschool children from the early language in Victoria study: Implications for intervention. *Emotional and Behavioural Difficulties, 19* (1), 7-27.

Carpenter, J. L., & Drabick, D. A. (2011). Co-occurrence of linguistic and behavioural difficulties in early childhood: A developmental psychopathology perspective. *Early Child Development and Care, 181* (8), 1021-1045. doi:http://dx.doi.org/10.1080/03004430.2010.509795

Clegg, J., Law, J., Rush, R., Peters, T. J., & Roulstone, S. (2015). The contribution of early language development to children's emotional and behavioural functioning at 6 years: an analysis of data from the Children in Focus sample from the ALSPAC birth cohort. *Journal of Child Psychology and Psychiatry, 56* (1), 67-75. doi:10.1111/jcpp.12281

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*(1), 155-159. doi:10.1037/0033-2909.112.1.155

Conti-Ramsden, G., & Durkin, K. (2015). What factors influence language impairment? Considering resilience as well as risk. *Folia Phoniatrica Et Logopaedica, 67* (6), 293-299.

Cole, P. M., Armstrong, L. M., & Pemberton, C. K. (2010). The role of language in the development of emotion regulation *Child development at the intersection of emotion and cognition* (pp. 59-77). Washington, DC: American Psychological Association; US.

Girard, L.-C., Pingault, J.-B., Doyle, O., Falissard, B., & Tremblay, R. E. (2016). Developmental associations between conduct problems and expressive language in early childhood: A population-based study. *Journal of Abnormal Child Psychology, 44* (6), 1033-1043. doi:http://dx.doi.org/10.1007/s10802-015-0094-8

Goldfeld S., Quach J., Nichols R., Reilly S., Ukomunne O.C., & Wake M (2012). Four-year-old outcomes of a universal infant-toddler shared reading intervention: the Let’s Read trial. *Archives of Pediatrics & Adolescent Medicine. 166* (11), 1045-1052. doi: 10.1001/archpediatrics.2012.1099

Goodman, R. (2001). Psychometric properties of the strengths and difficulties questionnaire. *Journal of the American Academy of Child and Adolescent Psychiatry, 40* (11), 1337-1345. doi:10.1097/00004583-200111000-00015

Kaufman, A. S., & Kaufman, N. L. (2004). *Kaufman Brief Intelligence Test*: Wiley Online Library.

Kiernan, K. E., & Mensah, F. K. (2009). Poverty, maternal depression, family status and children’s cognitive and behavioural development in early childhood: a longitudinal study. *Journal of Social Policy, 38* (4), 569–588.

Manolson, H. A., Ward, B., & Doddington, N. (1995). *You make the difference in helping your child learn*: The Hanen Centre.

Morgan, P. L., Farkas, G., Hillemeier, M. M., Hammer, C. S., & Maczuga, S. (2015). 24-Month-Old Children with Larger Oral Vocabularies Display Greater Academic and Behavioral

Functioning at Kindergarten Entry. *Child Development, 86* (5), 1351-1370. doi:10.1111/cdev.12398

Plomin, R., Price, T. S., Eley, T. C., Dale, P. S., & Stevenson, J. (2002). Associations between behaviour problems and verbal and nonverbal cognitive abilities and disabilities in early childhood. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 43* (5), 619-633. doi:10.1111/1469-7610.00051

Reilly, S., McKean, C., Morgan, A., & Wake, M. (2015). Identifying and managing common childhood language and speech impairments. *British Medical Journal, 350*, 10. doi:10.1136/bmj.h2318

Reilly, S., Wake, M., Ukoumunne, O. C., Bavin, E., Prior, M., Cini, E., Conway, L., Eadie, P., & Bretherton, L. (2010). Predicting language outcomes at 4 years of age: findings from Early Language in Victoria Study. *Pediatrics, 126* (6), e1530-e1537. doi:10.1542/peds.2010-0254

Rescorla, L., & Achenbach, T. M. (2002). Use of the language development survey (LDS) in a national probability sample of children 18 to 35 months old. *Journal of Speech, Language, and Hearing Research, 45* (4), 733-743.

Roos, E. M., & Weismer, S. E. (2008). Language Outcomes of Late Talking Toddlers at Preschool and Beyond. *Perspectives in Language Learning Education, 15* (3), 119-126. doi:10.1044/lle15.3.1

Roy, P., Kersley, H., & Law, J. (2005). The Sure Start Language Measure Standardisation Study. http://tna.europarchive.org/20070101101348/http://www.dfes.gov.uk/research/programmeofresearch/projectinformation.cfm?projectid=14628&resultspage=1

Semel, E., Wiig, E. H., & Secord, W. A. (2006). *The Clinical Evaluation of Language Fundamentals - Preschool, Second Edition (CELF-P2): Australian Standardised Edition*. NSW, Australia: Harcourt Assessment Inc.

Silva, P. A., Williams, S., & McGee, R. (1987). A longitudinal study of children with developmental language delay at age three: later intelligence, reading and behaviour problems. *Developmental Medicine and Child Neurology, 29*, 630-640.

St Clair, M. C., Pickles, A., Durkin, K., & Conti-Ramsden, G. (2011). A longitudinal study of behavioral, emotional and social difficulties in individuals with a history of specific language impairment (SLI). *Journal of Communication Disorders, 44* (2), 186-199. doi:10.1016/j.jcomdis.2010.09.004

Stevenson, J., Richman, N., & Graham, P. (1985). Behaviour problems and language abilities at 3 years and behavioural-deviance at 8 years. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 26* (2), 215-230. doi:10.1111/j.1469-7610.1985.tb02261.x

Tomblin, J. B., Zhang, X., Buckwalter, P., & Catts, H. (2000). The association of reading disability, behavioral disorders, and language impairment among second-grade children. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 41* (4), 473-482.

Toppelberg, C. O., & Shapiro, T. (2000). Language disorders: a 10-year research update review. *Journal of the American Academy of Child and Adolescent Psychiatry, 39* (2), 143-152.

Ukoumunne, O. C., Wake, M., Carlin, J., Bavin, E. L., Lum, J., Skeat, J., Williams, J., Conway, L., Cini, E., & Reilly, S. (2012). Profiles of language development in pre-school children: a longitudinal latent class analysis of data from the Early Language in Victoria Study. *Child: Care Health and Development, 38* (3), 341-349. doi:10.1111/j.1365-2214.2011.01234.x

Vallotton, C., & Ayoub, C. (2011). Use your words: The role of language in the development of toddlers' self-regulation. *Early Childhood Research Quarterly, 26* (2), 169-181. doi:10.1016/j.ecresq.2010.09.002

Vittinghoff, E., Glidden, D.V., Shiboski, S.C., & McCulloch, C.E. (2011). Regression methods in biostatistics: linear, logistic, survival, and repeated measures models. 4th Edition. Springer. doi:10.1007/978-1-4614-1353-0

Wake, M., Levickis, P., Tobin, S., Gold, L., Ukoumunne, O. C., Goldfeld, S., Zens, N., Le, H. N. D., Law, J., & Reilly, S. (2015). Two-Year Outcomes of a Population-Based Intervention for Preschool Language Delay: An RCT. *Pediatrics*, *136*(4), E838-E847. doi:10.1542/peds.2015-1337

Wake, M., Tobin, S., Girolametto, L., Ukoumunne, O. C., Gold, L., Levickis, P., Sheehan, J., Goldfeld, S., & Reilly, S. (2011). Outcomes of population based language promotion for slow to talk toddlers at ages 2 and 3 years: Let's Learn Language cluster randomised controlled trial. *BMJ (Clinical Research Ed.)*, *343*, d4741-d4741. doi:10.1136/bmj.d4741

Watt, N., Wetherby, A., & Shumway, S. (2006). Prelinguistic predictors of language outcome at 3 years of age. *Journal of Speech, Language, and Hearing Research*, *49* (6), 1224-1237. doi:http://dx.doi.org/10.1044/1092-4388%282006/088%29

Whitehouse, A. J. O., Robinson, M., & Zubrick, S. R. (2011). Late talking and the risk for psychosocial problems during childhood and adolescence. *Pediatrics, 128* (2), e324-e332. doi:10.1542/peds.2010-2782

Yew, S. G. K., & O'Kearney, R. (2015a). The Role of Early Language Difficulties in the Trajectories of Conduct Problems across Childhood. *Journal of Abnormal Child Psychology*, *43* (8), 1515-1527. doi:10.1007/s10802-015-0040-9

Yew, S. G. K., & O'Kearney, R. (2015b). Early language impairments and developmental pathways of emotional problems across childhood. *International Journal of Language and Communication Disorders, 50* (3), 358-373.

Zimmerman, I. L., Steiner, V. G., & Pond, R. E. (2002). *The Preschool Language Scale, 4th Edition*: The Psychological Corporation.

Zubrick, S. R., Taylor, C. L., Rice, M. L., & Slegers, D. W. (2007). Late language emergence at 24-months: An epidemiological s tudy of prevalence, predictors, and covariates. *Journal of Speech, Language, and Hearing Research, 50* (6), 1562-1592. doi:10.1044/1092-4388(2007/106)

Table 1: Sample demographics

	n	*n* (%) or *M* (*SD)*
Gender, male	200	104 (52.0)
First-born child	200	74 (37.0)
Full-term gestation (≥37 weeks)	200	179 (89.5)
Birthweight (*g*)	193	3381.5 (616.9)
SEIFA index score of disadvantage [a]	200	1026.0 (53.9)
Maternal age at child age 12-months	200	34.3 (4.5)
NESB 10hrs/week at 12-months	200	19 (9.5)
In intervention arm of trial	200	102 (51.0)
At least one parent in paid work	192	190 (99.0)
Parent education (n=199): Not complete high school		40 (20.1)
Completed high school		65 (32.7)
Completed diploma/tertiary qual/postgrad		94 (47.2)

Table 2: Child language and SEB adjustment scores

Child language scores [b]		*n*	*M* (*SD*)	Low language *n* (%)
Receptive language:	24-months	198	90.4 (14.0)	65 (32.8)
	36-months	193	98.5 (15.1)	24 (12.5)
	48-months	196	94.6 (13.9)	34 (17.4)
Expressive language:	24-months	198	91.5 (12.0)	29 (14.7)
	36-months	192	100.9 (14.5)	17 (8.9)
	48-months	195	97.5 (14.3)	28 (14.4)
SEB adjustment		*n*	*M* (*SD*)	
Externalising Behaviours: [c]	24-months	191	12.2 (7.6)	
	36-months	192	11.1 (7.3)	
	48-months	190	5.5 (3.5)	
Internalising Behaviours: [d]	24-months	191	5.4 (4.6)	
	36-months	192	6.3 (4.9)	
	48-months	192	2.8 (2.5)	
				Borderline *n* (%)[e]
SDQ subscales:	Hyperactivity/inattention	193	3.2 (2.2)	25 (13.0)
	Conduct problems	191	2.3 (1.8)	47 (24.6)
	Peer problems	192	1.2 (1.4)	33 (17.2)
	Emotional symptoms	194	1.6 (1.6)	46 (23.7)

Note. SEIFA = Socio-Economic Index for Areas, NESB = Non-English-Speaking Background (child exposed to non-English language >10hrs/week), SEB = Social, emotional & behavioural adjustment score, SDQ = Strengths & Difficulties Questionnaire

[a] SEIFA: M (1000), SD (100), higher scores indicate less disadvantage; [b] PLS-4 at 24- & 36-months, CELF-P2 at 48-months; [c] CBCL at 24- & 36-months: Externalising = Aggressive Behaviours & Attention Problem; SDQ at 48-months: Externalising = Hyperactivity & Conduct Problems; [d] CBCL Internalising = Withdrawn, Anxious/depressed, Somatic Complaints, Emotionally Reactive subscales; SDQ Internalising = Peer Problems & Emotional Symptoms

[e] Cut-points for normal and borderline/clinical are: Hyperactivity-inattention 0-5, 6-10; Conduct problems 0-2, 3-10; Peer problems 0-2, 3-10; Emotional symptoms 0-3, 4-10.

Table 3: Correlation matrix of language and SEB measures

Measure **Correlation** p-value	1:	2:	3:	4:	5:	6:	7:	8:	9:	10:	11:
1. 24m Receptive											
2. 24m Expressive	**.62**										
	<.001										
3. 36m Receptive	**.67**	**.51**									
	<.001	<.001									
4. 36m Expressive	**.62**	**.55**	**.79**								
	<.001	<.001	<.001								
5. 48m Receptive	**.59**	**.41**	**.71**	**.68**							
	<.001	<.001	<.001	<.001							
6. 48m Expressive	**.50**	**.40**	**.66**	**.75**	**.74**						
	<.001	<.001	<.001	<.001	<.001						
7. 24m Internalising	**-.19**	**-.10**	**-.22**	**-.14**	**-.17**	**-.17**					
	.01	.17	.003	.06	.02	.02					
8. 24m Externalising	**-.09**	**.05**	**-.13**	**-.01**	**-.08**	**-.06**	**.65**				
	.20	.46	.08	.85	.27	.41	<.001				
9. 36m Internalising	**-.11**	**-.08**	**-.22**	**-.13**	**-.18**	**-.13**	**.68**	**.49**			
	.12	.26	.002	.09	.02	.08	<.001	<.001			
10. 36m Externalising	**-.15**	**-.06**	**-.20**	**-.07**	**-.13**	**-.04**	**.45**	**.70**	**.56**		
	.03	.42	.01	.36	.08	.58	<.001	<.001	<.001		
11. 48m Internalising	**-.13**	**-.07**	**-.14**	**-.13**	**-.16**	**-.11**	**.27**	**.15**	**.48**	**.21**	
	.08	.34	.06	.08	.03	.15	<.001	.04	<.001	.004	
12. 48m Externalising	**-.23**	**-.11**	**-.26**	**-.16**	**-.14**	**-.05**	**.17**	**.42**	**.23**	**.55**	**.31**

	.001	.14	<.001	.03	.06	.46	.02	<.001	.002	<.001	<.001

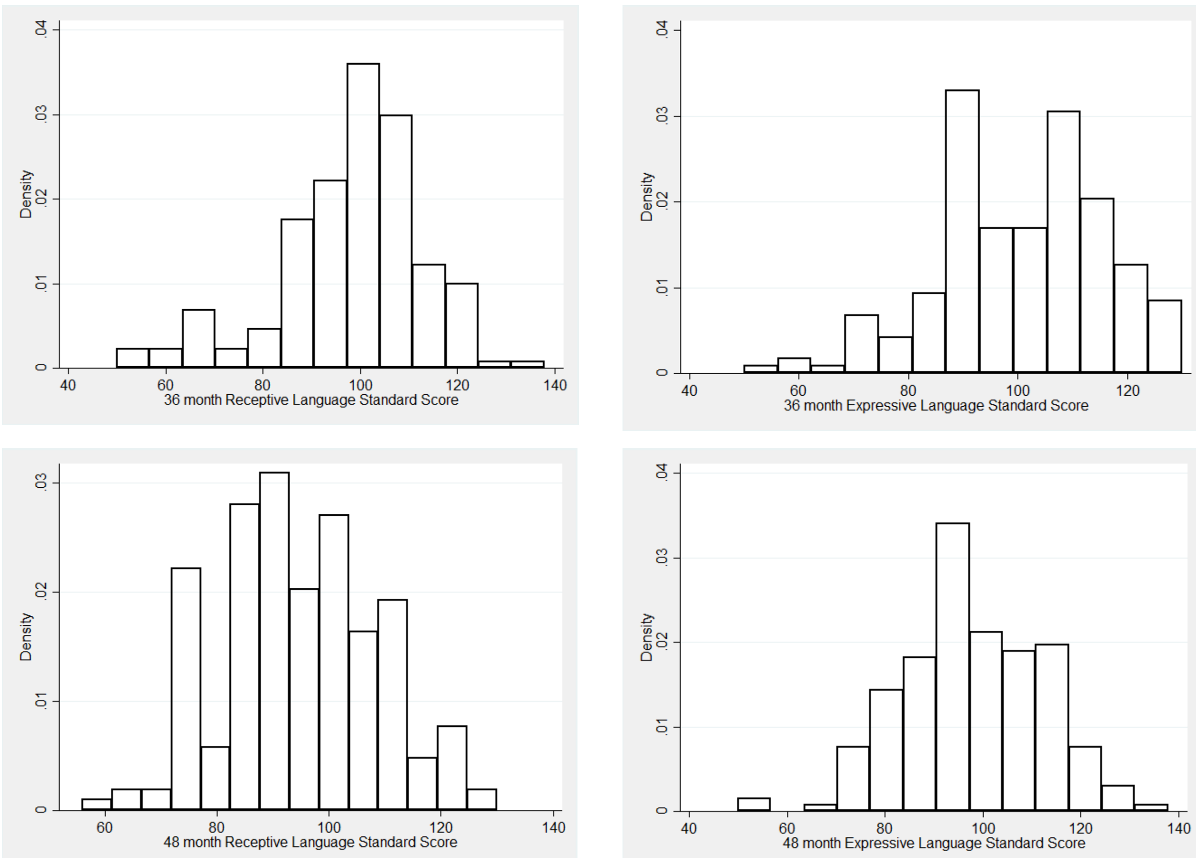
1: 24m Receptive language standard score (SS) (PLS-4); 2: 24m Expressive language SS (PLS-4); 3: 36m Receptive language SS (PLS-4); 4: 36m Expressive language SS (PLS-4); 5: 48m Receptive language SS (CELF-P2); 6: 48m Expressive language SS (CELF-P2); 7: 24m Internalising behaviour score (CBCL); 8: 24m Externalising behaviour score (CBCL); 9: 36m Internalising behaviour score (CBCL); 10: 36m Externalising behaviour score (CBCL); 11: 48m Internalising behaviour score (SDQ); 12: 48m Externalising behaviour score (SDQ)

Table 4: Associations between receptive and expressive language and internalising and externalising behaviours

Language domain [a]	SEB adjustment [b]	Model 1: Unadjusted				Model 2:Adjusted [c]			Model 3: Adjusted [d]		
		β [95% CI] [g]	p	R^2	Inter *p*	β [95% CI]	p	R^2	β [95% CI]	p	R^2
Expressive	Internalising	-0.11 [-0.22, -0.01]	.03	1.2	.92	-0.12 [-0.22, -0.02]	.02	6.4	-0.08 [-0.17, 0.01]	.10	9.2
Expressive	Externalising	-0.02 [-0.14, 0.10]	.74	0.00	.26	-0.03 [-0.15, 0.10]	.69	1.3	0.03 [-0.09, 0.18]	.61	7.1
Receptive	Internalising	-0.19 [-0.31, -0.08]	.001	3.6	.83	-0.21 [-0.33, -0.10]	<.001	9.0	-0.16 [-0.26, -0.07]	.001	11.0
Receptive	Externalising				.45			5.7			8.8
	Quadratic	0.07 [0.002, 0.14]	.04	4.2		0.08 [0.01, 0.15]	.03		0.06 [-0.01, 0.13]	.09	
	Cubic	-0.04 [-0.07, -0.02]	.002	4.2		-0.04 [-0.07, -0.02]	.001		-0.03 [-0.06, -0.003]	.03	

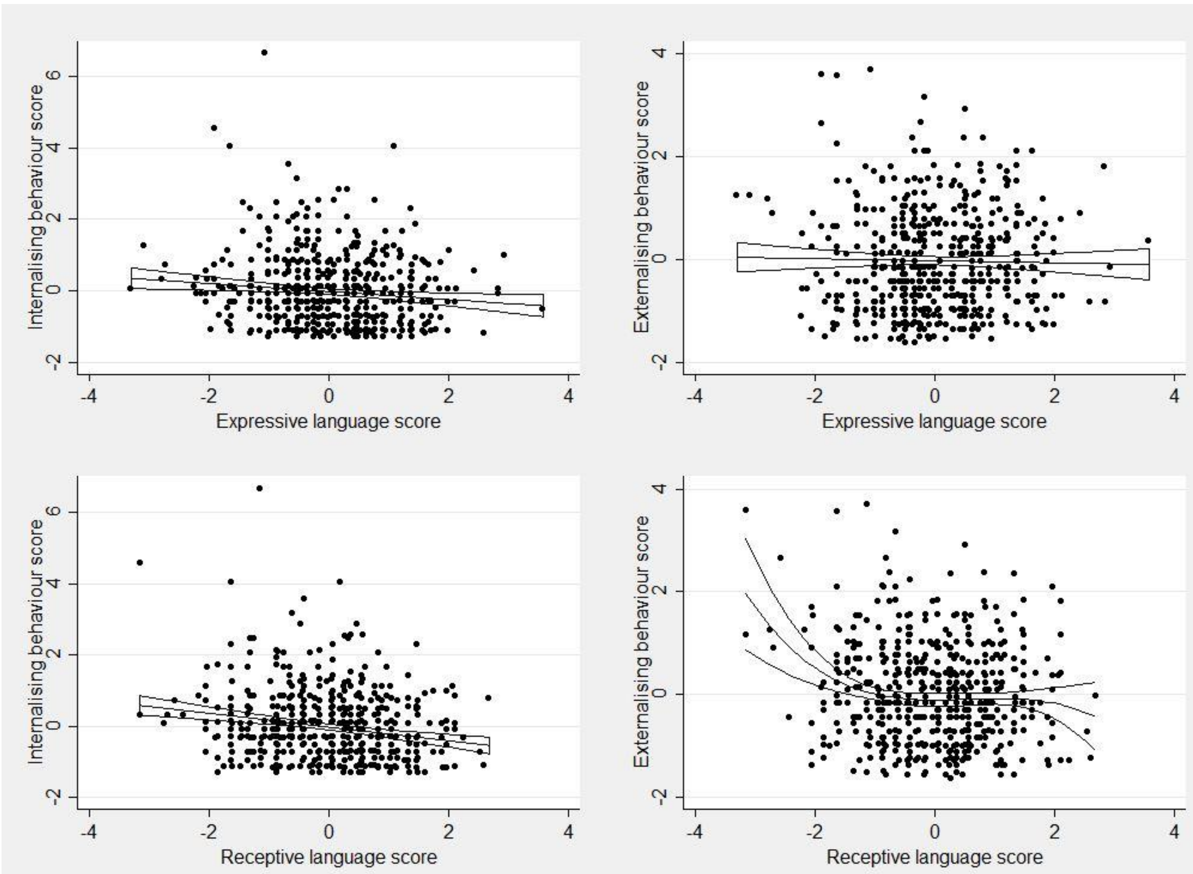
Note. CI = confidence interval, SEB = Social, emotional and behavioural adjustment score, R^2 = percentage, Inter p = p-value for test for interaction by age. **[a]** PLS-4 at 24- & 36-months, CELF-P2 at 48-months; **[b]** CBCL at 24- & 36-months, SDQ at 48-months; **[c]** Adjusted for biological exposures: child age, gender, gestation, birthweight, birth-order; **[d]** Adjusted for biological and environmental exposures: child age, sex, gestation, birthweight, birth-order, treatment group, SEIFA, NESB, parental education, maternal age, parental employment; **[g]** Interpret coefficients as effect sizes with the exception of the coefficients for the curved association between receptive language and externalising behaviour.

Figure 1: Distribution of receptive and expressive language standard scores at 36- and 48-months in a sample of slow-to-talk toddlers, n=193-196



Note: PLS-4 at 24- & 36-months, CELF-P2 at 48-months; Typical population mean for PLS-4 and CELF-P2 is 100, SD 15.

Figure 2: Associations between receptive and expressive language (z-scores) and internalising and externalising behaviours (z-scores) between 24- and 48-months in a sample of slow-to-talk toddlers



Note: PLS-4 & CBCL at 24- & 36-months, CELF-P2 & SDQ at 48-months

Supplementary Tables

Supplementary Table 1: Expressive Language and Internalising Behaviour: Regression Models Fitted

Model	Language modelled as:	β [95% CI]	p	Model	Language modelled as:	β [95% CI]	p
1.	Linear	-.11 [-.22, -.01]	.03	4.	Linear	-.13 [-.28, -.02]	.10
2.[a]	Linear	-.10 [-.28, .08]	.27		Cubic	.005 [-.02, .03]	.67
	Categorical_2	-.15 [-.46, .16]	.34	5.	Linear	-.13 [-.28, .03]	.10
	Categorical_3	-.19 [-.58, .21]	.35		Quadratic	.03 [-.01, .08]	.14
	Categorical_4	-.02 [-.57, .52]	.94		Cubic	.004 [-.02, .03]	.74
	Categorical_constant	.06 [-.25, .38]	.70	6.	Quadratic	N/A	
3.	Linear	-.12 [-.22, -.01]	.03		Cubic	N/A	
	Quadratic	.03 [-.01, .08]	.13				

Models: 1. Linear, 2. Linear & non-linear, 3.Linear & quadratic, 4. Linear & cubic, 5. Linear, quadratic & cubic, 6. Quadratic & cubic

[a]Wald – Linearity test F(3, 199) = 1.06, p=.37

Supplementary Table 2: Expressive Language and Externalising Behaviours: Regression Models Fitted

Model	Language modelled as:	β [95% CI]	p	Model	Language modelled as:	β [95% CI]	p
1.	Linear	-.02 [-.14, .10]	.74	4.	Linear	-.04 [-.11, .19]	.63
2.[a]	Linear	-.17 [-.39, .05]	.14		Cubic	-.02 [-.05, .01]	.26
	Categorical_2	.12 [-.16, .40]	.39	5.	Linear	.04 [-.11, .18]	.63
	Categorical_3	.10 [-.25, .46]	.56		Quadratic	.05 [-.01, .11]	.08
	Categorical_4	.47 [-.05, .99]	.08		Cubic	-.02 [-.04, .004]	.11
	Categorical_constant	-.20 [-.47, .08]	.16	6.	Quadratic	N/A	
3.	Linear	-.02 [-.14, .09]	.68		Cubic	N/A	
	Quadratic	.05 [-.01, .11]	.12				

Models: 1. Linear, 2. Linear & non-linear, 3.Linear & quadratic, 4. Linear & cubic, 5. Linear, quadratic & cubic, 6. Quadratic & cubic

[a]Wald – Linearity test $F(3, 199) = 1.99$, $p=.12$

Supplementary Table 3: Receptive Language and Internalising Behaviours: Regression Models Fitted

Model	Language modelled as:	β [95% CI]	p	Model	Language modelled as:	β [95% CI]	p
1.	Linear	-.19 [-.31, -.08]	.001	4.	Linear	-.15 [-.31, .001]	.051
2.[a]	Linear	-.16 [-.43, .11]	.24		Cubic	-.01 [-.07, .04]	.63
	Categorical_2	-.07 [-.35, .22]	.65	5.	Linear	-.17 [-.32, -.01]	.03
	Categorical_3	-.08 [-.49, .34]	.72		Quadratic	.04 [-.03, .11]	.25
	Categorical_4	-.10 [-.70, .51]	.75		Cubic	-.01 [-.06, .04]	.76
	Categorical_constant	-.04 [-.25, .32]	.81	6.	Quadratic	N/A	
3.	Linear	-.19 [-.29, -.08]	.001		Cubic	N/A	
	Quadratic	.04 [-.04, .13]	.27				

Models: 1. Linear, 2. Linear & non-linear, 3.Linear & quadratic, 4. Linear & cubic, 5. Linear, quadratic & cubic, 6. Quadratic & cubic

[a]Wald – Linearity test $F(3, 199) = .07$, $p=.98$

Supplementary Table 4: Receptive language and Externalising Behaviours: Regression Models Fitted

Model	Language modelled as:	β [95% CI]	p	Model	Language modelled as:	β [95% CI]	p
1.	Linear	-.14 [-.26, -.02]	.02	4.	Linear	-.01 [-.16, .14]	.90
2.[a]	Linear	-.29 [-.56, -.01]	.04		Cubic	-.05 [-.09, -.01]	.02
	Categorical_2	.02 [-.30, .34]	.90	5.	Linear	-.03 [-.18, .12]	.67
	Categorical_3	.09 [-.38, .56]	.71		Quadratic	.07 [.003, .14]	.04
	Categorical_4	.44 [-.23, 1.1]	.20		Cubic	-.04 [-.07, .0003]	.05
	Categorical_constant	-.16 [-.51, .19]	.38	6.	Quadratic	.07 [.002, .14]	.04
3.	Linear	-.13 [-.24, -.02]	.02		Cubic	-.04 [-.07, -.02]	.002
	Quadratic	.09 [.01, .17]	.03				

Models: 1. Linear, 2. Linear & non-linear, 3.Linear & quadratic, 4. Linear & cubic, 5. Linear, quadratic & cubic, 6. Quadratic & cubic

[a]Wald – Linearity test $F(3, 199) = 1.75$, $p=.16$

Supplementary Table 5: Variability in language and SEB associations by child age: Tests of interaction by wave

Language domain [a]	SEB adjustment [b]		Interaction term	β [95% CI]	p	Combined Wald test across interaction terms
Expressive	Internalising		Wave2*Expressive	-.03 [-.18, .12]	.72	*F* (2, 199) = .08, p= .92
			Wave3*Expressive	-.005 [-.20, .19]	.96	
Expressive	Externalising		Wave2*Expressive	-.12 [-.27, .03]	.12	*F* (2, 199) = 1.36, p= .26
			Wave3*Expressive	-.11 [-.28, .07]	.23	
Receptive	Internalising		Wave2*Receptive	-.03 [-.19, .13]	.72	*F* (2, 199) = .19, p= .83
			Wave3*Receptive	.03 [-.16, .23]	.72	
Receptive	Externalising	*Quadratic*	Wave2*Receptive	-.09 [-.25, .08]	.29	*F* (4, 199) = .93, p=.45
			Wave3*Receptive	-.05 [-.22, .13]	.60	
		Cubic	Wave2*Receptive	-.03 [-.09, .04]	.41	
			Wave3*Receptive	-.03 [-.10, .04]	.41	

Note: Reference group is Wave 1, 24-months. Wave2 is 36-months; Wave3 is 48-months. CI = confidence interval, SEB = Social, emotional and behavioural adjustment score, R^2 = percentage. **[a]** PLS-4 at 24- & 36-months, CELF-P2 at 48-months; **[b]** CBCL at 24- & 36-months, SDQ at 48-months