

Predictors in Infancy for Language and Academic Outcomes at 11 Years

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abstract

OBJECTIVES: To examine the contribution of early life factors and preschool- and school-aged language abilities to children's 11-year language and academic outcomes.

METHODS: Participants ($N = 839$) were from a prospective community cohort study of 1910 infants recruited at 8 to 10 months of age. Early life factors included a combination of child (prematurity, birth weight), family (socioeconomic disadvantage, family history of language difficulties), and maternal factors (education, vocabulary, and age). Language (standardized assessment of receptive and expressive skills) and academic (national assessment) outcomes at 11 years were predicted by using a series of multivariable regression models.

RESULTS: Early life factors explained 11% to 12% of variance in language scores at 11 years. The variance explained increased to 47% to 64% when language scores from 2 to 7 years were included. The largest increase in variance explained was with 4-year language scores. The same early life factors explained 13% to 14% of academic scores at 11 years, with increases to 43% to 54% when language scores from 2 to 11 years were included. Early life factors adequately discriminated between children with typical and low language scores but were much better discriminators of children with typical and low academic scores. When earlier language scores were added to models then the area under the curve increased to 0.9 and above.

CONCLUSIONS: Children's language outcomes at 11 years are accurately predicted by their 4-year language ability and their academic outcomes at 11 years are predicted by early family and home environment factors. Children with low language abilities at 11 years consistently performed more poorly on national assessments of literacy and numeracy.



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WHAT'S KNOWN ON THIS SUBJECT: Low language abilities can be partly explained by child, family, and environmental factors. However, earlier language achievement is a better predictor. Fluctuations in language abilities are common in young children, creating challenges for accurate early identification and provision of intervention.

WHAT THIS STUDY ADDS: Language ability at 4 years was the best predictor of 11-year language outcomes, and 4 years was the best age to discriminate between typical and low language abilities. Early family and home factors best predicted academic outcomes at 11 years.

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Children's early language abilities are widely accepted to be foundational to preschool learning and longer-term academic achievement.^{1,2} Delays in early language development are common,^{3,4} yet some children appear to resolve their difficulties early whereas others go on to have persistent difficulties.^{5,6} Predicting which children are most likely to have persistent language and academic difficulties⁷ has the potential for early targeted intervention to reduce poorer long-term outcomes. The relative influence of biological³ and environmental factors⁸ changes over time; however, whether this continues or stabilizes beyond 7 years is unknown. Understanding whether children's earlier language skills continue to explain larger proportions of variance in language and academic outcomes compared to other risk factors is required. Knowing the optimal time(s) to assess children's language to accurately identify and predict those most likely to experience persistent language and academic difficulties and provide intervention is critical. Yet it is not clear if there is a single time point, or a combination, in the preschool and early school years that optimizes prediction of later difficulties. Better understanding the influence of predictors is a clinical and educational imperative, particularly given the well-documented poorer social, occupational, and economic lifelong outcomes of adults with persistent developmental language disorders.^{9,10}

The US Preventive Services Task Force¹¹ and a systematic review a decade later¹² concluded there was inadequate evidence to recommend primary preventive screening for speech and language delay. Testing for "cumulative risk" by using a set of theoretically grounded risk factors for language outcomes, although constructive, resulted in small proportions of the variance in

outcomes being explained.^{8,13} Individual variability in language development in early childhood and the instability in language outcomes from birth to 7 years^{5,8} make screening, diagnostic, and early intervention decisions difficult in all but the most severe cases.

Previous longitudinal studies have tracked the language skills of preschool-aged children through completion of school and beyond,^{2,14} but few have community-based samples of children with repeated assessments beginning in the first year. Consequently, they are unable to address longitudinal questions about early identification of language difficulties. Drawing on a longitudinal community cohort, in which language was assessed at multiple points in the preschool and early school years, our objective was to build clinically applicable evidence for the best age at which to assess and most accurately identify children who are likely to experience persistent language difficulties. We used a biodevelopmental framework¹⁵ to inform and investigate the effectiveness of early life risk factors and language abilities at 2, 4, 5, and 7 years to predict language and academic skills at 11 years. Three sets of factors were identified from previous systematic reviews to have proven associations with language outcomes: child (ie, sex, perinatal, twin and preterm birth, and birth order), family (ie, non-English-speaking background [NESB], socioeconomic status [SES], family history of speech and/or language difficulties), and maternal factors (ie, education, mental health, vocabulary, and age).^{2,4,12} These factors were used in previous reports at 2, 4, and 7 years.^{3,8,13} Understanding children's longitudinal developmental trajectories continues to be challenging. Whether the same child, family, and environmental factors impact language ability equally in

middle childhood as in preschool remains a largely open question.

Our aims were to (1) present academic outcomes for groups of children with typical language skills and those with low language outcomes at 11 years, (2) determine how accurately a set of early risk factors predict 11-year language and academic outcomes, and (3) determine if prediction is more accurate when language abilities measured at 2, 4, 5, and 7 years are considered alongside the early risk factors.

METHODS

Sampling and Participants

The Early Language in Victoria Study (ELVS) commenced in 2002, recruiting a community representative cohort of 1910 infants aged 7.5 to 10 months from 6 local government areas in metropolitan Melbourne, Victoria, representing the spectrum of SES according to an Australian Index of Disadvantage (Socio-Economic Indexes for Areas [SEIFA]).¹⁶ Further study protocols are reported elsewhere.¹⁷

Reported in this study are the "in-scope" 839 children from the ELVS cohort who completed (1) 11-year data collection, (2) language assessments at 2, 4, 5, and 7 years, and (3) the National Assessment Program – Literacy and Numeracy (NAPLAN) tests at any or all of the following year levels at school: grades 3, 5, and 7, on average approximately ages 8, 10, and 12 years. Participant numbers at each data collection point, illustrating attrition across the study, are detailed in Figure 1.

Measures

Risk Factors

Twelve risk factors associated with language development^{11,12} were collected at 8 to 10 months as described in previous reports of this cohort at 2, 4, and 7 years.¹⁷ The risk

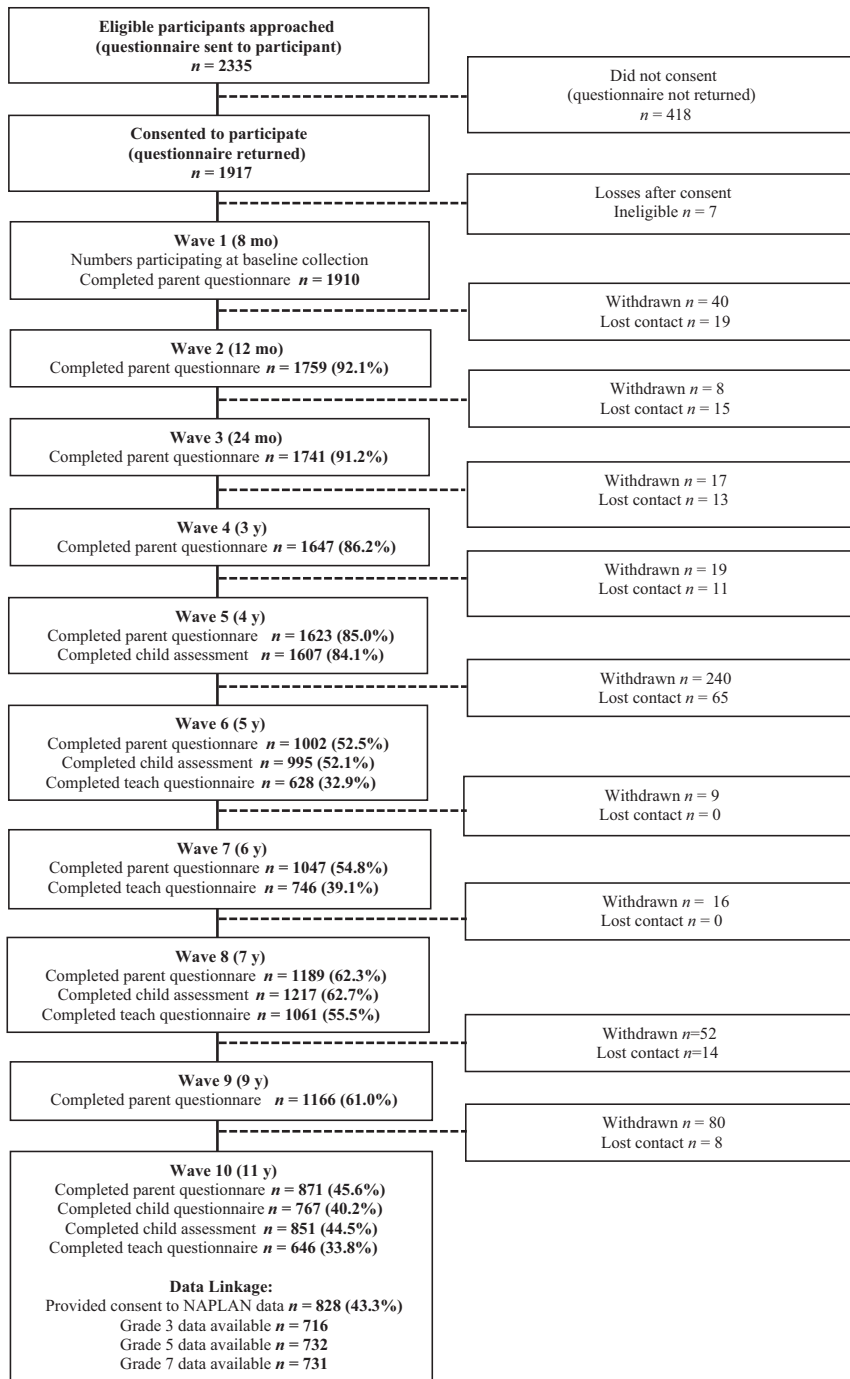


FIGURE 1 Participant flowchart from baseline (8 months) to 11 years (denominator for percentages is number participating at baseline [*N* = 1910]). Numbers vary at each wave because of participants' withdrawing, losing contact, or not participating in a particular wave but returning at a later stage.

factors included a range of sociodemographic variables related to the child (sex, twin birth, preterm birth, birth order, birth weight), mother (age, mental health, education, vocabulary), and family

(NESB, history of speech and language difficulties, SES).

Maternal mental health was determined by using the Kessler Psychological Distress Scale.¹⁸ Scores

were defined as below 4 ("no mental health problem") and 4 to 24 ("likely mental health problem"). Maternal vocabulary was measured by using the Mill Hill Vocabulary Scale¹⁹ with a possible maximum score of 44. Families who reported a main language other than English spoken to the child at home were classified as NESB. SES was measured by using the population standardized SEIFA Index of Relative Socio-economic Disadvantage (mean = 1000; SD = 100).¹⁶

Language Measures

When children were 2 years old, parents completed the MacArthur-Bates Communicative Development Inventory: Words and Sentences, adapted (with permission) for Australia.²⁰ Late talking was defined by standardized scores below the 10th percentile. At 4 years, children completed the Clinical Evaluation of Language Fundamentals (CELF) Preschool, Second Edition, Australian Standardization,²¹ and at 5 and 7 years, they completed the Clinical Evaluation of Language Fundamentals Preschool, Fourth Edition (CELF-4).²² The CELF yields receptive and expressive language scores with a mean of 100 and an SD of 15.

Academic Skills

Academic ability was measured by using data from the Australian NAPLAN. NAPLAN is a set of basic skills tests administered annually to students in grades 3, 5, 7, and 9 across all Australian jurisdictions. NAPLAN is designed to assess students' skills in reading, writing, numeracy, and language, namely, spelling, grammar, and punctuation. NAPLAN tests are mandated national assessments with scores ranging from 0 to 1000. We report on outcomes for the 5 domains of NAPLAN: reading, spelling, grammar and punctuation, writing, and numeracy. Victorian State means and SD were used as reference points.

TABLE 1 Characteristics at Baseline of Participants and Nonparticipants at 11 Years

Baseline and Characteristics ^a	Nonparticipants at 11 y (n = 1071)	Participants at 11 y (n = 839)	P
Female, %	496 (46.3)	449 (53.5)	<.01
Twin birth, %	35 (3.3)	18 (2.2)	.14
Preterm birth (<36 wk' gestation), %	30 (2.8)	29 (3.5)	.41
Birth wt (kg), mean ± SD	3.4 (0.5)	3.4 (0.5)	.56
Birth order, %			
First	531 (49.9)	422 (50.4)	.53
Second	379 (35.6)	293 (34.9)	
Third	121 (11.4)	105 (12.5)	
Fourth or later	33 (3.1)	18 (2.2)	
NESB, %	100 (9.3)	26 (3.1)	<.01
Maternal education level, % years of completed schooling			
≤12 y	287 (26.9)	160 (19.1)	<.01
13 y	444 (41.6)	321 (38.4)	
Degree or postgraduate	337 (31.5)	356 (42.5)	
SES SEIFA score, mean ± SD	1029.7 (65.1)	1044.2 (53.6)	<.01
Family history of speech and/or language difficulties, %	273 (25.5)	202 (24.1)	.48
Maternal mental health symptoms (Kessler), %	295 (31.8)	260 (31.6)	.93
Maternal vocabulary score (Mill Hill), mean ± SD	26.5 (5.3)	28.7 (4.6)	<.01
Maternal age at baseline, mean ± SD	31.3 (4.7)	32.5 (4.2)	<.01

Participants completed direct assessment of both receptive and expressive language at 11 years. The mean ± SD for child age at 11-year assessment is 11.29 ± 0.23 years. *P* values were derived through comparisons between those completing 11-year assessment and those lost to follow-up by using either χ^2 tests for categorical variables or *t* tests for continuous variables.

^a Baseline represents data collected at 8–10 and 12 mo.

Outcomes

The outcomes of interest at 11 years were children's language and academic skills. Language skills at 11 years were measured by using the CELF-4. Low language was determined when either receptive or expressive standard scores were ≥ 1.25 SDs below the mean (ie, ≤ 81 standard score). This is consistent with previous reports and with other analyses completed with the ELVS cohort.^{7,8}

The academic outcomes of interest were grade 7 NAPLAN scores for reading and for grammar and punctuation. Low academic ability was determined by scale scores that were ≥ 1.25 SDs below the Victorian State mean.

Analyses

Correlations between predictor variables are reported and considered with respect to stability of language over time. Academic outcomes are reported separately for the children with typical language and those with low language scores at 11 years. The NAPLAN scores of each group were

estimated with 95% confidence intervals (CIs) at grades 3, 5, and 7, and proportions were compared by using univariable logistic regression (aim 1).

To determine how accurately the 12 risk factors predicted 11-year language and academic outcomes, multivariable linear regressions were completed with CELF-4 language scores and NAPLAN scores (aim 2). These linear regressions enabled us to look at the influence of predictors across the full spectrum of language abilities. Multivariable logistic regressions were fitted for children with a low language or academic outcome to determine if the influence of the predictors was stronger or weaker for children with compromised language and academic skills.

To examine whether prediction of 11-year language outcomes was more accurate when earlier language abilities were considered, grouped predictors ranging from the earliest applicable model with early risk factors and 2-year late-talker status to the latest applicable model with

the 7-year CELF receptive and expressive language scores alone were used (aim 3). This analysis was restricted to a common sample of children with complete measures for all of the predictive models specified as follows:

1. early risk factors and 2-year late-talker status;
2. early risk factors, 2-year late-talker status, and 4-year CELF language scores;
3. 4-year CELF language scores only;
4. early risk factors, 2-year late-talker status, 4-year CELF language scores, and 5-year CELF language scores;
5. 5-year CELF language scores only;
6. early risk factors, 2-year late-talker status, 4-year CELF language scores, 5-year CELF language scores, and 7-year CELF language scores; and
7. the 7-year CELF language scores alone.

A similar analytical approach was taken for regression models of academic outcomes, with the added

TABLE 2 Correlations Between Predictor Variables (From Birth Through 7 Years) for the Language and Academic Outcomes at 11 Years

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Sex	1.00	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Twin birth	0.02	1.00	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Preterm	0.00	0.15*	1.00	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Birth wt	-0.15*	-0.26*	-0.40*	1.00	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Birth order	0.00	0.04	-0.02	0.05*	1.00	—	—	—	—	—	—	—	—	—	—	—	—	—	—
NESB	0.00	-0.02	-0.02	-0.03	-0.01	1.00	—	—	—	—	—	—	—	—	—	—	—	—	—
Maternal education	-0.05*	0.04	-0.02	0.06*	-0.09*	0.04	1.00	—	—	—	—	—	—	—	—	—	—	—	—
SEIFA score	-0.01	0.02	-0.02	0.06*	0.01	-0.20*	0.22*	1.00	—	—	—	—	—	—	—	—	—	—	—
Family history	-0.02	-0.04	-0.03	0.00	0.16*	-0.05	-0.09*	-0.02	1.00	—	—	—	—	—	—	—	—	—	—
Mental health	-0.01	0.00	0.00	0.02	0.04	0.06*	-0.01	-0.03	0.08*	1.00	—	—	—	—	—	—	—	—	—
Maternal vocabulary	0.00	0.04	0.01	0.07*	0.08*	-0.31*	0.28*	0.27*	-0.01	-0.02	1.00	—	—	—	—	—	—	—	—
Maternal age	0.01	0.01	-0.01	0.00	0.30*	0.06*	0.06*	0.16*	0.02	0.02	0.29*	1.00	—	—	—	—	—	—	—
Late talker	-0.03	-0.03	0.00	-0.02	0.11*	0.11*	-0.09*	-0.08*	0.10*	0.03	-0.07*	0.05*	1.00	—	—	—	—	—	—
Receptive language 4 y	0.15*	-0.01	0.02	0.05*	-0.07*	-0.24*	0.22*	0.22*	-0.11*	-0.04	0.30*	0.10*	-0.32*	1.00	—	—	—	—	—
Expressive language 4 y	0.10*	-0.02	0.01	0.06*	-0.12*	-0.27*	0.21*	0.23*	-0.13*	-0.05*	0.33*	0.08*	-0.41*	0.79*	1.00	—	—	—	—
Receptive language 5 y	0.17*	-0.04	-0.02	0.05	-0.07*	-0.10*	0.16*	0.18*	-0.11*	0.02	0.19*	0.11*	-0.27*	0.71*	0.62*	1.00	—	—	—
Expressive language 5 y	0.12*	-0.06	-0.04	0.06	-0.09*	-0.14*	0.18*	0.19*	-0.11*	-0.03	0.27*	0.09*	-0.35*	0.69*	0.77*	0.65*	1.00	—	—
Receptive language 7 y	0.14*	-0.05	-0.02	0.05	-0.10*	-0.04	0.15*	0.12*	-0.09*	0.00	0.13*	0.05	-0.26*	0.59*	0.54*	0.62*	0.58*	1.00	—
Expressive language 7 y	0.07*	-0.09*	-0.03	0.07*	-0.16*	-0.03	0.21*	0.15*	-0.09*	0.00	0.20*	0.07*	-0.34*	0.67*	0.73*	0.62*	0.75*	0.66*	1.00

(1) Sex, (2) twin birth, (3) preterm birth (<36 weeks), (4) birth wt (per kg), (5) birth order, (6) NESB, (7) maternal education level, (8) SEIFA score, (9) family history of speech and/or language difficulties, (10) maternal mental health symptoms, (11) maternal vocabulary score, (12) maternal age, (13) late talker, (14) receptive language age 4, (15) expressive language age 4, (16) receptive language age 5, (17) expressive language age 7, and (18) expressive language age 7. —, not applicable.

* Correlations significant at $P < .05$.

TABLE 3 Multiple Variable Linear Regression Analysis of CELF-4 Standard Scores and Logistic Regression Analysis of Language Status at 11 Years With Respect to Early Life Factors

	Language Score						Low Language Status ^a					
	Receptive (<i>n</i> = 839) ^a			Expressive (<i>n</i> = 839) ^a			Receptive (<i>n</i> = 61 [7.27%]) ^a			Expressive (<i>n</i> = 48 [5.72%]) ^a		
	Mean Difference ^b	95% CI	<i>P</i>	Mean Difference	95% CI	<i>P</i>	OR	(95% CI)	<i>P</i>	OR	(95% CI)	<i>P</i>
Child												
Female	0.06	−1.67 to 1.79	.95	1.57	−0.20 to 3.35	.08	0.72	0.43 to 1.21	.22	0.46	0.25 to 0.84	<.01
Twin birth	−4.20	−10.17 to 1.77	.17	−8.59	−14.69 to −2.49	<.01	2.63	0.74 to 9.35	.14	5.05	1.59 to 15.97	<.01
Preterm birth (<36 wk)	−3.07	−7.80 to 1.67	.20	−3.37	−8.22 to 1.49	.17	1.50	0.44 to 5.09	.52	1.23	0.28 to 5.33	.78
Birth wt, per kg	1.17	−0.53 to 2.88	.18	1.48	−0.26 to 3.22	.09	1.04	0.62 to 1.74	.88	0.84	0.48 to 1.50	.56
Birth order												
First	(Referent)	—	—	(Referent)	—	—	(Referent)	—	—	(Referent)	—	—
Second	−2.22	−4.12 to −0.33	.02	−2.06	−4.00 to −0.12	.04	1.30	0.72 to 2.32	.38	1.39	0.73 to 2.66	.31
Third	−3.90	−6.61 to −1.18	<.01	−4.40	−7.19 to −1.62	<.01	1.60	0.75 to 3.44	0.23	1.44	0.59 to 3.49	.43
Fourth or later	−7.27	−13.26 to −1.28	.02	−8.10	−14.24 to −1.96	.01	1.90	0.42 to 8.73	0.41	2.51	0.54 to 11.68	.24
Family												
NESB	−1.10	−6.09 to 3.90	.67	−1.09	−6.21 to 4.04	.68	1.06	0.25 to 4.62	.93	1.39	0.32 to 6.06	.66
SEIFA score	0.01	−0.01 to 0.02	.39	0.02	−0.00 to 0.03	.07	1.00	0.99 to 1.00	.16	1.00	0.99 to 1.00	.18
Family history of speech and/or language difficulties	−2.82	−4.83 to −0.80	<.01	−3.04	−5.11 to −0.97	<.01	1.13	0.62 to 2.05	.68	1.63	0.87 to 3.03	.13
Mother												
Maternal education level												
≤12 y	(Referent)	—	—	(Referent)	—	—	(Referent)	—	—	(Referent)	—	—
13 y	0.02	−2.36 to 2.40	.99	0.88	−1.54 to 3.30	.47	0.96	0.50 to 1.85	0.90	0.61	0.30 to 1.23	.17
Degree or postgraduate	4.62	2.27 to 6.96	<.01	6.61	4.23 to 8.99	<.01	0.45	0.22 to 0.94	0.04	0.37	0.17 to 0.79	<.01
Maternal mental health symptoms	−1.13	−3.01 to 0.74	.24	−0.69	−2.60 to 1.23	.48	1.31	0.76 to 2.28	0.33	1.17	0.62 to 2.18	.63
Maternal vocabulary score, per point	0.39	0.20 to 0.58	<.01	0.45	0.26 to 0.64	<.01	0.98	0.92 to 1.04	0.45	0.95	0.90 to 1.01	.13
Maternal age at baseline, per y	0.20	−0.01 to 0.40	.06	0.22	0.01 to 0.43	.04	1.01	0.95 to 1.07	0.83	0.99	0.92 to 1.06	.72

—, not applicable.

^a Children with complete predictor and outcome data.

^b Mean difference refers to the average difference between the reference group (eg, boys) and the comparator group (eg, girls) in the outcome (eg, receptive language score).

predictor of 11-year language scores included. The proportion of variance explained (R^2) and the area under the curve (AUC) are reported for regression models. All analyses were completed in Stata MP 15.0 (Stata Corp, College Station, TX).²³

Ethical approval was obtained from the Royal Children's Hospital (23018 and 27078) and La Trobe University Human Ethics Committee (03-32). All

participants and their caregivers provided informed written consent before participation.

RESULTS

The characteristics of the in-scope (*n* = 839) and the nonparticipant (*n* = 1071) groups are presented in Table 1, which illustrates that attrition resulted in differential characteristics to the original sample. By 11 years,

participants were more likely to be female, live in areas of comparatively less disadvantage and have mothers who were older, and have higher vocabulary and educational attainments than nonparticipants. In addition, there were fewer NESB families.

Language Outcomes

The range of language abilities and the prevalence of language difficulties

TABLE 4 Proportion of Variance in CELF-4 Standard Scores Explained and Accuracy of Predictors in Discriminating Between Children With and Without Low Language Status at 11 Years ($n = 588$)

Model	Language Score ^a		Low Language Status ^b			
	Receptive	Expressive	Receptive		Expressive	
	R^2	R^2	AUC ^c	95% CI	AUC	95% CI
(1) predictors in infancy only	0.11	0.12	0.67	0.57 to 0.77	0.79	0.70 to 0.87
(2) as (1) plus late talking status (2 y)	0.14	0.17	0.71	0.60 to 0.81	0.83	0.74 to 0.92
(3) as (2) plus receptive and expressive language scores (4 y)	0.38	0.48	0.83	0.76 to 0.89	0.90	0.84 to 0.96
(4) receptive and expressive language scores only (age 4)	0.38	0.48	0.82	0.75 to 0.89	0.90	0.84 to 0.96
(5) as (3) plus receptive and expressive language scores (5 y)	0.41	0.54	0.88	0.84 to 0.92	0.92	0.88 to 0.97
(6) receptive and expressive language scores only (age 5)	0.37	0.51	0.87	0.83 to 0.91	0.92	0.86 to 0.97
(7) as (5) plus receptive and expressive language scores (7 y)	0.47	0.64	0.92	0.89 to 0.95	0.97	0.93 to 1.00
(8) receptive and expressive language scores only (age 7)	0.45	0.61	0.91	0.87 to 0.94	0.97	0.94 to 1.00

^a Linear regression examining continuous language scores included the full set of 12 predictor variables.

^b Logistic regression examining language cut points included only 11 of these (twin status was excluded because of no participants from this category in the low receptive or expressive language group).

^c AUC value of 0.5 indicates chance discrimination, 0.7 to 0.8 moderate, 0.8 to 0.9 good, and 1 indicates perfect discrimination.

of the in-scope sample are comparable to other community cohorts and our previous reports.¹³ The mean CELF-4 receptive and expressive scores were 99.39 (SD 12.81) and 101.58 (SD 13.15), respectively. A total of 61 (7.3%) children presented with low receptive language scores and 48 (5.7%) children with low expressive language scores. A total 3.9% had low scores in both receptive and expressive language.

The correlations between the 12 predictor variables included in the regression analyses are provided in Table 2 and correlations between all predictor and outcome variables are presented in Supplemental Table 8. In the linear regression analyses examining prediction of 11-year language skills (aim 2), 4 of the 12 risk factors (birth order, maternal education, maternal vocabulary, and family history of speech and/or language difficulties) were associated with both receptive and expressive language scores (Table 3). In the logistic regression model, maternal education was the only common risk factor for predicting language ability and discriminating between low and typical language status. At 11 years, the odds of low receptive language were lower with higher maternal education (odds ratio [OR] 0.45; 95% CI 0.22 to 0.94) and the odds for low

expressive language were lower for girls (OR 0.46; 95% CI 0.25 to 0.84); higher maternal education (OR 0.37; 95% CI 0.17 to 0.79); and for twins (OR 5.05; 95% CI 1.59 to 15.97) (Table 3).

The variance explained and AUC for language outcomes with the different models are presented in Table 4 for the 588 participants for whom there were complete case data (aim 3). Together, the 12 risk factors in infancy accounted for 11% and 12% of the variance in receptive and expressive language scores at 11 years, respectively (model 1). Modest increases occurred with model 2 and more substantial increases to 38% and 48% with 4-year language scores (model 3). There was minimal change to the proportions with 5-year language scores (model 5), but they increased to 47% and 64% with the addition of 7-year language scores (model 7). The AUC was 0.67 (receptive) and 0.79 (expressive) for the 11 risk factors included (model 1), representing discrimination little better than chance. AUC values increased incrementally with the different models up to 0.97 when 4-, 5-, and 7-year language scores were included (model 7), suggesting good to excellent discrimination between children with typical and low language skills (Table 4). Both R^2 and AUC values were almost identical

when the contribution of 7-year language scores to 11-year language ability was considered alone (model 8).

Academic Outcomes

Academic outcomes of participants from 8 to 11 years are described in Table 5 and compared between children with typical or low language status at 11 years (aim 1). NAPLAN literacy (reading, spelling, grammar and punctuation, writing), and numeracy measures at the commencement of national testing around 8 years, and 2 subsequent time points were significantly lower for children with low language who scored ~1 SD below the mean of the typical group. Differences did not increase or attenuate over time.

In the linear regression analyses examining prediction of academic outcomes (aim 2), 5 of the 12 risk factors (preterm birth, birth order, socioeconomic disadvantage, and maternal age, education, and vocabulary) and language ability were associated with grade 7 NAPLAN reading scores (Table 6). Grammar and punctuation were predicted by 9 of the 12 risk factors. In the logistic regression model, sex, maternal vocabulary, and maternal age predicted reading scores, and socioeconomic disadvantage predicted grammar and punctuation

TABLE 5 Academic Ability in Children With Low Language at 11 Years Versus Those With Typical Language

NAPLAN (Scale Scores)	Victorian State, ^a Mean (SD)	<i>n</i>	Receptive				Expressive			
			Typical Mean (SD)	Low Mean (SD)	95% CI	<i>P</i>	Typical Mean (SD)	Low Mean (SD)	95% CI	<i>P</i>
Reading										
Grade 3	432.0 (82.0)	604	484.8 (84.8)	387.3 (61.8)	-128.39 to -66.71	<.01	483.3 (85.1)	372.5 (58.2)	-150.45 to -71.11	<.01
Grade 5	509.8 (73.1)	621	556.6 (75.9)	451.2 (50.5)	-132.54 to -78.35	<.01	555.1 (76.3)	434.0 (41.1)	-155.61 to -86.52	<.01
Grade 7	545.6 (64.2)	622	586.4 (67.4)	501.6 (52.8)	-108.61 to -61.00	<.01	585.0 (67.8)	487.9 (47.0)	-127.89 to -66.28	<.01
Spelling										
Grade 3	423.3 (77.3)	603	452.2 (72.8)	372.6 (55.0)	-106.02 to -53.04	<.01	449.9 (73.8)	388.9 (54.1)	-96.44 to -25.53	<.01
Grade 5	500.9 (70.1)	622	527.4 (66.7)	444.9 (51.7)	-105.67 to -59.29	<.01	525.4 (67.9)	447.4 (39.8)	-108.82 to -47.30	<.01
Grade 7	543.7 (68.8)	623	569.5 (63.6)	497.5 (51.9)	-94.50 to -49.54	<.01	567.9 (64.2)	499.8 (56.0)	-97.34 to -38.78	<.01
Grammar and punctuation										
Grade 3	437.7 (81.5)	603	487.2 (86.2)	389.1 (87.5)	-129.79 to -66.34	<.01	484.7 (88.4)	400.0 (56.3)	-127.03 to -42.24	<.01
Grade 5	508.2 (73.2)	622	555.1 (77.3)	457.5 (56.4)	-124.41 to -70.76	<.01	553.1 (78.1)	448.6 (46.0)	-139.89 to -69.09	<.01
Grade 7	543.2 (70.4)	623	584.8 (75.8)	497.5 (51.8)	-113.97 to -60.66	<.01	583.2 (76.3)	487.6 (33.4)	-130.17 to -61.13	<.01
Writing										
Grade 3	428.1 (59.1)	602	449.3 (50.9)	408.9 (53.4)	-59.17 to -21.58	<.01	448.9 (50.5)	393.8 (64.8)	-79.06 to -31.14	<.01
Grade 5	480.8 (58.3)	622	507.9 (54.9)	447.7 (50.9)	-79.47 to -41.00	<.01	506.9 (55.1)	435.2 (51.4)	-96.83 to -46.47	<.01
Grade 7	530.0 (65.1)	621	558.8 (67.6)	489.0 (48.2)	-93.71 to -46.10	<.01	557.2 (68.1)	494.3 (50.2)	-93.89 to -31.95	<.01
Numeracy										
Grade 3	408.9 (67.6)	600	448.5 (72.6)	376.8 (48.2)	-97.64 to -45.80	<.01	446.9 (72.7)	376.5 (47.5)	-104.45 to -36.48	<.01
Grade 5	496.6 (65.2)	620	531.7 (69.7)	434.8 (54.8)	-121.56 to 72.36	<.01	529.7 (70.8)	432.3 (51.6)	-129.54 to -65.21	<.01
Grade 7	555.9 (67.2)	623	585.8 (65.1)	515.3 (51.9)	-93.52 to 47.54	<.01	584.7 (65.4)	502.6 (39.5)	-111.84 to -52.50	<.01

^a Mean achievement by state taken from NAPLAN National Reports 2012, 2014, and 2016 for grades 3, 5, and 7, respectively.

scores. At grade 7, the odds of having a low reading score were lower for girls (OR 0.40; 95% CI 0.19 to 0.87); the ORs for other significant risk factors were close to 1.0.

The variance explained and AUC for academic outcomes with the different models are presented in Table 7 for the 472 participants for whom there were complete case data (aim 3). When considering academic outcomes, the 12 risk factors accounted for 13% and 14% of the variance in reading and grammar and punctuation scores, respectively, at grade 7 (model 1). These proportions did not meaningfully increase for

model 2 but increased to 34% and 26% when 4-year language scores were included (model 3). Seven-year language scores explained little additional variance (43% and 36%) (model 7); however, 11-year language scores increased the proportions to 54% and 43%, respectively (model 9). These proportions remained similar when only 11-year language scores were included (model 10). The AUC was 0.70 (reading) and 0.88 (grammar and punctuation) for the 8 of 9 risk factors included (model 1), representing moderate discrimination. AUC values increased to 0.91 (reading) and 0.97 (grammar and punctuation) when 4-, 5-, 7- and

11-year language scores were included (model 9), suggesting good to excellent discrimination between children with typical and low academic ability.

DISCUSSION

There is a pattern across the school years of early cumulative risk factors explaining less variance in language outcomes as children get older. Conversely, language scores from 2 to 7 years explain significantly more variability, with early risk factors contributing little to additional risk of low language outcomes. This is consistent with our earlier finding

TABLE 6 Multiple Variable Linear Regression Analysis of Grade 7 NAPLAN – Reading and Grammar and Punctuation Scores and Logistic Regression Analysis of Low Academic Ability at Year 7 With Respect to Early Life Factors

	NAPLAN (Scale Scores)						Low Academic Ability ^a					
	Reading (n = 729) ^a			Grammar and Punctuation (n = 729) ^a			Reading (n = 32 [4.39%]) ^a			Grammar and Punctuation, (n = 23 [3.16%]) ^a		
	Mean Difference ^b	95% CI	P	Mean Difference	(95% CI)	P	OR	95% CI	P	OR	(95% CI)	P
Child												
Female	1.09	−8.83 to 11.01	.83	8.97	−2.05 to 20.00	.11	0.40	0.19 to 0.87	.02	0.48	0.20 to 1.14	.10
Twin birth	−18.97	−50.89 to 12.95	.24	3.63	−31.91 to 39.18	.84	1	—	—	1	—	—
Preterm birth (<36 wk)	−12.18	−39.95 to 15.59	.39	−39.47	−70.25 to −8.69	<.01	0.95	0.12 to 7.22	.96	2.96	0.65 to 13.42	.16
Birth wt (per kg)	8.82	−0.76 to 18.40	.07	11.63	0.96 to 22.29	.03	1.27	0.63 to 2.53	.50	0.61	0.29 to 1.29	.20
Birth order												
First	(Referent)	—	—	—	—	—	—	—	—	—	—	—
Second	−9.89	−20.78 to 1.01	.08	−11.06	−23.21 to 1.09	.07	1.56	0.69 to 3.54	.28	1.19	0.44 to 3.23	.74
Third	−25.13	−40.87 to −9.39	<.01	−21.74	−39.14 to −4.34	<.01	2.64	1.01 to 6.90	.05	2.90	1.01 to 8.38	.05
Fourth or later	−21.76	−55.70 to 12.19	.21	−1.59	−39.43 to 36.25	.93	2.03	0.25 to 16.68	.51	2.71	0.32 to 22.80	.36
Family												
NESB	−3.82	−28.77 to 21.14	.76	32.52	4.85 to 60.19	.02	0.74	0.10 to 5.63	.77	1.06	0.14 to 8.15	.95
SEIFA score	0.16	0.06 to 0.25	<.01	0.12	0.01 to 0.22	.03	1.00	0.99 to 1.00	.39	0.99	0.99 to 1.00	.04
Family history of speech/ language difficulties	−5.97	−17.71	.32	−14.80	−27.83 to −1.77	.03	1.11	0.49 to 2.52	.80	0.92	0.34 to 2.51	.87
Mother												
Maternal education level												
≤12 y	(Referent)	—	—	—	—	—	—	—	—	—	—	—
13 y	−4.37	−18.05 to 9.30	.53	−6.08	−21.24 to 9.08	.43	1.36	0.52 to 3.55	.53	2.61	0.74 to 9.19	.13
Degree/postgraduate	23.19	9.76 to 36.61	<.00	26.17	11.29 to 41.06	<.00	0.74	0.26 to 2.07	.56	0.75	0.18 to 3.18	.70
Maternal mental health symptoms	−1.19	−11.95 to 9.56	.83	4.37	−7.62 to 16.36	.48	0.92	0.42 to 2.03	.84	0.33	0.10 to 1.11	.07
Maternal vocabulary score, per point	2.69	1.63 to 3.75	<.00	1.96	0.77 to 3.15	<.00	0.91	0.84 to 0.97	.01	0.93	0.86 to 1.01	.11
Maternal age at baseline, per y	1.97	0.80 to 3.14	<.00	2.29	0.98 to 3.59	<.00	0.92	0.84 to 1.00	.04	0.94	0.85 to 1.03	.19

—, not applicable.

^a Children with complete predictor and outcome data.

^b Mean difference refers to the average difference between the reference group (eg, boys) and the comparator group (eg, girls) in the outcome (eg, receptive language score).

that language ability at 4 years more accurately predicted low language at 7 years than a range of early child, family, and environmental factors.¹³ These findings align well with arguments of the necessity for early support around risk factors in children’s environments, and for later intervention efforts that focus on consolidation of existing language skills.

Using early risk factors alone to discriminate between children with typical versus low language reduces to little better than chance from 7 to 11 years. Marked improvement in discrimination occurred when 4-year language scores were included, with marginal improvement when 5- and 7-year language scores and early predictors were included. It is plausible that discrimination

improves as language abilities stabilize from 4 to 7 years and through 11 years as previously demonstrated in this cohort.⁷ Importantly, earlier language ability at 4 years continues to predict language outcomes at 11 years, as it did at 7 years,¹³ in a largely similar sample. However, the similarity of discrimination at 4 and 5 years suggests that decisions regarding

TABLE 7 Proportion of Variance in Grade 7 NAPLAN – Reading and Grammar and Punctuation Scores Explained and Accuracy of Predictors in Discriminating Between Children With and Without Low Academic Ability (*n* = 472)

Model	NAPLAN (Scale Scores) ^a		Low Academic Ability ^b			
	Reading	Grammar and Punctuation	Reading		Grammar and Punctuation	
	<i>R</i> ²	<i>R</i> ²	AUC ^c	95% CI	AUC	95% CI
(1) predictors in infancy only	0.13	0.14	0.70	0.58 to 0.83	0.88	0.83 to 0.94
(2) as (1) plus late talking status (2 y)	0.14	0.15	0.75	0.64 to 0.86	0.89	0.83 to 0.94
(3) as (2) plus receptive and expressive language scores (4 y)	0.34	0.26	0.79	0.69 to 0.89	0.89	0.83 to 0.95
(4) receptive and expressive language scores only (age 4)	0.34	0.26	0.79	0.70 to 0.89	0.89	0.83 to 0.95
(5) as (3) plus receptive and expressive language scores (5 y)	0.39	0.31	0.85	0.73 to 0.97	0.89	0.83 to 0.96
(6) receptive and expressive language scores only (age 5)	0.37	0.30	0.83	0.71 to 0.96	0.89	0.82 to 0.96
(7) as (5) plus receptive and expressive language scores (7 y)	0.43	0.36	0.87	0.77 to 0.97	0.93	0.89 to 0.98
(8) receptive and expressive language scores only (age 7)	0.40	0.34	0.83	0.75 to 0.92	0.91	0.84 to 0.98
(9) as (7) plus receptive and expressive language scores (11 y)	0.54	0.43	0.91	0.83 to 0.99	0.97	0.96 to 0.99
(10) receptive and expressive language scores only (age 11)	0.51	0.41	0.89	0.82 to 0.96	0.96	0.92 to 0.99

^a Linear regression examining continuous NAPLAN scores included the full set of 12 predictor variables.

^b Logistic regression examining reading included only 8 predictor variables (twin status, birth order, premature, and NESB were excluded because of no participants from these categories in the low reading group); logistic regression examining grammar and punctuation included only 9 of the predictor variables (twin status, premature, and NESB were excluded because of no participants from these categories in the low grammar and punctuation group).

^c AUC value of 0.5 indicates chance discrimination, 0.7 to 0.8 moderate, 0.8 to 0.9 good, and 1 indicates perfect discrimination.

early intervention can be reliably made at 4 years, thereby maximizing the opportunity for improvements during the preschool period.

Early life risk factors, reflecting aspects of the child’s biological predisposition and the home learning environment, previously revealed to be important predictors at 4 years,⁸ continued to predict language outcomes across 6 years of formal schooling, indicating their importance in building the foundations for later language skills. This is consistent with language growth models for this cohort, which revealed the relative contribution of modifiable factors, such as shared book reading, to language growth trajectories between 4 and 7 years.²⁴ The social gradient, often observed in language outcomes, was not evident in this cohort, possibly reflecting that the in-scope ELVS cohort was more socially advantaged than the Victorian population. Consequently, these predictive models may not generalize immediately to populations with more pronounced risk factors.

Of the child factors, only twin birth was associated with poorer language

outcomes. The environment for first born children appears to put them at a developmental advantage for language abilities, a robust finding replicated across our previous analyses at earlier ages.^{8,13} However, it does not significantly discriminate between low and typical language abilities at 11 years.

Not surprisingly, low language scores at 11 years are associated with poorer academic skills, and children with low language scored consistently lower across reading, spelling, and writing assessments. However, on average, scores were rarely >1.25 SD below the mean. Children in our sample with typical language were ~0.5 SD above the state average in national assessment results, whereas the children with low language abilities were 0.5 SD below.

The findings are novel in using a set of early risk factors measured in infancy to discriminate what we defined as “low academic ability” from NAPLAN results at 11 years. Unlike our findings for language, these risk factors alone provided good discrimination. This finding may reflect that we did not include an intermediary variable of earlier academic abilities as we did in our

predictive models for language outcomes. Academic ability encompasses a range of skills, such as reading, writing, and spelling, most of which are not usually assessed before formal schooling.

When language scores at 11 years were added to the model for academic outcomes, discrimination was excellent. The steady increase in discrimination of academic abilities between 2 and 7 years may represent children’s varied participation in preschool with a transition to more consistent accumulation of school instruction by 11 years that impacts on learning over and above the influence of the family and home environment. The findings suggest that for children from more disadvantaged circumstances (than the ELVS cohort) we could expect low language abilities to further compound their academic vulnerabilities.

The results reported here do not indicate differential prediction of receptive and expressive language skills but rather that general language difficulties impact on academic difficulties in late primary school. Consequently, we recommend a focus on a child’s overall communication

competence, including pragmatic and functional language skills. This aligns with contemporary definitions of developmental language disorders and the imperative to consider children's language abilities in multiple contexts when making diagnostic decisions.²⁵

The strengths of ELVS include the prospective measurement of a range of child, family, and environmental factors from infancy through to middle childhood. The initial sample frame and attrition have led to the ELVS cohort being more advantaged with respect to characteristics including maternal education and SES that are associated with better language outcomes. Thus, the risk factor associations and prediction of language outcomes may be understated. ELVS remains one of the largest cohorts of children with robust measures of language, literacy, and academic abilities collected over multiple time points and linkage with national assessment data. Although, in this study, we investigated the importance of earlier language abilities to predict later language outcomes, in future analyses, researchers could similarly examine how earlier academic abilities predict later academic outcomes.

CONCLUSIONS

Low language ability at 11 years is associated with poor academic skills. In regard to predicting language outcomes at 11 years, our finding that language assessments at 4 years is more predictive suggests that assessment and intervention could be initiated as early as the year before school commencement. Given the significant and negative association between low language and academic skills, interventions targeted and delivered in preschool have the potential to minimize differences between children at school entry and maximize critical early learning opportunities.

In contrast, children who are likely to show low academic achievement can be adequately discriminated earlier and by early risk factors alone. The vital importance of family characteristics and home learning environments to children's learning experiences and eventual educational attainment are clearly emphasized here. These findings suggest potential for future research to focus on the impact of participation in high-quality preschool and school learning in ameliorating the educational vulnerability of children with low language skills.

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ABBREVIATIONS

AUC: area under the curve
CELf: Clinical Evaluation of Language Fundamentals
CELf-4: Clinical Evaluation of Language Fundamentals Fourth Edition
CI: confidence interval
ELVS: Early Language in Victoria Study
NAPLAN: National Assessment Program – Literacy and Numeracy
NESB: non-English-speaking background
OR: odds ratio
SEIFA: Socio-Economic Indexes for Areas
SES: socioeconomic status

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