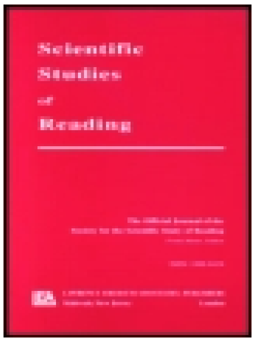

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Reading and Oral Vocabulary Development in Early Adolescence

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ABSTRACT

International assessments show that 20% of adolescents cannot read simple texts with understanding. Despite this, research has focused on early reading in childhood and skilled reading in adulthood, neglecting reading development during adolescence. We report a longitudinal study assessing reading and vocabulary development at 12, 13 and 14 years in a sample of 210 adolescents who were unselected for ability. Word reading accuracy, word reading fluency, reading comprehension, receptive vocabulary and expressive vocabulary were assessed using standardized assessments. Latent variable models showed consistent rank order amongst individuals (high stability), significant progress over time, and evidence that achievement gaps between the least and most able adolescents were narrowing. Oral vocabulary knowledge and reading comprehension were best conceptualized as indices of a common language construct. Low levels of reading proficiency were also observed in a substantial proportion of this sample, underlining the importance of providing ongoing reading and language support during adolescence.

Despite a widespread assumption that children can read when they leave primary education, international assessments show that 20% of adolescents are not able to read simple texts accurately and with understanding (Jerrim & Shure, 2016). These pupils will struggle to read independently, limiting access to the curriculum and hampering educational progress. Yet, very little is known about reading difficulties and reading development in adolescence, with research and theory focusing on reading in childhood and adulthood. Particularly lacking are longitudinal studies of adolescent reading: to our knowledge only one study has tracked reading within adolescence (see Francis, Shaywitz, Stuebing, Shaywitz, & Fletcher, 1996). We collected longitudinal data on word reading and reading comprehension at ages 12, 13 and 14 years. Spoken vocabulary knowledge was also assessed, as it is crucial for successful reading comprehension.

Reading development in adolescence

Beginning readers must learn how letters map onto sounds and then to read words and sentences accurately and efficiently. Once accurate and efficient reading is in place, a reader can allocate resources to reading comprehension, which is underpinned by spoken language comprehension (e.g., Gough & Tunmer, 1986). By late childhood, most children can read a range of texts accurately, efficiently and with comprehension, so it might be tempting to assume that little reading development takes place after this point. However, we know that the brain continues to develop during adolescence (Blakemore, 2018), and this includes the brain regions involved in reading (e.g., Ben-Shachar, Dougherty, Deutsch, & Wandell, 2011). Longitudinal studies of reading development in

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adolescence are scarce and existing studies have measured adolescent reading just once (e.g., Duff, Tomblin, & Catts, 2015; Eklund, Torppa, Aro, Leppänen, & Lyytinen, 2015; Landerl & Wimmer, 2008; Reynolds & Turek, 2012). However, there is evidence that reading abilities grow within adolescence. Francis et al. (1996) observed growth in a reading composite until approximately 15 years, though growth slowed across childhood (see also, Lervåg, Melby-Lervåg, & Hulme, 2018; Quinn, Wagner, Petscher, & Lopez, 2015) and adolescence.

Tracking growth has been the focus of most longitudinal research but Bornstein, Putnick, and Esposito (2017) highlighted another developmental process: stability, the rank order of individuals within the distribution. Bornstein, Hahn, Putnick, and Suwalsky (2014) tracked language development from 20 months to 14 years, showing that stability increases with age (see also Bornstein, Hahn, & Putnick, 2016), and is extremely high between the ages of 10 and 14 years (r = .99). Bornstein et al. used different indicators to form a latent language construct for each time point; at 10 and 14 years the construct reflected reading as well as oral language. High stability between late childhood (9–10 years) and adolescence (14–16 years) has also been reported for latent word reading accuracy measures (Hulslander, Olson, Willcutt, & Wadsworth, 2010) and observed reading fluency measures (Eklund et al., 2015; Landerl & Wimmer, 2008).

Growth and stability can also be distinguished from spread (see Figure 1), which relates to whether the distribution of scores over time stays the same, decreases, indicating a compensatory pattern, or increases, such that the "rich get richer and the poor get poorer" (so called Matthew effects; Pfost, Hattie, Dörfler, & Artelt, 2014; Stanovich, 1986). Matthew effects have been reported for reading comprehension between 7 and 10 years (Quinn et al., 2015), and for vocabulary knowledge between childhood and 16 years (Duff et al., 2015). However, a compensatory pattern has also been reported for a reading composite between 6 and 12 years (Shaywitz et al., 1995). A recent meta-analysis shows inconsistency across studies but suggests that Matthew effects were more likely for sensitive and reliable reading measures (Pfost et al., 2014). In sum, limited longitudinal research

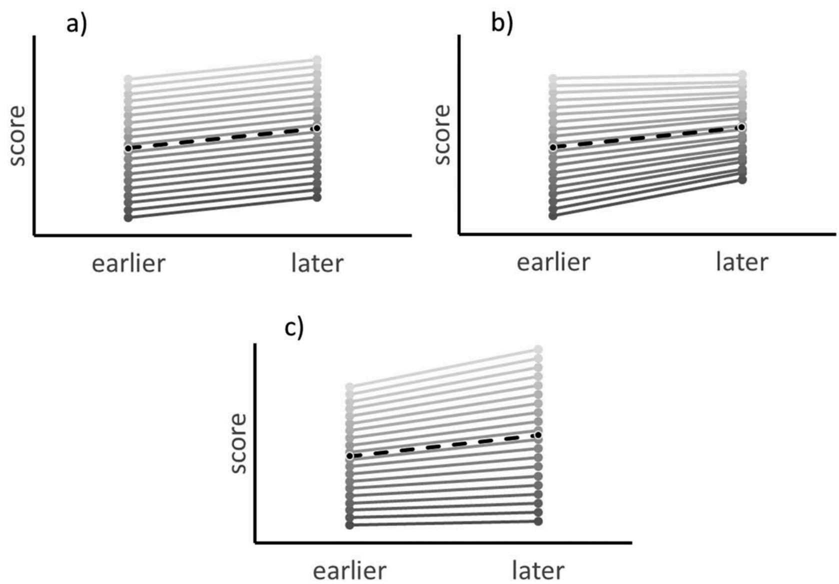

Figure 1. Hypothetical illustration of how spread can be consistent (a), decrease, indicating a compensatory pattern (b), or increase, indicating a Matthew effect (c).

Note. Growth, stability and spread are statistically independent from each other. In this example, there is there is consistent mean growth (black dashed line) and perfect stability (gray solid lines), with earlier rank in distribution identical to later rank.

indicates that in adolescence, reading growth slows to a plateau (Francis et al., 1996), rank order amongst individuals is high (Bornstein et al., 2014) and the spread of reading abilities might be consistent, widen or narrow (Pfost et al., 2014).

Reading comprehension, word reading and oral vocabulary in childhood and adolescence

The simple view of reading sees reading comprehension as the product of decoding and listening comprehension (Gough & Tunmer, 1986). However, this view may be "too simple" (e.g., Kirby & Savage, 2008). It has been suggested that other factors are also important for reading comprehension, including reading fluency, oral vocabulary knowledge, grammar and higher-level processes such as inference (Language and Reading Research Consortium (LARRC), 2015; Lervåg et al., 2018). Indeed, recent instantiations of the simple view refer more comprehensively to "word recognition" or "word reading" and "language comprehension" (e.g., Tunmer & Chapman, 2012). The simple view components underpin other theoretical frameworks such as the reading systems framework (Perfetti & Stafura, 2014) and direct and inferential mediation (DIME) model (e.g., Ahmed et al., 2016; Cromley & Azevedo, 2007), though these approaches additionally emphasize the importance of background knowledge (see also Barnes, Ahmed, Barth, & Francis, 2015) and integrating information to build a mental representation of the text (cf. Gernsbacher, Varner, & Faust, 1990; Kintsch, 1998).

The simple view predicts that the relative contribution of word reading and language comprehension to reading comprehension will change with development. For beginning readers, word reading abilities are the primary influence on reading comprehension but this shifts to language comprehension in mid-late childhood (Foorman, Koon, Petscher, Mitchell, & Truckenmiller, 2015; LARRC, 2015; Lervåg et al., 2018). Thus, word reading does not appear to be an important predictor of individual differences in reading comprehension during adolescence (Foorman et al., 2015). In contrast, language proficiency continues to explain variation in reading comprehension throughout the lifespan. Our study assesses these ideas in a longitudinal study (12–14 years). We focus on one aspect of language, oral vocabulary knowledge, or knowledge of the spoken (phonological) forms and meanings (semantics) of words. Logically, a reader must understand the words in a text to understand it. Indeed, the lexical quality hypothesis (Perfetti & Hart, 2002) emphasizes the importance of high quality lexical representations (i.e. those with well integrated word forms and meanings) for reading development. Other theoretical approaches also highlight the importance of lexical knowledge for the comprehension processes that allow readers to build a mental representation of the text (e.g., inference, integration; Cromley & Azevedo, 2007; Perfetti & Stafura, 2014). Ahmed et al. (2016) showed that for adolescents (ages 12– 14), vocabulary knowledge made the strongest contribution to reading comprehension, both directly, and indirectly via inferencing, as compared to other key variables (word reading, background knowledge, inferencing and strategies).

Intervention studies and longitudinal research provide strong evidence that, in childhood, oral vocabulary knowledge plays a causal role in explaining variation in reading comprehension. In an intervention with 8–9 year olds, improvements in reading comprehension brought about by an oral language intervention were partly mediated by gains in oral vocabulary knowledge (Clarke, Snowling, Truelove, & Hulme, 2010; see also Elleman, Lindo, Morphy, & Compton, 2009). Longitudinally, Quinn et al. (2015) showed that between 7 and 10 years, oral vocabulary knowledge predicted subsequent growth in reading comprehension. Reynolds and Turek (2012) assessed oral vocabulary knowledge and reading comprehension in adolescence (age 15 years) as well as childhood (ages 9 and 11). Again, vocabulary predicted growth in reading comprehension.

Reciprocal relations between oral vocabulary knowledge and reading comprehension might also be expected because reading provides opportunities for new words to be learned and for existing lexical representations to be refined (Nation, 2017; Ricketts, Bishop, Pimperton, & Nation, 2011; Wagner & Meros, 2010). Such reciprocity has been reported in some longitudinal studies with children (e.g., Cain & Oakhill, 2011; Verhoeven, van Leeuwe, & Vermeer, 2011), but not in Quinn et al. (2015). Arguably, the role of reading in oral vocabulary growth may become even more important in adolescence and adulthood as pupils encounter texts that contain more low frequency words that rarely occur in spoken language. However, Reynolds and Turek (2012) did not observe this pattern. In the present study, we build on research by Reynolds and Turek by using latent variables to index oral vocabulary knowledge and reading comprehension and extend Quinn et al.'s study by investigating development beyond childhood. We extend both studies by tracking development within adolescence and including a latent measure of word reading.

The present study

We measured oral vocabulary knowledge, word reading and reading comprehension longitudinally from 12 to 14 years to investigate how these capacities develop and interact within adolescence. Multiple measures of each construct were administered allowing latent variables to be used to control for measurement error. We addressed the following research questions:

(1) Do word reading, reading comprehension and oral vocabulary show stability in the rank order of individuals over time?
(2) Is there growth in word reading, reading comprehension and oral vocabulary knowledge over time?
(3) Do attainment gaps between the most and least able individuals widen, narrow or stay the same over time?
(4) What are the developmental relationships between word reading, reading comprehension and oral vocabulary knowledge between 12 and 14 years?

We predicted that there would be high stability in reading and oral vocabulary as this has been observed for reading accuracy and fluency (Eklund et al., 2015; Hulslander et al., 2010), and language (Bornstein et al., 2016, 2014). We also expected to see growth in reading (Francis et al., 1996) and oral vocabulary knowledge (Duff et al., 2015). Since Francis et al. investigated growth in a composite reading measure, we sought to replicate growth when word reading and reading comprehension were modeled separately. We anticipated Matthew effects for oral vocabulary knowledge (Duff et al., 2015) but that spread for reading might remain constant, widen or narrow (Pfost et al., 2014). We expected oral vocabulary knowledge to predict growth in reading comprehension, but not vice versa (Reynolds & Turek, 2012). Finally, we did not expect word reading to make a unique contribution to reading comprehension during adolescence (Foorman et al., 2015).

Method

Participants

210 pupils (102 girls, 49%) aged 11– 12 years (M_{age} = 12.01, *SD* = .33) were recruited from three socially mixed mainstream schools in England. They had received six or seven years of schooling (and formal literacy instruction) by the beginning of the study. At recruitment (Time 1), 14% of participants were in receipt of free school meals (n = 29), an index of family income, 13% were recorded as being on the special educational needs register (n = 27) and 8% spoke English as an additional language (n = 17), consistent with concurrent national data for England (free school meals: 16%, special educational needs: 8%, English as an additional language: 13%). Participants were followed longitudinally at two further time points at ages 12– 13 (M_{age} = 13.07, *SD* = .34) and 13– 14 (M_{age} = 14.01, *SD* = .33). Testing points were approximately 12 months apart (Difference Time 1 vs. Time 2: M = 12.45 months, *SD* = .52; Difference Time 2 vs. Time 3: M = 11.11 months, *SD* = .51). Attrition rates were low, with 6% and 5% lost between Times 1 and 2, and Times 2 and 3, respectively (Time 2 N = 196; Time 3 N = 187). Ethical approval for the study was provided by the University of Reading Ethics Committee and the study conforms to the British Psychological

Society Code of Ethics and Conduct. Participants assented to take part and informed consent was provided by their legal guardians.

Materials and procedure

At each time point, participants completed a battery of standardized assessments to characterize the sample (see Table 1). A subset were included in analyses to address our hypotheses. Tasks were administered individually in a fixed order across two 60-minute sessions.

Nonverbal reasoning

This was measured using the Matrix Reasoning subtest of the Wechsler Abbreviated Scale of Intelligence – Second Edition (WASI-II; Wechsler, 2011), which is a pattern completion task. The WASI-II provides US norms (t-scores: *M* = 50, *SD* = 10).

Table 1. Descriptive statistics at Time 1 (11–12 years), Time 2 (12–13 years) and Time 3 (13–14 years).

			Raw score			Normed score			
Task	*n*	*M*	*SD*	range	task maximum	*M*	*SD*	range	Reliability
T1 Nonverbal reasoning[1]	210	17.07	4.55	5 – 26	30	48.36	10.08	25 – 75	.86
T2 Nonverbal reasoning[1]	196	17.80	4.33	5 – 27	30	48.52	9.94	25 – 78	.85
T3 Nonverbal reasoning[1]	187	18.88	3.98	8 – 28	30	49.85	9.78	28 – 80	.82
T1 TOWRE word reading[2]	208	74.46	11.53	29 – 99	108	99.34	15.00	55 – 136	.90
T2 TOWRE word reading[2]	195	77.14	10.97	39 – 102	108	98.98	14.52	62 – 139	.84
T3 TOWRE word reading[2]	187	81.61	11.67	42 – 108	108	101.66	15.43	63 – 142	.84
T1 CC2 regular word reading	210	36.81	4.03	17 – 40	40	-	-	–	.88
T2 CC2 regular word reading	196	37.47	3.15	20 – 40	40	-	-	–	.85
T3 CC2 regular word reading	187	38.05	2.48	22 – 40	40	-	-	–	.93
T1 CC2 irregular word reading	210	25.17	4.82	8 – 39	40	-	-	–	.83
T2 CC2 irregular word reading	196	27.21	5.13	13 – 39	40	-	-	–	.87
T3 CC2 irregular word reading	187	27.97	4.68	13 – 38	40	-	-	–	.92
T1 CC2 nonword reading	210	31.68	7.50	2 – 40	40	-	-	–	.77
T2 CC2 nonword reading	196	32.38	6.87	3 – 40	40	-	-	–	.84
T3 CC2 nonword reading	187	33.98	6.03	2 – 40	40	-	-	–	.91
T1 SWRT word reading[2]	208	49.61	8.23	21 – 68	70	101.59	13.33	<70 – >130	.93
T2 SWRT word reading[2]	193	51.91	7.66	27 – 69	70	100.53	13.30	<70 – >130	.92
T3 SWRT word reading[2]	186	54.15	7.45	28 – 70	70	100.44	13.01	<70 – >130	.92
T1 YARC passage 1.1A[2]	207	6.88	2.97	0 – 13	13	103.13	13.42	<70 – >130	.76
T2 YARC passage 1.1A[2]	194	7.79	2.95	0 – 13	13	103.42	13.46	<70 – 128	.78
T3 YARC passage 1.1A[2]	186	9.10	2.45	1 – 13	13	105.99	11.46	<70 – 123	.72
T1 YARC passage 1.2A[2]	207	6.92	2.84	0 – 12	13	101.88	13.35	<70 – 126	.76
T2 YARC passage 1.2A[2]	194	7.44	2.80	0 – 13	13	100.53	13.01	<70 – 126	.76
T3 YARC passage 1.2A[2]	186	8.72	2.43	1 – 13	13	103.05	11.62	<70 – 124	.71
T1 YARC passage 2.2A[2]	205	4.45	2.79	0 – 12	13	102.41	11.88	77 – 131	.74
T2 YARC passage 2.2A[2]	193	4.99	2.85	0 – 13	13	100.95	11.77	73 – 131	.74
T3 YARC passage 2.2A[2]	185	6.23	2.61	1 – 12	13	102.74	10.61	79 – 127	.71
T1 BPVS vocabulary[2]	210	135.60	13.94	88 – 161	168	92.91	13.43	<70 – 126	.94
T2 BPVS vocabulary[2]	196	140.91	12.93	95 – 167	168	96.64	14.60	<70 – 135	.94
T3 BPVS vocabulary[2]	187	144.93	11.28	106 – 167	168	99.32	13.94	<70 – 132	.93
T1 WASI vocabulary[1]	210	30.60	6.15	13 – 43	53	50.85	9.82	26 – 77	.83
T2 WASI vocabulary[1]	196	31.80	6.39	5 – 43	53	50.35	9.97	20 – 75	.85
T3 WASI vocabulary[1]	187	34.41	5.57	14 – 46	53	52.60	9.38	24 – 79	.81

Notes. T1 = Time 1 (11–12 years); T2 = Time 2 (12–13 years); T3 = Time 3 (13–14 years); WASI = Wechsler Abbreviated Scales of Intelligence; British Picture Vocabulary Scale; TOWRE = Test of Word Reading Efficiency; CC2 = revised Castles and Coltheart test; SWRT = Single Word Reading Test; YARC = York Assessment of Reading Comprehension; [1]t-score (*M* = 50, *SD* = 10); [2]standard score (*M* = 100, *SD* = 15); Reliability: all Cronbach's α for raw scores except TOWRE word reading, which was time limited so test-retest reliability from the test manual is reported for the relevant age ranges (see supplementary materials for correlations over time)

Word reading

This was assessed using Form A of the Test of Word Reading Efficiency – Second Edition (TOWRE-2; Wagner, Torgesen, & Rashotte, 2011), the revised Castles and Coltheart test (CC2; Castles et al., 2009)[1] and the Single Word Reading Test (SWRT) from the York Assessment of Reading Comprehension (Stothard, Hulme, Clarke, Barnby, & Snowling, 2010). The TOWRE-2 includes a Sight Word Efficiency (SWE) subtest in which word reading efficiency is indexed by the number of words read correctly in 45 seconds. The CC2 includes 40 regular words, 40 irregular words and 40 nonwords, with item type interleaved. Only the irregular word reading subtest from the CC2 was included in analyses (see below). The SWRT includes 70 words. The CC2 and SWRT are untimed measures and reading accuracy is measured as the number of items read correctly. Norms (standard scores: $M = 100$, $SD = 15$) for this age range were available for the TOWRE-2 (US norms) and SWRT (UK norms) but not for the CC2.

Reading comprehension

This was assessed with three passages (length in words: $M = 468.67$, $SD = 3.79$) from the York Assessment of Reading for Comprehension (YARC; Stothard et al., 2010): one fiction passage (Schoolboy: 1.1A) and two nonfiction passages (Bees: 1.2A, Louise Nevelson: 2.2A). For each passage, silent reading was followed by 13 open-ended comprehension questions that tapped literal and inferential understanding. Passages 1.1A and 1.2A are age-appropriate whereas passage 2.2A is more difficult (aimed at 15–16 year olds) and includes more complex language. The YARC provides UK norms ($M = 100$, $SD = 15$) and ability scores. Ability scores were calculated from the Rasch model and express reading ability on an interval scale; such scores are not age adjusted.

Oral vocabulary knowledge

This was indexed by the British Picture Vocabulary Scale – Third Edition (BPVS-3; Dunn & Dunn, 2009) and the Vocabulary subtest of the WASI-II (Wechsler, 2011) to capture both breadth and depth of vocabulary knowledge. The BPVS-3 was used as a measure of receptive vocabulary knowledge. Participants are given a word and are asked to select the matching picture from an array of four options. The Vocabulary subtest of the WASI-II is a measure of expressive vocabulary in which children are asked to define words verbally. The BPVS-3 provides UK norms ($M = 100$, $SD = 15$), and the WASI-II generates US norms ($M = 50$, $SD = 10$).

Results

Table 1 shows the means and standard deviations for all observed measures at each time point (Time 1– 3), along with maximum scores and reliabilities. The means and standard deviations for age-standardized measures indicated a distribution of scores that was commensurate with test norms. Notably, the mean standard scores for BPVS vocabulary at Time 1 and Time 2 was a little lower than the other means, though these means are still within the average range. Raw scores indicated ceiling effects on one measure (CC2 regular word reading) and large variation in vocabulary knowledge, word reading and reading comprehension in early adolescence. While there was no evidence of floor effects on any measure, there was evidence of low levels of vocabulary knowledge and reading proficiency.

Confirmatory factor analysis (CFA), measurement invariance and stability of word reading, reading comprehension and vocabulary

All further analyses were conducted with raw scores from each observed variable except reading comprehension where we used ability scores that account for differences in difficulty across passages (for correlations, see Supplementary Materials). We used structural equation models in Mplus 8.0 (Muthén and Muthén (1998-2017)) and Full Information Maximum Likelihood (FIML) was used to handle missing data, which was minimal (see Table 1). The first step was to use confirmatory factor analysis (CFA) to establish factor structures for word reading, reading comprehension and vocabulary at Times 1– 3 and assess measurement invariance across time. Assessing measurement invariance enabled us to investigate whether the three constructs could be defined in the same way across time. We tested whether, over time, factor loadings for observed variables were consistent (metric invariance) and whether both factor loadings and intercepts for observed variables were consistent (scalar invariance). Establishing measurement invariance was a necessary step before estimating growth in the latent variables.

In the first CFA (Figure 2(a)), raw scores on three word reading measures were used as indicators for a latent word reading construct at each time point: the Test of Word Reading Efficiency (TOWRE-2), the Castles and Coltheart test (CC2, irregular word reading only) and the Single Word Reading Test (SWRT). The CC2 regular word reading measure was omitted due to ceiling effects, and CC2 nonwords because it measured nonword rather than word reading. For the latent word reading construct there was only partial metric invariance ($\Delta\chi^2$ (2) = 3.794, p = .150) across time, with factor loadings for TOWRE-2 varying across time. This indicates that performance on word reading tests developed at an uneven rate. Given this partial metric invariance, factor loadings of TOWRE-2 and all intercepts were estimated freely across time. For this model we found strong factor loadings and excellent fit to the data, χ^2 (17) = 22.352, RSMEA = .039 (90% CI = .000-.078), CFI = .998, TLI = .995, SRMS = .035. Coefficient H indicated excellent construct reliability, H = .930, H = .904 and H = .930, at Times 1– 3, respectively. We found high correlations between factors at Times 1– 3, indicating almost full stability in the rank order between children across time.

In the second CFA (Figure 2(b)), raw scores on the three reading comprehension passages were used as indicators of a latent reading comprehension construct at each time point. The reading comprehension model showed full scalar invariance ($\Delta\chi^2$ (8) = 7.150, p = .521), showing that the indicators changed equivalently across time. Therefore, factor loadings and intercepts were fixed to

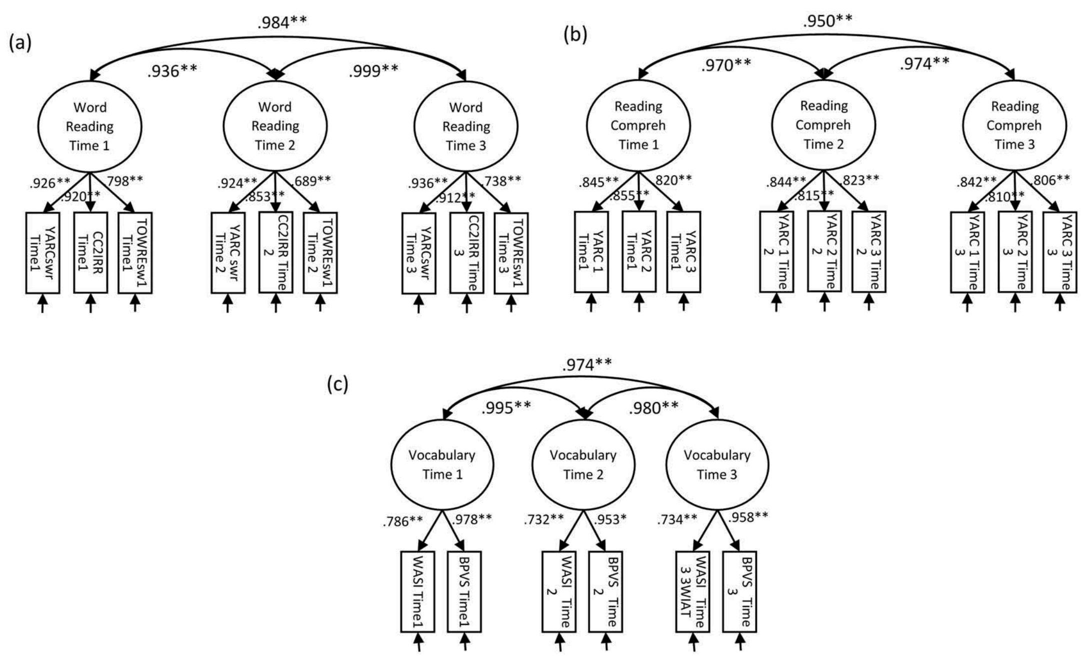

Figure 2. Confirmatory factor analyses with standardized estimates of: word reading (a), reading comprehension (b) and vocabulary (c).

Note. Time 1: 11–12 years; Time 2: 12–13 years; Time 3: 13–14 years be equal across time. This model had strong factor loadings and excellent fit, χ^2 (23) = 19.154, RSMEA = .000 (90% CI = .000-.045), CFI = 1.00, TLI = 1.00, SRMS = .041, and very good construct reliability, *H* = . 879, *H* = .868 and *H* = .861, for Times 1– 3, respectively. Again, high correlations between factors indicated very high stability over time.

In a final CFA (Figure 2(c)), raw scores on the two observed vocabulary variables were used as indicators of a latent vocabulary construct at each time point. Here we found metric invariance ($\Delta\chi^2$ (2) = 3.809, *p* = .149) but only partial scalar invariance across time ($\Delta\chi^2$ (3) = 4.722, *p* = .192): the intercept of the BPVS at Time 2 was significantly different from Time 1 and Time 3. Therefore, we fixed factor loadings and intercepts to be equal across time, with the exception of the Time 2 BPVS intercept, which was estimated freely. This model had strong factor loadings and showed an excellent fit, χ^2 (6) = 5.333, RSMEA = .000 (90% CI = .000-.084), CFI = 1.00, TLI = 1.00, SRMS = .052, and excellent construct reliability, *H* = .930, *H* = .904 and *H* = .930, for Times 1–3, respectively. Once more, high correlations between the time points indicated extremely high stability. In sum, the CFAs yielded latent constructs for word reading, reading comprehension and vocabulary with good reliabilities and very high longitudinal stabilities, as expected.

Growth and spread in word reading, reading comprehension and vocabulary

Next, we estimated unconditional growth models to address our hypotheses about growth and spread. Reading comprehension and vocabulary had full and partial scalar measurement invariance across time, respectively. Therefore, we estimated growth factor models for these two processes. As only partial metric invariance was found for word reading, we estimated a parallel growth model with separate intercepts and slopes for each of the three measures of word reading. Reading comprehension, vocabulary and SWRT word reading fitted a linear growth pattern well and the slope factor was coded 0, 1, 2. As the TOWRE-2 and the CC2 word reading measures had non-linear growth curves, the first factor loading of the slope was coded 0, the factor loading in the middle was freely estimated and the last factor loading coded 2. In these models the intercept is defined as the initial status (performance at Time 1) and the slope reflects average growth per year between the first and the last time point.

The unstandardized means of the intercept (initial status) and the slopes (growth), together with their standard deviations and the standardized residuals, are shown in Table 2 (the unstandardized residuals are fixed to be equal for the same variables across time). The means of the slopes can be interpreted as the mean growth per year. As illustrated by significant slope means, there was significant growth in all processes. The standard deviations of the slopes indicate little variation in the growth rates of the children. Variation in growth rates (around the mean growth) was significant for the latent vocabulary construct and one observed word reading variable (SWRT), but not significant for the latent reading comprehension construct. For the TOWRE-2 and CC2 word reading measures, we fixed the slope variance to zero as the original estimations gave a negative

Table 2. Parameters for growth models.

	Intercept *M* (*SD*)	Slope *M* (*SD*)	Correlation Intercept-Slope	Residual T1	Residual T2	Residual T3
Reading comprehension	.000[a] (11.435**)	4.423** (1.352)	−.790**	.026	.032	.038
Vocabulary	.000[a] (5.025**)	1.738** (.699*)	−.844**	.005	.007	.009
Word Reading:						
TOWRE SWE	74.347** (10.612**)	3.423** (.000[a])	_ [b]	.139**	.139**	.139**
CC2 irregular	25.171** (4.598**)	1.351** (.000[a])	_ [b]	.128**	.128**	.128**
SWRT	49.630** (7.966**)	2.179** (1.166**)	−.433**	.049**	.055**	.059**

Note. T1 = Time 1 (11–12 years); T2 = Time 2 (12–13 years); T3 = Time 3 (13–14 years); intercepts and slopes are unstandardized; residuals are standardized; [a] = Fixed to zero; [b] = As there is no variation in the slopes, no correlations between intercepts and slopes are possible; *$p \leq .05$; **$p \leq .01$

but nonsignificant variation (i.e., a nonsignificant Heywood case). The correlations between initial status and growth for the three estimated slopes (reading comprehension, vocabulary and SWRT) were negative, indicating decreased spread over time. All models had small residuals and fitted the data very well (reading comprehension: χ^2 (26) = 34.475, RSMEA = .040 (90% CI = .000-.072), CFI = .994, TLI = .992, SRMS = .071; vocabulary: χ^2 (9) = 9.805, RSMEA = .021 (90% CI = .000-.082), CFI = .999, TLI = .999, SRMS = .060; word-level reading: χ^2 (31) = 56.760, RSMEA = .063 (90% CI = .036-.088), CFI = .989, TLI = .988, SRMS = .079). In sum, for word reading, reading comprehension and oral vocabulary knowledge there was significant growth and decreased spread (cf. Figure 1(b)), with the latter indicating a narrowing of performance gaps over time.

Predicting growth between processes

Having investigated developmental processes (stability, growth and spread), we examined developmental relations between oral vocabulary knowledge and reading, addressing the following hypotheses: (1) oral vocabulary knowledge would predict growth in reading comprehension; (2) reading comprehension would not predict oral vocabulary knowledge; and (3) word reading would not predict growth in reading comprehension. To do this, we compared two models: a model with only paths from the intercept to the slope of each process (e.g., word reading intercept to word reading slope; see panel a of Figure 3); and a model that additionally included the three hypothesized paths from intercept to slope across the processes (see panel b of Figure 3). As before, we modeled the three word-level reading measures separately. Therefore, we compared three pairs of models, one including each word reading measure. Chi-square difference tests showed no significant difference between any of the three pairs of models: TOWRE-2: $\Delta\chi^2$ (3) = 6.604, p = .086, CC2: $\Delta\chi^2$ (3) = 1.901, p = .593, SWRT: $\Delta\chi^2$ (3) = 4.475, p = .215. Therefore, we favored the more parsimonious models, which did not include paths between processes. Panel c of Figure 3 shows the final model with SWRT word reading, with nonsignificant correlations between the residuals deleted (the other two models yielded equivalent findings, details can be found in the Supplementary Materials). Model fit for this model was very good: χ^2 (130) = 155.699, p = .062, RSMEA = .031 (90% CI = .000-.047), CFI = .994, TLI = .993, SRMS = .065. The very high regressions between intercepts and their corresponding slopes show that initial status is a strong predictor of subsequent progress for word reading, reading comprehension and oral vocabulary knowledge.

Are reading comprehension and vocabulary separable from each other?

Figure 3(c) shows an extremely high correlation between reading comprehension and vocabulary intercepts. This led us to explore whether these constructs were separable from each other at the three time points. To do this we compared two CFA models (see Figure 4). Both models included latent variables for vocabulary and reading at all time points. One model included correlations between both processes at all time points (see panel a of Figure 4), while the second included a second-order language factor for each time point, defined by measures of vocabulary and reading comprehension (see panel b of Figure 4). A chi-square difference test showed no significant difference between the two models ($\Delta\chi^2$ (6) = 2.238, p = .897), therefore we favored the more parsimonious second-order model with fewer parameters. This model shows that at each time point, vocabulary and reading comprehension load on the same language factor with no evidence for separable reading comprehension and vocabulary factors.

The final model appears in Figure 5. The factor loadings of the three common language constructs in this model were very high varying from .971 to 1.0 and the correlations between the three time points were essentially perfect (rT1-T2 = 1.00, rT2-T3 = .989 and rT1-T3 = .988). A lower Bayesian Information Criteria (BIC) for a model where the correlations between the three common language constructs are fixed to one (16,570.097 vs. 16,582.799) suggested that the rank order was perfectly

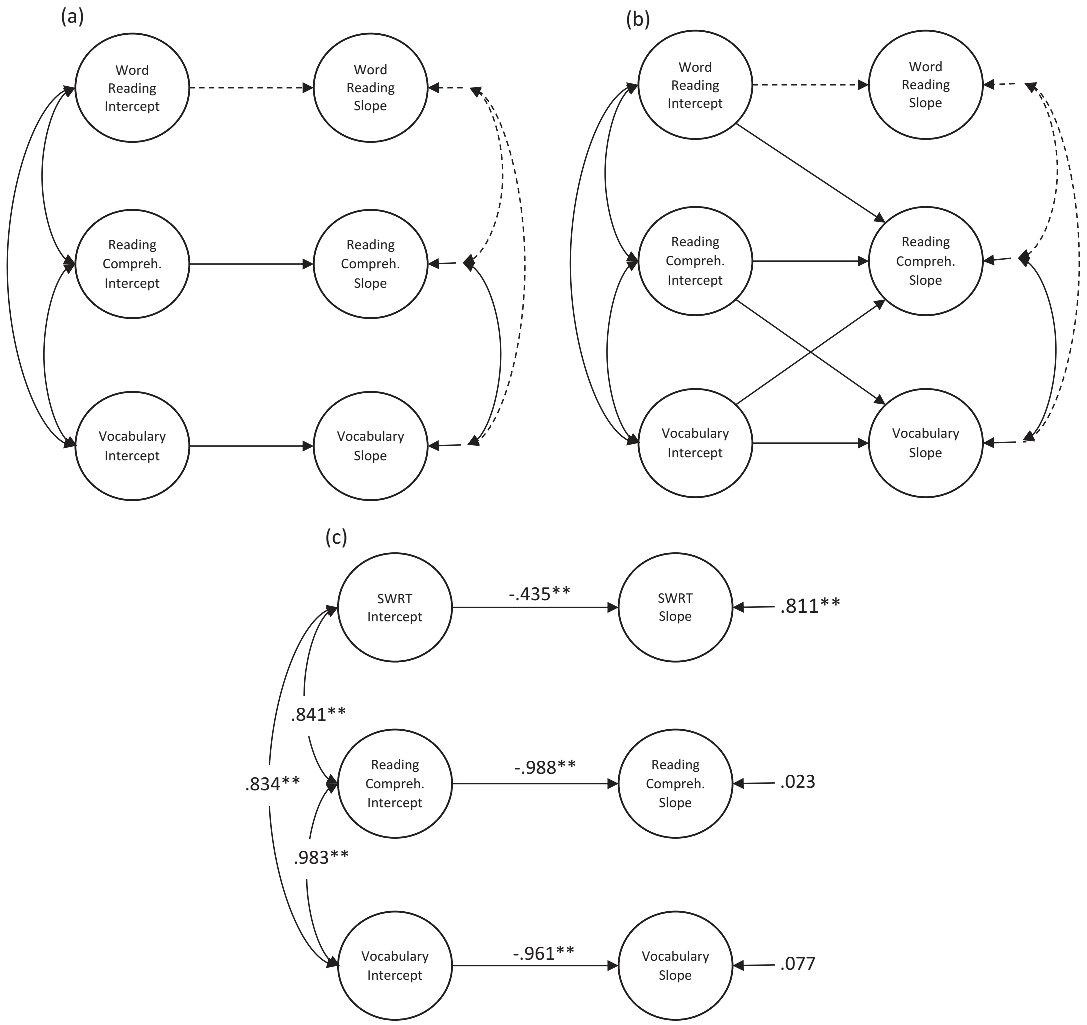

Figure 3. Models establishing prediction of growth between processes. Panel (a) shows a model with paths from the intercept to slope of each process, panel (b) shows paths from the intercept to slope plus hypothesized paths between processes, and panel (c) shows the final model of growth between processes with the SWRT measure of word reading with standardized estimates.

Notes. Three pairs of models were compared, one with each word reading measure (SWRT, TOWRE SWE, CC2 irregular). As the variance of the slopes in the TOWRE and the SWRT models were fixed to zero, the dashed lines in (a) and (b) were only estimated for the SWRT model. The TOWRE and CC2 models are presented in the Supplementary Materials.

preserved across the three time points of the study. This model had an excellent fit to the data, χ^2 (81) = 71.678, p = .761, RSMEA = .000 (90% CI = .000-.028), CFI = 1.00, TLI = 1.00, SRMS = .061.

Discussion

We tracked word reading, reading comprehension and oral vocabulary knowledge from 12–14 years. For each construct, we observed high stability in the rank order of individuals, significant growth, and evidence that achievement gaps were narrowing. Most strikingly, our analyses indicated that, during this period, reading comprehension and oral vocabulary knowledge were best conceptualized as reflecting a single higher order language construct.

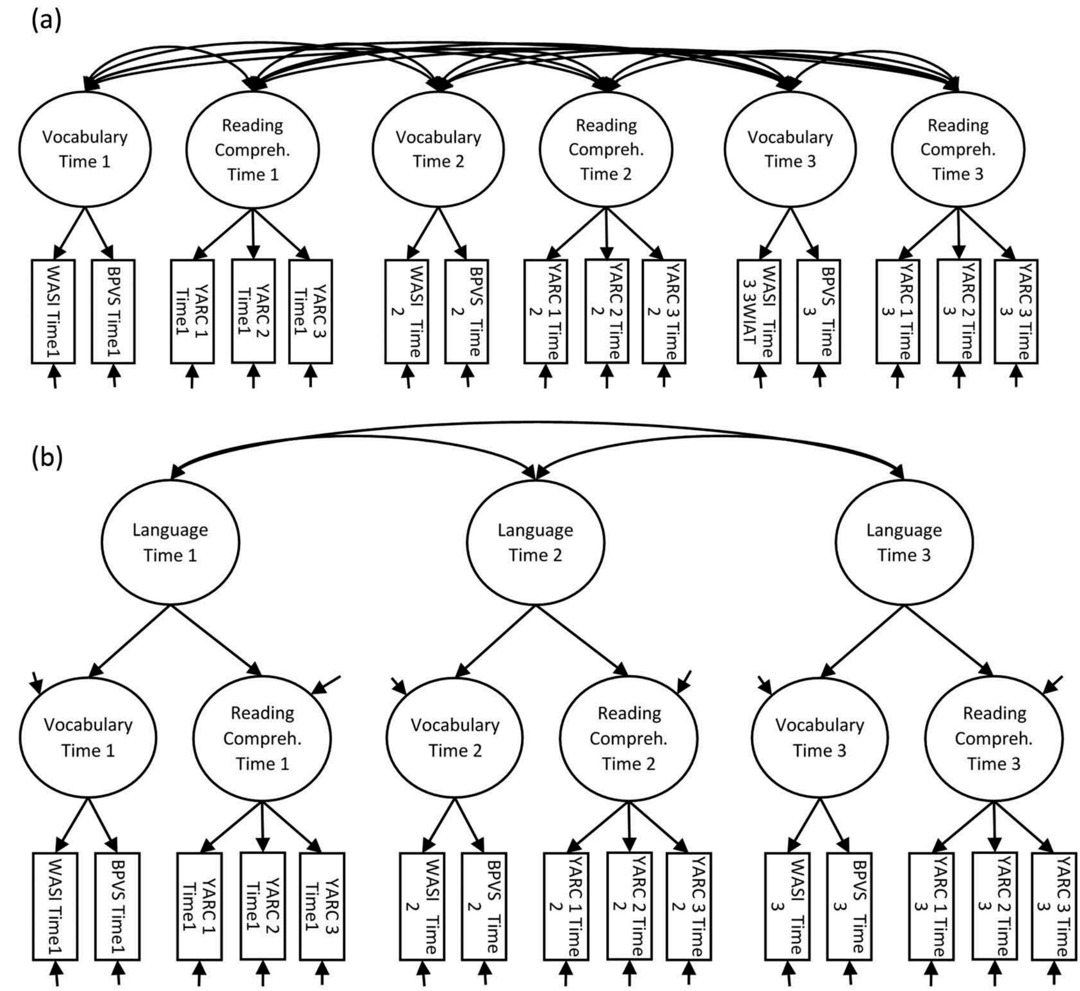

Figure 4. Model comparison used to establish whether reading comprehension and vocabulary are separable. Panel (a) shows a model with correlations between processes at all time points, panel (b) shows a model with a second-order language factor for each time point.

Note. Time 1: 11–12 years; Time 2: 12–13 years; Time 3: 13–14 years

Adolescent development in reading and vocabulary: stability, growth, and spread

Stability in the rank order of individuals was extremely high for word reading, reading comprehension and oral vocabulary knowledge latent constructs. Previous studies have noted similarly high stability from late childhood (age 9 or 10) to adolescence (age 14) in latent measures of language (Bornstein et al., 2014) and word reading accuracy (Hulslander et al., 2010), and observed measures of reading fluency (Eklund et al., 2015; Landerl & Wimmer, 2008). Notably though, stability appears to be lower earlier in development (e.g., Eklund et al., 2015), and for subgroups of children, as demonstrated by the existence of reading difficulties that resolve or emerge in late childhood and early adolescence (e.g., Catts, Compton, Tomblin, & Bridges, 2012; Torppa, Eklund, van Bergen, & Lyytinen, 2015).

Growth over time was significant for word reading, reading comprehension and oral vocabulary knowledge between the ages of 12 and 14. While growth was fairly minimal in real terms (see Table 1), this could still be functionally important. Only one study had tracked reading development within

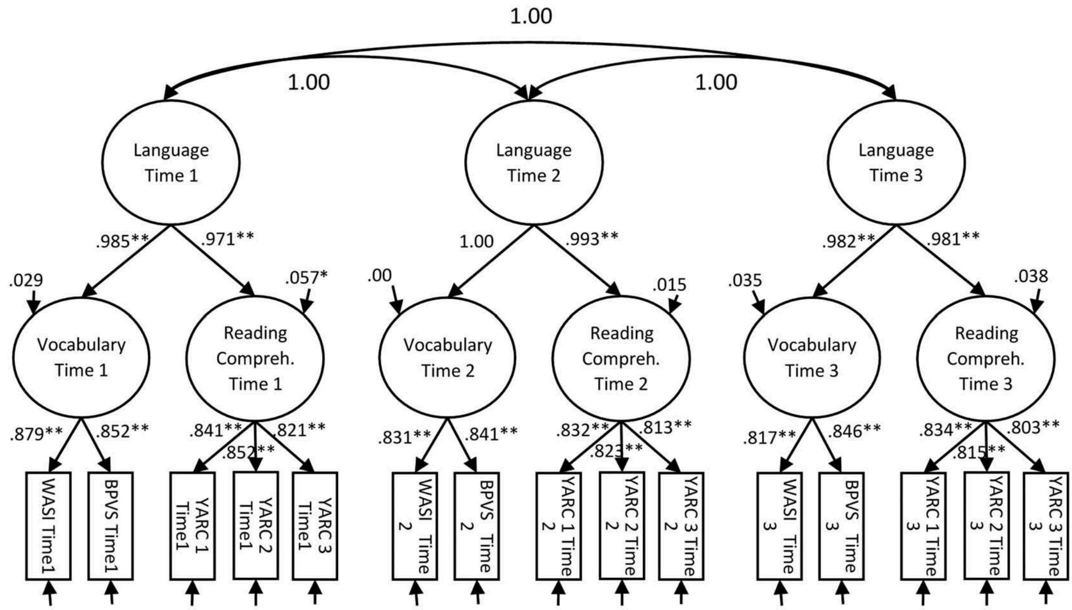

Figure 5. Final model with second-order language factor for each time point.
Note. Time 1: 11–12 years; Time 2: 12–13 years; Time 3: 13–14 years; estimates are standardized

adolescence (Francis et al., 1996) and our findings resonate with this study in showing that reading continues to grow well into adolescence.

In relation to spread, our analyses revealed negative intercept-slope associations, indicating that for word reading, reading comprehension and vocabulary, attainment gaps between the highest and lowest performing pupils were reducing in early secondary school. Notably, this effect was more pronounced for reading comprehension and vocabulary than for word reading. Our findings are in line with Shaywitz et al. (1995), who observed this for reading. Like them, we think it unlikely that this reflects poor measurement sensitivity due to ceiling effects (see Table 1). Instead, we interpret this correlation as indicating a compensatory pattern of growth in early adolescence, such that lower achieving individuals show more growth than higher achieving peers who are approaching a natural plateau in development. Also, some of our participants may have received effective intervention, though we did not collect information about this. Importantly, our findings do not support the existence of "Matthew effects" for reading and oral vocabulary knowledge in early adolescence, contrasting with previous research (Duff et al., 2015; Quinn et al., 2015). Like Pfost et al. (2014), we call for further longitudinal research to reconcile mixed findings. One possibility is that while achievement gaps widen in childhood, compensatory patterns characterize adolescent development.

Though achievement gaps may be narrowing in adolescence, they were not closing. Coupled with limited (though significant) growth and almost perfect stability between 12 and 14 years, this may indicate a rather bleak picture for addressing language and literacy difficulties at this point in time. However, without systematic instruction and intervention in secondary school, this conclusion is premature. In England, whilst there is a clear curriculum for teaching foundational readings skills (e.g., word reading, using comprehension strategies) in the primary classroom, these skills are rarely taught in secondary schools and teachers report that they lack the knowledge and resources to do this. It is entirely plausible that with professional development and appropriate instruction and intervention tools, secondary schools can promote reading abilities (cf. Hulslander et al., 2010). Indeed, promising intervention approaches have yielded modest improvements in reading comprehension for secondary pupils (Clarke, Paul, Smith, Snowling, & Hulme, 2017; Scammacca, Roberts, Vaughn, & Stuebing, 2015; Vaughn et al., 2013). For those at the bottom of our distribution even modest improvements could be functionally important.

Developmental relationships between reading and oral vocabulary in adolescence

For word reading, reading comprehension and oral vocabulary knowledge, initial status in each construct was an extremely strong predictor of growth in that construct, leaving very little scope for predicting additional variation in growth (cf. Hulslander et al., 2010). Further analyses showed word reading at 12 years did not predict subsequent growth in reading comprehension, and that reading comprehension and vocabulary were best captured as a single construct. Before we consider the theoretical implications of these findings, some methodological considerations are worthy of note. One reason for the particularly close relationship between oral vocabulary knowledge and reading could be that the reading comprehension task that we used is particularly dependent on oral vocabulary knowledge. We measured reading comprehension with three passages from the York Assessment of Reading for Comprehension (YARC; Stothard et al., 2010). The YARC categorizes comprehension questions by type (vocabulary but also literal, knowledge-based inference etc), and answering seven of the 39 questions at each time point indexed vocabulary knowledge for low frequency words: e.g., what does "commissions" mean? Post-hoc analyses estimated alternative latent constructs for reading comprehension that did not include the vocabulary-dependent questions. The relationship between reading comprehension and vocabulary knowledge remained extremely high (r = .95 – .99) indicating that these vocabulary items did not unduly influence our findings.

In a similar vein, our findings may have been influenced by our choice to administer multiple measures from a single reading comprehension test (Stothard et al., 2010), rather than multiple tests. We chose to use the YARC because it is the only age-appropriate individually administered reading comprehension test with UK norms. It is also valid and reasonably reliable given the complexity of measuring reading comprehension (see Table 1 for Cronbach's alpha, and Supplementary Materials for test-retest reliability). We also chose to administer the same YARC passages each year. It is possible (though perhaps unlikely) that our growth estimates are influenced by familiarity with the passages in addition to reading comprehension development. If this was the case, narrowing in achievement gaps could, in part, reflect poorer comprehenders showing greater benefit from annual re-reading. It would be useful for future research to replicate our findings with more than one standardized assessment of reading comprehension (cf. Catts, 2018) and by using different, but equated, passages across time.

A strength of our study is that our latent oral vocabulary construct captured breadth and depth, as well as receptive and expressive knowledge about words. However, vocabulary knowledge extends beyond lexical knowledge (Smith & Murphy, 2014) and our measures focused on knowledge of everyday words, rather than academic vocabulary or knowledge of words that is closely linked to the secondary school curriculum (Laufer & Nation, 1995; Snow, 2010). Further, oral vocabulary is just one aspect of oral language. Grammar, inferencing and listening comprehension also deserve attention in adolescence as these variables explain individual differences in reading comprehension in childhood, both concurrently (e.g., LARRC & Logan, 2017) and longitudinally (LARRC & Chiu, 2018; Lervåg et al., 2018). Inferencing is also a strong concurrent predictor of reading comprehension in adolescence (Ahmed et al., 2016) and vocabulary and grammar may be discrete constructs in adolescence (Tomblin & Zhang, 2006), and therefore show different longitudinal relationships with reading comprehension. Beyond oral language, there are other factors that may be important for adolescent reading comprehension including reader-level variables like attention, motivation for reading and amount of reading practice (Arrington, Kulesz, Francis, Fletcher, & Barnes, 2014; McGeown, Duncan, Griffiths, & Stothard, 2015; Mol & Bus, 2011), and text-level factors like text type (Francis, Kulesz, & Benoit, 2018).

The simple view of reading (Gough & Tunmer, 1986) posits that reading comprehension is the product of word reading and oral language comprehension processes. Returning to our findings, we observed correlations between word reading and reading comprehension that are equivalent to existing concurrent studies (García & Cain, 2014). However, and in line with cross-sectional findings (Foorman et al., 2015; Language and Reading Research Consortium (LARRC), 2015), our findings suggest that by 12 years, a shift has occurred such that word reading is no longer such a strong predictor of individual differences in reading comprehension in English. Rather, oral language (as indexed here by vocabulary knowledge) and reading comprehension are closely intertwined (cf. Ahmed et al., 2016), and these constructs are less closely related to word reading. This does seem to contradict Foorman et al.'s cross-sectional observation of that word reading fluency and oral vocabulary can be captured as a single lexical construct in adolescence. It also raises interesting questions about the dimensionality of oral and written language in adolescence that should be addressed in future longitudinal research.

Though we hypothesized that oral vocabulary knowledge would predict subsequent growth in reading comprehension (Reynolds & Turek, 2012), exploratory analyses indicated that oral vocabulary knowledge and reading comprehension could be captured as a single construct. Key theoretical perspectives emphasize the importance of oral vocabulary knowledge for reading comprehension. In the reading systems framework (Perfetti & Stafura, 2014) and related approaches (e.g., Perfetti & Hart, 2002), strong connections between word forms and meanings are critical for reading comprehension. There are a number of mechanisms that might explain the close relationship between oral vocabulary knowledge and reading comprehension. Oral vocabulary knowledge will make direct contributions to reading comprehension by allowing readers to understand individual words in a text. In addition, efficient retrieval of meaning will free resources so that the reader can engage in higher level comprehension processes like integration and inference (cf. Perfetti & Hart, 2002). The relationship between oral vocabulary knowledge and reading comprehension may also be mediated by integration processes and the ability to make inferences (e.g., Barnes et al., 2015; Ahmed et al., 2016; LARRC, Currie & Muijselaar, 2019). On the one hand, knowledge of the meanings of specific words may be important for making inferences, and therefore for building a mental representation of the text. Conversely, being able to make inferences is thought to be important for using context to learn the meanings of new words. Oral vocabulary knowledge may also reflect the contribution of background knowledge more broadly. Indeed, reading comprehension will be influenced by a reader's background knowledge of the text (e.g., Ahmed et al., 2016).

Conclusions

We tracked oral vocabulary knowledge and reading from 12– 14 years in 210 adolescents, obtaining multiple indicators for word reading, oral vocabulary knowledge and reading comprehension so that we could model these constructs using latent variables that control for measurement error. Our findings indicate that reading and vocabulary show high stability in the rank order of individuals, and continue to grow in early adolescence, with decreasing variation amongst individuals. These findings underline the importance of conducting further language and literacy research with adolescents. Data are needed to conceptualize changes in adolescent reading so that we can constrain theories of reading development. This will add to a growing broader understanding of the important changes that occur during adolescence (Blakemore, 2018). A better understanding of adolescent reading development will inform educational strategies and interventions for supporting adolescent reading. Indeed, during adolescence, reading becomes an increasingly important mechanism for learning and yet we know little about how to support reading effectively at this point. Our findings indicate that any such support should emphasize oral vocabulary knowledge, as well as reading abilities.

Note

1. The CC2 can be accessed freely from Macquarie University: https://www.motif.org.au/home/test/cc2.

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Author contributions

Jessie Ricketts conceived of and led the study, and took the lead in manuscript writing. Arne Lervåg led the data modelling and contributed to manuscript writing. Nicola Dawson and Lucy A. Taylor contributed to study design and manuscript preparation. Charles Hulme contributed to study design, data analysis and manuscript writing.

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