

The Relationship Between Reading and Intelligence in Primary School Aged Children: Implications for Definitional Models of Dyslexia

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Abstract: The validity of definitional models of developmental dyslexia (DD) derived from the difference between intelligence and reading quotients, is challenged by the failure of these models to consider expected developmental changes in the relationship between these constructs. The purpose of this study was to examine age-related changes in the correlations between verbal and nonverbal intelligence and reading ability. One hundred and twenty six children aged between 7 - 11 years of age were administered the Peabody Picture Vocabulary Test - Third Edition (PPVT-III, a measure of verbal intelligence) the Raven Coloured Progressive Matrices (CPM, as a measure of non-verbal intelligence) and various measures of reading ability (the Neale Analysis of Reading Ability - Revised, NARA, and selected subtests from the Woodcock-Johnson Tests of Achievement- Revised, WJ-Ach). The PPVT-III had significantly stronger correlations than the CPM with reading rate, single word reading, and a measure of text comprehension. Both measures correlated poorly with pseudo-word reading. Despite differences between the two intelligence measures, both correlated more strongly with measures of reading comprehension than with traditionally defined measures of decoding ability. These results are discussed in the context of the validity of current definitions of DD. The need for greater consideration of the appropriateness of certain assessment measures at various ages both in testing and in the interpretation of previous studies, is highlighted.

Keywords: Reading ability, verbal intelligence, nonverbal intelligence, dyslexia.

INTRODUCTION

Developmental dyslexia (DD) is often diagnosed when reading achievement is not commensurate with benchmarks such as intellectual functioning, chronological age, or educational instruction [1]. Definitions of DD based on a discrepancy between intellectual functioning and some measure of reading achievement have been particularly popular, despite wide criticisms regarding usage [2-9]. Such models have been criticized on the basis of poor validity, being more susceptible to effects of regression to the mean, lack of discriminative and predictive power, and unreliability [3, 4, 7, 10-21]. Regression-based models have been developed to overcome some of these problems (i.e., regression to the mean). The focus of the majority of these models is centered on the relationship between intelligence and reading achievement and this lingers as a contentious issue.

Toth and Siegel [22] argued that reading and intelligence should be unrelated given the assumption that “dyslexia is caused by some form of highly circumscribed cognitive deficit which does not affect IQ”. Others have challenged the empirical validity of this statement arguing that reading disability limits maturation in many other cognitive domains (e.g., vocabulary, general knowledge, etc.) [23-26].

The correlation between intelligence and reading has different roles in discrepancy and regression formulae. For discrepancy-based models, the weaker the correlation between intelligence and reading, then the more reliable the intelligence-achievement difference score [20, 27-30]. Conversely, for regression-based models a stronger relationship between reading and intelligence is required to reduce errors in prediction [27, 31-33]. The challenge is reaching consensus as to what is an acceptable relationship between reading and intelligence, in order to satisfy both theoretical and psychometric specifications.

The correlation between intelligence and reading has been variously estimated to lie between 0.05 to 0.80 [20, 34-40]. It is likely that the diversity in correlations may be attributed to the measures of intelligence and reading adopted by individual researchers. Measures of reading comprehension tend to be more strongly correlated with intelligence than are measures for orthographic decoding [13, 39, 41]. Measures of verbal intelligence (e.g., verbal intelligence quotient (VIQ), Vocabulary or Peabody Picture Vocabulary Test - Third Edition (PPVT-III)) have also been shown to be more closely associated with reading ability than nonverbal intelligence [13, 19, 40, 41]. This is not surprising given that VIQ is derived from tests based on vocabulary, syntactic knowledge, linguistic coding ability, and short-term verbal memory [13, 19, 25].

The use of VIQ in estimating the relationship between intelligence and reading ability is problematic for two reasons. First, the relationship is likely to be overestimated

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as the same as the language-based abilities underlie performance on both VIQ and reading measures [19]. Second, if a child has compromised language abilities, then VIQ is not necessarily going to reflect the child's true 'intellectual capacity' [7, 12, 15, 19, 36, 38, 40, 42-44]. Poor reading can adversely affect scores on traditional intelligence tests; and conversely, impoverished intellectual capacity can impede reading development [43].

Nonverbal intelligence measures (e.g., matrix reasoning tests) have been considered an alternative to VIQ [14, 36, 37]. Stanovich *et al.* [40] examined the relationship between the Raven's Standard Progressive Matrices Test (SPM), the Gates-MacGinitie Reading Tests, and the Reading Survey of the Metropolitan Achievement Test. Correlations ranged from 0.30 in elementary grades to a high of 0.70 in grades 9 and above. Stanovich *et al.* [40] did not favour the SPM stating "*intelligence tests like the Raven, which do not directly tap a recognized sub-skill of reading, but are instead measures of abstract reasoning or 'mental energy' but supposedly in the quintessence of g.... are generally poor predictors of reading ability*". Others oppose this view arguing that moderate to large effects exist for the relationship between reading and matrix reasoning tasks [35-38].

The child's developmental stage may also influence the strength of the correlation between reading and intelligence [40]. At 5-7 years of age most children have a limited sight word vocabulary and minimal awareness of orthographic and phonologic principles [45]. For very young learner readers, reading is effortful with decoding placing greater demands on attention and other cognitive resources, than text comprehension [25, 40, 45, 46]. With cognitive maturation and the associated learning of orthographic and phonologic principles, reading becomes automatic and fluent, and more attentional resources are available to be allocated to understanding the semantic meaning of the text [46, 47]. This process occurs from 7 years of age and with reading experience and further development of language skills, growth in meta-cognitive abilities (i.e., comprehension and intellectual functioning) can be expected [43, 46]. Therefore the correlation between reading and intelligence (particularly verbal intelligence) is strongest when the child is a proficient reader, rather than in the early stages of reading development [36-38, 40]. The importance of choice of research measures for different age groups is also highlighted.

In summary, the correlation between reading and intelligence is fundamental to discrepancy and regression based models of DD. If the correlation between reading and intelligence does fluctuate with development as expected, then the psychometric properties of these models must vary depending on the age of the child [20, 27, 31, 48]. These models may also fluctuate depending of the measures of intelligence and reading administered. If such factors are not considered, then the validity of the diagnosis of DD is undermined.

Thus the first aim of the study was to determine verbal intelligence would be a stronger predictor of reading ability than nonverbal intelligence for children aged between 7 and 11 years. Two popular measures of intellectual functioning based on their relative independence of reading ability for successful task completion [49, 50] are contrasted; a verbal

measure the PPVT-III and a non-verbal measure the Raven's Coloured Progressive Matrices (CPM). We have also elected to use an array of reading measures pertinent to both decoding or comprehension abilities, as the second aim was to establish whether verbal and nonverbal intelligences are more strongly correlated with measures of reading comprehension than decoding ability across all age levels. Here reading comprehension is defined as the ability to analyse, create a mental representation of, and to appreciate what is written in print [51, 52]. Decoding is defined simply as efficient word recognition or word retrieval [51].

MATERIALS AND METHODOLOGY

Design

This is a cross-sectional cohort study of primary school aged children in five age groups: 7 years; 8 years; 9 years; 10 years; and 11 years.

Participants

The sample comprised 126 children (62 male, 64 females) from two state primary schools within the state of Victoria, Australia ranging in age from 7 to 11 years. These schools were arbitrarily selected from two of the nine Department of Education, Employment and Training (DEET) regions to ensure sample diversity. The two regions were the Northern and Southern Metropolitan regions. Active parental consent [53] was sought for each child as prescribed by the State Government and institutional ethics committees. Children were issued a consent form, which parents completed and returned the form if they wished their child to participate in the study.

A priori sample size calculations and power analysis were conducted using the software package Sample Power - Release 2 [54]. Given previous reports of moderate to strong correlations (i.e., $r = 0.30$ to $r = 0.50$), an alpha of .05, and power set at .80; between 26 and 82 children were required for the study. Sufficient power to detect both moderate to large effects was assumed with the obtained sample of 126 children.

Children were excluded from the study if they had a diagnosis of mental retardation (e.g., intelligent quotient (IQ) < 70), neurological anomalies (e.g., epilepsy, traumatic brain injury), did not speak English as a first language, or they had visual or hearing impairments that may have impeded reading acquisition.

Data were collected between February 2002 and November 2004.

Measures

The measures selected for use in this study have frequently been employed in the learning and reading disability literatures for diagnostic purposes.

Intellectual Ability

Two different measures of verbal and nonverbal intellectual functioning were selected: the *PPVT-III* and the *CPM*. Dunn & Dunn (1997) advocated that the *PPVT-III* serves two purposes: first, to measure an individual's listening comprehension or receptive vocabulary; and second, to serve as a screening tool for verbal ability [49]. A

Task Force under the guidance of the Board of Scientific Affairs (BSA) of the American Psychological Association (APA) highlights the PPVT-III as a discrete measure of verbal intelligence [55] assessing the ability to select from an array of four pictures, the picture that best represents the spoken word. It has demonstrated usefulness in populations such as gifted children, children with mental retardation, autism, cerebral palsy, expressive language deficits and DD [49]. Its value for assessing receptive vocabulary or estimating verbal intelligence in DD is of particular importance, as it does not require reading or writing for successful test performance. On this basis, it has been argued that it represents the purest measure of verbal ability in these children [49].

The CPM is a nonverbal matrix reasoning task that estimates the nonverbal component of Spearman's *g* factor [50]. It provides an unbiased estimate of fluid intelligence for children with reading or language disabilities [35, 40]. It comprises 36 brightly coloured items differing in terms of increasing complexity. A multiple choice response style is demanded with children selecting the best fitting piece from an array of six stimuli.

The PPVT-III and the CPM are both reliable measures [49, 50, 64]. Additionally, both measures have been validated against other intelligence measures. For example, the PPVT-III correlates strongly with traditional indices of intelligence such as FIQ ($r = .90$), VIQ ($r = .91$), and PIQ ($r = .90$) [49]. Similar correlations have also been noted in other studies [56, 57]. The CPM also has strong correlations with FIQ ($r = .91$), VIQ ($r = .84$), and PIQ ($r = .83$) from the WISC [58]. It is important to note that the PPVT-III and CPM are not perfectly correlated with the Wechsler Scales, with some variance being left unexplained.

Reading Ability

Neale Analysis of Reading Ability - Revised (NARA) [59] comprises graded short-passages and through assessing a child's oral reading skills derives indices of conventional reading speed, accuracy, and comprehension. Reading *Rate* provides an index of the child's normal reading speed and is converted to the number of words read per minute. Reading *Accuracy* is the number of errors accumulated when reading the passages and reading *Comprehension* involves assessment of what the child remembers regarding the content of the passages. The NARA has been standardized Australian primary school children and for children in several other countries, making it an ideal reading measure for the present study.

Reading-related subtests from the Woodcock-Johnson Tests of Achievement (*WJ-Ach*) were used [60]. *Letter-Word Identification* gauges both the ability to identify and recognize a series of isolated letters and words, and can be considered a measure of both sight word recognition and decoding ability [61]. *Word Attack* is a pseudo-word reading task that evaluates phonic and structural analysis skills. Pseudo-word reading is the purest index of decoding ability devoid of lexical content [62, 63]. *Passage Comprehension* is a cloze sentence task requiring the silent reading of a sentence and naming of a missing word. *Reading Vocabulary* assesses both word recognition and the ability to

name words with similar (synonyms) or opposite (antonyms) meanings [60].

Procedure

All tests were administered to the children by trained clinicians. Standard administration guidelines were followed. Children were individually assessed in a quiet room separate from their main classrooms. Two one hour sessions were conducted on separate days approximately one week apart. Test order was counterbalanced to minimize the effects of test order bias.

Data Analysis

Analyses were based on standard scores with a mean of 100 and a standard deviation of 15. Standard scores were unavailable for the NARA and the CPM and had to be calculated. Standard scores for the NARA were derived using the raw scores for Rate, Accuracy, and Comprehension compared to the age-appropriate averages and standard deviations reported by Neale (1991). The CPM standard scores were calculated using descriptive data from a normative study for primary school children from Victoria Australia [56].

Some children had incomplete data; however, the percentage of missing data per variable was no more than 5% (i.e. 6 cases). Using Little's MCAR test from the Missing Value Analysis module of the Statistical Package for the Social Sciences 15.0 (SPSS), it was determined that there was no significant discrepancy between the pattern of missingness and 'missing completely at random' (MCAR), $\chi^2(91) = 94.487, p = .380$, and accordingly missing data was imputed using the expectation maximization (EM) algorithm [65]. This method of imputation is superior to mean substitution and regression methods as it does not overestimate the variance or interfere with covariance matrices [65]. The complete data set created through the EM algorithm was used in the proceeding analyses.

Several techniques screened the data for normality, heteroscedasticity, homogeneity of variance, and for outliers, including visual inspection of histograms, boxplots and scatterplots, as well as checking of statistics such as skewness, kurtosis, and the Kolmogorov-Smirnov test. No outliers were observed and there were no violations to the statistical assumptions.

A diverse range of statistical techniques were used for data analysis, including Pearson Product Moment Correlation Coefficients (Pearson's r), the William's t test, factor analysis, and standard regression analyses.

Pearson Product Moment Correlation Coefficients (Pearson's r) were employed to examine the zero-order relationships between the reading measures, the PPVT-III, and the CPM. The criteria used to evaluate the strength of Pearson's r were $r = .1$ a small effect, $r = .3$ a moderate effect, and $r = .5$ a large effect [66]. These correlations are reported for both the total sample of 126 children as well as separately for the five age groups.

To establish whether the PPVT-III had significantly higher correlations than the CPM, with the reading measures, the William's t test was adopted. This statistic tests the hypothesis that there will be no statistical difference between

two correlations from dependent samples ($H_0: \rho_{ZX} = \rho_{ZY}$) [67]. For example, the William's t test can be used to determine whether a correlation of 0.69 is significantly higher than a correlation of 0.45. The formula for William's t test is as follows:

$$t = \frac{(r_{ZX} - r_{ZY})\sqrt{(N - 3)(1 + r_{XY})}}{\sqrt{2|R| + \frac{(r_{ZX} - r_{ZY})^2(1 - r_{XY})^3}{4(N - 1)}}} \quad (1)$$

where $|R|$ is the determinant of the correlation matrix R .

This statistic is distributed on a t distribution and can be compared to a critical value of t with degrees of freedom (df) $N - 3$. In this study, as the hypothesis was directional a one-tailed test was used with an alpha (α) of .05. That is, does the PPVT-III have a significantly higher correlation with a reading measure than the CPM? Additionally, these analyses were confined to the total sample rather than to the separate age levels because of limited sample size.

As there were several reading measures, principal axis factor analysis with direct oblimin (oblique) rotation was to reduce the number of variables. Factor scores were derived using the regression approach. They have a mean of 0 and a variance that equates to the squared multiple correlation (SMC) between the variables and the factors [65]. These factor scores were transformed so they were on the same scale as the other measures (i.e. a mean of 100 and a standard deviation of 15). The correlations of the PPVT-III and the CPM with these factors were then contrasted using the William's t test.

A series of multiple regression analyses examined the combined contribution of the CPM and the PPVT-III to the explanation of variance in each of the reading measures.

RESULTS

Descriptive statistics (means and standard deviations) for the intelligence and reading measures for the total sample as well as for the five age levels is displayed in Table 1. A series of one-way analysis of variance (ANOVAs) determined the comparability of the age groups on each of

the measures. There were no significant differences between any of the age groups on any of the measures and all means were within the 'average' range (standard score range 90-109 [68]).

Table 2 comprises the Pearson correlations of the PPVT-III and the CPM with the various measures of reading ability for the total sample as well as for the five age groups. Correlations for the overall sample ranged from weak to moderate, with the PPVT-III having stronger correlations with the reading measures than the CPM. Significant differences, as determined by the results of the William's t tests, between the correlations of the CPM and the PPVT-III were noted for: Rate, William's $t(123) = -1.88, p = .031$; NARA Comprehension, William's $t(123) = -1.92, p = .029$; Letter-Word Identification, William's $t(123) = -1.78, p = .039$; and Reading Vocabulary, William's $t(123) = -2.13, p = .018$.

Noteworthy is that the strength of the correlations between the CPM and the PPVT-III with the reading measures appeared to fluctuate with the age of the child. For the 7-year olds, there were no relationships between the intelligence and reading measures, whereas for the 8 year olds there was a sudden increase in the strength of the associations, to the point where significant moderate to strong correlations were observed. The strength of the correlations declined slightly with age, particularly those correlations between the CPM and reading. At 11 years of age, the correlations between the intelligence and reading measures once again strengthen.

The pattern matrix from the principal axis factor analysis based on the total sample is displayed in Table 3. Two factors were derived from the factor analysis. The first factor represents 'Decoding' ability with variables loading highest on this factor including Word Attack, Accuracy, Letter Word Identification and Rate. The second factor was representative of 'Comprehension' of written material with variables loading highest on this factor including Reading Comprehension, Passage Comprehension, and Reading Vocabulary. 'Decoding' accounted for 69.43% of the variability, and 'Comprehension' explained 5.05% of the variance.

Table 1. Descriptive Statistics (Means = M and Standard Deviations = SD) for Intelligence and Reading Measures for Each Age Level and for the Total Sample (n = 126)

Measure	Total Sample (n = 126)		7 Years (n = 19)		8 Years (n = 27)		9 Years (n = 23)		10 Years (n = 32)		11 Years (n = 25)	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
CPM	99.01	±13.32	100.65	16.09	96.81	14.06	101.53	9.82	98.13	15.06	98.95	10.92
PPVT-III	96.71	13.12	100.21	13.69	95.07	12.61	97.75	13.48	98.94	12.8	92.00	12.74
NARA Rate	101.84	14.04	101.21	14.84	104.04	14.96	100.96	17.05	101.51	10.94	101.17	13.85
NARA Accuracy	97.22	15.68	100.86	16.94	103.79	17.82	94.25	14.15	93.27	12.26	95.15	15.88
NARA Comprehension	96.78	12.06	104.02	13.75	97.41	11.86	94.74	10.99	95.14	11.82	94.57	10.82
Letter-Word Identification	104.11	18.79	108.14	17	107.52	23.09	101.35	15.97	104.16	16.67	99.84	20.01
Passage Comprehension	97.75	12.47	103.87	10.57	99.85	16.68	96.92	9.59	97.31	10.56	90.64	12.68
Word Attack	106.77	21.78	106.88	21.96	111.18	24.19	103.98	23.65	105.91	17.87	105.6	22.75
Reading Vocabulary	98.87	14.24	103.93	12.27	99.96	18.06	96.38	11.52	101.06	11.94	93.32	14.74

Table 2. Pearson Zero-Order Correlations Between Measures Verbal and Nonverbal Intelligence and Reading Ability for the Total Sample of 126 Children and for the Five Age-Levels

	Total Sample		7 Years (n = 19)		8 Years (n = 27)		9 Years (n = 23)		10 Years (n = 32)		11 Years (n = 25)	
	CPM	PPVT-III	CPM	PPVT-III	CPM	PPVT-III	CPM	PPVT-III	CPM	PPVT-III	CPM	PPVT-III
NARA Rate	0.15	0.33**	0.01	-0.06	0.41*	0.41*	0.09	0.49*	0.03	0.23	0.26	0.55*
NARA Accuracy	0.28**	0.41**	0.06	0.04	0.68**	0.59**	0.35	0.65**	0.01	0.41*	0.34	0.48*
NARA Comprehension	0.37**	0.53**	0.17	0.22	0.78**	0.54**	0.39	0.75**	0.17	0.37*	0.51**	0.86**
Letter-Word Identification	0.25**	0.41**	-0.06	-0.03	0.70**	0.59**	0.29	0.43*	-0.01	0.36*	0.25	0.52**
Passage Comprehension	0.38**	0.51**	0.02	0.20	0.65**	0.67**	0.42*	0.65**	0.31	0.32	0.49*	0.55**
Word Attack	0.20*	0.26**	-0.08	-0.24	0.69**	0.54**	0.27	0.33	-0.04	0.17	0.16	0.39
Reading Vocabulary	0.42**	0.59**	0.25	0.24	0.69**	0.72**	0.37	0.49*	0.28	0.49*	0.53**	0.77**

* $p < 0.5$; ** $p < .01$.

The William's t test was used to contrast the correlations that the PPVT-III and the CPM had with the two factors. There was no difference between the PPVT-III ($r = 0.39$, $p < .01$) and the CPM ($r = 0.26$, $p < .01$) with respect to their correlations with the 'Decoding' factor, William's $t(123) = -1.41$, $p = .08$; however, the PPVT-III ($r = 0.59$, $p < .01$) had a significantly higher correlation with the 'Comprehension' factor, than did the CPM ($r = 0.39$, $p < .01$), William's $t(123) = -2.30$, $p = .011$.

Table 3. Factor Loadings from a Principal Axis Factor Analysis with Direct Oblimin Rotation Depicting the Underlying Relationships Between Different Measures of Reading Ability

Reading Measure	Factor 1 'Decoding'	Factor 2 'Comprehension'
Word Attack	1.05	-0.15
NARA Accuracy	0.77	0.18
Letter-Word Identification	0.72	0.25
NARA Rate	0.52	0.20
NARA Comprehension	-0.05	0.75
Reading Vocabulary	0.15	0.75
Passage Comprehension	-0.04	0.90
Percent of variance explained by factor	69.43%	5.05%

The PPVT-III had significantly higher correlation with 'Comprehension' than with 'Decoding', William's $t = -5.81$, $p < .01$. A similar result was obtained for the CPM as it had a significantly higher correlation with 'Comprehension' than it did with 'Decoding', William's $t = -3.50$, $p < .01$.

Table 4 comprises the Multiple R^2 , standardised regression (β), and semi-partial squared (sr^2) coefficients for each regression analysis. For the 'Comprehension' factor, nearly 40% of the variance was explained by both the PPVT-III and the CPM, compared with only 17% of the variance in the 'Decoding' factor. The PPVT-III and the CPM explained the least amount of variability (only 8%) in pseudo-word reading.

In summary, the PPVT-III as a measure of verbal intelligence was significantly more strongly correlated than the CPM with the rate of reading, single-word reading, vocabulary or word knowledge, and understanding of what was read in a text. Overall, both verbal and nonverbal intellectual ability was more strongly correlated with text comprehension rather than with measures of orthographic and phonological decoding.

DISCUSSION

Understanding and quantifying the relationship between intelligence and reading ability is fundamental for the validity and reliability of the discrepancy- and regression-based models of DD. This study explored the relationships of two measures of intellectual ability, namely the PPVT-III and the CPM, with an array of reading tests. Correlations between reading and intelligence measures ranged from 0.15 (for Rate and CPM) to 0.53 (for NARA Comprehension and the PPVT-III) (refer to Table 2), indicating that for this sample of children, intelligence explains approximately 29%¹ of the variability in reading ability which is lower than previous estimates [35-40]. A reason for this disparity is that earlier studies have administered group based tests to large samples of children [35, 37, 38, 40]. Group administered tests differ from individually administered tests in terms of form, design of questions, response format, flexibility, and norms [32].

Intelligence, Decoding and Reading Comprehension

Reading ability can be subdivided into a number of subcomponents [46, 51, 69, 70] and in this study factor analysis revealed two factors: 'Decoding' (explaining 69.43% of the variability) and 'Comprehension' (explaining 5.05% of the variability). Measures loading on the 'Decoding' factor included reading speed and accuracy, word identification, and pseudo-word reading, with this factor explaining nearly 70% of the variability in reading ability. Neither the PPVT-III nor the CPM had strong correlations with the 'Decoding' factor, and these two intelligence measures combined to account for only 17% of

¹ Coefficient of determination (r^2) for the correlation between NARA Comprehension and the PPVT-III.

Table 4. Multiple R^2 , Standardized Regression Coefficients (β) and Squared Semi-Partial Correlations (sr^2) from a Series of Standard Regression Analyses with the PPVT-III and the CPM as Predictors of Reading Ability

Measure	R^2 ^a	CPM		PPVT-III	
		β ^b	sr^2 ^c	β	sr^2
'Decoding' factor	.168**	.136	.016	.341**	.101
NARA Rate	.110**	.035	.001	.318**	.088
NARA Accuracy	.184**	.137	.016	.360**	.112
Letter-Word Identification	.180**	.113	.011	.371**	.119
Word Attack	.079**	.112	.013	.213*	.039
'Comprehension' factor	.388**	.221**	.042	.508**	.225
NARA Comprehension	.322**	.207*	.037	.459**	.183
Passage Comprehension	.301**	.221**	.042	.428**	.159
Reading Vocabulary	.394**	.238**	.049	.502**	.219

* $p < .05$, ** $p < .01$.^a R^2 refers to the proportion of variability in reading ability that is predicted from the best linear combination of the PPVT-III and the CPM [65].^b β or beta is that standardized regression coefficient.^c sr^2 is the squared semi-partial correlation coefficient which indicates "the unique contribution of the IV to R^2 in that set of IVs".

the variability in this factor. The lack of disparity between the PPVT-III and CPM is interesting given claims that measures of nonverbal intelligence are unimportant for learning to read [34, 71, 72].

Although the PPVT-III and the CPM correlations with 'Decoding' factor did not differ, differences were found with individual measures loading on this factor. The PPVT-III had significantly stronger correlations with reading rate and single word reading than the CPM; however, no differences were found for pseudo-word reading and reading accuracy. Models of word reading may aid in the interpretation of these findings. It has been hypothesized that two distinct but interrelated processes underpin the ability to recognize single words; the first is phonological decoding of words, and the second is orthographic analysis of the word's structure [51, 73, 74]. Both processes are necessary but neither are sufficient for skilled word reading [73]. It may be the case that Rate from the NARA and Letter-Word Identification are more indicative of orthographic skills than phonological ability. The reverse may be true for Word Attack, a reported pure measure of phonological decoding ability [74]. Accuracy from the NARA may represent an exception to this distinction as higher scores on this task may depend on phonological and orthographic decoding, as well as articulation. It appears that the PPVT-III has stronger correlations with tasks more dependent on orthographic decoding than those requiring phonological analysis of words. A child with an enriched vocabulary is more likely to rapidly recognize words and read at a faster rate, than a child with an impoverished vocabulary who neither has access to a familiar word nor has a template of semantic expectancy of the word [40, 43, 51]. Conversely, simple pseudo-word reading, a measure devoid of both lexical and semantic factors, is less likely to be constrained by either verbal or nonverbal intelligence [63]. Such generalisations, however, are limited by the lack of a clear differentiation and understanding of what cognitive abilities underpin these measures of 'Decoding'.

The divergence between correlations of the PPVT-III and the CPM with 'Comprehension' is not unforeseen. Measures of verbal intelligence share the same underlying cognitive abilities as reading comprehension: vocabulary, short-term memory, linguistic understanding, and acquired knowledge. As the PPVT-III assesses both listening comprehension and receptive vocabulary, a greater shared variance with the 'Comprehension' would be predicted. It should also be highlighted that both measures of intellectual ability combine to explain approximately 39% of the variability in 'Comprehension', which is over double that explained in 'Decoding', highlighting that decoding and comprehension are largely independent in terms of information processing [52].

Comprehension from the NARA and Passage Comprehension from the WJ-R Ach differed in their relationships with the PPVT-III and the CPM. For Passage Comprehension there was no significant difference between its correlations with the PPVT-III and the CPM, whereas the NARA Comprehension had a significantly higher correlation with the PPVT-III than the CPM, highlighting that although the two measures are purported to assess reading comprehension they are measuring distinct aspects of reading and require different underlying skills for successful performance on each task [63]. Nation and Snowling reported that word recognition was more important for comprehension tasks involving sentence completion whereas for text comprehension tasks such as the NARA, listening comprehension was a better predictor of ability. That is, unsurprisingly higher level linguistic ability, related to verbal intelligence, is more crucial for text comprehension tasks.

Age and the Relationship Between Intelligence and Reading

The research observations described here mainly pertain to the total sample of children of 126 children aged between 7.00 and 11.92 years. Noteworthy, however, is that the

correlations between reading and intelligence measures seemed to fluctuate with the age of the child. For the 7 year olds, there was no relationship between the measures of reading and intellectual abilities; conversely for 8 year olds, the strength of the correlations increased dramatically, particularly the correlations of the CPM with the Accuracy, NARA Comprehension, Word Attack, Letter-Word Identification. However, the CPM, became less important beyond 8 years, with the PPVT-III being more strongly related to these reading variables. Age-related changes in the association between reading and intelligence have been previously reported with the correlations generally augmenting in strength with age [19, 36, 39, 40, 75]. However, further examination of the developmental changes in the association are important given that the correlations obtained in the current study indicate that distinct aspects of intelligence and reading may be pertinent at different ages. However, the small sample sizes within each age group, limits our ability to infer the extent to which this may be the case.

Implications

There are several implications of these findings for the diagnosis of DD. First, fluctuations in the strength of the association can impact directly on the reliability of discrepancy and regression formulae. A strong correlation between scores on intelligence and reading measures (e.g. between Comprehension and PPVT-III) is desirable for regression formulae, reducing the chances of making errors in prediction [32, 33]. Alternatively, such a strong correlation would be likely to reduce the reliability and increase the standard error of measurement for the discrepancy score [27]. Hence, the likelihood of accurate diagnosis will depend on which measurement tools are administered and the statistical model adopted.

A second related concern is the relationship of measures of intelligence with pseudo-word reading. Current views of DD are that it is a manifestation of deficits in phonological processing or the ability to process sound-to-grapheme correspondences [1, 62, 63, 72, 77]. Pseudo-word reading tasks are often purported to provide the best method of measuring phonological decoding ability [13, 62, 63]. Both verbal and nonverbal intelligence, however, have little impact on pseudo-word reading [13], and in this study the PPVT-III and the CPM only accounted for 8% of the variability in scores on Word Attack. If such tasks are implemented in discrepancy or regression formulas, the resulting diagnosis is likely to be invalid with high rates of both false positive and false negative diagnoses. With high rates of false positive clinical research groups are likely to be heterogeneous. This heterogeneity is likely to reduce generalisability of results and may account for inconsistent findings across studies. For example, it has been claimed that if measures such as VIQ or PPVT are used in the diagnosis of DD, then a deficit in pseudo-word reading is clearly apparent in children with reading problems [74]. This 'deficit' has been observed to dissipate when PIQ or the matrix reasoning tasks are used to identify children with reading problems [74]. Such studies do not consider the poor association between both verbal- and non-verbal intelligence and pseudo-word reading. This leads us to question current conceptualizations of DD and highlights how malleable

definitions and research findings may be to the selection of measurement tools.

CONCLUSIONS

Several conclusions can be drawn from the study's findings. First, the PPVT-III does not necessarily have significantly higher correlations with the reading measures than the CPM. Differences between these measures are largely governed by the types of reading measures under examination. The PPVT-III appears to have stronger relationship with tasks involving orthographic processing and higher order functions such as working memory and linguistic comprehension. Second, both the PPVT-III and the CPM have significantly higher correlations with measures of reading comprehension, than with lower level decoding and word recognition skills. Third, as both of these measures of intelligence are weakly correlated with pseudo-word reading, their use in discrepancy and regression models of DD may be questioned. It is important to highlight that the choice of reading and intelligence measures can dictate who is identified as having a reading disability. More careful thought and understanding is required for the choice of measurement tools employed to assess these constructs and how test selection impacts on the diagnostic models used for DD.

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