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An Additive Simple View of Reading Describesthe Performance of Good and Poor Readersin Higher Education

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Abstract

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Cover Page Footnote

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According to Gough and Tunmer (1986), in a 'Simple View of Reading' (SVR), Reading comprehension (RC) = Decoding (D) x Linguistic Comprehension (C). To further evaluate this model, this paper describes an exploratory study of the performance of 60 university students, the majority of whom received academic accommodations at university to compensate for significant reading delays. Results showed that both D and C predicted reading comprehension well. An additive model (D + C) fitted the data no better than a product model (D x C). Similar results were obtained when cumulative grade point average rather than reading comprehension was used as the dependent variable. D but not RC was correlated with phonological awareness and (less reliably) with rapid naming ability. Implications of these findings for the Simple View of Reading and for the support of university students with reading problems are considered.

Many researchers believe that to understand the complex phenomenon of reading comprehension, it is helpful to identify a simpler picture with a limited number of constituent processes of reading comprehension (e.g. Aaron, 1991, 1997; Carr & Levy, 1990; Curtis, 1980; Gough & Tunmer, 1986; Hoover & Gough, 1990; Joshi & Aaron, 2000; Perfetti, 1991). To date much attention has been devoted to explorations of the constituents of reading comprehension

ability in children. The present paper first reviews some of this work and extends it to consider the performance of university students with- and without-reading difficulties.

The 'Simple View of Reading'

One influential class of simple model is based on listening comprehension and word decoding skills (Carver, 1997; D'Angiulli & Siegel, 2003; Gough & Tunmer, 1986; Royer & Sinatra, 1994; Siegel, 1989). In Gough and colleagues' influential 'Simple View of Reading' (SVR, Gough & Tunmer, 1986; Hoover & Gough, 1990; Tunmer & Hoover, 1992), reading comprehension (RC) is determined by the product of distinct decoding (D) and linguistic comprehension (C) sub-skills (RC = D x C). In this account, word decoding skills involve assembly of word pronunciations from letter-sound knowledge as well as direct single word reading skills. The SVR model is well-supported among young children by the following observations: a) it is quite possible to find many children who have good decoding skills on the one hand and poor text comprehension skills on the other (e.g. Catts, Hogan & Fey, 2003; Healy, 1982; Nation & Snowling, 1997, 1998) as well as the reverse (e.g. Byrne & Fielding-Barnsley, 1995; Catts, et al., 2003; Hulme & Snowling, 1992; Shankweiler, et al., 1999), with individual differences in word reading and listening comprehension proving to be strong predictors of reading comprehension (e.g. Nation & Snowling, 1997; Stanovich, 1986) ; b) D and C also explain additional proportions of variance in reading comprehension across populations of average readers (e.g. Carr & Levy, 1990; Carver, 1997; Hoover & Gough, 1990; Vellutino, Tunmer, Jaccard, & Chen, 2007); c) Longitudinally, this two-factor SVR model is a stable predictor of reading over the first four years or so of reading acquisition (Catts, et al., 2003; Demont & Gombert, 1996; Johnston & Kirby, 2006; Oakhill, Cain, & Bryant, 2003; Tunmer & Hoover, 1992).

Is The Product or the Sum of D and C the Best Fit SVR Model?

One area where the predictions of the SVR model have been less-consistently validated is in the manner through which D and C combine to predict reading comprehension. Hoover & Gough explored the components of reading comprehension in 254 children between grades 1 and 4. They reported that reading comprehension best fitted a *product* (RC = D x C) model rather than a *sum* model (RC = D + C). Conceptually, the product model assumes that both D and C are strictly necessary but that neither D nor C are individually sufficient components of reading comprehension. On the other hand, the additive model

suggests that D and C are sufficient but not necessary for reading comprehension and thereby allows the possibility that D and/or C could be bypassed in successful reading comprehension.

Evidence exists supporting the additive model over the product SVR model. Chen and Vellutino (1997) tested a slightly more complex statistical model that incorporated both the product and the sum of D and C (RC = D + C + (D x C)) to explore the two accounts. Chen and Vellutino report that the product term rarely added at all to the additive terms in predicting reading comprehension between grades 2 and 6 ($r^2 = 0$). The product term did however predict a non-significant additional 3% of the variance in 37 average-reading grade 7 children. It may be that with larger samples this effect would have been significant, suggesting a possible developmental trend.

The SVR and older readers

In a recent study, Savage (2006) explored the performance of 15 year olds with severe reading delays to evaluate the SVR model. As in the studies with younger children by Chen and Vellutino (1997), an additive model (D + C) fitted the data well when either non-word decoding or text reading accuracy was used as an index of D. The addition of the product term (D x C) did not add to the predictive power of the model. From this view then both D and C are involved in reading, comprehension but the models did not support the *necessary* role for either D or C suggested by the product model.

One reason that an additive model might best fit data for older poor readers is that older poorer readers may take advantage of compensatory strategies to at least partly bypass their basic weaknesses in decoding. Evidence from case studies of literate adults with very poor decoding abilities suggests that poor decoding need not mean poor reading comprehension (e.g. Campbell & Butterworth, 1985; Funnell & Davison, 1989; Holmes & Standish, 1996; Temple & Marshall, 1983). Jackson and Doellinger (2002) were able to identify a group of 6 students from a screening sample of 196 students with extremely poor non-word decoding skills but who nevertheless demonstrated average or even above-average text-reading abilities. Jackson and Doellinger termed this group 'resilient readers'. Similar results have been reported in university students by Hatcher, Snowling, and Griffiths (2002).

In a recent study again with university students, Jackson (2005) showed that the reading comprehension skills of typical second and third year undergraduate students were well-described by word decoding accuracy, reading

speed and text comprehension accuracy. However component word reading skills were not strongly related to individual differences in success in postsecondary education, and modest correlations were evident between text comprehension and university course attainment measures (GPA). A small subset of the poorest readers ($N = 15$) did show lower attainment scores than their more expert peers. These findings led Jackson to conclude that while there is some evidence of *group* differences between proficient and the least proficient readers in terms of D and C, the clear association between individual differences in word recognition efficiency, listening comprehension, and reading comprehension reported in typical young children may be less relevant to individual differences in attainment in adult learners. This is an important conclusion to draw given the implications it may have for models of support for students at university. For example, such a finding might suggest that the assessment of, and pedagogical support for, component D and C skills is not supported by research. Given their importance, these results would clearly benefit from general replication. We therefore set out to do this here.

In addition, it is perhaps important to note that the Jackson (2005) study was based solely on a sample of students attending an undergraduate educational psychology course. While there exists no direct evidence on this issue, it may be that by the nature of the materials and professional experiences, professors in such courses are particularly attuned to the needs of students experiencing literacy problems in a way that does not apply in other disciplines. A related issue is that the measure used in the analysis was attainment in the educational psychology course from which the students were recruited. A more generalizable picture would emerge by taking the cumulative (i.e. the university terminal) grade point average (CGPA) of a more diverse group of students studying a range of disciplines besides educational psychology.

A second issue is that in studies of individual differences in younger children it has been common to use samples containing a large number of poorer readers and typical readers to help elucidate what underlies such variation in ability (e.g. Savage et al., 2005; Wolf & Bowers, 1999) rather than explore performance of a small number of atypical readers as Jackson (2005) did. We therefore sought to obtain a mixed sample containing many typical and many weaker readers attending university.

Finally, much of the research to date has been based on the use of single measures of D, C and RC, and as noted above there have been quite mixed patterns of results. In statistical terms we would argue that any analysis of individual differences in reading will be strengthened by the construction of latent variables based on multiple measures of D and C constructs. Findings from

studies using these latent variables are more likely to be replicable in future studies over associations based on single manifest variables that may be unreliable (see e.g. Savage, Cornish, Manly, & Hollis, 2006; Wagner, Torgesen, & Rashotte, 1994). We thus adopt this approach here.

In addition to these specifically methodological issues, we wish to explore the role of other potential explanatory theoretical factors in reading comprehension. Two variables that have had a central place in reading research over recent years are phonological awareness, and rapid automatized naming (RAN). Both phonological awareness and RAN are assumed to predict reading comprehension through enabling efficient word reading, and both may contribute distinctly (Byrne & Fielding-Barnsley, 1995; Johnston & Kirby, 2006; Wolf & Bowers, 1999). These assumptions are explored in cohort of adults with- and without documented reading difficulties.

We therefore undertake an exploratory study addressing the following questions concerning the reading ability of university students:

1) What role do phonological skills and rapid naming processes have in the SVR?

2) Does the product rather the sum of D and C best predict reading comprehension and CGPA?

Method

Participants

The majority of students who took part in this study attended McGill University. Unlike many studies of university students with a reading disability which test only undergraduates, this study included a number of graduate students, including several students who were studying at levels beyond a master's degree (Doctorate, Medical Residency, post-Master's degree Law, and post-Master's degree Medicine). These students are a particularly interesting group because of their proven high levels of academic achievement. Five undergraduate students were recruited from Concordia University, the other university in the city with English as the language of teaching. An attempt was made to recruit further Concordia students through contacts with the Services for Students with Disabilities but only three students responded. Two additional Concordia students were recruited by the second author, one of whom fit

the reading disability criteria and one of whom was included in the control group.

Students who had a diagnosis of reading disability all had a current full psycho-educational assessment completed by a qualified professional psychologist and were registered with the Office for Students with Disabilities at their respective universities on that basis. The second author had access to these reports for the purpose of assessing the qualifications for service provision. The McGill students responded to a letter, sent by the second author to all OSD students who could qualify for the study on the basis of these reports, explaining the purpose of the project. The same letter was distributed by the equivalent office at Concordia University. Interested students returned a signed permission slip in a stamped return envelope. All but six of the potentially eligible McGill University students answered in the affirmative, thereby providing a broad range of university years and academic disciplines. Except for one student, all students were first language English speakers. The one exception, a McGill graduate student, had had all his education in English. None had previous histories of difficulty with other sensory disabilities or with brain trauma. They all received academic accommodations in university, such as extra time on exams, use of a computer with spell check, books in audio format.

The typical readers were recruited on an ad hoc basis either from the student employee and volunteer pool of the Office for Students with Disabilities at McGill, or were friends of participants. All except two were first language English speakers. The two exceptions, both graduate students, had had all their education in English. They were all given or sent a copy of the same request letter and signed the same permission slip. No student in either group was paid for their participation. They all willingly volunteered their time.

Forty-five students with assessment results indicative of a reading disability were given the initial tests. Forty of these were included in the final data analysis. Two left McGill before the second testing session took place, one withdrew after the first session, one received a second diagnosis of ADHD during the testing period and one was excluded because of potential confounds related to his personal circumstances (mature student, 60 years of age, education only to Grade Six in a rural, non-Canadian setting, with no other recent educational experience). Twenty-one control participants were recruited and 20 are included in the data analysis as one left McGill before the second testing session. Demographic data for the group are contained in Table 1. The somewhat varied regional distribution in terms of origin, should, to some

Table 1
Demographic Information

Variables	Groups		
	RD Group	Control Group	Total Group
Gender			
Female	21	12	33
Male	19	8	27
Mean Age	24.6	25	25
Age Range	18-49	20-38	18-49
Faculty			
Undergraduates			
Arts	14	7	21
Social Work	2	0	2
Science	4	3	7
Engineering	4	1	5
Fine Arts	1	1	2
Music	1	0	1
Management	0	1	1
Recreation	2	0	2
Graduates			
Medicine	4	0	4
Medical Research	1	0	1
Occupational Health	1	0	1
Arts	0	4	4
Law	2	0	2
Social Work	0	1	1
Science	2	2	4
Education	1	0	1
Agricultural Science	1	0	1
Origin			
Quebec	14	8	22
Ontario	15	4	19
Newfoundland	2	0	2
Nova Scotia	1	1	2
P.E.I.	0	1	1
Saskatchewan	0	1	1
Alberta	0	1	1
B.C.	1	1	2
United States	7	2	9
U.K.	0	1	1

degree, mitigate against the chances of findings reflecting the effects of one regional educational system.

Materials

Reading comprehension. Reading comprehension was measured using the Nelson-Denny Reading Test, Form G, Comprehension sub-test (Brown, Fishco, & Hanna, 1993). The test consists of one one-page passage and six half-page passages, followed by a set of multiple choice questions. It was administered in the regular timed format, though participants who had not finished by the standardized time limit of 20 minutes were asked to mark the question they were answering at that point and were then told to continue with the test. Each individual's total time for completing the test was noted. Scores were calculated using the standard procedure, utilizing norms appropriate for the university level (e.g. Grade 13 for 1st year students; Grade 16 for 4th year and graduate students. Unfortunately the test does not provide norms above the undergraduate level and it would clearly have been preferable if these had been available. The norms provided on the test for extended time administration were not used because many students took longer than permitted by those norms (32 minutes).

Listening comprehension. To measure how students comprehended spoken text, both forms (Forms G and H) of the Woodcock Reading Mastery Test-Revised (Woodcock, 1987), Passage Comprehension subtest were recorded onto cassette tape. This is an untimed cloze type test. The reader had a English Canadian accent and delivered each item by reading the sentence and indicating the space to be filled by the missing word by saying the word "blank". Students responded orally with an appropriate word. The reader delivered the two versions of the test at different speeds. Form G was recorded at approximately 115 words per minute, and Form H was recorded at approximately 195 words per minute. Since this test was not timed, students were permitted to pause the tape while they thought of an answer. They were permitted to rewind the tape for each question once. The action was recorded on the test sheet, but only first time answers were counted. Testing on both forms was commenced at item 33. Raw scores were converted to standard sores and percentiles using the formula provided in the test manual for the Passage Comprehension sub-test. Even though the test was not being used in its standardized form it was felt that using the standardized scoring procedures was more likely to give a fairer basis for comparison within the group than simply using the raw scores. The standardized formula takes account of differences in educational level. It also gave a potential comparison with tests from the same reading battery which were being used to measure additional skills.

Phonological awareness. Phonological awareness was measured using the Auditory Analysis Test developed by Rosner and Simon (1971). It consists of forty words, from which the students were asked to delete single phonemes from the start or end of a word, and single phonemes from blends, or syllables. The examiner introduced the task by using three examples. No repetitions were permitted. Words became increasingly more difficult as the test proceeded. Total raw scores, percentage total scores, and odd/even raw scores were computed. In order to confirm the reliability of test scores, the split half reliability (Spearman-Brown corrected) of odd/even items for the whole group was computed and found to be acceptable (.71.)

Spelling. Spelling was measured using the Wide Range Achievement Test (WRAT-3) (Wilkinson, 1993), Tan Form, Spelling subtest. This test, which is not timed, requires the student to write down the spelling of forty dictated words of increasing complexity. Each word is read out loud by the examiner, repeated in a sentence, and re-read. The entire test was administered in the standard manner, except that inclusion of the word in a sentence was begun at item 30 rather than at the first item. Item 12 was also included in a sentence because its form is ambiguous. Scoring was according to standardized norms, and the grade equivalent, standard, and percentile scores were recorded.

Phonological coding skill. This was first measured using the Woodcock Reading Mastery Test-Revised (Woodcock, 1987), Form G, Word Attack subtest, using the standard procedure and scored according to standard administration. Students were shown a series of non-words and asked to pronounce them out loud. It was emphasized that pronunciation should sound as if it was an English word, since a number of the words on the test could be pronounced as if they were French words. This test is not timed. Both standard and percentile scores were recorded.

Word identification skill. This was first measured using the Woodcock Reading Mastery Test-Revised (Woodcock, 1987), Form G, Word Identification sub-test, which was administered beginning at item 74 and scored according to standard test administration. Students are shown a series of words and asked to read them out loud. This test is not timed. Both standard and percentile scores were recorded.

Experimental words. Three lists of 30 words each, one of regular, one of irregular, and one of pronounceable, orthographically legal non-words, taken from Castles and Coltheart (1993), were administered. According to Castles and Coltheart, regularity was determined using established norms. In the present study the words were entered as separate lists onto a computer database

and presented in lower case letters in the centre of a computer screen attached to a Pentium computer. Response latencies were measured with a timing mechanism attached to the computer which recorded the difference in milliseconds between the onset of the stimulus on the screen and the first vocalization. A voice operated relay interfaced with the computer via a small microphone. The stimulus disappeared at the point of vocalization. The time between the disappearance from the screen of one word and the onset of the next was approximately 2 seconds. Students were instructed that they would be seeing three separate lists of words. The characteristics of each list were explained and the students were instructed to say each word out loud as quickly but as accurately as possible using English pronunciation. In order to familiarize the participants with the format of the procedure, six practice words (words, that, have, no, meaning, whatsoever) were administered at the start. The lists were administered in the following order: regular words, followed by irregular words, and finally the non-words. There was a pause between each list. All times which were related to mechanical errors were recorded and excluded from the analysis. These amounted to one percent or less of the total responses, distributed across all word groups. All pronunciation errors were recorded. Strict criteria were applied to the pronunciation of non-words (Gottardo, Chiappe, Siegel, & Stanovich, 1996). That is, all vowel and consonant pronunciations had to match those in some real word (gead/read; toud/loud). Incorrectly-pronounced words were also excluded from analyses. Average latencies were computed for all correctly-pronounced words in each set of words per individual. As well as average reaction times per list, raw score correct responses per list were recorded.

Vocabulary. Vocabulary was measured using the Wechsler Adult Intelligence Scale-Revised (Wechsler, 1981), Vocabulary subtest. This test was administered according to standard procedures. Standard score equivalents of raw scores were recorded.

Rapid automatized naming. Rapid Automatized Naming (RAN) (Denkla & Rudel, 1976) was measured using a set of 50 single digits arranged horizontally in five rows of ten digits on an eight by eleven inch sheet of paper. The student was handed the sheet and asked to begin reading the digits out loud on the command of "GO". The result was timed on a hand held digital stopwatch in seconds. The intent was to record errors but only one student made errors and so this was not used in the analysis..

Biemiller-type tests. Biemiller (1978, 1981) developed a speed test for young children and adults consisting of a set of single letters, two passages, and two sets of words from the passages arranged in random order. The intent of this

procedure, which is an extension of a single letter RAN test, is to measure the relationship between the speed at which single letters, words in context and words out of context can be read orally. Since the original test passages were designed for very young children they were not used for this age and educational level. Two passages were taken from age appropriate reading material, one from Shapiro (1993, p.105) and one from Shaywitz, (1996, p.98). The letter section consisted of 50 randomly ordered single letters arranged horizontally on a page in three rows. Passage One consisted of 98 words, and Passage 2 of 77 words. A set of 50 words from each passage were arranged in random order. The test was administered in the following order: Letters, Passage One, Words from Passage One, Passage Two, Words from Passage Two. Reading times were measured using a hand held digital stopwatch. The results were converted to seconds per letter for the individual letters, and seconds per word for the other items.

Design and Procedure

All tests were administered by the second author. Depending on the time availability of each student, Session One tests were administered individually, or in groups of up to four people. Group participants were not sorted by group membership. Session Two tests were administered on an individual basis. The second session of testing was administered in one period on a different day. Depending on individual performance rates, in total it took more than two hours. Some students requested a short rest break during the second session and this was accommodated.

Tests were administered in the following order: *Session One:* Nelson Denny Reading Test, Reading Comprehension subtest (Form G); Wide Range Achievement Test-3 (Tan Form), Spelling subtest. *Session Two:* Woodcock Reading Mastery Test-Revised (Form G), Passage Comprehension subtest recorded on to tape at 115 words per minute; Woodcock Reading Mastery Test-Revised (Form G), Word Attack subtest; Woodcock Reading Mastery Test-Revised (Form G), Word Identification subtest; Rosner Auditory Analysis Test; RAN digits; Biemiller-Type Tests: Letters, Passage One, Words One, Passage Two, Words Two; Wechsler Adult Intelligence Test-Revised, Vocabulary subtest; Woodcock Reading Mastery Test-Revised (Form H), Passage Comprehension subtest recorded onto tape at 195 words per minute; Castles and Coltheart (1993) Experimental Words Reaction Time Test.

Results

In the first phase of analyses descriptive statistics for all measures taken were collated. There were $N = 60$ observations for all variables except for the Cumulative Grade Point Average (CGPA) measure which was based on $N = 36$ observations. This CGPA figure is reduced as a large proportion of our sample ($N = 20$) were graduate students with no current CGPA score available. In addition data from five students attending the other city university, Concordia University were unavailable. As the aim of the study was to explore the broad factors associated with reading and CGPA performance, preliminary data variable collation was undertaken. Preliminary analyses showed that the Biemiller -Type sub-test reading speed scores were all closely correlated ($r > .7$ in all cases), so were amalgamated into a single Biemiller-Type test sum score based on the *z*-transformed variable scores. A similar pattern was evident for the Castles and Coltheart regular, exception, and non-word reading speed scores so these *z*-scores for accurate responses were amalgamated into a single averaged Castles and Coltheart test reading speed sum score.

Preliminary analyses of these psychometric scores revealed that there was a normally distributed range of performance on all these tests. There was no significant skew in any of these reading–related measures ($s < 2.5$) using conventional approaches to evaluating data normality (Tabacknik & Fidell, 2001). Importantly this confirms that, across the sample as a whole, there were no signs of ceiling effects on tests administered (most students did not achieve maximum scores on tests) and that the results were therefore suitable for general linear statistical analyses.

The mean standard scores for the Woodcock-Johnson word identification and word attack measures were 102.90 ($SD = 10.51$) and 104.83 ($SD = 15.02$) respectively. These mean scores of course reflect the balanced mix of capable and less capable readers in the present sample. For poor and average reader subgroups, the mean standard scores were 99.63 ($SD = 10.37$) and 109.45 ($SD = 7.38$) respectively for word identification and 99.55 ($SD = 14.39$) and 115.40 ($SD = 9.97$) respectively for word attack. Independent samples *t*-tests confirmed that these subgroup differences were significant (t (58) = 3.78, p < .001 for word identification, t (58) = 4.42, $p < .001$ for word attack). The spelling standard score for the whole sample was 108.20 ($SD = 11.87$). Considered separately for poor and average reader subgroups, the mean standard scores were 103.75 ($SD = 10.37$) and 109.45 ($SD = 7.38$) respectively, a difference that was again statistically significant, t (58) = 4.82, $p < .001$. The WAIS vocabulary percentile for the whole group was 68.42 ($SD = 21.56$) showing that

the sample had, as expected for a university student sample, strong verbal ability. The CGPA for the sample was 3.09 (*SD* = .44).

1. What role do phonological skills and rapid naming processes have in the SVR?

The first set of analyses explored the correlation between decoding, listening comprehension, reading comprehension, vocabulary, RAN and phonological processing variables. Full details of the inter-correlations for these measures are provided in Table 2. Inspection of this table reveals that there were positive correlations between reading comprehension and the two listening comprehension measures, and with the WAIS vocabulary measure. Reading comprehension was also correlated with all word-level measures: Woodcock Reading Mastery word attack and word identification, the Castles and Coltheart and Biemiller combined word set variables.

Phonological awareness was a strong correlate of word identification and word attack and spelling but a less strong predictor of the composite Castles and Coltheart and Biemiller reading speed measures. RAN was a generally weak predictor of most of these measures but was a strong predictor of the Castles and Coltheart composite which was not significantly correlated with phonological awareness performance. Reading comprehension was not correlated with either the Rosner phonological awareness task or RAN. Noteworthy among the other correlations was the finding that the listening comprehension measures were generally only modestly correlated with word reading measures such as the Castles and Coltheart and Biemiller composites and the word attack and word identification measures.

2. Does the product rather the sum of D and C best predict reading comprehension and CGPA?

In order to answer this question we sought to construct latent variables for D and C using preliminary data reduction techniques. These are therefore first described below.

Principal Components Analyses

A prerequisite to testing the SVR model using a latent variable is to establish whether reading tasks on the one hand (Castles and Coltheart and Biemiller words, spelling, word attack and word identification measures) and the two listening comprehension measures on the other hand would load on two distinct factors in principal components analysis, as predicted by the Simple

Table 2
Inter-Correlations between Reading, Listening, RAN and Phonological Processing Measures

Measures	1	2	3	4	5	6	7	8	9	10	11	12
1. Reading coprehension	—	.42***	.39**	.50***	.34**	.36**	.37**	-.46***	.84***	.25	-.03	.41*
2. CGPA		—	.34*	.41**	.40*	.34*	.39*	-.34*	.44**	.38*	-.11	.26
3. Listening A			—	.71***	.18	.14	.10	-.16	.18	.17	.10	.36**
4. Listening B				—	.40**	.39**	.33**	-.30	.43***	.36**	-.09	.51***
5. Word attack					—	.72***	.69***	-.37**	.45***	.69***	-.29*	.47***
6. Word identification						—	.77***	-.44***	.41***	.62***	-.15	.58***
7. Spelling							—	-.54***	.49***	.60***	-.23	.46***
8. Coltheart words								—	-.40**	-.23	.47***	-.24
9. Biemiller tasks									—	.29*	.00	.46***
10. Rosner Phonological awareness										—	-.25	.39**
11. RAN											—	-.11
12. WAIS vocabulary												—

* *p* < .05, ** *p* < .01, *** *p* < .001.
Note. All correlations based on *N* = 60 observations except CGPA which is based on *N* = 36 observations

View of Reading. As the word attack measure was closely correlated with word reading and is frequently subsumed into latent reading variables in other published studies of this type it was considered a measure of reading for the present purposes. Preliminary analyses of the suitability of the data for these analyses were first undertaken. The sample–size was relatively modest. The ratio of cases to variables of 8.57:1 was however adequate (Tabachnik & Fidell, 2001). Inspection of the correlation matrix had already identified many correlations in excess of .3. The Keizer-Meyer-Olkin value of 0.69 exceeded the recommended value of .6. Finally, Bartlett's test of sphericity was strongly statistically significant ($\chi^2 = 130.57$, $p < .001$), supporting the factorability of the correlation matrix.

As recommended by Tabachnik and Fidell, (2001), preliminary analyses were run with orthogonal rotation as well as oblique rotation as well as with factor analytic approaches such as principal axis factoring to confirm the robustness of findings from PCA. The results are much the same using factor analytic or PCA methods or oblique or orthogonal rotation. As the results of different approaches did not differ and as PCA has been widely-used to test the SVR model it was adopted here. D and C factors are considered distinct in theoretical terms and the two latent variable were not significantly correlated ($r = .20$, *ns*), thus an orthogonal rotation was appropriate.

A principal components analysis using varimax rotation was thus undertaken on these data. This analysis revealed only two factors with eigenvalues exceeding 1. The first factor explained 50.67% of the variance and the second factor explained 19.80% of the variance. Loadings of variables on factors and communalities are shown in Table 3. To aid interpretation loadings higher than 0.35 are underlined. It can be seen from this analysis that all of the reading and spelling variables loaded strongly on a single and rather general factor that might be called 'Decoding'. The second factor might be called 'Listening Comprehension' as both listening comprehension tasks but none of the word reading tasks loaded strongly on it. Two latent variables derived directly from the residualized factor scores from the PCA analysis were then used in subsequent regression analyses.

Regression Analyses Predicting Reading Comprehension

The main hypothesis derived from the SVR model that we set out to test was that the relationship between D and C predicting Reading Comprehension should be best described by a product relationship (R = D x C) rather than an additive relationship (R = D + C). Following Johnston and Kirby (2006), prior

Table 3
Factor Loadings and Communalities (h²) for Principal Components Analysis with Varimax Rotation on Reading, Decoding, Language and Cognitive measures

Measure	Component 1 Decoding	Component 2 Comprehension	Communality h^2
Listening A	.02	.94	.88
Listening B	.33	.87	.87
Word attack	.82	.15	.70
Word identification	.87	.10	.76
Spell	.91	.04	.83
Coltheart words	-.65	-.15	.44
Biemiller words	.62	.28	.46
Percent of Variance	50.67 %	19.80 %	

to further analyses, a constant (10) was added to all D and C latent variable scores in order to eliminate negative values. In regression analyses, where reading comprehension was the dependent variable, there were $N = 60$ cases. Thus it was possible to run 3-step analyses with an acceptable case to variable ratio of 20:1 (Tabachnik & Fidell, 2001). Accordingly, D and C latent variables were entered singly in the first two steps of regressions as an *additive* model (formally, $R = b_0 + b_1 D + b_2 C$). In a second *product* model the product terms of D and C were computed and subsequently entered at step 3 (formally, $R = b_0 + b_1 D + b_2 C + b_3 D \times C$). The regression models for reading comprehension, depicted in Table 4, reveal that when C was entered at step 2 after D at step 1, it was a strong predictor of Reading Comprehension. However, no significant additional variance was explained by the (D x C) product model when entered at step 3.

In addition we tested whether an additive model added to the capacity to predict reading comprehension *after* the product model was first considered. The product term (D x C) was entered at step 1 of regression analyses. The D and C latent variables were then entered singly in the second and third steps of regressions as an additive model (formally, $R = b_0 + b_1 D \times C + b_2 D + b_3 C$). The

regression models for reading comprehension, depicted in Model B of Table 4, reveal that when D and C were entered at steps 2 and 3 after D x C at step 1, no significant additional variance was explained by the additive (D + C) model.

The regression models for cumulative GPA are based on $N = 36$ cases, so 3-step regressions would not have an acceptable case-to-variable ratio (Tabachnik & Fidell, 2001). Separate 1 and 2-step regressions were therefore undertaken contrasting respectively, the total amount of variance explained by a product term (D x C) with that of an additive term (D + C). Inspection of Table 4 reveals that when the C is entered at step 2 after D at step 1 it was a modest predictor of CGPA explaining 5% of unique variance, but that this escaped conventional significance ($p = .08$). The additive model explained 22% of the variance in CGPA. The (D x C) product model was entered alone as a predictor of CGPA. It explained a very similar 23% of the variance in CGPA.

Table 4
Regression Analyses Exploring Predictors of Reading Comprehension and CGPA (Final Regression Models)

Step	Independent Variable	β	R^2
	Reading Comprehension		
Model A			
1	Decoding (D)	.44	.22***
2	Listening Comprehension (C)	.68	.20***
3	D x C	2.28	.02
Model B			
1	D x C	.68	.44***
2	Decoding (D)	-.02	.00
3	Listening Comprehension (C)	-1.14	.00
	CGPA		
1	Decoding (D)	.44	.17**
2	Listening Comprehension (C)	.28	.05
3	D x C	.51	.23**

Note: ** = $p < .01$, *** = $p < .001$.

Discussion

The present study sought to explore two questions concerning the performance of group of 60 university students of mixed typical-atypical poor readers and spellers. Our questions were:

1) What role do phonological skills and rapid naming processes have in the SVR?

2) Does the product rather the sum of D and C best predict reading comprehension and CGPA?

Turning to the first question, concerning the role of RAN and phonological awareness in the SVR model, analyses revealed that neither RAN nor phonological awareness correlated with individual differences in reading comprehension among university students. On the other hand, phonological awareness was a strong correlate of word reading and spelling, particularly of the accuracy measures (word attack and word reading) consistent with other studies of adults (Lesaux, Rufina Pearson, & Siegel, 2006). RAN on the other hand was a weaker and frequently non-significant predictor of word reading and spelling. These results are consistent with a general view that emphasizes the role of RAN and phonological awareness in word-level skills. This pattern however is not mirrored in correlations with reading comprehension, consistent with the view that phonological awareness is not directly relevant to reading comprehension (e.g. Cunningham, 1993). The finding that RAN predicted some reading speed measures (i.e., the Castles and Coltheart words) better than phonological awareness did is consistent with the idea that RAN is closely related to reading fluency (e.g. Manis & Freedman, 2001; Wolf & Bowers, 1999). On the other hand, the inconsistent nature of this association across other speeded reading measures (i.e., the Biemiller stimuli, spelling and reading accuracy) is not consistent with some previous reports of significant associations between RAN and word reading ability (e.g. Wolf & Bowers, 1999) and of some previous reports of an association between RAN and reading in adults (Van Den Bos, Zijlstra, & Spelberg, 2002). These results are consistent with the view that RAN may not be a particularly powerful associate of word reading abilities (e.g. Savage, 2004; Vukovic & Siegel, 2006).

Our second question was whether the product rather the sum of D and C best predicted reading comprehension and CGPA. Preliminary factor analysis provided evidence of separable D and C constructs in reading measures. One factor loaded strongly only with Listening Comprehension measures, the second factor loaded strongly only with spelling, decoding, reading rate, and reading accuracy measures consistent with the basic tenets of SVR model

(Gough & Tunmer, 1986; Hoover & Gough, 1990). A fundamental additional tenet of Gough and Tunmer's (1986) SVR model is that a product relationship rather than a simple additive relationship characterizes the interaction of decoding and listening comprehension skills in predicting reading comprehension. This claim was evaluated in the present study by contrasting an *additive* model with an *additive plus product* model (Chen & Vellutino, 1997). Contrary to the SVR account, no analyses provided support for the *additive plus product* over the *additive* model of decoding and listening comprehension skills in reading comprehension. There was also no evidence from analyses providing support for the *product plus additive model* over the *product* model of decoding and listening comprehension skills in reading comprehension.

While the additive model was as good a fit to the present data as the product model was for reading comprehension, the 2-factor model escaped conventional significance when CGPA was used as the dependent variable. Decoding was a strong predictor of CGPA, and there was however a strong trend for comprehension to predict CGPA after decoding was considered. In this sense the data may be somewhat different from those reported recently by Jackson (2005), who found that individual differences in CGPA and reading comprehension were not well-predicted by individual differences in decoding or listening comprehension measures across a typical reader sample. Why might our results differ? Our patterns may reflect the wider sampling of students from all disciplines across the university as well as the use of cumulative rather than single-course GPA. However the differences between the present findings and those reported by Jackson (2005) may be more apparent than real, because she also reported that a sub-group of poorer readers did indeed have lower GPA scores. Thus it may be that in both studies, with samples with wide variation in reading ability and containing significant numbers of poor readers, the SVR model provides a good global description of university student performance.

The absence of an *additional* D x C interaction effect in the present data after an additive model is first considered is contrary to that reported for young typical readers described by Gough and colleagues (e.g. Tunmer & Hoover, 1992), but consistent with the results reported in typical readers by Chen and Vellutino (1997) and in teenage poor readers (Savage, 2006). There was also no additional effect for the additive model after the product model was first considered, suggesting that the two models have equal explanatory power for reading comprehension. Our results could thus suggest that the poor readers in this study were, at least to a degree, able to compensate for very poor decoding skills. It may be that the poor readers here are using strategies such as contextually-based word analysis or word-specific knowledge that have been reported

by other researchers on the basis of single cases or small groups of older poor decoders (e.g. Holmes & Standish, 1996; Jackson & Doellinger, 2002; Temple & Marshall, 1983).

We suggest on the basis of these findings that any additional explanatory power for a Simple View of Reading based on the product term rather than the sum of decoding and listening skills might be limited to samples of relatively young children rather than older readers (Gough & Tunmer, 1986). Empirical differences between product and additive SVR models may reflect the differential influence of a very few cases where $D = 0$ or $C = 0$. Young children without any decoding skills will doubtless find reading comprehension a major challenge, and so the product model may provide a good fit in such samples. Older poor readers, especially those attending universities, may have the time, experience, and wider abilities to evolve compensatory word and text reading strategies as well as to develop at least some basic decoding skills. Thus, in these older samples, an additive model and a product model are likely to be equally good predictors of reading performance.

Limitations of the present research

Before concluding, a number of potential limitations to the present findings should be considered. Firstly the sample is relatively modest in size, so the study must be considered exploratory at this stage. Results should be replicated in order to be confident in their generality. This issue applies particularly to analyses exploring CGPA, which are based on $n = 36$ observations. On the other hand our data reflect the performance of a range of students across university disciplines themselves coming from provinces across Canada and from the United States. We have occasionally used measures where standard scores are not available for the age-range we have been studying, and have modified a test of reading comprehension to measure listening comprehension. This should not overly-affect our study looking at the pattern of individual differences as effects will be equal for all, and there were no signs of ceiling effects in these measures. Nevertheless, future research in this domain should consider adding measures of reading comprehension, decoding and listening comprehension standardized for Canadian adults such as the currently available WIAT-II

Implications for supporting poorer readers in University

The main finding of our analysis is that the SVR model provides a good description of the variability among readers including the very poorest readers at university. We therefore argue that the implications are two-fold. Firstly, that

assessment of the component skills of reading comprehension in clinics serving university students should consider D and C factors first and foremost in evaluating reading comprehension issues. In this way professionals can describe strengths and difficulties experienced by students in a more precise and principled fashion that also takes full account of individual differences present in the university student population more generally. Secondly, our results suggest that poorer readers at university will likely benefit from differentiated supports depending on independent needs in the domains of word recognition fluency and accuracy as well as in more global listening comprehension abilities. The SVR model thus offers the exciting possibility of differentiating the kinds of suggested supports required to students with diverse literacy needs that may be more precise and effective. The SVR account thus provides a helpful working model for all of those in universities attempting to meet the needs of this community most effectively.

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Authors' Note

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