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Exploring moderational and mediational relations among word reading, vocabulary, sentence processing and comprehension for struggling adult readers

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Background: A significant portion of adults struggle to read at a basic level. Word reading (defined here as decoding and word recognition) appears to play a pivotal role for this population of readers; however, less is known about how word reading relates to other important semantic processes (e.g., vocabulary, sentence processing) known to account for a large portion of variance in reading comprehension. This study used the Reading Systems Framework to explore the extent that moderational and mediational relations existed between word reading and semantic processing abilities in predicting reading comprehension.
Methods: Participants (N = 169) completed the Reading Inventory and Scholastic Evaluation, which consists of a series of subtests intended to measure decoding/word recognition, vocabulary, sentence processing and reading comprehension.
Results: A moderated mediation model was constructed to assess the extent to which moderational and mediational relations between word reading and semantic processing were predictive of comprehension. Results suggested that word reading moderated the effect of vocabulary knowledge on comprehension among struggling adult readers. Additionally, semantic processing at the word (i.e., vocabulary) and sentence level both significantly mediated the relation between word reading and comprehension.

Conclusions: Word reading moderated the relation between vocabulary and comprehension for struggling adult readers. Readers with greater word reading ability benefited most from having a higher degree of vocabulary knowledge. Vocabulary and sentence processing mediated the relation between word reading and comprehension. Thus, word reading appears to serve as an important gateway for struggling readers, and, as such, interventions targeting component skills of reading may have a limited impact on reading literacy tasks until word reading skills are developed.

Keywords: adult literacy, struggling adult readers, reading comprehension, decoding, semantic processing, moderation, mediation

Highlights

What is already known about this topic

- A significant portion of adults struggle to read at a basic level.
- Difficulties with word reading have consistently emerged among this population.
- Struggling adult readers appear to struggle with other component reading skills as well (e.g., vocabulary, sentence processing).

What this paper adds

- The present study explored the extent to which moderational and mediational relations existed between word reading ability and semantic processing in predicting reading comprehension among struggling adult readers.
- Word reading ability moderated the relation between vocabulary knowledge and reading comprehension, suggesting that the relation between vocabulary and reading comprehension is strongest for those who are more proficient word readers.
- Semantic processing (i.e., vocabulary and sentence processing) mediated the relation between word reading and reading comprehension, suggesting that they play an explanatory role.
- This study lends support to the Reading Systems Framework (Perfetti & Stafura, 2014), which highlights the interactive nature of reading skills.

Implications for theory, policy or practice

- Word reading is important but not sufficient for promoting comprehension in struggling adult readers.
- Adult literacy programmes need to foster multiple component skills that support reading and comprehension; however, doing this is difficult and developing best practices is something that requires additional research.
- The Reading Systems Framework (Perfetti & Stafura, 2014) provides a viable theoretical framework for understanding the strengths and challenges of struggling adult readers.

- Results are of theoretical importance as they help test and refine aspects of the Reading Systems Framework.

Approximately one-fifth of adults in the United States struggle to read at a basic level (National Center for Education Statistics [NCES], 2019). The ability to read has an immense impact on an individual's economic and social success and is directly tied to important issues such as civic engagement, health choices and educational attainment (Kirsch et al., 1993; Kutner et al., 2005; Miller et al., 2010). Struggling adult readers are heterogeneous, and many adult literacy interventions intended to improve adult literacy skills have limited success (Greenberg et al., 2011; Lesgold & Welch-Ross, 2012; Scarborough et al., 2013). As such, a growing body of research has explored the relative strengths and challenges of these readers to inform literacy programmes on how best to support struggling adult readers (e.g., Greenberg et al., 1997, 2002; Sabatini et al., 2010; Talwar et al., 2018, 2020; To et al., 2016).

Of the reading challenges found among this population of readers, difficulties related to word reading (defined here as decoding and word recognition) are prominent (Barnes et al., 2017; Braze et al., 2016; Fracasso et al., 2016; Greenberg et al., 1997, 2002; MacArthur et al., 2010; Mellard et al., 2010; Sabatini et al., 2010; Talwar et al., 2018; Thompkins & Binder, 2003). Word reading is important, in part, because it functions as a gateway that enables subsequent semantic processing (e.g., accessing the meaning of words, computing the meaning of sentences) to occur that supports comprehension (Gough & Tunmer, 1986). However, it is not sufficient for comprehension as it does not guarantee proficiency in these semantic processes (Cain & Oakhill, 2007). This may help explain why interventions focused on struggling adult readers have yielded limited gains, except in improving decoding skill (e.g., Alamprese et al., 2011). While word reading appears to be critical for these readers, reading comprehension involves a series of other component reading skills (e.g., vocabulary, morphology, sentence processing) that are known to be important in this population and others (Barnes et al., 2017; Cain & Oakhill, 2007; Mellard et al., 2010; Sabatini et al., 2018; Tighe & Schatschneider, 2016). Importantly, these component reading skills do not operate independently of one another, but rather, are thought to interact in complex ways (Perfetti et al., 2005; Perfetti & Stafura, 2014; Sabatini et al., 2019).

In the present study, we utilised the Reading Systems Framework (RSF; Perfetti & Stafura, 2014) to explore the ways in which word reading ability and semantic processing at the word (vocabulary) and sentence level interact to predict reading comprehension among struggling adult readers. Based on the RSF, it is possible that moderational and/or mediational relations exist among these skills. The purpose of this paper was to test these possibilities. Understanding the role of word reading in relation to other component reading skills may provide additional insights into improving interventions and adult basic education programmes.

RSF

Although the Simple View of Reading (SVR; Gough & Tunmer, 1986) has been prominent in adult literacy research (e.g., Sabatini et al., 2010; Talwar et al., 2021), it has come under criticism (Barnes et al., 2017; Florit & Cain, 2011; Kirby & Savage, 2008; Sabatini

et al., 2010; Talwar et al., 2018). The SVR assumes that comprehension arises from an interaction between word reading and oral language processes. While there are virtues to parsimony in theory, the SVR arguably underspecifies the complex nature of semantic language processes (i.e., how lexical, sentence and discourse-level processes operate) and the nature of comprehension (i.e., the importance of inferences in establishing coherence).

In contrast, the RSF offers a valuable lens to explore comprehension difficulties among struggling readers in that it addresses the relationships between word, sentence and discourse-level processes (Perfetti et al., 2005; Perfetti & Stafura, 2014). The RSF is not a formal model of reading, but rather was proposed as a theoretical framework to guide research questions to examine key relationships among literacy constructs. In the present study, we focused on exploring moderational and mediational relationships between reading processes that are implied by assumptions of the RSF.

The RSF makes several important assumptions about the semantic processes that support comprehension. First, it assumes that reading involves a set of subprocesses that operate at the word, semantic (i.e., lexical) and discourse levels. These processes are thought to operate asynchronously (i.e., may start and stop at different times) and in parallel (Just & Carpenter, 1992; McClelland et al., 1986). The RSF posits that the systems that support processing at these different levels are highly interconnected such that there are interactions between various reading processes (Perfetti & Stafura, 2014). These processes may be asynchronous in that some processes (e.g., computing the semantic meaning of sentences) require the output of other processes, but will, nonetheless, operate as soon as sufficient input is provided (Just & Carpenter, 1992).

The second assumption is that comprehension arises through complex word-to-text integration processes within a cognitive system with limited resources. Words in a text are processed and integrated into a reader's mental representation, which is continuously updated to reflect a reader's understanding (Kintsch, 1988; Perfetti et al., 2008; Zwaan & Radvansky, 1998). Unique from other models of comprehension that assume that integration operates on propositional representations constructed from reading text sentences (e.g., Kintsch, 1988), the RSF assumes that integration also occurs on a word-by-word basis, wherein readers accrue an understanding of the text as each individual word is processed (Perfetti & Helder, 2020; Perfetti & Stafura, 2014). Thus, the RSF emphasises the importance of semantic processing at the word level for comprehension and, arguably, places less emphasis on propositions derived from sentences as the main unit of analysis.

The third assumption is that the speed of lexical activation and quality of a reader's lexical representation affect the ease at which integration processes occur (i.e., lexical quality hypothesis; Perfetti, 2007; Perfetti & Adlof, 2012). Readers with high quality lexical representation have "accessible, well specified and flexible knowledge of word forms and meanings" (Perfetti & Adlof, 2012, p. 9). This includes knowledge of a word's spelling, pronunciation and meaning (Perfetti, 2007). High-quality semantic representations allow a reader to quickly activate appropriate word meanings based on context with minimal processing effort, which eases the integration process.

The fourth assumption is that "pressure points" exist within the framework, wherein difficulties in one system affects processing in other systems up or downstream (Perfetti, 2007; Perfetti & Hart, 2002; Perfetti & Stafura, 2014). For example, according to the RSF, semantic knowledge serves as a pressure point in the system as it is uniquely positioned between the lower-level word reading processes at one end and higher-level discourse processes at the other (Perfetti & Stafura, 2014). While Perfetti and

Stafura (2014) argue for the existence of pressure points within the framework, they are vague in defining the nature of the relationships that might exist between different reading processes. On one hand, one could argue that the relations are moderational, in that proficiency at one level of processing affects the relationship between a different level of processing and an outcome (Baron & Kenny, 1986). However, on the other hand, the relations between processes may be mediational, wherein the relation between two variables (e.g., word reading and comprehension) is explained by a third variable (Baron & Kenny, 1986). Importantly, these types of relations are not necessarily mutually exclusive in that both moderational and mediational relations may exist (Fairchild & MacKinnon, 2009; Muller et al., 2005). In the present study, we were interested in the relations among word reading, semantic processing (at the word and sentence levels) and comprehension. With the notion of pressure points in mind, we generate and test hypotheses that specify the relations among component reading skills.

Importance of Word Reading and Semantic Processing

Word Reading

In line with the RSF, we recognise word reading as a pressure point for struggling adult readers. Word reading has emerged as a prominent and consistent predictor of reading comprehension across models that control for varying reading-related skills (e.g., Mellard et al., 2010; Sabatini et al., 2010; Tighe et al., 2019). Additionally, investigations of reader profiles suggest a clear link between deficits in word reading and poor comprehension performance (Mellard et al., 2016; Sabatini, 2002, 2003; Strucker & Davidson, 2003; Talwar et al., 2020).

Word reading may be especially important given its role as a gateway to semantic knowledge and subsequent comprehension processing. When word reading is slow or effortful, it consumes one's working memory capacity (e.g., García & Cain, 2014; Just & Carpenter, 1992; Perfetti & Helder, 2020). As such, deficiencies in word reading are thought to constrain processes at the local and global discourse levels (Perfetti & Helder, 2020; Yang et al., 2007). Given the salient importance of decoding in the adult literacy context, we hypothesised that proficiency in word reading may moderate the influence of semantic processing skills on reading comprehension.

Semantic Processing at the Word Level

At the word level, semantic processing involves deriving units of meaning from text. There is a growing body of research emphasising the importance of vocabulary knowledge among struggling adult readers (Fracasso et al., 2016; Hall et al., 2014; Taylor et al., 2012; Tighe & Schatschneider, 2016). In a meta-analysis involving 16 studies conducted among struggling adult populations, vocabulary knowledge emerged as an important predictor of comprehension, displaying a moderate relation with reading comprehension (r = .52; Tighe & Schatschneider, 2016). The extent to which vocabulary knowledge accounts for unique variance over and above other component reading skills has, however, varied across studies (Braze et al., 2016; Fracasso et al., 2016; Hall et al., 2014; Sabatini et al., 2010; Taylor et al., 2012). If semantic knowledge interacts with word reading ability, as we argue here, it is plausible that the effect of vocabulary may, at times, be overshadowed given the amount of shared variance between word reading and language comprehension measures (Braze et al., 2016; Sabatini et al., 2010). Consistent with this

claim, large disparities between decoding skill and vocabulary knowledge (i.e., weak decoding and strong vocabulary or vice versa) have been found among struggling adult readers that result in different profiles of readers for which comprehension scores appear near equivalent (Binder & Lee, 2012; Strucker & Davidson, 2003; Talwar et al., 2020).

Semantic Processing at the Sentence Level

Sentence processing is understudied among struggling adult readers; however, limited research suggests that one's ability to accurately read sentences quickly and efficiently may be an important predictor of comprehension among this population (Mellard et al., 2010; Sabatini et al., 2010; Tighe & Schatschneider, 2016). Moreover, research indicates that struggling adult readers may lack skill in terms of the ability to construct novel sentences using a group of words (Taylor et al., 2012). Sentence comprehension involves both syntactic and semantic processing (Ng et al., 2017; Perfetti et al., 2008; Traxler, 2014; van Gompel, 2013). While we acknowledge the important role of syntactic parsing in sentence processing, the present study focuses on the role of semantic processing given its importance in the RSF.

The Current Study

The purpose of this study was to explore the ways in which word reading ability and semantic processing at the word (i.e., vocabulary) and sentence level related to one another in predicting reading comprehension among struggling adult readers. While the RSF emphasises the importance of word-level processing in integration (i.e., word-to-text integration), theories of comprehension emphasise the role of sentence-level semantics (McNamara & Magliano, 2009). Based on the existing literature and our interpretation of the RSF, we proposed two non-competing hypotheses. According to the *moderational hypothesis*, decoding and word recognition moderate the relation(s) between reading comprehension and vocabulary and/or sentence processing. According to RSF (Perfetti & Stafura, 2014), component reading skills are highly interconnected such that the ability to access lexical knowledge is affected by one's ability to read words. Moreover, the ability to efficiently process sentences is affected by one's ability to decode words and access/integrate lexical knowledge. As such, in the present study, we hypothesised that decoding and word recognition would moderate the effect of semantic processing (at the word and/or sentence level) on reading comprehension. We predicted the nature of the interaction would be such that increasing word reading ability would strengthen the relation between component reading skills and reading comprehension.

A second hypothesis was proposed to explore mediational relations among component reading skills. According to the *mediational hypothesis*, word reading impacts comprehension indirectly through semantic processing. The RSF specifies semantic processing as an important pressure point given that it sits between word reading processes at one end and discourse processing at the other (Perfetti & Stafura, 2014). Moreover, there is some evidence that the relation between word reading and comprehension is mediated by other component skills of reading comprehension (e.g., inference; Oslund et al., 2018), which raises the possibility that its relation with comprehension could be mediational in nature.

Here, we test the extent to which semantic processing at the word (i.e., vocabulary) and sentence level explains the relation that exists between word reading and comprehension. Importantly, as noted earlier, these hypotheses are not mutually exclusive. As such, it is possible that both moderational and mediational relations exist among variables in predicting comprehension.

Methods

Participants

Participants were 169 individuals from a larger research project (see the IES grant associated with this article). Participants were enrolled in adult literacy classes targeting third through eighth grade (mid-elementary school and middle school) reading levels in major metropolitan areas in the southeastern United States and central Canada. The sample included 120 women and 49 men between the ages of 17–73 years (M = 42.11; SD = 14.38). Most participants identified as Black or African American (77%), and a much smaller group identified as White (17%). All participants were native speakers of English. Participants' data were selected from the larger research project data collection only if they completed all relevant measures for the current study. Thus, there were no missing data in the sample.

Measures

As part of a larger assessment battery, participants completed the Reading Inventory and Scholastic Evaluation (RISE; Sabatini et al., 2019). RISE is a web-based assessment battery consisting of a series of subtests intended to measure the component reading skills listed below, as well as reading comprehension. RISE has been normed on large samples of readers from Grades 5 through 10 (middle school through early high school; Sabatini et al., 2019). Each subscale has been shown to have good reliability (all Cronbach's α estimates >.80), and there is evidence of concurrent validity given RISE's ability to predict standardised state test scores (O'Reilly et al., 2012; Sabatini et al., 2013, 2019).

Decoding/Word Recognition

To assess proficiency in word reading, RISE tests one's proficiency in decoding (i.e., the ability to generate plausible pronunciations for printed words) and word recognition (i.e., the accumulation of sight word knowledge for real words in one's native language; Sabatini et al., 2019). In this task, participants determined whether a stimulus was a word, non-word or pseudohomophone (i.e., a word sounding exactly like a real word) as quickly as possible. Non-words consisted of made-up words that covered a broad range of spellings and morphological patterns (e.g., clort, plign), whereas, pseudohomophones were non-words intended to sound like real words when decoded properly (e.g., maik – make; brane – brain). Real words were selected to cover a wide frequency range and were intended to assess one's ability to automatically recognise a word without needing to decode it (e.g., elect, symbolic; Ehri, 2005; Sabatini et al., 2019). This task involves decoding in that it requires generating possible pronunciations for non-words and pseudohomophones (though the pronunciations may not necessary be made out loud). It also involves word recognition in that it requires identifying words that have likely been

encountered many times (Ehri, 2005; Sabatini et al., 2019). This subtest contained 52 items.

Vocabulary

To assess vocabulary knowledge, participants were presented with a target word and asked to select the appropriate synonym or meaning-related word. This task specifically targeted tier 2 (i.e., general academic words; e.g., admonish, retrospect) and tier 3 (words used less frequently outside of a specific domain/discipline; e.g., photosynthesis) words (see Beck et al., 2008) as well as polysemous words (i.e., words with more than one meaning) with lesser known secondary meanings (e.g., the word *prime* may refer to mathematics (i.e., numbers) or the quality of an object; Papamihiel et al., 2005; Sabatini et al., 2019). This subtest contained 35 items.

Sentence Processing

The sentence processing measure focused on one's ability to construct meaning from print at the sentence level (Sabatini et al., 2019). Similar to traditional MAZE assessments, in this task participants read sentences and filled in the blank with the appropriate word (e.g., "The dog that chased the cat around the yard spent all night: barking, meowing, writing"). This subtest contained 24 items.

Reading Comprehension

The purpose of the reading comprehension subtest was to assess one's discourse-level understanding of a text, without the need to reason with/about information in the text (Sabatini et al., 2013, 2019). Participants read three short passages and answered multiple-choice questions associated with the texts (six to seven items per passage, with a total of 19 items). Questions focused on students' ability to locate information in the text, paraphrase information and make inferences. In the present study, this measure served as the dependent variable.

Procedure

Trained research assistants administered the RISE in a quiet setting at the participants' adult literacy programme sites. Participants worked independently on either a laptop or desktop computer. They used headphones to listen to verbal instructions and pressed the 1, 2 and 3 keys on the keyboard to select their answers. Data were recorded automatically by the RISE system. RISE took approximately one hour to complete.

Analytic Approach

As discussed in the Introduction, the RSF suggests that word reading works together with semantic processing skills to facilitate comprehension. However, the RSF does not specify whether the relationships between word reading and other component reading skills are mediational or moderational in nature. As such, a moderated mediation model was constructed, which allows for both types of relationships (i.e., moderational and mediational) to be tested simultaneously (i.e., in the same model; Edwards & Lambert, 2007; Hayes, 2015). The moderated mediation model was constructed with the PROCESS macro

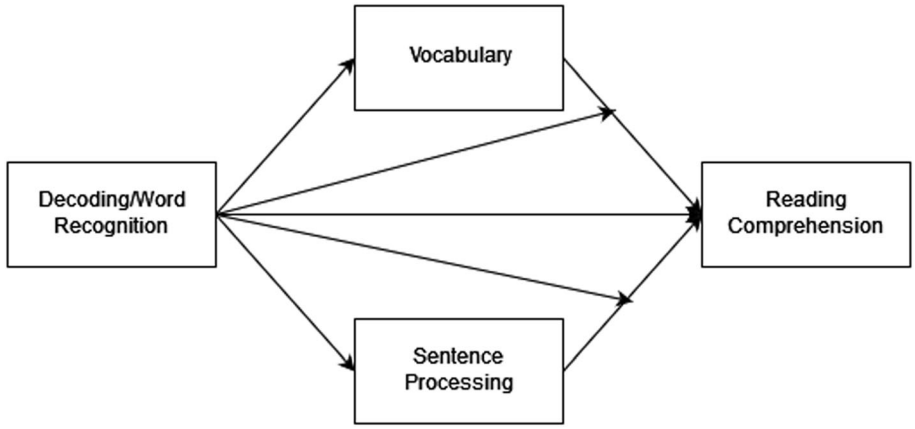

Figure 1. Schematic representation of model tested in the current study

(Hayes, 2018) for SPSS (version 26; IBM Corp, 2021) using 10,000 bootstrapped samples. The PROCESS macro (Hayes, 2018) uses a regression-based approach to test direct and indirect relationships between observed variables. As such, it is specifically designed to test simple and complex moderational and mediational relationships. Given that adding moderating/mediating variables comes at a cost to statistical power, PROCESS uses bootstrapping to calculate standard errors and confidence intervals (Hayes, 2022). In the model used in the current study, the relationship between decoding/word recognition and reading comprehension was mediated by both vocabulary and sentence processing, thus testing the mediational hypothesis. In addition, decoding/word recognition moderated the relationship between reading comprehension and vocabulary as well as the relationship between reading comprehension and sentence processing, thus testing the moderational hypothesis. A schematic representation of this model is displayed in Figure 1.

Results

Descriptive statistics for measures are shown in Table 1, and bivariate correlations between measures are shown in Table 2.

As mentioned previously, a model was constructed to simultaneously test the moderational and mediational hypotheses using Hayes' (2018) PROCESS Macro (version 3.0) for SPSS (version 26; IBM Corp, 2021). The unstandardised path model is displayed in Figure 2. Unstandardised estimates were used in the current study because standardised estimates of the beta-weights are not available in PROCESS when a moderated mediation model is used. These unstandardised beta-weights can be interpreted as the number of units that the outcome variable changes in response to a 1-unit change in the predictor variable.

As can be seen in Figure 2, decoding/word recognition significantly and positively predicted both vocabulary and sentence processing, which in turn significantly and positively predicted reading comprehension. Additionally, Table 3 displays indirect path coefficients. These estimates refer to the effect of the predictor variable (i.e., decoding/word recognition) on the outcome variable (i.e., reading comprehension) through the mediators (i.e., vocabulary and sentence processing). These estimates are calculated by taking the product of the beta-weights between the predictor variable and

Table 1. Descriptive Statistics for RISE Measures.

	Potential score range	*N*	Minimum	Maximum	Mean	*SD*
Decoding/word recognition	190–310	169	224	268	243.52	9.25
Vocabulary	190–310	169	227	277	250.40	11.90
Sentence processing	190–310	169	228	263	250.49	6.94
Reading comp.	190–310	168	237	273	254.83	8.02

Table 2. Correlation Matrix for RISE Measures.

	1.	2.	3.	4.
1. Decoding/word Recognition		.69	.47	.52
2. Vocabulary			.62	.62
3. Sentence processing				.52
4. Reading comprehension				

All relationships significant at the $p < .01$ level.

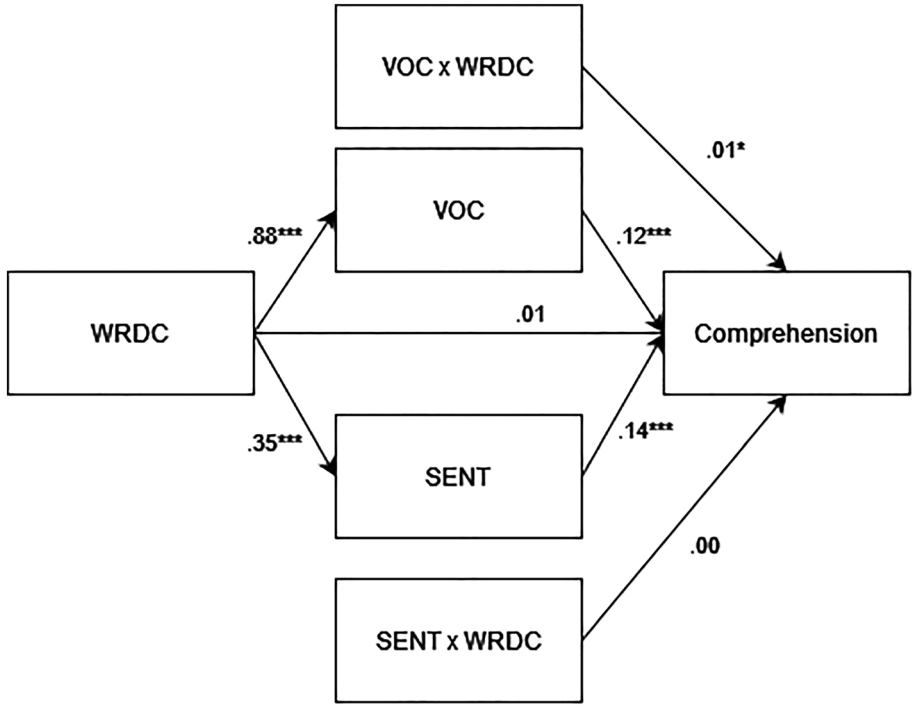

Figure 2. Model path estimates (unstandardised). *$p < .05$, ***$p < .001$

Table 3. Indirect Path Coefficients and 95% Bootstrapped Confidence Intervals (Unstandardised).

			95% CI for indirect effect	
	b	*SE*	Lower bound	Upper bound
Decoding/word recognition → Vocabulary → Reading comprehension	1.90	.50	.87	2.84
Decoding/word recognition → Sentence processing → Reading comprehension	.68	.39	.06	1.58

Table 4. Moderation Effects by 25th and 75th Percentiles of RISE Decoding/Word Recognition (Unstandardised).

			95% CI for indirect effect	
	b	*SE*	Lower bound	Upper bound
Vocabulary (25th percentile of decoding/word recognition)	.08	.03	.02	.14
Vocabulary (75th percentile of decoding/word recognition)	.15	.03	.09	.22

mediator and between the mediator and the outcome variable. As can be seen in Table 3, decoding/word recognition significantly and positively predicted reading comprehension via indirect paths through both vocabulary and sentence processing. Furthermore, vocabulary and sentence processing fully mediated the relationship between decoding/word recognition and reading comprehension.[1] In sum, these results support the mediational hypothesis.

In addition to mediational effects, we also tested whether moderational effects existed between decoding/word recognition and the vocabulary and sentence processing variables. As can be seen in Figure 2, there was no significant moderation between decoding/word recognition and sentence processing. However, there was a significant interaction between decoding/word recognition and vocabulary such that higher scores on decoding/word recognition and vocabulary predicted higher reading comprehension scores multiplicatively. To understand the nature of this interaction, the interaction effect was tested at the 25th and 75th percentiles of decoding/word recognition. Splitting the data into quartiles is relatively common practice (e.g., Spichtig et al., 2016) and allows researchers to test differences between relatively low and high levels of a variable to determine differential patterns of relationships. To ensure that the split between upper and lower quartiles was substantial, an independent-samples *t*-test was conducted to compare the quartiles on levels of decoding/word recognition. This test was significant, $t(72.77) = 27.06$,[2] $p < .001$, indicating that the upper quartile ($M = 256.02$, $SD = 4.71$) had significantly higher decoding/word recognition scores than the lower quartile ($M = 232.80$, $SD = 3.14$). Table 4 displays the results of the interaction test at the 25th and 75th percentiles. As can be seen, while there is a positive interaction between the variables at the 25th percentile of decoding/word recognition, the effect is stronger at the 75th percentile. This indicates that at higher levels of word recognition and decoding ability, increases in vocabulary predict even stronger comprehension. In sum, these results support the moderational hypothesis.

Discussion

The present study explored the relations among word reading, semantic processing at the word and sentence level and comprehension in struggling adult readers. This was accomplished by testing moderation and mediation hypotheses regarding the relationship between word recognition/decoding, vocabulary, sentence processing and reading comprehension as measured by the RISE. There was evidence for the moderational hypothesis such that the relation between vocabulary and comprehension changed as a function of proficiency in word recognition/decoding. As demonstrated in Table 4 (and Figure 2), the relation between vocabulary and reading comprehension was strongest for the most proficient word readers (i.e., those in 75th percentile). There was also evidence for the mediational hypothesis in that both vocabulary and sentence processing were found to fully mediate the relation between word recognition/decoding and reading comprehension. These findings are consistent with research suggesting that the speed and accuracy by which words are recognised has a significant impact on lexical activation, which, consequently, impacts comprehension outcomes (Perfetti & Hart, 2002; Wang et al., 2019).

There is considerable research that shows direct relationships between word reading and comprehension outcomes in children and adolescent readers (e.g., Ahmed et al., 2016; Cromley & Azevedo, 2007; Oslund et al., 2018); however, this relationship has been shown to weaken over time (i.e., grade levels) as the relationship between vocabulary and comprehension strengthens (Braze et al., 2016; García & Cain, 2014; Vellutino et al., 2007). Moreover, this relationship appears to be highly contingent upon a reader's skill level (e.g., Cutting & Scarborough, 2006; Keenan et al., 2008; Swanson & Berninger, 1995). As such, as readers become more proficient at word reading, the *relative* importance of vocabulary increases. One would expect a direct relationship between word recognition/decoding and comprehension in struggling adult readers, given struggling adult readers face challenges with word identification processes (e.g., Braze et al., 2016; Greenberg et al., 1997, 2002; Sabatini et al., 2010; Talwar et al., 2018). However, as noted above, the relationship between word reading and comprehension was fully mediated by vocabulary and sentence processing.

There are studies that have shown the presence of a direct relationship between word reading and comprehension in early to late adolescent readers (Cromley & Azevedo, 2007; Oslund et al., 2018). However, Ahmed et al. (2016) tested direct and indirect relationship between multiple components of reading with comprehension in a diverse sample of readers from 7th to 12th grade. They found inconsistences regarding whether there was a direct relationship between word reading and comprehension across the grade levels; there were direct relationships for Grades 10–11, but not for Grades 7, 8, 9 and 12. The fact that more grade levels showed no evidence supporting direct relationships than grade levels showing support for direct relationships is consistent with the results of the present study. Moreover, the results are consistent with other evidence supporting an indirect, mediational relation of vocabulary (e.g., Protopapas et al., 2007). That said, clearly more research is needed to understand the relations between the component skills of reading and comprehension in struggling adult readers.

It is also important to acknowledge that the present study does not preclude the possibility that there is a bidirectional relationship between word reading and vocabulary. For example, it is possible that vocabulary is moderating the relationship between decoding/word recognition and reading comprehension rather than the reverse. We propose this possibility for two reasons. First, there is some evidence that the component

processes that comprise language processing (oral or reading) are highly interactive such that processes that start relatively early can also be affected by the processes that start relatively late and by contexts effects (e.g., Just & Carpenter, 1992; McClelland et al., 1986). Additionally, while there is considerable research showing that reading leads to the growth of vocabulary knowledge (e.g., Cunningham, 2005; Wasik et al., 2016), there is also some evidence that developing a greater vocabulary also affects proficiencies in word reading (Hulme et al., 2019). However, these studies focus on children, and research on the reciprocal nature of word reading and vocabulary growth in struggling adult readers would have important implications for theory and practice.

Implications for Theory

Support for moderational and mediational hypotheses is both consistent with and informs the RSF. First, the significant pathway from word recognition/decoding through vocabulary to comprehension is consistent with the word-to-text integration assumption (Perfetti & Stafura, 2014). However, the fact that the pathway through sentence processing was also correlated with comprehension is consistent with theories of text comprehension that emphasise that integration operates at sentence-level semantics (e.g., Kintsch, 1988). The RSF places greater emphasis on words as the fundamental unit of integration at the discourse level; however, the size of the coefficients indicates that the relationship between vocabulary and comprehension is comparable to the relationship between sentence processing and comprehension.

The results of the present study also provide support for the pressure point assumption. As noted in the Introduction, Perfetti and Stafura (2014) are arguably ambiguous regarding what kinds of relations constitute pressure points. The results of the present study demonstrate that mediational and moderational relationships exist with respect to word recognition, vocabulary and comprehension outcomes and, as such, afford greater specification in the framework regarding what kinds of relationships constitute a pressure point.

The SVR (Gough & Tunmer, 1986) has arguably been the theoretical grounding for a majority of the research on struggling adult readers (e.g., Braze et al., 2016; Sabatini et al., 2010; Talwar et al., 2018). However, it is generally considered to be overly simplistic given that it combines various component skills (e.g., vocabulary, inferencing, etc.) into a single factor (i.e., oral language comprehension) and largely ignores important interactions that exist between component skills beyond word reading (decoding and fluency; Duke & Cartwright, 2021; Florit & Cain, 2011; Johnston & Kirby, 2006; Kirby & Savage, 2008). Moreover, the SVR postulates a moderational relationships between word reading and oral language proficiency and does not specify that there may be mediational relationships. As such, the SVR cannot account for evidence in favour of the mediational hypothesis, particularly full mediation with respect to word recognition/decoding, vocabulary and comprehension.

Implications for Interventions

This research may have important implications for interventions among struggling adult readers. Intervention and instruction among struggling adult readers have proved challenging with limited success (Calhoon et al., 2013; Greenberg et al., 2011;

Lesgold & Welch-Ross, 2012; Scarborough et al., 2013). Findings from this study suggest that adults enrolled in adult education programmes may benefit most from instruction once they are able to quickly and accurately engage word reading processes (Perfetti & Hart, 2002; Wang et al., 2019). We find this encouraging given that interventions among this population have been shown to improve decoding skill (e.g., Alamprese et al., 2011; Gray et al., 2018).

While interventions focused on word reading skills may prove beneficial, efficient word reading alone is not sufficient to activate semantic knowledge. Struggling adult readers may have lower semantic knowledge (i.e., knowledge of vocabulary, morphology) due to a lack of word reading skill and, consequently, print-exposure (e.g., the "Matthew Effect"; Ari, 2013). Improving semantic processing at the word and sentence level has generally proved to be more challenging for struggling adult readers (Calhoon et al., 2013; Greenberg et al., 2011; Lesgold & Welch-Ross, 2012; Scarborough et al., 2013). Research among students in Grades 5–10 (i.e., middle school through early high school) suggests that there may be a "decoding threshold", wherein a minimum level of decoding ability is necessary before higher-level processes become impactful (Wang et al., 2019). According to this view, the positive linear relation between decoding and comprehension may only be observed once a reader has met a certain level of decoding ability. While there is some evidence of thresholds existing among struggling readers in college (Magliano et al., 2023), future research is needed to explore whether a threshold exists for this unique, heterogeneous population of readers and the extent to which this affects interventions.

Limitations and Future Directions

One limitation of the current study is that the RISE measure had not been specifically normed for struggling adult populations at the time at which this study was conducted. While this is typical of other measures used among this population, this may be an important factor to consider given that some measures may not function as expected (Greenberg et al., 2009; Nanda et al., 2010). The research necessary to formally assess the reliability and validity of RISE in a population of struggling adult readers is ongoing, and the present study demonstrates that this line of research is warranted.

The present study was also limited in terms of the number of measures used. There are numerous facets of reading comprehension that could be explored through various measures. For example, in the present study, we utilised a measure of word reading that focused on decoding and word recognition (determining whether a stimulus was a word, non-word or pseudohomophone). Future research should explore other important aspects of word reading, including phonological awareness and orthographic knowledge (Ehri, 2014; Greenberg et al., 1997). Additionally, in terms of vocabulary, the measure used in the present study was a written measure that focused on assessing recognition of synonyms as well as semantically associated words. Other studies among struggling adult readers have focused on oral vocabulary measures (e.g., Fracasso et al., 2016; Mellard et al., 2012; Sabatini et al., 2010). The RSF assumes that quick, automatic word identification is the nexus to semantic processing. As such, we argue that it makes sense to use a reading, rather than oral, vocabulary test. Regardless, future research should seek to include other measures of semantic processing (e.g., morphology, syntactic processing).

Finally, it should be noted that while the current study's model was theoretically grounded in the RSF (Perfetti & Stafura, 2014) and other relevant literature, the data used

in the current study were cross-sectional in nature. As such, there may be other ways to model the mediational relationships between decoding/word recognition, vocabulary, sentence processing and reading comprehension that more accurately reflect the underlying processes involved in reading. Future work will need to disentangle these possibilities.

Conclusions

The results of the present study show that word reading affords semantic processing that supports comprehension, but that proficiency in word reading affects the nature of that relationship in struggling adult readers. The results are supportive of the importance of word reading training in adult literacy programmes and indicate that word reading enables semantic processing that is important for comprehension (e.g., inference). These findings have important implications for adult literacy education. Finally, we encourage adult literacy researchers to consider theoretical frameworks, such as the RSF, as an alternative to the SVR, to account for the complex relations between the component skills of reading and comprehension.

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Conflict of Interest

There are no conflicts of interest to disclose.

Code Availability

Not applicable.

Data Availability Statement

Data available upon request from authors.

Endnotes

[1] Note that although we are using the phrase "fully mediated", we do not have the proper methodology (i.e., manipulation in an experimental design) to establish causality for true mediation.

[2] Levene's test indicated significantly different variances between the quartiles, $F(1,85) = 8.28$, $p = .005$, so a t-test with Satterthwaite-corrected degrees of freedom was conducted.

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