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Empirical Article

Vocabulary and reading comprehension: what are the links in 7- to 10 year-old children?

EMILIE DUJARDIN,^{1,2,3}  JEAN ECALLE,¹  PAULINE AUPHAN,^{1,2} NICOLAS BAILLOUD¹ and ANNIE MAGNAN¹¹Laboratoire EMC Etude des mécanismes cognitifs – MSH LSE (USR CNRS 2005) – Université Lyon 2, LabEx CORTEX ANR-11-LABX-0042, Université de Lyon, Lyon, France²Association Agir Pour l'Ecole – Paris, Paris, France³Centre de Recherches sur la Cognition et l'Apprentissage (CeRCA), Université de Poitiers, Université de Tours, CNRS, Poitiers, FranceDujardin, E., Ecalle, J., Auphan, P., Bailloud, N. & Magnan, A. (2023). Vocabulary and reading comprehension: what are the links in 7- to 10 year-old children? *Scandinavian Journal of Psychology*.

The aims of the present study are: (1) to examine the contribution that vocabulary makes to reading comprehension in the Simple View of Reading model in French-speaking children aged from 7 to 10 years based on the use of an index of efficiency (i.e., speed-accuracy index); and (2) to investigate the extent to which the contribution of vocabulary to reading comprehension might change according to children's school grade level. Measures of vocabulary depth, word reading (i.e., three levels of word representations, namely orthography, phonology, semantics), listening, and reading comprehension were collected using computer-based assessments in children from Grades 2 to 5 ($N = 237$). We examined the contribution of vocabulary in two contrasted groups: a younger group consisting of children from Grades 2–3 and an older group with children from Grades 4–5. A confirmatory factor analysis revealed that vocabulary is a factor separate from word reading, listening and reading comprehension. Moreover, the results from a structural equation modeling analysis showed that word reading and listening comprehension fully mediated the relation between vocabulary and reading comprehension. Consequently, vocabulary had an indirect effect via word reading on reading comprehension in both groups. Finally, word reading had a greater effect on reading comprehension than listening comprehension in both groups. The results suggest that word reading plays a central role in reading comprehension and is underpinned by the influence of vocabulary. We discuss the results in the light of the lexical quality hypotheses taken together with reading comprehension.

Key words: Simple view of reading, lexical quality, children, vocabulary.

Emilie Dujardin, Centre de Recherches sur la Cognition et l'Apprentissage (CeRCA), Université de Poitiers, Université de Tours, CNRS, Poitiers, France.
e-mail: emilie.dujardin@univ-poitiers.fr

INTRODUCTION

Reading comprehension (RC) is a complex activity involving many components and has been widely studied by researchers in different languages whose orthography varies along the orthographic transparency continuum (i.e., the correspondence between letters and sounds). The relationship between literacy skills (e.g., phonological awareness, memory, vocabulary, rapid naming) and reading varies with language transparency (Ziegler, Bertrand, Tóth *et al.*, 2010). Most studies have attempted to identify the components of RC in order to enhance and complement existing models (see Hoover & Gough, 1990; Tunmer & Chapman, 2012). One of the best-known models, the Simple View of Reading (SVR; Gough & Tunmer, 1986), posits that RC is the product of two components: decoding (which constitutes word reading – WR – for the authors) and linguistic comprehension (sometimes refers to listening comprehension – LC). The link between these components evolves with age. At the beginning of learning-to-read, decoding plays a more important role than LC in RC (Hoover & Gough, 1990). Furthermore, language transparency moderates the relationship between decoding and RC: decoding is a more important predictor in inconsistent orthographies (see Caravolas, Lervåg, Mikulajová, Defior, Seidlová-Málková & Hulme, 2019). The SVR model has been complemented by adding certain components, such as vocabulary for instance (e.g., Tunmer & Chapman, 2012).

A more recent and more complex model, the Reading Systems Framework (RSF; Perfetti & Stafura, 2014), attempts to integrate many components, from word identification processes (visual input) through to higher-level processes of RC. Without the objective of this paper being to test this complex model, we refer to it because the role of word knowledge in this model is central. Indeed, the RSF model is based on the word-to-text integration processes and considers three sources of knowledge during reading: orthographic, phonological and semantic, requiring the retrieval of word meaning in order to make sense of text. These processes are linked by the lexicon (including meaning, morphology and syntax). Only the semantic knowledge is stored in the lexicon. The lexicon is thus considered as an intermediary between visual input and RC. In other words, this model seems to consider vocabulary (“meaning”) as one of the mediator variables between single WR and comprehension. According to the Lexical Quality Hypothesis (Perfetti, 2007), WR implies high-quality lexical representation at different levels (i.e., orthography, phonology, and semantics). Precise knowledge about these components (and especially the retrieval of word meaning) is required for efficient RC. This is acquired progressively, and therefore develops with age. In our study, we have measured the three components of WR.

Efficiency is not measured simply in terms of the speed or accuracy of the response but also involves a ratio between them (Perfetti, 2007). However, this measure is not used in studies.

Indeed, most studies have used measures of correct response scores for all literacy tests. However, they do not tell us whether some children take longer to respond correctly or not. In some cases, authors have measured time-limited correct response scores. Some children will manage to answer all the items and others will not. However, this does not mean that the children do not know the items but simply that it takes them longer to answer. Richter, Isberner, Naumann and Neeb (2013) pointed out that a child's knowledge of a word is important (accuracy), but that so, too, is how quickly the child accesses that knowledge (time). According to Perfetti (2007), efficient reading would not necessarily be fast reading, as accuracy must also be taken into account. An index that takes account of both speed and accuracy would be useful for determining the efficiency of the processes: the higher the score, the more efficient the process being measured, with children taking longer to answer correctly or answering faster at the expense of accuracy.

Research on the role of vocabulary in learning to read has increased considerably over the past decade (e.g., Cho, Capin, Roberts, Roberts & Vaughn, 2019; Protopapas, Mouzaki, Sideridis, Kotsolakou & Simos, 2013). This paper aims to: (1) examine the contribution made by vocabulary depth to the RC of 7 to 10-year-old French-speaking children based on the use of an index of efficiency; and (2) specify if the contribution of vocabulary to RC changes as a function of children's school grade level. After a short presentation of the SVR model, we examine a number of works investigating the role of vocabulary in this model in children (i.e., different languages, grades, longitudinal or cross-sectional studies).

What model of reading: a simple view or a more complex model?

According to the SVR framework, RC is a function of WR and linguistic comprehension. Linguistic comprehension is based more on oral language skills (i.e., meaning, sentence- or discourse-level) than WR (based on decoding skills). For a good reader, WR implies quick and accurate access to lexical representations in the mental lexicon (Hoover & Gough, 1990; Tunmer & Chapman, 2012). This skill is acquired through the mechanism of grapheme-phoneme correspondence (i.e., the correspondence of a printed letter to a sound), and develops as children learn to read. Learning to read appears to be easier for transparent languages (Ziegler *et al.*, 2010). Hoover and Gough (1990) attributed great importance to WR and linguistic comprehension in explaining RC over time.

The SVR model has been widely tested in different languages, but most particularly in English. Recently, in a meta-analysis of 56 studies of English-speaking children from G1 to G6 (5 to 13-year-olds), Ripoll Salceda, Aguado Alonso and Castilla-Earls (2014) found that decoding and linguistic comprehension explain 50% of the variance in RC. Moreover, the authors highlighted the fact that written word identification is a component of decoding that is more closely related to RC (see also Richter *et al.*, 2013) during the early grades (1 to 3; 6 to 8 year-old), whereas its importance decreases in the upper grades at a time when the relationship between linguistic comprehension and RC increases (G4 to 6, 9 to 13 year-old). In French-speaking children in Grades 1–2 (6 to 7-year-olds), Megherbi, Seigneuric

and Ehrlich (2006) examined the contribution of decoding skills (by means of non-word reading tests) and linguistic comprehension to RC (using the same text presented in the oral and written modalities, respectively). A hierarchical regression analysis on the correct response scores revealed that linguistic comprehension makes a greater contribution than WR to RC in both grades. The authors suggested that this finding could be related to the orthographic transparency of the French language, which is more transparent than English. The authors also suggested taking account of vocabulary knowledge.

Despite the language-related differences in the results, the SVR model provides a good description of success in RC in native English-speakers and English-learners (Cho *et al.*, 2019; Joshi, Tao, Aaron & Quiroz, 2012), as well as in Spanish- and Chinese-speakers (see Joshi *et al.*, 2012). However, WR and LC explain 50% of the variance of RC (Ripoll Salceda *et al.*, 2014), and the SVR model therefore needs to be improved in order to explain the complex process of RC. Tunmer and Chapman (2012) consequently suggested “relaxing” the SVR model by introducing another component, i.e., vocabulary.

What is the role of vocabulary in the SVR?

Vocabulary is a more global language skill related to LC and decoding (e.g., Ouellette, 2006; Ouellette & Beers, 2010) and predicts children's future RC (Tunmer & Chapman, 2011). Vocabulary knowledge grows with age (Perfetti, 2007). To determine the role of vocabulary in the SVR model, it is necessary to identify its place in the model and the link (direct or indirect) it has with the other components. In the context of the SVR model, vocabulary could be considered as a component of LC (e.g., Protopapas *et al.*, 2013; Tunmer & Chapman, 2012), or as a distinct factor (e.g., Kim, 2017; Verhoeven, Voeten & Vermeer, 2019). In the same way as studies that consider vocabulary as part of linguistic comprehension (e.g., Massonnié, Bianco, Lima & Bressoux, 2019; Protopapas *et al.*, 2013; Tunmer & Chapman, 2012; see also Braze, Katz, Magnuson *et al.*, 2016 in adults; Huo, Koh, Cheng, Marinova-Todd & Chen, 2021 in children learning French in L2), studies that consider vocabulary as a separate factor maintain the structure of the SVR model (WR, LC and RC; Cho *et al.*, 2019; Kim, 2017; Verhoeven *et al.*, 2019). Furthermore, studies show that WR contributes more strongly than LC to RC in English (in children in G2; Kim, 2017; Tunmer & Chapman, 2012; in G4, Cho *et al.*, 2019 for non-English learners but not for English learners), in French (in children from G1 to G2 Huo *et al.*, 2021; in G1 Massonnié *et al.*, 2019; but see Megherbi *et al.*, 2006), but not in Dutch (Verhoeven *et al.*, 2019 in children from kindergarten to G2).

Vocabulary as a part of linguistic comprehension. Linguistic comprehension would imply that individual words are retrieved in lexical memory in order to determine meaning and syntax and construct the significance of utterances. According to this definition, vocabulary knowledge is involved and this is why some researchers have suggested that vocabulary is a dimension of linguistic comprehension (vocabulary and LC in a single factor) in various languages (French: Huo *et al.*, 2021; Massonnié *et al.*, 2019; Greek: Protopapas, Simos, Sideridis & Mouzaki, 2012; English: Tunmer & Chapman, 2012).

Tunmer and Chapman (2012) tested the varying role of vocabulary in this model in G2 students (7-year-olds). They assessed decoding by means of WR and non-word reading tests, while also assessing LC (e.g., answering oral questions) and RC (e.g., answering questions) by means of two parallel forms of the test, and also assessed vocabulary. The authors ran a hierarchical regression analysis on the number of correct responses. These showed that vocabulary made an additional contribution over and above the initial model, which included WR and LC. More precisely, they performed an exploratory factor analysis which showed that vocabulary and LC loaded on a single factor (i.e., linguistic comprehension; see also Protopapas *et al.*, 2012 for similar results in Greek-speaking children). Moreover, a structural equation model (SEM) analysis revealed two statistically equivalent models (see Wagner, Herrera, Spencer & Quinn, 2015): the first one showed that RC was not only influenced directly by linguistic comprehension (i.e., LC and vocabulary knowledge), but also indirectly through WR, while the second indicated that RC was influenced directly by WR and indirectly through LC. Vocabulary could be incorporated with LC as a single factor in the SVR model.

The role of vocabulary in the SVR framework has been tested in other languages that are more transparent than English (in French as first language: Massonnié *et al.*, 2019 and as second language: Huo *et al.*, 2021; in Greek: Protopapas *et al.*, 2013). Massonnié *et al.* (2019) examined the relationship between the components of the SVR model in French children in G1 (6-year-old). The results showed that the factors of WR (word and pseudoword reading) and oral comprehension (vocabulary, syntax and oral text comprehension) make a distinct contribution to RC. Furthermore, the high correlation between vocabulary and LC led the researchers to consider these to be two dimensions of a more general factor: oral comprehension. In this study, vocabulary was measured with a classic multiple-choice picture task. Huo *et al.* (2021) used the same test of vocabulary as was used to measure LC in a longitudinal study from G1 (6-year-old) to G2 (7-year-old) in French-learning L2 Canadian children. In other words, LC was not directly measured. This study shows that vocabulary and WR (accuracy and fluency) make distinct contributions to RC for both grades, with a greater contribution of WR. Contrary to Megherbi *et al.* (2006), these last two studies show a greater contribution of WR fluency than LC to RC (Huo *et al.*, 2021; see Fig. 3, Massonnié *et al.*, 2019). This could be due to the fact that two measures were used to evaluate decoding skills or could be because Megherbi *et al.* (2006) measured WR accuracy without taking time into account.

In cross-sectional and longitudinal studies in Greek-speaking students in Grades 3–5, Protopapas *et al.* (2013) performed regression analyses on the correct response scores. The results showed that vocabulary (measured using a multiple-choice paradigm and a word definition task) shared and reduced the unique contribution of accuracy and fluency, word and pseudoword reading (measured both with no time limit and with a time limit), and LC to RC (both measured using multiple-choice questions). Moreover, vocabulary and LC made significant unique contributions to both concurrent and longitudinal RC. The SEM analysis revealed that vocabulary had an indirect effect on RC through LC. The authors concluded that vocabulary could be

considered as a part of linguistic comprehension (see also Protopapas *et al.*, 2012).

More recently, Braze *et al.* (2016) found similar results in young English-speaking adults with suboptimal reading skills. Latent variable and regression analyses support the conclusion that vocabulary is part of language comprehension and is not a direct predictor of RC. The authors highlighted the importance of the choice of literacy measures. These findings are based on multiple measures of each component. Regression analyses showed that the strength of decoding, vocabulary knowledge and LC effects differs depending on how RC is measured. For instance, only the measure of receptive vocabulary influences all measures of RC (see table 4 in Braze *et al.*, 2016).

While the latter five studies considered vocabulary as a component of linguistic comprehension, some studies have not come to the same conclusion. Indeed, vocabulary knowledge is thus considered to influence not only RC, but also WR and LC (e.g., Ouellette, 2006; Ouellette & Beers, 2010; Tunmer & Chapman, 2011).

Vocabulary as a factor distinct from word reading and linguistic comprehension. Vocabulary has been found to be a predictor of WR and/or RC (see Ouellette, 2006; Tunmer & Chapman, 2011). According to the Lexical Quality Hypothesis, the growth of vocabulary knowledge increases the precision not only of lexical representations but also of the syntactic knowledge that makes comprehension possible (Perfetti, 2007), both in written and oral language (Cho *et al.*, 2019). Thus, vocabulary could be viewed as a factor which is separate from WR and LC (in English and non-English-learning children with reading difficulties in G4–9-year-olds; in English-learning children in G2, 7-year-olds; and in Dutch L1 and L2-learning children from kindergarten to G2, 5 to 7-year-olds), and could influence RC directly and/or indirectly through WR and/or LC.

According to the RSF model (Perfetti & Stafura, 2014), word knowledge, that is to say vocabulary knowledge, is essential to RC, and links WR processes to RC. WR appears to be an important source of differences in RC (Perfetti, 2007). Poor WR performance could lead to poor RC performance. Thus, vocabulary can influence RC, either indirectly via WR or directly. Kim (2017) performed an SEM and showed that LC (assessed using oral questions on narrative texts, multiple-choice questions and comprehension questions) mediated the relation between vocabulary (measured using a multiple-choice picture selection and object-picture identification tasks) and RC (measured using completion tasks and multiple-choice questions). Cho *et al.* (2019) examined the contribution of linguistic comprehension (vocabulary – multiple-choice picture paradigm, and LC – completion task) and WR (letter identification and a time-limited sight WR task) to RC (multiple-choice questions, a completion task, and a sentence veracity assessment task). The SEM analysis showed that the relation between vocabulary and RC varied depending on the group (English learners vs. non-English learners). Indeed, for the non-English learners, vocabulary had a direct effect on RC, whereas for English learners, it had an indirect effect on RC not only via WR but also via LC.

Word knowledge is essential for developing not only WR and RC, but also LC (Perfetti & Stafura, 2014). Vocabulary knowledge is not restricted to the oral or written modalities (e.g.,

Cho *et al.*, 2019). Thus, the early quality of children's mental lexicon influences their later LC and RC (Verhoeven *et al.*, 2019). The additional role of lexical quality (i.e., speech decoding, morphological knowledge, and vocabulary) in predicting RC has been investigated in children learning to read Dutch as L1 and in children learning to read Dutch as L2 from kindergarten (5-year-olds) to G2 (7-year-olds; Verhoeven *et al.*, 2019). The SEM analysis showed that WR (assessed with a time-limited read-aloud task) and LC (comprehension questions) predicted future RC (multiple-choice questions) for both types of learners. RC was also predicted by morphological and vocabulary knowledge, both directly and indirectly via LC. In other words, the authors found an indirect effect of vocabulary on RC via LC. LC and WR contribute directly to RC, while these components are predicted by many cognitive language skills (Cho *et al.*, 2019; Kim, 2017; Verhoeven *et al.*, 2019). Vocabulary knowledge appears to be a foundational skill necessary, but not sufficient, for LC and WR.

In summary, the contribution of vocabulary to RC in the SVR model is not clear, either when it is considered as a component of linguistic comprehension (with LC) or when it is thought of as a distinct factor included in the model. The relationship between the components of reading varies depending on school grade, language, type of learner reader and, most importantly, the way in which the components are measured. The results of studies are generally presented in terms of correct response scores on literacy skills measures (Cho *et al.*, 2019; Kim, 2017; Verhoeven *et al.*, 2019), or in terms of a time limit (e.g., Verhoeven *et al.*, 2019). Using a time limit would not be sufficient since participants might answer some of the items below the time limit and others above, and it would then be necessary to take this into account in the calculation of the index.

THE CURRENT STUDY

The aim was to examine the contribution of vocabulary to RC in the SVR model in a sample of French-speaking 7 to 10-year-old children and across primary grades (G2 to G5). Some studies have tried to clarify the role of vocabulary in the SVR model. However, this has only been done twice in French (in children in G1, Massonnié *et al.*, 2019; in French L2 learners from G1 to G2, Huo *et al.*, 2021). We investigated this issue in French-speaking children once more, using a new assessment design in order to measure two important reading outcomes, namely speed and accuracy. The ratio between them was thought to index the efficiency of the reading processes. Moreover, we used a written word identification test including the three levels of word representation (i.e., orthography, phonology, and semantics – see Perfetti, 2007; Ripoll Salceda *et al.*, 2014) and two measures of vocabulary depth knowledge.

To meet our objective, we had to answer two research questions. The first research question was: What contribution does vocabulary make to RC in 7 to 10-year-old French-speaking children? This question refers to the role of vocabulary in the SVR model: Is vocabulary an independent factor in this model or can we consider that it is an integral component of WR or LC? And if vocabulary is an independent component, does it influence RC directly or indirectly through WR and/or LC? To answer this question, a CFA was performed to test whether vocabulary loads

on the language comprehension component, the WR component or a separate factor. In addition, based on the factor structure determined by the CFA, an SEM analysis tested the relationship (e.g., direct or indirect) between the different components in RC. Based on the literature, we expected that WR would contribute more to RC for younger children, and LC would contribute more to RC for older children. Moreover, we expected that vocabulary would be an independent factor in the SVR model. The second research question referred to the possible change in the contribution made by vocabulary as a function of children's school grade level. Indeed, because WR becomes more automated and vocabulary increases with grade level, we expected the contribution of vocabulary to RC to increase in older children to the detriment of that of WR. In other words, we hypothesized that vocabulary makes a greater contribution in the SVR model for older children.

Participants

The reading skills¹ of children ($N = 243$) from urban primary schools in the East of France were evaluated using computer-based tasks. The grade samples were taken from Grade 2 (24 boys/27 girls; $M_{\text{age}} = 7;7$), Grade 3 (19 boys/32 girls; $M_{\text{age}} = 8;6$), Grade 4 (41 boys/38 girls; $M_{\text{age}} = 9;6$), and Grade 5 (28 boys/34 girls; $M_{\text{age}} = 10;4$). No children with specific problems were included in this study and none had repeated a school year. They were all French-speaking. The present study was undertaken with the agreement of the academic authorities and all the participants' parents were informed.

Material

The software program consisted of several tasks addressing three components of reading ability, namely WR, vocabulary and comprehension in the oral and written modes. The participants performed two trials before each WR and vocabulary task.

Word reading. Three tasks were administered in order to assess the orthographic, phonological and semantic levels of the lexical representations involved in WR.

With orthographic discrimination, the children had to decide whether or not two pairs of items were identical: 16 "yes" (e.g., *tente [tent]-tente*) and 16 "no" (e.g., *rubis [ruby]/rudis*). The items consisted of 16 pairs of identical words and 16 words paired with 16 visually similar pseudo-words. They varied in length and frequency. With phonological decoding the children had to decide whether two pseudo-words could be pronounced in the same way: 10 "yes" (e.g., *baccal/baquai*) and 10 "no" (e.g., *rozan/rossan*). The items consisted of 16 pairs of pseudo-words of varying length (one or two syllables). With semantic categorization the children had to decide whether or not two words were semantically related: 18 pairs were related ("yes" responses: *pomme – poire* [apple – pear]) and 18 pairs were not related ("no" responses: *pomme – salon* [apple – living room]). The items consisted of 36 pairs of two-syllable words varying in lexical frequency and strength of association based on their semantic relationships (i.e., high or low). As to the scoring for each of the word level tasks, two measures were recorded, namely the number of correct responses and the response time. We eliminated

aberrant response times by means of a two-step operation for each child. First, response times that were over two standard deviations from the mean were replaced by the mean response time's child for each child. Then, in a second step, a mean response time was re-calculated for each child. Finally, the speed-accuracy indicator (SAI)² was calculated as the ratio of mean response times to correct responses.

Vocabulary depth. For the task, the children had to answer *Yes-No* questions, in response to both oral and written presentations, about eight target words extracted from each text in the comprehension tasks (i.e., listening and reading). For each word, the sentences referred to properties of the target word (e.g., *cat*, "Does a cat bark?," "no" answer expected) or to the category of the target word (e.g., "Is a cat a feline?," "yes" answer expected). Three questions were asked for each of the eight target words: two on properties and one on category. Consequently, the children had to respond to 96 questions (8 words \times 3 questions \times 4 texts), namely 48 yes-questions and 48 no-questions. Scoring for the vocabulary task was performed in a similar way as in the WR tasks by calculating a SAI.

Reading and listening comprehension In the reading comprehension task, the children had to read to themselves two texts (A and B) presented one after the other on the computer screen. Each of the texts was then followed by 12 questions, which the participants also read silently to themselves. After reading the questions, the participants could also have another look at the text. In the listening comprehension task, the children had to listen successively to two other texts (C and D)³ read aloud by the software. Each of the texts was then followed by 12 questions read by the software. In the listening condition, the participants could also listen to the question and possible answers again.

For each text used in the tasks, four questions related to explicit textual (literal) information, four required the construction of a text-connecting inference via the solving of an anaphora and four required the production of a knowledge-based inference. The questions were forced choice and the proposed responses consisted of two distractors and only one correct answer (see Appendix A for an example). To respond, the children had to click on the response they thought was correct. The order of the questions was randomized. In the silent reading comprehension task, recording started once the children had clicked to display all the possible answers. In the listening comprehension task, recording of the response time started once the questions and possible answers had been read aloud by the software.

The same indicator as in WR and vocabulary was calculated, namely the SAI. It was based on the scores and reaction times for the two texts in each comprehension task.

Procedure

The evaluation session took place in small groups (8–12 children) in the computer room of the childrens' schools. Each child was seated in front of a computer and was equipped with headphones. The children were seated in such a way that they could not communicate with one other or see each other's screens. The evaluation session lasted approximately between 45 min and 1 h and included the three WR tests (presented in random order)

followed by the two comprehension tasks (listening and reading conditions were counterbalanced) and then, finally, the vocabulary task. Short pauses were inserted between the tasks.

Data analysis

First, the data were submitted to a confirmatory factor analysis (CFA) in order to extract the main factors enabling us to address the research question concerning vocabulary as a factor that is potentially distinct from LC when testing various CFA models. To ensure that the factor structure is the same between groups, we performed an invariance analysis comparing configural, metric and scalar models. Second, we performed a SEM analysis to look for the best model for testing the role of vocabulary in RC. We tested three hypothesized models to determine the best-fitting latent variable model. After identifying the best model, we used it to perform grade-specific analyses in order to test the differences between groups.

The CFA and SEM analyses were performed with Mplus 8.1 (Muthén & Muthén, 1998–2017). For each analysis, we examined the model fit indices. Several criteria have to be met. First, a χ^2 degree of freedom ratio of less than 3 is needed (Schreiber, Nora, Stage, Barlow & King, 2006). Second, values >0.90 for the Tucker–Lewis (TLI) and comparative fit indices (CFI) are expected (Schreiber *et al.*, 2006), and values lower than 0.08 for the root mean square error of approximation (RMSEA) and the standardized root mean square residual (SRMR) are advisable (Schreiber *et al.*, 2006). Finally, the smallest values of the Akaike information criterion (AIC) and Bayes information criterion (BIC) are recommended (Burnham, Anderson & Burnham, 2002).

RESULTS

Overall, seven outliers, which deviated by 1.5 SDs from the first or third quartiles for each task over the whole sample, were removed. The overall analysis was performed on a sample of 237 children. Then, to respond to the research questions and, in particular, to examine the potential change in the contribution of vocabulary with age, we constituted two groups, namely the younger children from Grades 2 and 3 ($n = 101$) and the older ones from Grades 4 and 5 ($n = 136$). We preferred the constitution of two groups instead of four groups for two main reasons: first, the number of participant per groups is too small if we considered four groups ($n = 50$ for G2 for instance); second, the educational French system divides the 5 years of elementary school in three (preparatory class corresponding to G1, elementary classes – *cours élémentaires* in French – corresponding to G2/G3, and medium classes – *cours moyens* in French – corresponding to G4/G5).

Descriptive statistics and comparison of means scores (SAI) between the groups of grades

Table 1 shows the means, standard deviations and reliability (KR-20) in all the tasks for the two groups of grades (i.e., Grades 2–3 vs. Grades 4–5). As expected, the older children (Grades 4–5) performed better than the younger ones (Grades 2–3) in all the tasks (see Table 1 Appendix B for correlation matrix of literacy variables by grades' group).

Table 1. Mean scores (standard deviation) on each task as a function of the groups of grades and comparison with student *t* tests

Reliability ^a		Younger grades 2–3 N = 101	Older grades 4–5 N = 136	<i>t</i> test
Word reading				
OD	0.88	0.24 (0.10)	0.35 (0.12)	−7.13***
PD	0.77	0.23 (0.11)	0.28 (0.11)	−3.31**
SC	0.83	0.24 (0.12)	0.32 (0.11)	−5.84***
Vocabulary ^b				
Cat	0.59	0.82 (0.39)	1.10 (0.51)	−4.7***
Prop	0.75	0.75 (0.34)	1.04 (0.44)	−5.37***
Reading comprehension				
Lit	Text A: 0.70 ^c	0.13 (0.07)	0.21 (0.11)	−6.86***
Tcl	Text B: 0.75	0.14 (0.08)	0.20 (0.10)	−5.54***
Kbl		0.13 (0.09)	0.19 (0.10)	−5.01***
Listening comprehension				
Lit	Text C: 0.84	0.59 (0.32)	0.79 (0.34)	−4.6***
Tcl	Text D: 0.78	0.57 (0.29)	0.74 (0.36)	−4.05***
Kbl		0.50 (0.27)	0.72 (0.38)	−4.83***

Notes: Except for the Vocabulary coefficients, the other coefficients were calculated on a larger scale ($N = 485$, in Auphan, Ecalle & Magnan, 2019). OD = Orthographic Discrimination; PD = Phonological Decoding; SC = Semantic Categorization; Cat = Category; Prop = Properties; Lit = Literal; Tcl = Text-Connecting Inference; Kbl = Knowledge-Based Inference.

^aThe reliability coefficients for word reading and reading and listening comprehension have already been presented in another paper (Auphan, Ecalle & Magnan, 2019).

^bReliability for all the 96 questions: 0.82.

^cReliability coefficient on the 12 questions for each text.

*** $P < 0.001$.

** $P < 0.01$.

How many factors contribute to reading ability?

We expected a four-factor structure model. We used a model comparison analysis and model fit indices to compare the four expected dimensions (M1) to alternative structures (see Table 2). The alternative structures corresponded to: (1) three factors with WR with vocabulary included (M2 in Table 2); (2) three factors with LC with vocabulary included (M3 in Table 2); and (3) four factors with vocabulary with the semantic categorization of WR included (M4 in Table 2). The results of the CFA showed that WR, vocabulary, LC and RC loaded on four distinct factors (see Fig. 1). This model outperformed the alternative models (see Table 2). The results of this analysis suggest that vocabulary was a distinct factor. Invariance analysis revealed that metric and scalar models did not significantly differ from configural model (metric against configural models $\Delta\chi^2 = 6.02$, $P = 0.54$; scalar against configural $\Delta\chi^2 = 20.46$, $p = 0.12$), and scalar model

significantly differ from metric model ($\Delta\chi^2 = 15.49$, $p = 0.030$). These results suggest that the factor structure was the same as a function of groups, and that there is no need to constrain the intercepts to be identical according to the groups.

What is the role of vocabulary in reading ability?

The aim of this part of the Results section is to investigate which model – including WR, vocabulary and LC – can best explain RC for the overall sample. Three SEM models, with maximum likelihood robust estimator, were tested to determine how well the three latent constructs predicted RC, while attributing different roles to vocabulary.

First, we tested the direct effect of WR, LC, and vocabulary on RC (Model A). In this model, we forced the covariations between vocabulary and WR, between vocabulary and LC to be equal to 0. Second, we tested the mediating role of vocabulary on RC (Model B). Finally, we tested the direct and indirect effect, via WR and LC, of vocabulary on RC (Model C). As in our CFA analysis, we used model comparison analysis and model fit indices to determine the best model (see Table 3).

Model C showed good fit indices and differ significantly from Model A ($\Delta\chi^2 [1] = 33.89$, $p < 0.001$). The model involving the mediating role of vocabulary (Model B) and the Model A testing direct effects of LC, WR and vocabulary exhibited a lower fit and the SRMR was too high (SRMR = 0.101; 0.147). We did not retain those models.

Model C revealed an indirect effect of vocabulary on RC via LC ($\beta = 0.057$, SE = 0.024, $p = 0.02$) and WR ($\beta = 0.23$, SE = 0.072, $P = 0.001$). Model C suggested that WR and LC would be underpinned by the vocabulary (Fig. 2).

What is the role of vocabulary as a function of reading level?

The aim of this analysis was to test the developmental hypothesis of the role of vocabulary in the two groups (see Fig. 3). We tested Model C.⁴ The fit indices of Model C were acceptable, $\chi^2(92) = 147.493$, $P = 0.0002$; CFI = 0.948; TLI = 0.938; RMSEA = 0.071 [CI 0.049–0.092]; SRMR = 0.065; AIC = −2589.176; BIC = −2374.156. The main differences between the results for the overall sample and as function of group can be summarized as follows. First, in the younger group (Fig. 3a), no direct effect of vocabulary on LC was found ($\beta = 0.015$, SE = 0.115, $p = 0.89$), unlike in the case of the older group (Fig. 3b; $\beta = 0.366$, SE = 0.086, $p < 0.001$). Second, for the older group, no direct effect of LC on RC was found ($\beta = 0.109$, SE = 0.111, $P = 0.324$), unlike in the case of the

Table 2. Fitting statistics of models and alternative models from the confirmatory factor analysis (CFA)

CFA	χ^2	df	CFI	TLI	RMSEA (90% CI)	SRMR	AIC	BIC	$\Delta\chi^2$	≠Model	Δ CFI	Δ TLI
M (1)	49.22	38	0.998	.985	0.035 (0.000–0.061)	0.034	−2481.281	−2346.026	–	–	–	–
M (2)	194.095***	41	0.863	0.816	0.126 (0.108–0.144)	0.112	−2309.610	−2184.759	$\chi^2(3) = 117.28$ ***	1 vs. 2	−0.135	−0.169
M (3)	174.536***	41	0.880	0.840	0.117 (0.100–0.135)	0.103	−2336.648	−2211.797	$\chi^2(3) = 119.73$ ***	1 vs. 3	−0.118	−0.145
M (4)	134.113***	38	0.914	0.875	0.103 (0.085–0.123)	0.093	−2378.543	−2243.289	$\chi^2(0) = 0^a$	1 vs. 4	−0.123	−0.75

Notes: M = Model; $\Delta\chi^2$ = Satorra–Bentler chi square; Δ CFI = Difference Between CFI models; Δ TLI = Difference Between TLI models.

^adf = 0.

*** $P < 0.001$.

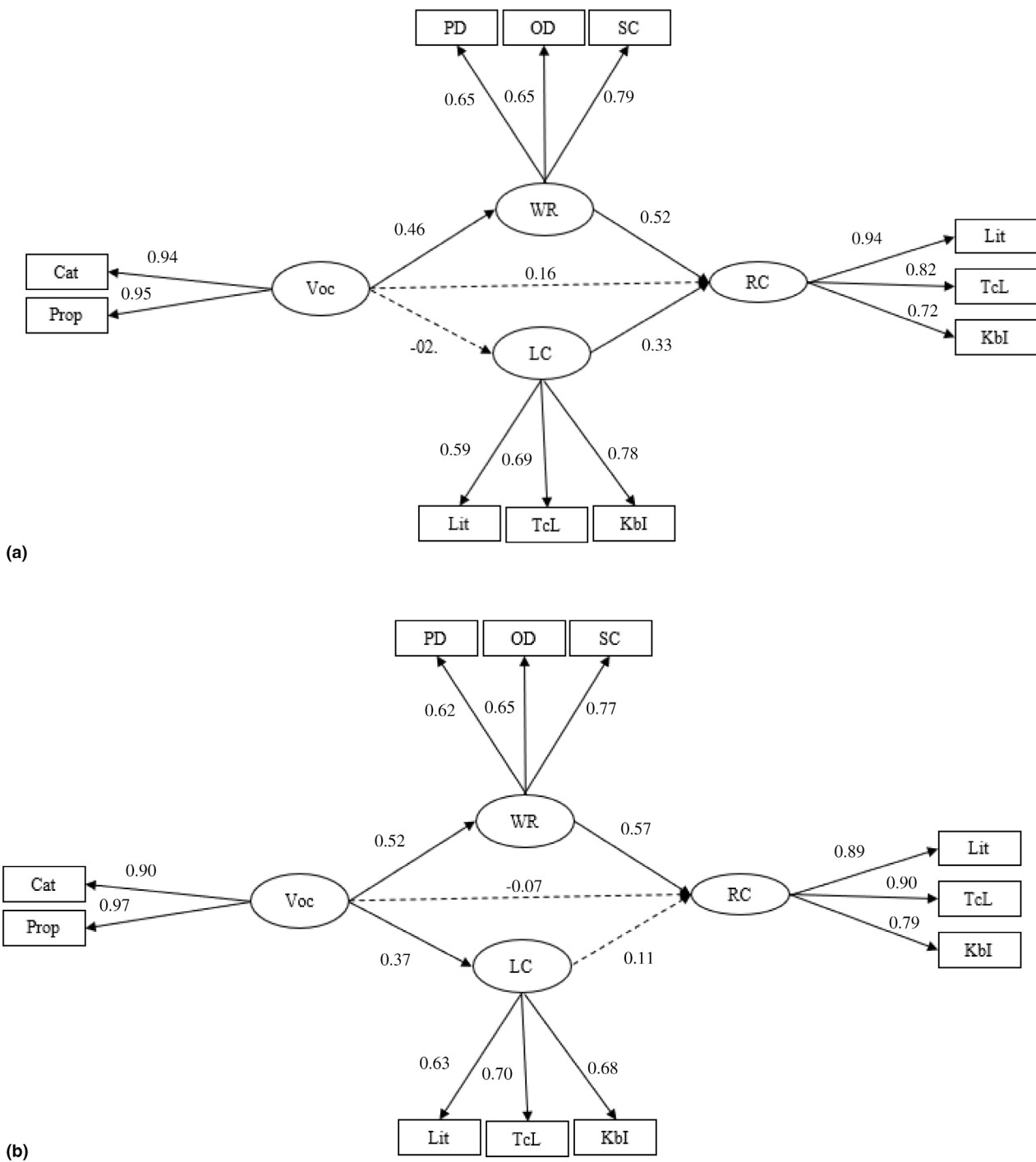


Fig 1. Structural equation model with word reading and listening comprehension playing a mediating role between vocabulary and reading comprehension (a) for the group of Grades 2–3 ($n = 101$) and (b) for the group of Grades 4–5 ($n = 136$).

Table 3. Fitting statistics of models and alternative models from structural equation modeling analysis

Models	χ^2	df	CFI	TLI	RMSEA (90% CI)	SRMR	AIC	BIC	$\Delta\chi^2$	\neq Model	Δ CFI	Δ TLI
M (A)	112.628*	40	0.935	0.911	0.088 (0.069–0.107)	0.147	-2413.231	-2284.913	-	-	-	-
M (B)	93.157***	41	0.952	0.935	0.075 (0.055–0.095)	0.101	-2430.844	-2302.525	$\chi^2 (1) = 0.51$	1 vs. 2	0.017	0.024
M (C)	52.803†	39	0.988	0.983	0.039 (0.000–0.063)	0.042	-2479.512	-2347.726	$\chi^2 (1) = 33.89***$	1 vs. 3	0.053	0.072

Notes: $\Delta\chi^2$ = Satorri–Bentler chi square; Δ CFI = Difference Between CFI Models; Δ TLI = Difference Between TLI Models.

† $P < 0.10$.

*** $P < 0.001$.

* $P < 0.05$.

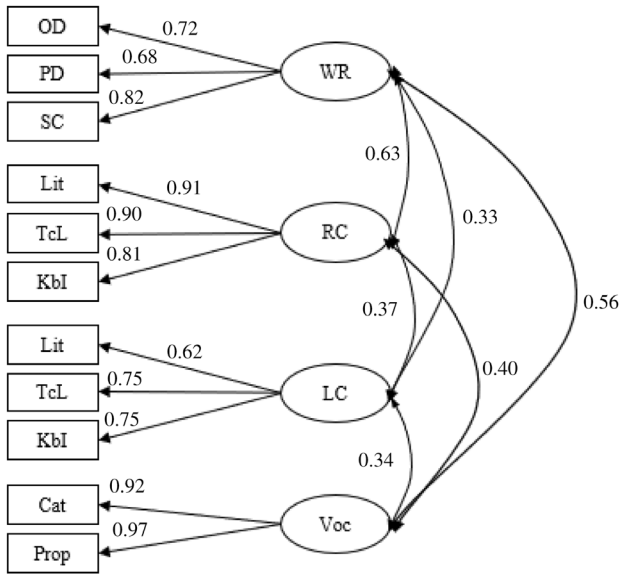


Fig 2. Confirmatory factor analysis for latent constructs of word reading, reading comprehension, listening comprehension and vocabulary.

younger group ($\beta = 0.329, SE = 0.101, p = 0.001$). An indirect effect of vocabulary, via WR, on RC was observed for both the younger group ($\beta = 0.242, SE = 0.078, p = 0.002$) and the older group ($\beta = 0.296, SE = 0.095, p = 0.002$). Finally, no indirect effect of vocabulary via LC on RC was found for either group (younger group, $\beta = -0.005, SE = 0.038, p = 0.897$; older group, $\beta = 0.04, SE = 0.042, p = 0.345$).

DISCUSSION

Using the SVR model as a framework, we examined the contribution of vocabulary to RC in 7-10-year-old children from Grades 2 to 5 using an index of efficiency combining speed and accuracy. According to the SVR model (Gough & Tunmer, 1986; Hoover & Gough, 1990), RC involves two components: WR and linguistic comprehension. Recently, the SVR model has been complemented through the addition of vocabulary-related components (Tunmer & Chapman, 2012). A body of research has

attempted to define and specify the role of vocabulary in this model (e.g., Cho et al., 2019; Kim, 2017; Protopapas et al., 2012, 2013; Verhoeven et al., 2019). Based on these studies, we tested the contribution of vocabulary depth to RC in the SVR model and the differences in the contribution of vocabulary as a function of children’s school grade level. In the higher grades, we expected vocabulary to make a greater contribution to RC than WR. The main results of this study can be summarized as follows. Vocabulary is a factor that is distinct from WR, LC and RC. Furthermore, vocabulary depth appears to underpin WR and LC directly, and RC indirectly, and the extent to which it does so differs according to children’s school grade levels.

What is the contribution of vocabulary depth to reading comprehension in 7 to 10-year-old children?

First, we used a CFA analysis to test the factorial structures of the different components (i.e., vocabulary, LC, WR, and RC). Contrary to Massonnié et al. (2019), who concluded that vocabulary and LC are two dimensions of oral reading comprehension because of the strong correlation between them, our results revealed that vocabulary was a factor separate from WR, LC and RC, with a much weaker correlation between LC and vocabulary. This would most likely come from the way vocabulary was measured (PPVT for Massonnié et al., 2019; a yes-no question task on properties and categories for our study). Thus, our results support the idea that these components are four distinct factors. This finding is consistent with previous studies in English and non-English learners (Cho et al., 2019), as well as in English speakers in Grade 2 (Kim, 2017), and Dutch L1 and L2 learners (Verhoeven et al., 2019). Vocabulary is therefore a theoretically and statistically different concept from WR, LC and RC. Vocabulary is a complex concept implying several dimensions. Measure vocabulary is therefore complex. In our study, we have measured vocabulary by asking questions about word properties and word semantic category with questions involving a yes-no response (i.e., is the cat a feline?). These two tasks require precise knowledge, referring to the depth of vocabulary (see Ouellette & Shaw, 2014). Based on the framework of the lexical quality hypothesis (Perfetti, 2007), we

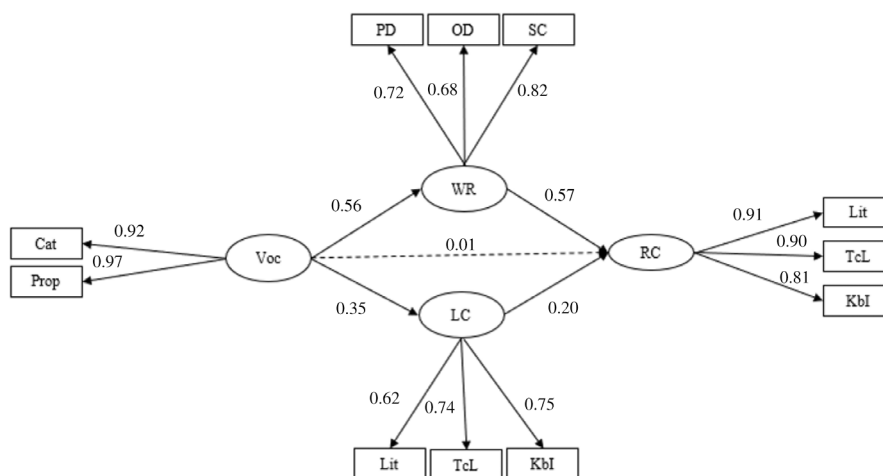


Fig 3. Structural equation model with word reading and listening comprehension playing a mediating role between vocabulary and reading comprehension for the overall sample ($N = 237$).

proposed measures of orthography, phonology and semantics. The semantic aspects have been measured using a semantic categorization task (i.e., are the two words part of the same semantic field? *apple/pear*) is a task requiring less precise knowledge, we do not ask for the child to know the semantic field. In addition, in order to test whether the semantic categorization could have been part of the vocabulary, we compared different factorial structures (see Results section): one in which the semantic categorization would be loaded into the “word reading” factor, the other in the “Vocabulary” factor. The results suggest that semantic categorization is part of word reading (see also Cho *et al.*, 2019). Our result seems consistent with earlier findings since vocabulary is a strong independent predictor of the latter concepts (e.g., Ouellette, 2006; Ouellette & Beers, 2010).

Second, SEM analyses showed that WR made a greater contribution to RC than LC (0.57 vs. 0.20). This result is consistent with previous studies (see Huo *et al.*, 2021; Massonnié *et al.*, 2019 with a measure of WR fluency; but see Megherbi *et al.*, 2006 with a measure of WR without taking time account). In our study, we used an index of efficiency that takes account time and three levels of word representation. According to the Lexical Quality Hypothesis (Perfetti, 2007), three levels of word representation would be needed to identify words and determine lexical quality: orthography, phonology, and semantics. Richter *et al.* (2013) examined the extent to which lexical quality might influence text comprehension in German children in Grades 1 to 4. They showed that text comprehension skills were explained by both speed and accuracy. In our study, WR was measured using these three levels of word representations, and we calculated an index of efficiency that combined speed and accuracy. High lexical quality (i.e., high level of precision and quick access to different levels of word representation) implies better RC than low lexical quality (i.e., low level of precision and slow access to different levels of word representation). Our results thus support the idea that WR is a more important contributor to RC than LC for French learners.

Finally, we examined the role of vocabulary by testing different paths models. SEM analyses revealed that vocabulary had an indirect effect on RC via LC and WR in 7 to 10-year-old French-speaking children (see also Cho *et al.*, 2019 for the effect in English learners). This result is consistent with previous recent studies which have shown that vocabulary indirectly influences RC in all aspects of oral language (Cho *et al.*, 2019; Kim, 2017; Verhoeven *et al.*, 2019) and WR (Cho *et al.*, 2019). Ouellette (2006) showed that different dimensions of vocabulary (i.e., receptive and expressive, breadth and depth of vocabulary) are related to reading skills (i.e., WR, decoding, RC). The increase in vocabulary knowledge would require children to develop both efficient WR and LC processes (e.g., Ouellette, 2006). Indeed, the more precisely children know words, the better their performance in WR and LC. Moreover, the contribution of vocabulary to WR was higher than that of LC (0.56 vs. 0.35), with no direct effect of vocabulary on RC. These results suggest that the effect of vocabulary is fully mediated by WR and LC. The direct effect of vocabulary on RC is found when other skills are controlled, that is, WR related skills (e.g., Ouellette, 2006; Ouellette and Beers, 2010). Furthermore, the fact that we found an indirect effect of vocabulary via LC and WR

could be explained in part by the fact that the vocabulary task was presented in two modalities (oral and written). Our task therefore involved both written and oral processing mechanisms. The advantage of this dual mode of presentation is that we can measure the level of children’s vocabulary, regardless of any difficulties they may have in WR and LC.

Furthermore, Braze *et al.* (2016) showed that vocabulary breadth (measured using a multiple-choice picture paradigm) has an effect on RC, whether measured using multiple-choice questions, sentence completion, or the selection of pictures that match a sentence. In contrast, vocabulary depth only affects RC as measured by multiple-choice questions. Finally, it should be noted that in studies showing an indirect effect of vocabulary on RC via WR and LC, vocabulary was only measured using a multiple-choice picture paradigm (Cho *et al.*, 2019; Kim, 2017). Studies that have concluded that vocabulary is related to RC have measured vocabulary depth and breadth without differentiating between them in the analyses. To determine the role of vocabulary, it is necessary to know how to measure it, and, in particular, to identify the dimension the researcher wishes to study. Indeed, the same response processes are not involved depending on whether vocabulary is measured using a multiple-choice picture paradigm, open-ended questions, or multiple-choice questions that examine the dimensions of depth (definition) or breadth (word knowledge). It is certainly more difficult to give a definition than it is to say whether the word matches a picture. It would therefore seem to be necessary to decide whether vocabulary is considered to be general knowledge related to the world, or specific knowledge related to a text, for example.

What is the contribution of vocabulary depth as a function of children’s school grade level?

With school grade level, vocabulary knowledge increases, isolated WR becomes more automated, and oral comprehension improves. We could therefore assume that the contribution of vocabulary differs according to reading levels, or more precisely according to grade. We tested the role of vocabulary according to grade level. The SEM analysis revealed that WR was more strongly related to RC than LC in both groups (younger and older). This supports previous results in French-speaking children (Massonnié *et al.*, 2019; see also Huo *et al.*, 2021 in L2 French learners), in English and non-English learners (Cho *et al.*, 2019), and in English-speakers in Grade 2 (Kim, 2017). As claimed by the Lexical Quality Hypothesis (Perfetti, 2007), WR appears to be an important source of differences in RC. WR therefore remains an important factor to be taken into account in order to identify children’s comprehension difficulties (see Nation, 2019).

In both groups, we also found an indirect effect of vocabulary on RC via WR, but not via LC, thus confirming that WR is essential for RC (e.g., Cho *et al.*, 2019; Perfetti, 2007). We did not find the expected greater direct effect of vocabulary than WR on RC for older children. This present finding confirms those of previous studies, showing that vocabulary appears to be a skill that is related to RC through the mediating factor of WR (e.g., Cho *et al.*, 2019; Kim, 2017; see also Ouellette & Beers, 2010 for similar results with WR controlled for). In our study, we measured the three components of lexical quality (i.e., phonology, orthography, and semantics; see

Perfetti, 2007) involved in WR: The stronger the link between these components, the more efficient WR is. A large amount of vocabulary knowledge would require high lexical quality in order to retrieve word forms and meanings. Furthermore, the absence of an indirect effect of vocabulary on RC via LC for both groups did not reduce the importance of LC in the SVR model. Without wishing to contradict the literature claiming that vocabulary has an influence on RC, we propose more of a measurement-oriented interpretation. Indeed, vocabulary is measured based on words extracted from the texts for comprehension, which are themselves presented in the oral modality in the case of LC and the written modality for RC. Indeed, this result could be explained by the nature of the vocabulary task. This task was designed using words extracted from LC and RC texts, and was presented in the oral and written modalities. Thus, unlike in the WR tasks, the items in the vocabulary tasks were presented in the texts, thus making it possible to ensure that the children either did or did not have prior knowledge of the presented texts. It might be of value to add another vocabulary test, which is not linked to the comprehension tasks, in order to test this hypothesis.

Finally, the lack of a link between LC and RC in the older group is surprising. According to the developmental hypothesis, in the early stages of learning to read, WR is the component that most fully explains RC. Once word identification processes are more automated, the child becomes a more established reader. Oral comprehension would therefore become the component that explains RC performance in older children (e.g., Nation, 2019). While we found the expected effects in the youngest children (G2-3), we did not demonstrate the direct effect of LC on RC in the older children, and we therefore did not demonstrate the indirect effect of vocabulary on RC via LC. We can assume that the parallel oral/written measure, coupled with a vocabulary test on words in the text, may have masked, or diminished, the potential effects. It therefore seems essential to present non-parallel texts for comprehension in order to measure LC and RC, as well as vocabulary tests that are not text-based. Furthermore, if we focus on measures of LC and RC, different types of questions are used: multiple-choice questions (Braze *et al.*, 2016; Cho *et al.*, 2019; Kim, 2017; Protopapas *et al.*, 2013; Tunmer & Chapman, 2012; Verhoeven *et al.*, 2019), gap-filling questions (Braze *et al.*, 2016; Cho *et al.*, 2019; Kim, 2017; Tunmer & Chapman, 2012), open-ended questions (Kim, 2017; Tunmer & Chapman, 2012), veracity questions involving a yes/no answer (Cho *et al.*, 2019). Finally, some studies have increased the number of LC measures in order to better understand and operationalize this component, and more specifically in English (Braze *et al.*, 2016; Cho *et al.*, 2019; Kim, 2017; Tunmer & Chapman, 2012). Thus, even if French is a more transparent language than English, a larger number of comprehension measures should be used in future studies.

Limitations

We have identified several limitations to the present study. First, the present study used a cross-sectional design with children in Grades 2 to 5. The role of vocabulary in the SVR model as a function of children's grades could be examined more thoroughly in a larger sample of children from Grades 2 to 5. Furthermore, studies with a longitudinal design would be needed in order to test the hypothesis that vocabulary predicts WR and LC. The third

limitation concerns the measurement of vocabulary. The vocabulary test in our study measured the depth of vocabulary (i.e., the meaning of words) with one new test, which had a low reliability coefficient (0.59). A new version of our test would be tested. It would be also interesting to add a measure of vocabulary breadth (i.e., the number of known words). Indeed, Ouellette (2006) pointed out that these different dimensions of vocabulary would have effects on WR (i.e., breadth) and on RC (i.e., depth). A further study should integrate breadth vocabulary as well as depth vocabulary (e.g., with a new version of our test and a standardized depth vocabulary measure). Finally, we did not have socio-demographic information about the sample. In the context of the Component Model of Reading (Aaron, Joshi, Gooden & Bentum, 2008), in addition to the cognitive domains (i.e., WR, comprehension), both ecological (e.g., familial and academic environments) and psychological domains (e.g., motivation, interest) are thought to be involved in the explanation of reading performance. Further research involving these different domains would be needed to better apprehend the success of RC.

CONCLUSION AND IMPLICATIONS

We found that the contribution of WR remains an important factor in RC (see also Nation, 2019 in children with language difficulties). In the RSF (Perfetti & Stafura, 2014) and SVR models, WR plays a central role in RC. The measure of WR, including three components of word representation from the Lexical Quality Hypothesis (Perfetti, 2007; i.e., orthography, phonology, and semantics) should be systematically measured. Moreover, without contradicting the SVR model including vocabulary (Tunmer & Chapman, 2012), the RSF reports the pivotal role of vocabulary (i.e., "meaning" as it is reported in the Lexicon module), which is attributed an independent status. Our findings support this idea. We thus extend previous research (e.g., Cho *et al.*, 2019; Kim, 2017) by indicating that vocabulary should be considered as a separate factor in the context of the SVR model in French. The role of vocabulary in the SVR model should be examined as a separate factor. Moreover, by including a distinction between depth and breadth of vocabulary, we should be able to better understand its contribution to RC. Finally, although the SVR model is simple, it can guide the classification of reading profiles (see Nation, 2019). It is clear that the SVR model remains a good framework for explaining RC. Despite this, all the results of this and other studies suggest that vocabulary needs to be integrated and evaluated if we are to gain a better understanding of reading ability.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ENDNOTES

¹The data retained for this experiment in primary grades children have been extracted from a larger sample. The word reading and the two comprehension tasks are presented briefly here (for more details, see Auphan, Ecalle & Magnan, 2019).

$$^2\text{SAI} = \left(\frac{\text{Correct answers}}{\text{Total answers}} \times \frac{1}{\text{Mean response time}} \right) \times 1000$$

³The frequencies of the words in each text were controlled with the French MANULEX database (Lété, Sprenger-Charolles & Colé, 2004). Texts A and C, on the one hand, and B and D, on the other, were matched for difficulty using the Automated Reading Index and Gunning Fog Index (Mailloux, Johnson, Fisher & Pettibone, 1995), which takes account of the length of words and sentences.

⁴We added the direct effect of vocabulary on reading comprehension to determine the influence of grades. No direct effect was found for either group of grades.

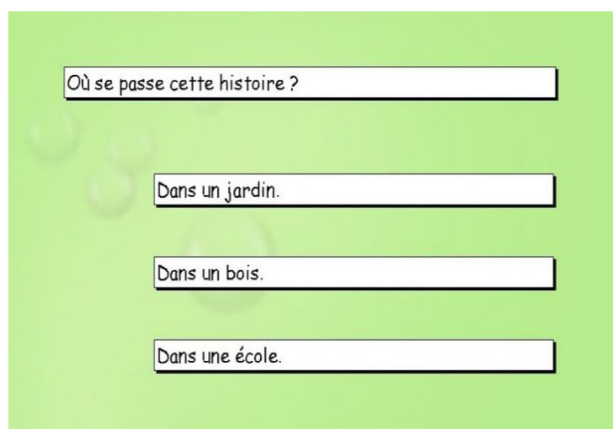
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APPENDIX A

Screenshot of a question (requiring a knowledge-based inference) in reading comprehension



Where is this story?
In a garden.
In a wood. In a school.

APPENDIX B

Correlation matrix for literacy variables by grades' groups

Variable	1	2	3	4	5	6	7	8	9	10	11
1. OD	—	0.577***	0.523***	0.442***	0.284**	0.364***	-0.063	0.010	0.059	0.323***	0.250*
2. PD	0.478***	—	0.596***	0.317***	0.107	0.147	0.078	0.044	-0.078	0.368***	0.289**
3. SC	0.490***	0.447***	—	0.557***	0.387***	0.455***	0.140	0.135	0.011	0.388***	0.348***
4. RC_Lit	0.258**	0.303***	0.391***	—	0.768***	0.694***	0.375***	0.258**	0.120	0.362***	0.357***
5. RC_Tel	0.197*	0.349***	0.453***	0.809***	—	0.752***	0.271**	0.212*	0.084	0.252*	0.278**
6. RC_Kbl	0.200*	0.282***	0.429***	0.689***	0.696***	—	0.200*	0.109	-0.051	0.262**	0.279**
7. LC_Lit	0.017	0.094	-0.008	0.121	0.115	-0.009	—	0.495***	0.406***	-0.125	-0.056
8. LC_Tel	0.174*	0.246**	0.086	0.181*	0.155	0.123	0.438***	—	0.546***	0.015	0.026
9. LC_Kbl	0.143	0.174*	0.079	0.118	0.100	0.077	0.343***	0.533***	—	-0.014	0.052
10. Cat	0.221**	0.362***	0.323***	0.221**	0.249**	0.281***	0.251**	0.183*	0.257**	—	0.891***
11. Prop	0.290***	0.368***	0.387***	0.208*	0.227**	0.222**	0.253**	0.198*	0.263**	0.870***	—

Note: The results for the G2-G3 group (n = 101) are shown above the diagonal. The results for the G4-G5 group (n = 136) are shown below the diagonal. RC = Reading Comprehension, LC = Listening Comprehension, OD = Orthographic Discrimination; PD = Phonological Decoding; SC = Semantic Categorization; Cat = Category; Prop = Properties; Lit = Literal; Tel = Text-Connecting Inference; Kbl = Knowledge-Based Inference.

*P < 0.05.

**P < 0.01.

***P < 0.001.