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Decoding and Reading Comprehension: A Meta-Analysis to Identify Which Reader and Assessment Characteristics Influence the Strength of the Relationship in English

J. Ricardo García
University of Salamanca

Kate Cain
Lancaster University

The twofold purpose of this meta-analysis was to determine the relative importance of decoding skills to reading comprehension in reading development and to identify which reader characteristics and reading assessment characteristics contribute to differences in the decoding and reading comprehension correlation. A meta-analysis of 110 studies found a sizeable average corrected correlation ($\bar{r}_c$ = .74). Two reader characteristics (age and listening comprehension level) were significant moderators of the relationship. Several assessment characteristics were significant moderators, particularly for young readers: the way that decoding was measured and, with respect to the reading comprehension assessment, text genre; whether or not help was provided with decoding; and whether or not the texts were read aloud. Age and measure of decoding were the strongest moderators. We discuss the implications of these findings for assessment and the diagnosis of reading difficulties.

Keywords: decoding, reading comprehension, reading development, reading skill, word recognition.

Reading comprehension and its development are highly dependent on a reader's ability to read written words accurately and fluently. The general consensus is that the automaticity of word reading is directly related to the cognitive resources that can be devoted to the processes involved in constructing meaning from text (e.g., Frederiksen & Warren, 1987; Jenkins, Fuchs, van den Broek, Espin, & Deno, 2003; Just & Carpenter, 1987; Perfetti, 1985; Walczyk, 2000). For that reason, many researchers regard word reading as the only skill—other than listening comprehension—required to understand written text, a view encapsulated in the simple view of reading (SVR; Gough, Hoover, & Peterson, 1996; Gough & Tunmer, 1986; Hoover & Gough, 1990).

According to the SVR framework, reading comprehension is the product of a reader's decoding (or word reading) skill and linguistic (or listening) comprehension (Gough & Tunmer, 1986; Hoover & Gough, 1990). In this article, we use the term *decoding* to refer to word reading generally, in the spirit of Hoover and Gough (1990). The SVR has guided the identification and study of different types of poor readers (readers with specific reading and listening comprehension difficulties) and has influenced the development of the reading curriculum in the United Kingdom (e.g., Stuart, Stainthorp, & Snowling, 2008) as well as investigations into the genetic basis of reading ability (Keenan, Betjemann, Wadsworth, DeFries, & Olson, 2006). For these reasons, it is essential that we understand better the factors that might influence the decoding–reading comprehension relationship that lies at the core of the SVR.

Despite the widely held view of the strong relationship between decoding and reading comprehension skill, substantial differences have been found in the percentage of variance in reading comprehension accounted for by different measures of decoding (Cutting & Scarborough, 2006; Keenan, Betjemann, & Olson, 2008). Although some researchers find that the contribution of decoding to reading comprehension is negligible, with R^2 values in the region of .0001 or .0005 (e.g., Berninger, Abbott, Vermeulen, & Fulton, 2006), other research suggests that decoding skill more or less fully predicts reading comprehension performance, with R^2 values in the region of .90 (e.g., Katzir et al., 2006).

Clearly, it is important to understand better the degree to which decoding skills account for reading comprehension performance and the factors that influence this relation. In the meta-analysis presented in this article, we explore two broad factors that might influence the strength of the association between the ability to decode words and the ability to understand written text: characteristics of readers and characteristics of assessments (of both word reading and reading comprehension).

Reader Characteristics

One hypothesis is that reading comprehension will be more greatly constrained by word reading ability in younger readers than in older ones. Gough et al. (1996) reached this conclusion in their review of 10 studies that reported correlations among word reading, listening comprehension, and reading comprehension. In total, these studies reported 17 correlations between word reading and reading comprehension with values ranging from $r = .18$ ($R^2 = .03$) to $r = .83$ ($R^2 = .69$); correlations decreased with increasing age of participants from Grade 1 to college students (see also Curtis, 1980; Francis, Fletcher, Catts, & Tomblin, 2004; Jenkins & Jewell, 1993; Vellutino, Tunmer, Jaccard, & Chen, 2007). Keenan et al. (2008) have also shown that decoding makes a larger contribution to reading comprehension for younger than for older readers. However, there are also studies in which, despite a wide age range and, therefore, range of reading level, age does not influence the relative contribution of decoding to reading comprehension (e.g., Cutting & Scarborough, 2006).

Longitudinal studies can shed light on the change in the relationship between decoding and reading comprehension. However, longitudinal studies to date provide a mixed picture: some show a very clear attenuation of the relationship between decoding and reading comprehension from the first to the last time point of evaluation (e.g., Abbott, Berninger, & Fayol, 2010; Burgoyne, Whiteley, & Hutchinson, 2011; Deacon & Kirby, 2004; Juel, 1988; Kim, Wagner, & Foster, 2011; Kim, Wagner, & Lopez, 2012), whereas in others, the correlations at the first and last time points are similar in magnitude (e.g., Cain & Oakhill, 2011; Cain, Oakhill, & Bryant, 2004; Compton, Fuchs, Fuchs, Elleman, & Gilbert, 2008; Manis, Seidenberg, & Doi, 1999; Oakhill, Cain, & Bryant, 2003; Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997; Wood, 2009). A critical contributory factor will obviously be the age range that is included. Other factors may be other reader and assessment characteristics that we explore in this meta-analysis.

Although age is a theoretically plausible mediator for the strength of the association between word reading and reading comprehension, it does not appear to account fully for the variability found in correlations between the two variables. Substantial differences in the magnitude of variance in reading comprehension explained by word reading arise when comparing same-age samples: $R^2 = .49$ (Blackmore & Pratt, 1997) versus $R^2 = .79$ (Rupley & Willson, 1997) in 6-year-olds; $R^2 = .13$ (Manis et al., 1999) versus $R^2 = .92$ (Katzir et al., 2006) in 7-year-olds; or $R^2 = .05$ (Cain et al., 2004; Oakhill et al., 2003) versus $R^2 = .80$ (Deacon & Kirby, 2004) in 8-year-olds. Thus, age may not be the only reader-related variable influencing the strength of the relationship between these two skills.

A second reader-related factor that might influence the strength of the relation between word reading and reading comprehension is the level of readers' word reading skill or decoding competence. If word reading ability determines reading comprehension level, we would predict that the two would share a stronger relationship in groups of poor word readers than in more competent readers. Several studies show this pattern (Ashbaker & Swanson, 1996; Curtis, 1980; Keenan et al., 2008; Swanson & Berninger, 1995), and indeed, in the Oakhill et al. (2003) study cited above, very poor word readers were excluded from the sample. These studies suggest that, in line with current theory, word decoding ability is an important determinant of reading comprehension level.

Other reader characteristics that might influence the relation are levels of listening comprehension and vocabulary knowledge. According to the SVR, reading comprehension is the product of two components: decoding and language (listening) comprehension (Gough & Tunmer, 1986; Hoover & Gough, 1990). Thus, a reader with exceptionally good levels of language comprehension might be able to compensate for poor word reading skills, at least to a limited extent. Indeed, not all children with developmental dyslexia have poor reading comprehension (Parrila, Georgiou, & Corkett, 2007). Conversely, readers with poor listening comprehension skills are likely to have poor reading comprehension (Cain, Oakhill, & Bryant, 2000; Stothard & Hulme, 1992).

Vocabulary knowledge is not only a strong correlate of discourse-level reading comprehension (Carroll, 1993) but also will support decoding (Protopapas, Mouzaki, Sideridis, Kotsolakou, & Simos, 2013; Tunmer & Chapman, 2012), influencing the relationship between our target variables. The relative importance of such knowledge may differ for different types of reader or age groups. In fact, not all poor comprehenders have weak vocabulary skills (Cain et al., 2004; Stothard & Hulme, 1992). In our analysis, we examined the effects of these variables in addition to both age and reader status. However, only a small number of the studies that met our inclusion criteria included measures of listening comprehension or vocabulary knowledge.

Characteristics of Reading Assessments: Decoding and Reading Comprehension

A second group of factors that might influence the strength of the decoding–reading comprehension relationship concerns the methods used to assess each component. Hoover and Gough (1990) defined the decoding component of the SVR as efficient word recognition, but suggested that an adequate measure for younger readers would be the ability to pronounce pseudowords. However, there is evidence that the type of material used to assess decoding may influence its relation with reading comprehension. Nation and Snowling (1997) found that three decoding measures (pseudoword reading, isolated word reading, or text reading) were differently related to reading comprehension with the weakest relationship found for pseudoword reading. These authors argued that the differences in the magnitude of the correlations may be related to the potential for semantic knowledge to influence performance on these decoding measures: Pseudoword reading cannot be informed by semantic knowledge, whereas the reading of isolated words and words in text, in particular, will be enhanced by the semantic knowledge of the reader through their ability to use contextual cues to aid decoding of an unfamiliar word.

The method used to assess reading comprehension may also affect the strength of its correlation with word reading (Francis et al., 2004). We considered three groups of aspects of the reading comprehension assessment: genre and format of the material, task and nature of information assessed, and administration procedures.

Genre and Format of the Reading Comprehension Material

There have been few comparisons of reading skills for different text genres (narrative vs. expository), in which the method of assessment is the same in both. Results of a study that did use the same methods of assessment for different genres (i.e., Best, Floyd, & McNamara, 2008) suggested that comprehension of a narrative text was more greatly influenced by decoding skills (R^2 between .39 and .42) than comprehension of an expository text (R^2 between .04 and .23) for third-grade readers. For expository text, word knowledge was a far better predictor of reading comprehension than decoding skill.

In addition to genre, format (i.e., single sentences or passages/paragraphs) can affect the decoding and reading comprehension relationship. Nation and Snowling (1997) found that the different decoding measures explained different amounts of variance in reading comprehension depending on the test used, with stronger relations evident when the comprehension measure had a sentence cloze format compared with one that involved passage reading and open-ended questions. This pattern is supported by other work (Andreassen & Bråten, 2010). One factor that may underlie these differences is the extent to which decoding errors influence performance on an individual comprehension item. In a sentence cloze task, accurate decoding of the words in the sentence and the completion choices is essential to respond correctly. In contrast, the relation between word reading and reading comprehension may be weaker for tasks that involve passage reading, in which inaccurate decoding of some words will not necessarily be detrimental to performance on the comprehension questions (unless these words are crucial to the passage meaning or question). Indeed, even if a critical word in a passage is not accurately decoded, subsequent information in the passage may help resolve its identity.

Task and Nature of Information Assessed

A wide range of tasks can be used to assess reading comprehension, including free recall, cued recall, multiple-choice tasks, open-ended questions, cloze, picture matching, and so on. Best et al. (2008) found that the method of assessment was related to the strength of the association between decoding skills and reading comprehension. This was particularly true for expository texts: When cued recall or multiple-choice tasks were used, the amount of variance explained by decoding was smaller ($R^2 = .04$) than when a free recall task was used ($R^2 = .23$).

These differences may be because of the extent to which the answers to the comprehension questions are passage-dependent (Keenan & Betjemann, 2006). Passage-dependent questions can only be answered accurately using information from the text and, therefore, rely on accurate word reading. Passage-independent questions can be answered from general knowledge and, as Keenan and Betjemann (2006) have shown, do not require reading of the actual text (see also Coleman, Lindstrom, Nelson, Lindstrom, & Gregg, 2010). As a result, there will be a stronger relation between word reading and reading comprehension performance when a large number of the items in the comprehension measure are passage-dependent, than when items are passage-independent. Because this factor (passage-dependent vs. passage-independent) varies at the item level, we could not include it in our analysis, but it is important to note.

Another important factor to consider is the nature of information assessed (literal or inferential) or, in other words, the nature of the reader's mental representation, textbase, or the situation model (Graesser, Millis, & Zwaan, 1997; Kintsch, 1994, 1998; van Dijk & Kintsch, 1983). Literal questions require recall or paraphrasing of information stated explicitly in the text, which corresponds to the textbase level of representation. Inferential questions tap the reader's situation model, a representation that incorporates a reader's background knowledge.

Administration Procedures

Tests of reading comprehension differ widely in how they are administered. For instance, some comprehension assessments, such as the *Neale Analysis of Reading Ability* (Neale, 1997; Neale, Christophers, & Whetton, 1989), allow the assessor to correct word reading errors. Thus, all the words in the passage will have been properly read by the child, or read to the child, before the comprehension questions are asked. Some assessments, such as the *Gates-MacGinitie Reading Test* (MacGinitie, MacGinitie, Maria, & Dreyer, 2000), not only provide access to the passage during question answering but also explicitly encourage participants to reread and check their responses. Some tests, such as the *Woodcock Reading Mastery Test* (Woodcock, 1987), do not impose a time limit, which will be beneficial to slower, less skilled, word decoders, whereas other tests do, for example, the *Gray Oral Reading Test* (Wiederholt & Bryant, 1992). These procedural differences may influence the strength of the decoding–reading comprehension relationship.

The influence of five factors relating to administration of the reading comprehension assessment was examined in our meta-analysis: whether or not help is provided with decoding the material to be understood, whether or not there is a time limit, whether or not participants are allowed to refer back to the comprehension material, whether or not the reading comprehension material is read aloud by the participant, and whether or not the assessment items are read by the assessor or participant. With respect to these variables, we would expect that the less demanding the conditions of reading comprehension assessment are, the weaker the decoding–reading comprehension relationship will be.

In sum, there are several potential moderators that might explain differences found in the amount of reading comprehension variance explained by decoding. See Table S1 (available online at http://RER.sagepub.com/supplemental) for a summary of the moderators to be explored and their predicted influence in the decoding and reading comprehension relationship.

Rationale for This Meta-Analysis

We have outlined a range of factors that might influence the strength of the association between word decoding and reading comprehension. These factors are unlikely to act independently but might, instead, interact. For instance, a reading comprehension assessment that allows rereading and imposes no time limit may modify the impact of word decoding skills on performance in groups of younger readers, but have little impact on the comprehension scores achieved by older readers. It would be difficult to take into account all these factors in a single study. The solution adopted here is to conduct a meta-analysis (Glass, McGaw, & Smith, 1981) to explore the contribution of each of these factors to the decoding–reading comprehension relationship and to explore some of the possible interactions between them. This methodological approach enables us to compare studies with different samples (on the basis of age, decoding competence, listening comprehension level, and vocabulary knowledge) and different methods of assessment. We addressed two main questions in our analysis:

The first question asked was, "What is the relative importance of decoding skills to reading comprehension during the course of reading development." This information is central to our understanding of literacy development. An analysis of the average amount and range of variance in reading comprehension that is explained by decoding skill is needed to understand more fully how it constrains reading comprehension at different points in development and in different types of readers. The second question was, "How does each of the two groups of factors (reader characteristics and characteristics of the assessment) contribute to differences in the strength of the word decoding–reading comprehension relationship." Given the substantial differences in the strength of the relation between decoding and reading comprehension that have been reported, it seems highly plausible that it will be influenced by more than one of these factors. Thus, a supplemental question was, "Do reader characteristics and assessment characteristics interact to influence this relationship." Our analysis will enable us to determine the relative influence of each factor and how some of these might interact during the course of literacy development.

Method

Literature Base

Relevant studies were identified through a search of English peer-reviewed journals articles in the PsycINFO and ERIC databases using all the possible combinations of a set of keywords related to decoding (decoding, nonword reading, pseudoword reading, reading ability, word reading) and to reading comprehension (reading comprehension, reading skill). Initially, the search was limited, as in other meta-analyses (e.g., van Steensel, McElvany, Kurvers, & Herppich, 2011), to a 20-year range (1989–2008), taking into account the time when the study was started. This search was later expanded to include the years 2009, 2010, 2011, and 2012. The different combinations of keywords yielded a total of 4,494 articles from PsycINFO and 903 from ERIC. After removing duplicates, the number of articles decreased to 2,489.

We selected only studies published in peer-reviewed journals to ensure that they met the research standards of the field (e.g., Bar-Haim, Lamy, Lee, Bakermans-Kranenburg, & van IJzendoorn, 2007; Ehri, Nunes, Stahl, & Willows, 2001; van Steensel et al., 2011). There are concerns about this procedure because of publication bias (e.g., Glass et al., 1981; Macaskill, Walter, & Irwing, 2001; Rosenthal, 1995); that is to say, only studies confirming the initial hypothesis are published. In the current meta-analysis, there is no reason to think that only substantial correlations between decoding and reading comprehension (or vice versa) will be found in published articles, because authors may be investigating different hypotheses—for or against a strong relationship between decoding and reading comprehension—and not all the articles that report correlations between these variables are directly studying these associations.

Inclusion Criteria

The abstracts of the 2,489 articles were reviewed and several types of studies were discarded: opinion and nonempirical articles, single case studies, studies not related to text reading, studies dealing with teachers and/or parents (not with readers), and studies conducted with special populations (e.g., people with brain lesions, deafness, autism, mental retardation, and attention deficit/hyperactivity disorder). If the information about these issues was not provided in the abstract, the main article was examined. When a study compared the results obtained from a sample with developmental problems with those obtained from a typically developing sample, only data relating to the former were excluded. We did not discard studies with participants with reading disabilities because one of our objectives was to explore how decoding competence affects the relationship between decoding and reading comprehension. A total of 1,288 articles were discarded after examining the abstracts, leaving 1,201 articles. The full text of 1,197 articles was obtained and closely reviewed (four could not be found) using the specific criteria described below.

First, we included only studies conducted in English. This criterion was established to control the possible impact of different writing systems in the relationship between decoding and reading comprehension (Florit & Cain, 2011). Three hundred and twenty studies were excluded for this reason. Although this is a large number, the majority also met at least one of the subsequent exclusion criteria.

Second, studies dealing with bilingual readers or learners of English as a second language were also excluded because a transfer or compensation effect between languages might influence the decoding–reading comprehension relationship (Sparks, Patton, Ganschow, & Humbach, 2008). One hundred and five studies were excluded because of this criterion.

Third, studies had to assess both decoding and reading comprehension with objective and quantitative tasks. As a result, 361 studies were removed because they did not use objective variables to measure reading (e.g., requiring teachers to rate children's reading ability based on their knowledge of children's achievement; Harlaar, Dale, & Plomin, 2005) or because they did not assess both decoding and reading comprehension. Fourth, if a composite measure of reading skill (decoding plus reading comprehension), decoding (e.g., speed of word reading plus letter knowledge), and/or reading comprehension (e.g., reading plus listening comprehension, or reading comprehension plus vocabulary) was used, the resulting correlation was not included because we wanted to explore how the relationship between decoding and reading comprehension is affected by the methods used to measure the variables; with a composite measure, it is not possible to separate the contribution made by each method. Thirty-nine studies were removed because they provided only correlations obtained with composite measures.

Fifth, the measures of decoding and reading comprehension used to calculate the correlations had to be taken at the same time point and in the same age group of readers (i.e., all the children had to be registered in the same school year rather than a range of school years), because we were interested in the concurrent relationship between both variables in order to investigate how the relationship between decoding and reading comprehension changed with age. This criterion was not applied to research with adults (aged 16 years and older) because it is reasonable to think that older readers will not improve their reading competencies as quickly as younger readers do. Fifty-five studies were excluded because of these criteria. Finally, selected studies had to report at least one correlation (r) between any measure of decoding and any measure of reading comprehension, or the percentage of variance (R^2) in reading comprehension accounted for by decoding. Two hundred and seven studies of the remaining studies did not include any of these data. A total of 110 studies met all the inclusion criteria.

Dependent/Criteria Variable

Our dependent/criteria variable of the decoding–reading comprehension relationship was Pearson's correlation, one of the main indices of effect size commonly used in meta-analyses (Lipsey & Wilson, 2001; Rosenthal, 1995). Most of the studies, except 18 (Arnell, Joanisse, Klein, Busseri, & Tannock, 2009; Benjamin & Schwanenflugel, 2010; Burke, Hagan-Burke, Kwok, & Parker, 2009; Dreyer & Katz, 1992; Elleman, Compton, Fuchs, Fuchs, & Bouton, 2011; Jarmulowicz, Hay, Taran, & Ethington, 2008; Joshi & Aaron, 2000; Kitz & Nash, 1992; Klauda & Guthrie, 2008; Landi, 2010; Leather & Henry, 1994; Lee, 2011; Miller & Schwanenflugel, 2008; Nunes, Bryant, & Barros, 2012; Pritchard & Romeo, 2000; Stuart, 2004; Taylor, Greenberg, Laures-Gore, & Wise, 2012; Zinar, 2000) provided more than one valid correlation. When only the R^2 value was provided, it was transformed to the corresponding correlation.

When data from the same sample were included in more than one article, the data were coded only once: Cain et al. (2004), Oakhill et al. (2003), and Cain and Oakhill (2011); Hecht, Burgess, Torgesen, Wagner, and Rashotte (2000), and Torgesen et al. (1997); Chen and Vellutino (1997) and Vellutino et al. (2007); Kim, Otaiba, et al. (2011), Kim, Wagner, and Foster (2011), and Kim et al. (2012); Kirby, Ball, Geier, Parrila, and Wade-Woolley (2011) and Kirby et al. (2012); McCutchen and Logan (2011) and McCutchen, Logan, and Biangardi-Orpe (2009). In the case of longitudinal studies, we coded correlations corresponding to all the points of evaluation. This procedure gave us a total of 650 correlations (or data points). Negative correlations that arose because speed of reading was measured were coded as positive to avoid interpretative problems, because our focus here is the strength of the relationship between variables.

Coding

Studies were coded according to reader characteristics and the characteristics of the assessments used to measure decoding and reading comprehension. Not all the studies provided sufficient information about all these variables and categories. When this happened, authors were contacted to ask them the missing information, which enabled us to complete some missing information. In addition to these variables, we coded the name of the reading comprehension test (when a published measure was used) and the number of participants (*N*) used to obtain each correlation. The latter is needed to weight each effect size, so that correlations obtained from larger samples are given more weight in the analysis than those obtained from smaller samples. The coding system for individual studies is given in Table S2 (available online at http://RER.sagepub.com/supplemental).

Interrater Reliability

Variables and categories were discussed until a consensus between the two authors was reached. Then, the two authors and a third coder each employed the coding system with five articles in the final sample to check that it was useful and understandable. At this stage, any clarifications to the coding system were introduced. The first author used this coding system to conduct the final coding of all studies. To assess intercoder reliability, another judge independently coded 10 of the studies. Across the total variable matrix, the mean kappa was .91, with acceptable kappa values for all codes as follows: .73 for age, 1 for type of reader, .87 for the decoding measure, 1 for reading comprehension test, .60 for reading comprehension format, .70 for the type of reading comprehension task, 1 for the information assessed, 1 for help provided with decoding, 1 for reading aloud, and 1 for participant reads test items.[1]

Overview of Studies

The 110 studies included in the meta-analysis represent a total of 42,916 participants obtained from 145 samples. The majority (54) used a correlational design. We include here all kind of methods aimed to analyze relationships between variables: structural equation modeling, regression equations, factor analysis, latent variable studies, and so on. Several studies also made group comparisons (29). There were some longitudinal studies (21) and a few experimental/instructional studies (6) in the final corpus (due, in part, to the selection criteria). The important features of all the studies can be found in Table S3 (available online at http://RER.sagepub.com/supplemental).

Meta-Analytic Procedures

The effect size index used for all outcome measures was Pearson's *r*, the correlation between decoding and reading comprehension. Three outliers (correlations greater than 2.5 standard deviations from the mean) were removed—one from Cain and Oakhill (2011), one from Sabatini (2002), and one from Welcome, Chiarello, Halderman, and Leonard (2009)—resulting in a final tally of 647 correlations and 144 samples (the correlation removed from Welcome et al., 2009, was the only one provided for one of their samples).

Analyses were based on Hunter and Schmidt's (2004) recommendations. We conducted a two-step or mixed meta-analysis because the data required for the corrections were not available for all studies, and because all correlations had to be corrected for error of measurement in the independent (decoding) and dependent (reading comprehension) variables, but only some had to be corrected for direct range variation in the variables of interest (the ones obtained from samples of poor or average decoders rather than unselected samples). Therefore, in the first step, these later correlations were individually corrected for range restriction when information about the standard deviation of a study's samples and populations were available.[2] This first meta-analysis produced a partially corrected mean and variance. In the second step, the methods of artifact distributions were used to correct for error of measurement. To obtain the factor of correction of the attenuation for measurement error we used, almost always, Cronbach's alpha or the KR-20 coefficient ("parallel forms reliability"), because the delayed parallel forms reliability was rarely available in the studies and test manuals. Thus, full correction for measurement error was not possible and the results reported are therefore conservative (i.e., they have a downward bias). We did not transform correlations to Fisher's *Zr* in order to avoid upwardly biased and less accurate estimations. Moreover, the random effect methods were preferred because they assume that the population parameter may be different from study to study.

Results

The results are organized into four main sections. First, we report the combined correlation collapsed over task types and reader characteristics. Second, we report the effects of reader characteristics on the correlation between decoding and reading comprehension. In the third section, we explore the effects of assessment characteristics. The fourth section explores if there are any interactions between reader and assessment characteristics that affect the decoding–reading comprehension correlation. The results are reported in Table 1.

Examining the Strength of the Decoding–Reading Comprehension Relationship

The 647 original uncorrected correlations (after removing outliers) ranged from .00 (Chen & Vellutino, 1997) to .96 (Katzir et al., 2006). Five hundred and sixty-three *p* values were provided, and 507 (90%) of these correlations were statistically significant at least at the .05 level. From the total pool of correlations, a set of 144 independent correlations was created with only one correlation per sample.

TABLE 1
Meta-Analytic Results

	κ[a]	*n*	$\bar{r}_c$	S^2_{rc}	S^2_{ec}	$100 * (S^2_{rc} / S^2_{ec})$	95% CI	
Main average corrected correlation	144	42,891	.74*	.0381	.0010	3.15%	.36, 1.0	
Reader Characteristics								
Hypothetical Categorical Moderators	κ[a]	*n*	$\bar{r}_c$	S^2_{rc}	S^2_{ec}	$100 * (S^2_{rc} / S^2_{ec})$	95% CI	Differences Between Subgroups
Age								
(a) Younger than 7	15	17,922	.74*	.0021	.0002	9.73%	.65, .83	a > f, g
(b) Between 7 and 8[b]	31	4,667	.83*	.1024	.0016	12.96%	.62, 1.0	b > f, g
(c) Between 8 and 9	27	4,802	.74*	.0241	.0018	7.78%	.44, 1.0	c > f, g
(d) Between 9 and 10	25	10,982	.86*	.0314	.0004	1.27%	.52, 1.0	d > g
(e) Between 10 and 12	20	2,245	.64*	.0233	.0040	16.77%	.34, .94	
(f) Between 12 and 16	14	933	.52*	.0153	.0079	36.66%	.28, .76	
(g) Older than 16	27	4,086	.41*	.0371	.0054	18.22%	.03, .78	
Type of reader								
(a) Poor decoders	22	3,127	.64*	.0663	.0036	6.02%	.13, 1.0	
(b) Unselected	99	37,430	.76*	.0340	.0007	2.54%	.40, 1.0	
(c) Average decoders	11	548	.60*	.0405	.0125	27.71%	.20, .99	
Hypothetical Continuous Moderators	κ[a]	*n*	R^2	Beta	95% CI			
Age	158	70,483	.25*	−.50	−.02, −.01			
Listening comprehension level	10	1,140	.40*	−.63	−.02, .00			
Vocabulary level	20	3,701	.20	−.44	−.01, .00			

(continued)

TABLE 1 (continued)

Hypothetical Categorical Moderators	κ^a	n	$\bar{r}_c$	S^2_{rc}	S^2_{ec}	$100 * (S^2_{rc} / S^2_{ec})$	95% CI	Differences Between Subgroups
Method Used to Assess Decoding and Reading Comprehension								
Decoding measure								
(a) Accuracy of word reading (in a list)	53	13,720	.86*	.0249	.0037	14.52%	.55, 1.0	**a** > d, **i**
(b) Speed of word reading (in a list)	8	1,217	.65*	.0141	.0036	24.11%	.42, .89	**b** > **i**
(c) Accuracy of word reading in context	18	1,410	.62*	.1012	.0085	9.99%	−.01, 1.0	**d** > **i**
(d) Speed of word reading in context	20	1,917	.48*	.0489	.0075	16.25%	.05, .91	**e** > **i**
(e) Accuracy of single word reading (fixed time)	47	7,912	.69*	.0557	.0023	4.64%	.23, 1.0	**f** > g, **i**
(f) Accuracy of word reading in context (fixed time)	34	21,960	.79*	.0087	.0004	4.25%	.61, .97	**g** > **i**
(g) Accuracy of pseudoword reading	63	7,537	.56*	.0412	.0048	12.58%	.16, .96	**h** > **i**
(h) Accuracy of pseudoword reading (fixed time)	24	20,722	.66*	.0143	.0005	4.19%	.42, .89	
(i) Lexical decision	16	2,515	.39	.0661	.0055	10.26%	−.11, .90	
Reading comprehension test								
(a) Gates–MacGinitie Reading Tests	18	1,862	.72*	.0171	.0041	21.68%	.47, .98	a > b, d
(b) Gray Oral Reading Test	6	634	.35*	.0140	.0088	45.69%	.11, .58	**c** > **b**, **d**, g
(c) Neale Analysis of Reading Ability	15	8,688	.96*	.0156	.0001	1.17%	.71, 1.0	e > b, d
(d) Nelson–Denny Reading Test	8	1,953	.26*	.0202	.0037	19.45%	−.01, .54	**f** > **b**, **d**
(e) Peabody Individual Achievement Test	6	273	.72*	.0200	.0052	20.59%	.44, 1.0	h > b, d
(f) Stanford Achievement Test	6	16,810	.75*	.0027	.0001	4.93%	.65, .85	i > d
(g) Spache Diagnostic Reading Scales	4	460	.62*	.0413	.0036	8.74%	.22, 1.0	j > b, d
(h) Wechsler Individual Achievement Test	13	2,843	.73*	.0163	.0013	8.59%	.48, .98	
(i) Woodcock–Johnson	11	2,938	.72*	.0389	.0012	3.59%	.34, 1.0	
(j) Woodcock Reading Mastery Test	32	3,376	.77*	.0270	.0025	9.80%	.45, 1.0	

(continued)

TABLE 1 (continued)

	κ^a	n	$\bar{r}_c$	S^2_{rc}	S^2_{ec}	100 * (S^2_{rc} / S^2_{ec})	95% CI	
Genre of the material								
(a) Narrative	17	1,313	.63*	.0311	.0064	18.94%	.29, .98	**a > b**
(b) Expository	13	2,217	.30	.0287	.0052	20.08%	−.03, .64	**c > b**
(c) Narrative and expository	80	22,056	.80*	.0375	−.0001	−.46%	.42, 1.0	
Format of the material								
(a) Single sentences	9	563	.55*	.0517	.0101	16.33%	.10, .99	
(b) Sentences and paragraphs	43	6,042	.74*	.0339	.0022	7.14%	.38, 1.0	
(c) Paragraphs or passages	97	35,782	.75*	.0380	.0008	2.63%	.37, 1.0	
Type of reading comprehension task								
(a) Multiple choice task	66	26,034	.70*	.0321	.0010	3.87%	.35, 1.0	
(b) Cloze task	34	3,736	.76*	.0275	.0026	9.96%	.43, 1.0	
(c) Open-ended questions	42	12,788	.86*	.0333	.0005	1.82%	.50, 1.0	
(d) Picture matching	6	273	.72*	.0200	.0052	20.59%	.44, .99	
Information assessed								
(a) Literal	49	4,808	.73*	.0364	.0035	10.03%	.35, 1.0	
(b) Inferential	15	3,517	.80*	.0374	.0015	4.26%	.42, 1.0	
(c) Literal and inferential	91	35,148	.76*	.0381	.0008	2.50%	.38, 1.0	
Help provided with decoding the reading comprehension material								
(a) Yes	17	8,748	.95*	.0172	.0002	1.25%	.69, 1.0	
(b) No	121	32,698	.69*	.0294	.0014	5.42%	.36, 1.0	
Time limit								
(a) Yes	49	9,482	.63*	.0553	.0027	6.08%	.17, 1.0	
(b) No	83	23,936	.71*	.0174	.0011	7.22%	.45, .97	
Option of rereading								
(a) Yes	92	35,676	.76*	.0371	.0008	2.48%	.38, 1.0	
(b) No	48	5,953	.69*	.0405	.0031	8.32%	.30, 1.0	
Reading aloud								
(a) Yes	10	858	.37*	.0299	.0021	24.03%	.05, .72	b > a

(continued)

TABLE 1 (continued)

	κ^a	n	$\bar{r}_c$	S^2_{rc}	S^2_{ec}	100 * (S^2_{rc} / S^2_{ec})	95% CI
(b) No	104	29,447	.70*	.0293	.0014	5.28%	.36, 1.0
Participant reads test items (e.g., questions)							
(a) Yes	80	10,109	.63*	.0675	.0040	6.86%	.13, 1.0
(b) No	16	1,418	.63*	.0305	.0052	16.03%	.29, .97

Interaction Between Reader Age and Method Used to Assess Decoding and Reading Comprehension

	κ^a	n	$\bar{r}_c$	S^2_{rc}	S^2_{ec}	100 * (S^2_{rc} / S^2_{ec})	95% CI	Differences Between Subgroups
Average corrected correlations								
(a) Younger (up to 10)	87	36,361	.80*	.0172	.0006	3.69%	.54, 1.0	a > b
(b) Older (more than 10)	61	7137	.47*	.0454	.0059	13.88%	.05, .89	

Age× Hypothetical Categorical Moderators	κ^a	n	$\bar{r}_c$	S^2_{rc}	S^2_{ec}	100 * (S^2_{rc} / S^2_{ec})	95% CI	Differences Between Subgroups
Age × Decoding measure								
(a) Younger: Accuracy of word reading (in a list)	32	11,510	.90*	.0157	.0003	2.16%	.66, 1.0	**a** > b, e, f, **g**, i, k, l, **m**, **o**, p, **q**
(b) Older: Accuracy of word reading (in a list)	21	2,210	.62*	.0224	.0045	19.09%	.33, .92	**b** > o, **q**
(c) Younger: Speed of word reading (in a list)	7	1,004	.67*	.0251	.0043	17.45%	.36, .98	**c** > g, o, **q**
(d) Younger: Accuracy of word reading in context	12	886	.84*	.0447	.0081	18.71%	.42, 1.0	**d** > g, m, o, **q**
(e) Older: Accuracy of word reading in context	6	537	.46*	.0332	.0089	26.92%	.10, .82	**e** > **q**
(f) Younger: Speed of word reading in context	9	907	.65*	.0276	.0063	21.72%	.32, .97	**f** > o, **q**

(continued)

TABLE 1 (continued)

	κ[a]	n	$\bar{r}_c$	S^2_{rc}	S^2_{ec}	100 * (S^2_{rc} / S^2_{ec})	95% CI	
(g) Older: Speed of word reading in context	11	1,010	.35*	.0253	.0083	29.62%	.04, .66	**h > q**
(h) Younger: Accuracy of single word reading (fixed time)	29	5,677	.75*	.0528	.0016	3.33%	.30, 1.0	**i > q**
(i) Older: Accuracy of single word reading (fixed time)	16	2,419	.57*	.0380	.0035	9.77%	.19, .96	**j** > b, e, f, **g**, i, k, **m**, **o**, p, **q**
(j) Younger: Accuracy of word reading in context (fixed time)	24	19,990	.80*	.0053	.0003	4.95%	.66, .95	**k** > g, m, **o**, **q**
(k) Older: Accuracy of word reading in context (fixed time)	10	1,970	.61*	.0048	.0027	27.46%	.47, .75	**l > q**
(l) Younger: Accuracy of pseudoword reading	35	4,813	.65*	.0341	.0034	10.76%	.29, 1.0	**m > q**
(m) Older: Accuracy of pseudoword reading	28	2,724	.41*	.0113	.0077	45.39%	.20, .62	**n** > e, g, m, **o**, **q**
(n) Younger: Accuracy of pseudoword reading (fixed time)	15	19,079	.68*	.0037	.0003	8.59%	.56, .80	**p** > o, **q**
(o) Older: Accuracy of pseudoword reading (fixed time)	9	1,643	.31*	.0053	.0047	52.64%	.17, .46	
(p) Younger: Lexical decision	7	600	.59*	.0173	.0099	40.40%	.33, .85	
(q) Older: Lexical decision	9	1,915	.34	.0631	.0040	8.40%	−.15, .84	
Age × Genre of the material								
(a) Younger: Narrative	11	933	.72*	.0160	.0047	25.58%	.47, .97	a > b, c, e
(b) Older: Narrative	6	380	.43*	.0218	.0114	34.74%	.14, .72	d > b, c, e
(c) Older: Expository	11	2,061	.27*	.0213	.0048	22.89%	−.01, .56	
(d) Younger: Narrative and expository	57	19,711	.85*	.0241	−.0003	−1.74%	.54, 1.0	
(e) Older: Narrative and expository	23	2,345	.46*	.0179	.0065	28.91%	.19, .72	

(continued)

TABLE 1 (continued)

	κ^a	n	$\bar{r}_c$	S^2_{rc}	S^2_{ec}	$100 * (S^2_{rc} / S^2_{ec})$	95% CI	
Age × Format of the material								
(a) Older: Sentences	6	364	.51*	.0604	.0091	13.09%	.03, 1.0	b > a, c, e
(b) Younger: Sentences and paragraphs	28	4,810	.82*	.0116	.0012	10.44%	.61, 1.0	d > a, c, e
(c) Older: Sentences and paragraphs	18	1,751	.54*	.0208	.0063	27.12%	.25, .82	
(d) Younger: Paragraphs or passages	57	31,084	.80*	.0152	.0004	2.98%	.55, 1.0	
(e) Older: Paragraphs or passages	41	4,738	.42*	.0417	.0065	17.04%	.02, .82	
Age × Type of reading comprehension task								
(a) Younger: Multiple choice task	35	21,419	.75*	.0076	.0005	6.58%	.58, .92	a > b, f
(b) Older: Multiple choice task	31	4,615	.40*	.0312	.0052	17.90%	.05, .74	c > b, d, f
(c) Younger: Cloze task	23	3,083	.82*	.0093	.0015	15.53%	.64, 1.0	e > b, d, f
(d) Older: Cloze task	14	1,172	.60*	.0216	.0063	26.67%	.31, .89	
(e) Younger: Open-ended questions	29	11,920	.90*	.0190	.0004	1.76%	.62, 1.0	
(f) Older: Open-ended questions	13	868	.45*	.0280	.0094	27.72%	.12, .78	
Age × Information assessed								
(a) Younger: Literal	30	3,747	.80*	.0150	.0020	13.13%	.56, 1.0	a > d, f
(b) Older: Literal	22	1,580	.58*	.0386	.0077	19.93%	.20, .97	c > b, d, f
(c) Younger: Inferential	11	2,675	.94*	−.0048	.0010	5.75%	.80, 1.0	e > d, f
(d) Older: Inferential	4	842	.42*	−.0033	.0036	109.09%	.31, .54	
(e) Younger: Literal and inferential	54	30,687	.80*	.0148	.0004	2.82%	.56, 1.0	
(f) Older: Literal and inferential	38	4,501	.41*	.0365	.0065	19.26%	.04, .79	
Age × Help provided with decoding the reading comprehension material								
(a) Younger: With help	13	8,560	.97*	.0097	.0001	1.59%	.77, 1.0	
(b) Older: With help	4	188	.49*	.0454	.0084	18.84%	.07, .90	a > b, c, d
(c) Younger: Without help	71	26,972	.75*	.0082	.0008	9.25%	.57, .92	c > b, d
(d) Older: Without help	53	6,245	.44*	.0390	.0061	16.43%	.06, .84	

(continued)

TABLE 1 (continued)

	κ^a	n	$\bar{r}_c$	S^2_{rc}	S^2_{ec}	$100 * (S^2_{rc} / S^2_{ec})$	95% CI	
Age × Time limit								
(a) Younger: Time limit	28	6,495	.73*	.0165	.0016	9.77%	.48, .98	a > b
(b) Older: Time limit	21	2,987	.37*	.0348	.0057	17.76%	.01, .74	c > b, d
(c) Younger: No time limit	50	20,931	.74*	.0065	.0006	10.47%	.59, .90	
(d) Older: No time limit	36	3,524	.52*	.0314	.0064	19.90%	.17, .87	
Age × Option of rereading								
(a) Younger: Option of rereading	54	30,771	.80*	.0157	.0004	2.90%	.56, 1.0	a > b, d
(b) Older: Option of rereading	38	4,905	.42*	.0348	.0057	17.15%	.05, .79	c > b
(c) Younger: No option of rereading	30	4,859	.77*	.0178	.0018	10.36%	.50, 1.0	
(d) Older: No option of rereading	21	1,613	.51*	.0427	.0085	20.06%	.10, .91	
Age × Reading aloud								
(a) Younger: Reading aloud	6	518	.47*	.0155	.0086	35.72%	.22, .71	c > a, **b**, d
(b) Older: Reading aloud	4	340	.22*	.0047	.0108	69.75%	.09, .36	
(c) Younger: No reading aloud	57	24,100	.75*	.0072	.0007	9.14%	.58, .92	
(d) Older: No reading aloud	50	5,866	.45*	.0377	.0061	17.12%	.07, .84	
Age × Participant reads test items (e.g., questions)								
(a) Younger: Reading test items	46	6,796	.76*	.0274	.0022	8.55%	.44, 1.0	a > b
(b) Older: Reading test items	37	3,832	.42*	.0469	.0074	17.07%	−.00, .84	c > b, d
(c) Younger: Does not read test items	10	936	.72*	.0166	.0038	20.49%	.47, .98	
(d) Older: Does not read test items	6	482	.45*	.0146	.0082	37.39%	.21, .69	

Note. CI = Confidence interval.

[a]Number of independent correlations included to calculate each combined correlation.

[b]The correlation from Kim, Petscher, Schatschneider, and Foorman (2010) corresponding to this age (.10) has been removed from this set of correlations because it was an outlier.

*$p < .05$ Combined correlations are considered significant when the corresponding confidence interval does not include the value 0.

When more than one relevant correlation was provided for a sample due to multiple measurements of the variables, we calculated the average and, from longitudinal studies, we included the correlation (or the average correlation) corresponding to the youngest group because this group always had the largest sample. The average corrected correlation was obtained, as explained above, following the procedures from Hunter and Schmidt (2004) for correcting error of measurement and range restriction, in both decoding and reading comprehension. As additional information to interpret this average, we also calculated the observed variance (S^2_{rc}), the sampling error variance (S^2_{ec}), the percentage of the observed variance explained by the sampling error variance ($100 * S^2_{rc} / S^2_{ec}$), and 95% confidence intervals (CI) for the average corrected correlation using Hunter and Schmidt's (2004) formulae.

The average corrected correlation ($\bar{r}_c$ = .74) was sizeable (Cohen, 1988) and significant: 95% CI [.36, 1.0]. The variance of the overall effect analysis explained by sampling error was 3.15%, which failed the 75% rule of Hunter and Schmidt (2004). This finding indicates that the pool of effect sizes is heterogeneous and a test for the presence of moderators is justified.

Do Different Reader Characteristics Affect the Strength of the Relationship Between Decoding and Reading Comprehension?

The characteristics considered in this set of analyses were age of reader, type of reader, listening comprehension level of reader, and vocabulary level of reader. For continuous variables (e.g., listening comprehension level), we conducted a meta-regression using the macros for SPSS provided by Wilson (2005). For testing each hypothetical categorical moderator, we created different subgroups of correlations choosing the ones more suitable according to the categories for each moderator from the total of 647 correlations. For example, in the case of type of reader, we had three categories and three groups of correlations: poor decoders, unselected, and average decoders. Correlations from the same sample/study could be included for more than one subgroup if the data were obtained with different measures and/or at different ages, but ensuring only one correlation (or average correlation) by study and sample in each subgroup. When there were fewer than four correlations in a group, the category was excluded from the analysis, because four is the minimum number of effect sizes required to conduct a meta-analysis (e.g., Bar-Haim et al., 2007).

For each group of correlations, we calculated the average corrected correlation and the same statistics obtained for the main average corrected correlation, as outlined above. With this information, and following Hunter and Schmidt's (2004) recommendations, we determined the presence of any individual moderator by considering (a) differences in the average corrected correlation among the categories of the moderator, (b) observed variances across the categories relative to the observed variance of the main average corrected correlation (the one obtained above), and (c) the degree of overlap in CIs among the categories. For a moderator to be considered present, the average corrected correlation among categories should be different, the variances for each category's average corrected correlation must be noticeably lower than the variance of the main average corrected correlation, and the ranges of the CIs for the categories need to be noticeably different. The right-hand column of Table 1 indicates which average corrected correlations are considered different because the degree of overlap between the CIs is less than the nonoverlapping part,[3] and the CI of the highest correlation overlapped only the upper level of the CI of the other category, and/or one of the CIs includes 0 (which means that the correlation is not significant). We identify the strongest differences (where one of the contrasted correlations is not significant or where there is no overlap between their CIs) by marking these in bold in Table 1. The correlations associated with letters that are both in bold differ significantly.

The Influence of Age

The age of participants ranged from 5 (Blackmore & Pratt, 1997) to 53 years (Sabatini, 2002) and all ages between these extremes were quite well represented. A meta-regression with age (years) as the independent variable and the decoding and reading comprehension direct corrected correlation as dependent variable was conducted.[4] Age was a significant moderator of the relationship between decoding and reading comprehension, explaining 25% of the systematic variance in the effect sizes. As the SVR predicts, the relationship between decoding and reading comprehension decreased with increasing chronological age ($\beta = -.50$).

To examine the effect of age more precisely, studies were classified by years into seven groups.[5] The extreme groups (younger than 7, between 10 and 12, between 12 and 16, and older than 16) represented more than a single chronological year range because there were fewer studies with these age groups. The other groups included only studies conducted with participants of the same age. The average corrected correlations for these groups were all significant but, as predicted by the SVR, the size of the correlation decreased from between $\bar{r}_c$ = .74-.86 for the four youngest groups to $\bar{r}_c$ = .41 for the oldest.

When comparing between groups, a key point in development was evident. The average corrected correlations between the youngest four age groups (up to 10 years) and the eldest three groups (older than 10 years) were noticeably different. Additionally, six of the seven variances for the average corrected correlations in each group were lower than the variance of the main average corrected correlation (.0381). These findings reinforce the idea that age is an important moderator of the decoding and reading comprehension relationship. Nevertheless, as the percentage variance explained by the sampling error was far from 75% in all groups, we can conclude that age was not the only moderator of the decoding–reading comprehension relationship.

The Influence of Reader Type

To establish if reader type moderated the strength of the association between decoding and reading comprehension, the independent correlations were classified into three groups: poor decoders (22 correlations), unselected (99 correlations), or average decoders (11 correlations). Twelve correlations were removed because they did not fit into any category: Some of them had been obtained from very heterogeneous samples (e.g., a sample of good decoders, readers with dyslexia, and low general achieving readers), and others concerned samples of readers with low reading comprehension.

The average corrected correlation between decoding and reading comprehension was significant for each of the three groups: poor decoders, $\bar{r}_c$ = .60; unselected readers, $\bar{r}_c$ = .76; and average decoders, $\bar{r}_c$ = .60. Contrary to our predictions, type of reader was not a moderator of the relation between decoding and reading comprehension; the variance of the three groups was similar or higher than the variance for the main average corrected correlation and there was substantial overlap between the three CIs.

The Influence of Listening Comprehension Level

A new set of independent correlations was created for the studies that reported a listening comprehension score that could be transformed into a percentage of success (i.e., when the average raw score and the maximum score was known). Unfortunately, although a total of 28 studies measured listening comprehension, only 10 provided the information necessary to include in our analyses. Listening comprehension level was a significant predictor (and moderator) of the relationship between decoding and reading comprehension, explaining a sizeable portion of the systematic variance in the effect sizes: $R^2 = .40$. The relationship between listening comprehension and the decoding–reading comprehension correlation was negative ($\beta = -.63$), which means that, in accordance with the predictions of the SVR, higher listening comprehension scores were associated with lower decoding–reading comprehension correlations.

The Influence of Vocabulary Level

We followed the same procedure as above to determine whether or not vocabulary level influenced the decoding–reading comprehension relationship. A new set of 20 correlations was created. Vocabulary level was not a significant predictor of the relationship between decoding and reading comprehension: $R^2 = .20$.

Do the Methods Used to Assess Decoding and Reading Comprehension Influence the Strength of Their Relationship?

The characteristics considered in this set of analyses relate to the methods and types of material used to assess decoding and the reading comprehension. We used the same methods to prepare data for analysis and to look for moderators, as described above.

Decoding

Measures of decoding were grouped into nine categories according to the stimuli used (words/pseudowords), the indicator considered (accuracy, speed, or accuracy within a fixed time), the presentation format (in a list or in context), and the task (reading or lexical decision). There were not enough correlations obtained with speed of pseudoword reading to calculate the average corrected correlation and perform the contrasts. Each category of decoding measure yielded a significant correlation between decoding and reading comprehension ($\bar{r}_c$ = .48.-.86), except lexical decision $\bar{r}_c$ = .39).[6] Additionally, differences between other two pairs of categories were apparent: Large parts of the CIs did not overlap (see Table 1). Accuracy of (single) word reading when items were presented in a list ($\bar{r}_c$ = .86), the measure of decoding most strongly related to reading comprehension reported higher correlation than speed of word reading in context ($\bar{r}_c$ = .48); and accuracy of word reading in context with fixed time ($\bar{r}_c$ = .79) was strongly correlated to reading comprehension than accuracy of pseudoword reading ($\bar{r}_c$ = .56). In sum, the measure used to assess decoding was another moderator of the decoding and reading comprehension relationship.

Reading Comprehension

Nine different groups of independent correlations were created to compare the correlations obtained with nine different tests of reading comprehension (see Table 1). The average corrected correlations corresponding to each test were all significant (ranged from $\bar{r}_c$ = .26-.96).[7] The average corrected correlation for the Nelson–Denny Reading Test ($\bar{r}_c$ = .26) and for the Gray Oral Reading Test ($\bar{r}_c$ = .35) were noticeably lower than the ones obtained for almost all other tests (large parts of the CI did not overlap). The average corrected correlation corresponding to the Neale Analysis of Reading Ability was higher than all the others. Therefore, we examined which features of these assessments contributed to these differences. To do this, we categorized the reading comprehension tasks into nine variables: genre and format of the material to be understood, type of reading comprehension task, information assessed, option of rereading, help provided with decoding, time limit, reading aloud, and whether participant reads the comprehension test items.

Multiple sets of independent correlations were created to analyze the moderator effect of each variable and to be able to contrast the different levels within each. Consequently, 23 new average corrected correlations and their corresponding statistics were calculated (see Table 1). Three variables relating to the procedure of administration were highly correlated (time limit, reading aloud, and reading of the comprehension test items by participants). One reason for this correlation might be that tests for which (a) there is no time limit, (b) the comprehension text is read aloud by the participant, and (c) the assessor reads the comprehension items also typically allow the assessor to provide help with decoding. Therefore, to check the specific influence of these three variables, we removed, just in the contrasts related with them, the correlations for assessments where help could be provided.

In general, whatever the nature of the reading comprehension assessment, it was significantly correlated with decoding and all the average corrected correlations were moderate to high ($\bar{r}_c$s > .37). The only exception was the average corrected correlation obtained with expository material, which was not significant ($\bar{r}_c$ = .30). Only two moderators were found: the genre of the material to be understood and whether or not the text was read aloud by the participant (see Table 1). In a more concrete way, the correlation between decoding and reading comprehension was higher when the material was narrative ($\bar{r}_c$ = .63) or narrative and expositive ($\bar{r}_c$ = .80) than when it was only expository, supporting the earlier study of Best et al. (2008). And the correlation was lower when participants read aloud ($\bar{r}_c$ = .37) than when they read silently ($\bar{r}_c$ = .70).

Interactions Between Readers and Method Used to Assess Decoding and Reading Comprehension

To explore possible interactions between reader and assessment characteristics, we created two different sets of correlations: one with studies conducted with samples up to 10 years and the other with studies conducted with samples older than 10 years. We made this decision post hoc for the following reasons. Age yielded a clear and significant impact on the decoding and reading comprehension correlation (higher than the other variables related to reader features); the 10-year point represented a drop in the strength of the decoding–reading comprehension relationship; and the number of independent average corrected correlations obtained in the two resulting groups (87 for younger, 61 for older) was sufficient to allow further contrasts. All the previous contrasts between the categories related to the assessment of decoding and reading comprehension were repeated separately for younger and older readers. We conducted only those analyses where we had the desired minimum of four correlations per category. Thus, not all moderators could be explored in both age groups.

All the new average corrected correlations were significant (see Table 1) except the correlation corresponding to the measures of lexical decision of older readers.[8] They ranged from .59 to .97 for younger readers (average corrected correlation = .80) and from .22 to .62 for older ones (average corrected correlation = .47). As expected, the correlations for younger readers tended to be higher than those for older readers, regardless of the assessment characteristics.

Slightly different patterns of moderators of the decoding–reading comprehension correlation arose for each group (see Table 1). For younger readers, there were three main moderators. First, for the decoding measures, the correlation with reading comprehension was higher for two of the real word reading accuracy measures (accuracy of word reading and accuracy of word reading in context with fixed time: $\bar{r}_c$ = .90,.80) than for one of the measures of speed of word reading ($\bar{r}_c$ = .65), and the measures of lexical decision ($\bar{r}_c$ = .59); and the first of those measures of reading accuracy additionally had higher correlations with reading comprehension than one of the measures of pseudoword reading ($\bar{r}_c$ = .65). Second, with respect to the option of providing help with the decoding material, the correlation was lower when help was not provided ($\bar{r}_c$ = .75) than when it was ($\bar{r}_c$ = .97). Third, the correlation was also lower when participants read aloud ($\bar{r}_c$ = .47) than when they read silently ($\bar{r}_c$ = .75). Genre of the material could not be explored because there were too few correlations for expository materials.

The pattern of relationships was more stable for older readers, for whom there was only one moderator: the decoding measure. All the measures, except speed of word reading in context ($\bar{r}_c$ = .35) and accuracy of pseudoword reading with fixed time ($\bar{r}_c$ = .31), resulted in higher correlations with reading comprehension than the measures of lexical decision ($\bar{r}_c$ = .34). Accuracy of word reading also yielded higher correlations ($\bar{r}_c$ = .62) than accuracy of pseudoword reading with fixed time ($\bar{r}_c$ = .31). And the average corrected correlation for accuracy of word reading in context with fixed time ($\bar{r}_c$ = .61) also resulted in higher correlations than speed of word reading in context ($\bar{r}_c$ = .35) and accuracy of pseudoword reading ($\bar{r}_c$ = .41).

In sum, for both age groups, pseudoword reading accuracy and lexical decision resulted in lower correlations than a measure of real word reading. Additionally, for younger readers, reading comprehension tests provided help to readers whereas decoding the materials resulted in higher correlations with decoding, and the correlation between decoding and reading comprehension was higher when participants read silently.

Discussion

In this meta-analysis, we examined the relative importance of decoding to reading comprehension and which reader and assessment characteristics moderated the strength of this relationship. In accordance with a wealth of previous research, we found that decoding and reading comprehension were strongly related across all ages. However, the variability in the sample indicated that this relation is moderated by some factors. Our meta-analytic technique revealed the following moderators:

two reader characteristics (age and listening comprehension level), the nature of the decoding assessment, and three characteristics of the reading comprehension assessment (genre of the material to be understood, whether or not help was provided with decoding, and whether or not the text was read aloud by the participant). The moderator effect of characteristics of the reading comprehension assessment was more salient for younger readers. We discuss these findings in relation to the implications for theoretical models of reading and reading development and for the assessment of reading and the diagnosis of reading difficulties.

Reader Characteristics

In support of the SVR, we found that the strength of the decoding–reading comprehension relationship decreased with increasing age. Although this is not always the case (e.g., Cutting & Scarborough, 2006), our finding concurs with a wealth of other research (Curtis, 1980; Francis et al., 2004; Gough et al., 1996; Jenkins & Jewell, 1993; Juel, 1988; Vellutino et al., 2007). Our meta-analysis represented a total of 42,891 readers ranging in age from 5 to 53 years and, therefore, offers strong support for this changing relationship across development.

Two additional findings provide a more detailed picture of the decoding–reading comprehension relationship during development. First, the relation is not linear. There is a point in development, around 10 years, where we found a reduction in the strength of the correlation. The reason for this shift may be related to a change in decoding ability, because other work has shown that 9-year-old English readers are close to developing fluent word reading (Wimmer & Goswami, 1994). As predicted by the SVR, as word reading becomes more fluent and efficient, the variance in reading comprehension by word reading skills will decrease and language comprehension processes will play a more influential role.

The second additional finding of note in relation to the development of decoding–reading comprehension relationship is that we did not identify a point in development when the correlation became negligible. This is in contrast to some other research (e.g., Palmer, MacLeod, Hunt, & Davidson, 1985). However, there are (at least) two strong reasons for why the relationship is evident across the age range. First, better decoders will be able to devote greater cognitive resources to the processes involved in constructing meaning from text, because they have fast and efficient word recognition skills (e.g., Frederiksen & Warren, 1987; Jenkins et al., 2003; Just & Carpenter, 1987; Perfetti, 1985; Walczyk, 2000). This will hold whatever the age range studied. Second, it may also be the case that better comprehenders read more and, through this exposure to print, increase their decoding skills (Stanovich, 1986).

Our data do not allow us to conclude which is the more plausible direction of this relationship, although both positions have empirical support. A key implication of our finding is that it is important to assess both decoding and reading comprehension to obtain an accurate profile of reading ability, whatever the reader's age. It may be the case that features of the particular writing system influence the decoding–reading comprehension relationship. For example, word reading accuracy and fluency take longer to achieve when learning to read in a deep orthography compared with a more shallow one (see Seymour, 2005, for a review). Thus, in general, decoding may have a greater influence on reading comprehension for readers of English than for readers of other languages, as has been shown in recent work (Florit & Cain, 2011), but we note that decoding is influential for shallow languages as well even in good decoders (Sánchez, García, & Gonzalez, 2007).

In addition to age, we examined three reader characteristics, decoding skill, vocabulary knowledge, and listening comprehension level. Only one of these characteristics, listening comprehension, had a moderating effect on the decoding–reading comprehension relationship. In accordance with the SVR, higher listening comprehension scores were associated with lower decoding–reading comprehension correlations. As noted above, the rationale stems from the SVR formula, in which reading comprehension is defined as the product of two components: decoding and language (listening) comprehension (Gough & Tunmer, 1986; Hoover & Gough, 1990).

We did not find the same relationship for vocabulary, despite the fact that vocabulary can be considered an indicator of a general language skill and that some have argued that it should be included in a reformulation of the SVR (e.g., Braze, Tabor, Shankweiler, & Mencl, 2007). The absence of an influence of vocabulary level may have arisen through its effect on reading comprehension directly and also indirectly through word recognition (Protopapas et al., 2013). If vocabulary knowledge influences both decoding and reading comprehension, it may not modify the strength of the relation between the two. Another possibility is that simple measures of vocabulary knowledge are less predictive of early reading comprehension than measures of more complex oral language (National Early Reading Panel, 2008). We note, however, the paucity of studies that included measures of vocabulary and how this variable was introduced in the meta-regression (as the percentage of success in the vocabulary test: the same concern is also valid to the results related to listening comprehension).

Against our expectations and some previous argument (Ashbaker & Swanson, 1996; Curtis, 1980; Keenan et al., 2008; Swanson & Berninger, 1995), the decoding and reading comprehension relationship was not higher when it was calculated with poor decoders. However, this finding concurs with our finding that the relation between these two component skills remains significant across age groups. Additionally, the studies included in the meta-analysis did not allow us to create two groups of maximum contrast (poor decoders vs. good decoders), which is needed to explore better this hypothetical moderator.

Assessment Characteristics

We now turn to a consideration of assessment characteristics. The most consistent moderator was the way that decoding was measured, which influenced the strength of the decoding–reading comprehension relationship regardless of age. Critically, we found that decoding accuracy of real words was more predictive of reading comprehension than other measures, such as measures of speed, pseudoword reading, and lexical decision. These results are supported by other recent work (Florit & Cain, 2011; Johnston & Kirby, 2006; Protopapas, Simos, Sideridis, & Mouzaki, 2012; Savage, 2001, 2006) and have important implications for the assessment of reading ability and also our theoretical models of reading.

Gough and Tunmer (1986) suggested that nonword decoding is the most appropriate measure of decoding for beginner readers. We do not argue against the validity of measures of pseudoword reading; they are, indeed, significantly related to reading comprehension (specially measures of phonetic decoding efficiency such as accuracy of pseudowords reading with fixed time) and provide important information about the decoding skills that are essential for readers of alphabetic orthographies. However, it is clear that measures of real word reading and pseudoword reading are not interchangeable, a fact that should be borne in mind when selecting reading ability assessments and diagnosing reading difficulties. Our data suggest that a measure of pseudoword reading might underestimate the influence of decoding on reading comprehension.

Readers with different core weaknesses (word reading or reading comprehension) are predicted by the SVR and their existence has been confirmed in a wealth of studies (Cain et al., 2000; Nation & Snowling, 1998). It is important that intervention targets the source of a weakness. A child who has comprehension problems because of weak word reading skills may benefit more from an intervention that targets word recognition rather than comprehension skills. Thus, we recommend that measures of decoding include both real and pseudowords, so that the precise nature of reading ability difficulties is identified.

In general, we found that word reading accuracy is a better predictor of reading comprehension than speed of word reading. This finding poses a challenge to our theoretical understanding of the decoding–reading comprehension relationship. A widely held belief is that faster word reading is associated with better comprehension, because more skilled word reading has greater cognitive resources available for higher level comprehension processes (e.g., Perfetti, 1985). But in relation to comprehension, access to the semantic as well as the phonological form is critical (Perfetti, 2007), and this aspect of word recognition may not be best captured by speeded measures of word reading.

Three characteristics of the reading comprehension assessment influenced the strength of the decoding–reading comprehension correlation. Genre was one. For the sample as a whole, the correlation was higher when the reading comprehension comprised narrative texts than when expository was used. This pattern converges with the data reported by Best et al. (2008), who found that decoding was more strongly predictive of comprehension of narrative texts than expository texts. Best et al.'s proposal was that, when readers have sufficient prior knowledge to understand a text, other abilities, such as decoding and vocabulary, are more influential on comprehension. Our analysis points to a need for educators and assessors to use a broad range of materials to assess comprehension that encompass a range of text structures to understand better a child's reading comprehension ability (see Williams, 2005, for elaboration on this point).

There were two unexpected findings in relation to the characteristics of the reading comprehension assessments, especially for younger readers. First, comprehension assessments that allowed the assessor to provide help with decoding were more strongly related to decoding performance than those in which help was not provided, although both correlations were strong ($\bar{r}_c$s > .74). When an assessor provides help to read incorrectly words, they ensure that the child has either read or had read to them all the words in the text. For that reason one might predict that the decoding–reading comprehension correlation would be reduced relative to assessments in which help was not provided, but this was not the case. One possibility is that, when the assessor provides help, the reader's comprehension is disrupted. As a result, the decoding–reading comprehension relationship is strengthened.

The second finding that warrants discussion was that reading comprehension assessments that involved silent reading were more strongly associated with decoding than those that required the text to be read aloud. Assessments that involve silent reading do not allow for a cutoff point when a child's decoding level has been reached within the item set. Thus, the decoding–reading comprehension correlation may be greater when this assessment procedure is used because, for some children, there will be many more comprehension items that exceed their decoding level.

However, it should be noted in relation to both of these points that these different procedures are used for different assessment tools that also differ in terms of materials and format, so other sources of influence on the decoding–reading comprehension are possible. In fact, 6 of the 10 correlations for the reading aloud measures for the whole sample, and 3 of the 6 correlations for the reading aloud measures for younger readers, were obtained from studies that used the Gray Oral Reading Test to assess reading comprehension. This test has a degree of dissociation between decoding and reading comprehension because it contains many passage-independent comprehension questions (Keenan & Betjemann, 2006) and, consequently, its average corrected correlation is one of the lowest: .35 (see Table 1). What is clear is that the procedures used in the reading comprehension assessment may influence the degree to which reading comprehension is dependent on an individual's decoding level and this should be considered when designing future reading comprehension assessments.

All the other variables related to the reading comprehension measure (format of the comprehension materials, type of reading comprehension task, information assessed, option of rereading, time limit, and whether participants read test items or not) did not moderate the correlation between decoding and reading comprehension. This result indicates that the relationship between decoding and reading comprehension is quite robust and reinforces the relevance of the moderators already found. But we cannot rule out the possibility that the interaction between other variables might influence the relationship, for example, the decoding measure and nature of the information assessed.

Limitations and Conclusion

Our conclusions came from the combined results of 110 studies conducted with more than 42,000 readers. Despite the scale of our literature search and the final sample size for our study, we have noted the following limitations: the lack of distinct groups of word readers; the small number of studies reporting listening comprehension and vocabulary; and the nature of the reading comprehension assessments in terms of key characteristics interconnected. Such factors prevented us from fully exploring the nature of the decoding–reading comprehension in relation to the potential moderators. In addition, only peer-reviewed journals articles were included in the search, which means that publication bias is not ruled out. Although, as we stated earlier, we do not believe that our findings are unduly biased in this way (because many of the studies included in our meta-analysis were not designed to test the questions set out here), this can be considered as a limitation of this meta-analysis (Glass et al., 1981; Macaskill, Walter, & Irwing, 2001; Rosenthal, 1995).

To summarize, this meta-analysis has confirmed that decoding and reading comprehension are related from childhood to adulthood in readers of English, although there is a point early in reading development where the strength of the relationship undergoes a significant change. This result confirms the relevance of instruction in both decoding and language comprehension in the classroom, even with adolescent readers. Nevertheless, our analysis has also shown that variables associated with the assessment of decoding and reading comprehension will also influence the strength of the relation. Critically, for our assessment of reading ability, the influence of the moderators associated with the procedure of assessing reading comprehension (providing help with the decoding of the material and asking the participant to read aloud or not) was restricted to young readers. On the contrary, the influence of the genre was only found for the whole sample of studies (before splitting by age). An accurate assessment of reading ability is necessary to diagnose reading difficulties early and to inform instruction and intervention. Our analysis strongly suggests that the nature of the assessment may influence the reading profile obtained. Thus, to get a good picture, it is important to combine different measures of decoding and different materials and procedures to assess reading comprehension.

Notes

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[1]The studies randomly selected did not provide sufficient information to calculate the kappa value in the coding of the listening and the vocabulary level, the genre of the material to be understood, the time limit, and the option of rereading. The reason for the low kappa for some codes is the specificity of information provided in articles. For example, not all studies provided mean ages, but instead reported the grade of the sample.

[2]The population standard deviation was obtained from the relevant manual of the test used to assess decoding and reading comprehension or from other studies conducted with the same measures and with a same age sample without range restrictions. To correct Savage's (2001) correlations from a sample of teenagers, we employed as reference standard deviation the reported value in the Neale manual for the oldest group included in the standardization (between 12:00 and 12:11).

[3]We have established these criteria to conclude that there are differences between categories after reviewing other meta-analyses. Su and Reeve (2011), for instances, consign the presence of a moderator even when the nonoverlapping part of two CIs is slightly smaller than the overlapping one.

[4]Eight studies were excluded from the meta-regression (Acheson, Wells, & MacDonald, 2008; Arnell et al., 2009; Bell & Perfetti, 1994; Kuperman & VanDyket,

2011; Mellard, Woods, & Desa, 2012; Vadasy & Sanders, 2008; Weems & Zaidel, 2004; Welcome et al., 2009) because they did not provide the exact age of participants. The study from Vadasy and Sanders, conducted with children, had to be also excluded from the next categorical analysis for the same reason.

[5]Other ways of dividing up the age groups resulted in the same pattern of findings.

[6]The inferior limit of the CI for accuracy of word reading in context was −.01, and therefore, the 0 value for this correlation was unlikely.

[7]The lower limit of the CI for the Nelson–Denny Reading Test was −.01, and therefore, the 0 value for this correlation was unlikely.

[8]The lower limit of the CIs for the category of older readers reading expository materials and for the category of older readers reading test items by themselves were −.01 and −.00, respectively. Therefore, the 0 value for these correlations was unlikely.

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Authors

J. RICARDO GARCÍA teaches educational psychology and learning disabilities in the Department of Developmental and Educational Psychology at the University of Salamanca (Spain); e-mail: jrgarcia@usal.es. His research interests include reading comprehension development, educational consultation, and analysis of educational practice.

KATE CAIN is a reader in language and cognitive development in the Department of Psychology at Lancaster University (the United Kingdom). Her research focuses on typical and atypical language and literacy development.