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Decoding and reading comprehension in English: a meta-analysis to identify which reader and assessment characteristics influence the strength of the relationship

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Decoding and reading comprehension in English: a meta-analysis to identify which

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DECODING AND READING COMPREHENSION: A META-ANALYSIS   2

Abstract

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 arose as the

strongest moderators. We discuss the implications for assessment and the diagnosis of

reading difficulties.

Key words: decoding, reading comprehension, reading development, reading skill, word

recognition

DECODING AND READING COMPREHENSION: A META-ANALYSIS   3

Decoding and Reading Comprehension: a Meta-Analysis to Identify which Reader and

Assessment Characteristics Influence the Strength of the Relationship

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 additional to 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 ability (i.e., 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 paper, 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 dyslexia and those with specific reading and listening

comprehension difficulties) and has influenced the development of the reading

curriculum in the UK (e.g. Stuart, Stainthorp, & Snowling, 2008) and investigations into

the genetic basis of reading ability (Keenan, Betjemann, Wadsworth, DeFries, & Olson,

2006). For those 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

DECODING AND READING COMPREHENSION: A META-ANALYSIS   4

of variance in reading comprehension accounted for by different measures of decoding

(Cutting & Scarborough, 2006; Keenan, Betjemann, & Olson, 2008). Whilst some

studies find that the contribution of decoding to reading comprehension is negligible,

with R^2 values in the region of .0001 or .0005 (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 (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 paper, 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 the readers and characteristics of

the assessments (of both word reading and reading comprehension). A table of these

influences is available online.

Reader Characteristics

      One hypothesis is that reading comprehension will be more greatly constrained

by word reading ability in young readers than in older ones. Gough et al. (1996) reached

this conclusion in their review of ten studies that reported correlations between 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 $r = .83$ ($R^2 = .68$) and which 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, Betjemann and Olson (2008) have also shown that decoding

makes a larger contribution to reading comprehension for younger than for older

readers. However, there are also studies where, despite a wide age range and, therefore,

range of reading level, age does not influence the relative contribution of decoding to reading comprehension (see, for example, Cutting & Scarborough, 2006).

Longitudinal studies can shed a 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 (Abbott, Berninger, & Fayol, 2010; Burgoyne, Whiteley, & Hutchinson, 2011; Deacon & Kirby, 2004; Juel, 1988; Kim, Wagner, & Foster, 2011; Kim, Wagner, & Lopez, 2012) whilst in others, the correlations at the first and last time points are similar in magnitude (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 the other reader (that is not age) 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: for example, $R^2 = .49$ (Blackmore & Pratt, 1997) vs $R^2 = .79$ (Rupley & Willson, 1997) in 6-year-olds, $R^2 = .13$ (Manis et al., 1999) vs $R^2 = .92$ (Katzir et al., 2006) in 7-year-olds, or $R^2 = .05$ (Cain et al., 2004; Oakhill et al., 2003) vs $R^2 = .80$ (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.

DECODING AND READING COMPREHENSION: A META-ANALYSIS   6

A second reader-related factor that might influence the strength of the relation

between word reading and reading comprehension is the type of reader, that is the level

of their 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 good ones. 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 but poor word reading skills

might be able to support (or compensate) their reading comprehension, 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).

Knowledge of word meanings (vocabulary) is 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 group. In fact, not all

DECODING AND READING COMPREHENSION: A META-ANALYSIS   7

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, as anticipated only a small number of the studies that

met our inclusion criteria included measures of listening comprehension and/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 argue 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. One study that did use the same

methods of assessment for different genres found 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

(Best, Floyd, & McNamara, 2008). For expository text, world knowledge was a far

better predictor of reading comprehension than decoding skill.

Not only genre, but also format (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 employed, with stronger

relations evident when the comprehension measure had a sentence cloze format

compared to 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

DECODING AND READING COMPREHENSION: A META-ANALYSIS   9

a passage is not accurately decoded, subsequent information in the passage may help to

resolve its identity.

Task and nature of the reading comprehension assessment. 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 due to 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 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, the

textbase or the situation model (Graesser et al., 1997; Kintsch, 1994; Kintsch, 1998; van

Dijk & Kintsch, 1983). Literal questions require recall or paraphrase of information

DECODING AND READING COMPREHENSION: A META-ANALYSIS   10

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, 1989, 1997), allow the assessor to correct

word reading errors: thus, all of the words in the passage will have been properly read

by the child, or read out 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 explicitly encourage participants to re-read 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, e.g., 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 (help with decoding, no time

limit, re-reading allowed, silent reading of the passage, and reading of the questions by

DECODING AND READING COMPREHENSION: A META-ANALYSIS   11

the examiner), 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. A

summary of the relation to be explored and their predicted influence in the decoding and

reading comprehension relationship is available online

Rationale for this Meta-Analysis

We have outlined a range of factors that might influence the strength of the

relation 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 re-reading 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 of these factors in a single study. The solution adopted here is to

conduct a quantitative or statistical 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:

1. 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

DECODING AND READING COMPREHENSION: A META-ANALYSIS   12

understand more fully how it constrains reading comprehension at different points in

development and in different types of reader.

2. How does each of the two groups of factor (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 subsidiary 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 they 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 key words related to decoding (decoding, non word reading, pseudoword

reading, reading ability[1], word reading) and to reading comprehension (reading

comprehension[1], reading skill[1]). Initially, the search was limited, as in other meta-

analysis (e.g., van Steensel, McElvany, Kurvers, & Herppich, 2011), to 20 years 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 key words yielded a total of 4494 papers from PsycInfo and 903 from

ERIC. After removing repeated papers, the number dropped down to 2489.

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-

DECODING AND READING COMPREHENSION: A META-ANALYSIS   13

Kranenburg, & van IJzendoorn, 2007; Ehri, Nunes, Stahl, & Willows, 2001; van

Steensel et al., 2011). There are concerns about this procedure because of "publication

bias" (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 papers, because

authors may be investigating different hypotheses - for or against a strong relationship

between decoding and reading comprehension - and not all of the papers that report

correlations between these variables are directly studying their relation.

Inclusion Criteria

The abstracts of the 2489 articles was reviewed to discard: opinion and non

empirical papers, single case studies, studies not related to text reading or dealing with

teachers and/or parents (not with readers), and studies conducted with special

populations (people with brain lesions, deafness, autism, mental retardation, ADHD and

so forth). If the information about these issues was not provided in the abstract it was

looked inside the full text. 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 1288 papers were discarded after the abstract revision

because they were opinion pieces and non-empirical papers, single case studies, studies

not related to text reading, studies that focused on teachers or parents (not readers) -and,

therefore, did not assess the variables of interest-, and studies conducted with special

populations. The full text of the remaining papers was obtained and closely reviewed (a

DECODING AND READING COMPREHENSION: A META-ANALYSIS   14

total of 1197 papers because four could not be found) by using, in a hierarchical way,

the specific criteria described below (the specific reasons of excluding each individual

paper can be provided by contacting the first author).

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 met at least one of the following 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

due to 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 (for example, 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 and, in a

DECODING AND READING COMPREHENSION: A META-ANALYSIS   15

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

their correlation had to be taken at the same time point and in the same age group of

readers (that is all of 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 (over 16 years old) 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 due to 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 (regression

coefficient). Two hundred and seven studies of the remaining studies did not offer any

of these data.

A total of 110 studies met all the inclusion criteria. Although many potential

studies were excluded for the reasons outlined above, the total number of studies is

substantial compared to other meta-analyses.

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 eighteen (Arnell, Joanisse, Klein, Busseri, & Tannock, 2009; Benjamin &

DECODING AND READING COMPREHENSION: A META-ANALYSIS   16

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 paper, the data were coded only once: e.g., Cain et al. (2004), Oakhill et al. (2003),

and Cain and Oakhill, (2011); Hecht, Burgess, Torgesen, Wagner, & Rashotte, (2000)

and Torgesen et al. (1997); Chen & Vellutino, (1997) and Vellutino et al. (2007); Kim

et al. (2011) and Kim et al. (2012); Kirby, Ball, Geier, Parrila, & Wade-Woolley, (2011)

and Kirby et al. (2012); McCutchen & Logan, (2011) and McCutchen, Logan, &

Biangardi-Orpe, (2009). In the case of longitudinal studies, the coded correlations

corresponded to only the youngest age group, because this group always had the largest

N. 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. A full list of

variables and categories is available online (see also Table 1, which includes these). 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.

Interrater Reliability

Variables and categories were discussed until a consensus between the two

authors was reached. Then, they and a third coder each employed the coding system

with 5 papers of 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. In order to establish the

intercoder reliability another judge independently coded ten 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[2].

Overview of Studies

The 110 studies included in the meta-analysis represent a total of 42916

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 modelling, regression equations, factor analysis, latent variable

studies, etc. Several studies also made group comparisons (29). There were some

DECODING AND READING COMPREHENSION: A META-ANALYSIS   18

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 an online summary.

Meta-Analytic Procedures

The effect size index (*ES*) used for all outcome measures was Pearson's *r*, the

correlation between decoding and reading comprehension. Three outliers (three

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, & Leonard, 2009) leaving a total 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 recommendations (2004). We

conducted a two-step meta-analysis (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[3]. This first

meta-analysis produced a partially corrected mean and variance. In a second step the

methods of artefact 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 KR-20 coefficient ("parallel forms reliability") because the

delayed parallel forms reliability was rarely available in the studies and test manuals.

DECODING AND READING COMPREHENSION: A META-ANALYSIS 19

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 significant. From the

total pool of correlations, a set of 144 independent correlations was created with only

one correlation per sample. 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. 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 variables (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 ($100*S^2_{ec}/$

S^2_{rc}) and the 95% confidence intervals for the average corrected correlation, using also

Hunter and Schmidt (2004)'s formulas.

The average corrected correlation ($\bar{r}_c$ = .74) was sizeable (Cohen, 1988) and

significant: 95% CI [.36, 1.0]. The percentage variance of the overall effect analysis

explained by sampling error was 3.15%, which failed the 75% rule of Hunter and

Schmidt (2004). It means that the pool of effect sizes is heterogeneous and that 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, from the total of 647 correlations, the ones more

suitable according to the categories for each moderator. 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/sample in each subgroup. When there were fewer than four correlations in a group

DECODING AND READING COMPREHENSION: A META-ANALYSIS   21

the category was excluded from the analysis, because four is the minimum number of

effect sizes required to conduct statistical 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

confidence intervals 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 confidence

intervals 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 confidence intervals is less than the non-overlapping

part[4], and the confidence interval of the highest correlation overlapped only the upper

level of the confidence interval of the other category, and/or one of the confidence

intervals 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 confidence intervals), 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

DECODING AND READING COMPREHENSION: A META-ANALYSIS   22

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[5]. 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[6]. 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 $\overline{r_c}$ = .74 - .86 for the four youngest groups to $\overline{r_c}$ =

.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,

6 of the 7 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. In order to establish if reader type moderated the

strength of the association between decoding and reading comprehension, the

DECODING AND READING COMPREHENSION: A META-ANALYSIS   23

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: $\overline{r}_c = .64$; unselected

readers: $\overline{r}_c = .76$; and average decoders: $\overline{r}_c = .60$). 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 confidence intervals.

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 (that is, 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)[7]. Each category of decoding measure yielded a significant correlation between decoding and reading comprehension ($\bar{r}_c$s = .48-.86), except lexical decision ($\bar{r}_c$ = .39)[8] which correlation could be considered significant lower than all the others except accuracy of word reading in context. Additionally, differences between other two pairs of categories were apparent: large parts of the confidence intervals 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 contrast 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 to .96)[9]. 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 one obtained for almost all

other tests (large parts of the confidence interval did not overlap with the others). 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 categorised 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 re-

reading, 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 there is no time limit, where the comprehension text is read aloud by the

participant, and where the assessor reads the comprehension items also typically allow

the assessor to provide help with decoding. Therefore, to check the specific influence of

DECODING AND READING COMPREHENSION: A META-ANALYSIS   26

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 of 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

moderatos were found: the genre of the material to be understood and whether or not the

text was reading 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

old. We made this decision posthoc 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 of 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 of the new average corrected correlations were significant (see Table 1)

except the correlation corresponded to the measures of lexical decision of older

readers[10]. 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 showed higher correlation 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 showed also higher correlation ($\bar{r}_c$ = .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) resulted also in higher correlation 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 that provided help to readers while 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 also 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 reading aloud by the participant). The moderator effect of characteristics of the reading comprehension assessment was more

DECODING AND READING COMPREHENSION: A META-ANALYSIS   29

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.

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 42891

readers ranging in age from 5 to 53 years old 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 critical change in the

strength of the correlation, which was a reduction in strength. 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

DECODING AND READING COMPREHENSION: A META-ANALYSIS   30

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 to 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 (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).

DECODING AND READING COMPREHENSION: A META-ANALYSIS   31

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 Simple View of Reading

(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 (NELP, 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.

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

DECODING AND READING COMPREHENSION: A META-ANALYSIS   32

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). They have important implications for the assessment of reading

ability and also our theoretical models of reading.

Gough and Tunmer (1986) suggest that non-word 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 like

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 (or is designed to compensate) 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 have 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 were 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

DECODING AND READING COMPREHENSION: A META-ANALYSIS   34

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 of 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 cut-off 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, six of the ten correlations for the reading aloud

measures for the whole sample, and three of the six correlations for the reading aloud

measures for younger readers, were obtained from studies that used the Gray Oral

Reading Test to assess reading comprehension. As we noted in the introduction, 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

DECODING AND READING COMPREHENSION: A META-ANALYSIS   35

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 re-reading, 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.

Our conclusions came from the combined results of 110 studies conducted with

a total of 42891 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 and other language also

restricted the hypotheses we could explore; and the nature of the reading comprehension

assessments in terms of key characteristics were confounded, in part, because some

related to just one or two measures. 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 a "publication bias" is not completely discarded. 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)

DECODING AND READING COMPREHENSION: A META-ANALYSIS   36

          To summarise, 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.

DECODING AND READING COMPREHENSION: A META-ANALYSIS   37

Footnotes

[1] The words appear in the Thesaurus.

[2] The studies randomly selected did not provided 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 papers. For example, not all studies provided mean ages, but instead reported the grade of the sample.

[3] 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).

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

[5] 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.

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

DECODING AND READING COMPREHENSION: A META-ANALYSIS   38

[7] There were not enough correlations obtained with speed of pseudoword reading to

calculate the average corrected correlation and perform the contrasts.

[8] The inferior limit of the confidence interval for accuracy of word reading in context

was -.01 and, therefore, the 0 value for this correlation was unlikely.

[9] The inferior limit of the confidence interval for the Nelson-Denny Reading Test was -

.01 and, therefore, the 0 value for this correlation was unlikely.

[10] The inferior limit of the confidence intervals 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. Therefore, the 0 value for these correlations was

unlikely.

DECODING AND READING COMPREHENSION: A META-ANALYSIS   39

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Table 1. Meta-Analytic Results

	k^1	n	$\bar{r}_c$	S^2_{rc}	S^2_{ec}	$100 * (S^2_{ec}/S^2_{rc})$	95%CI	Differences between subgroups
Main average corrected correlation	144	42891	.74*	.0381	.0010	3.15%	.36,1.0	
Reader characteristics								
Hypothetical categorical moderators	k^1	n	$\bar{r}_c$	S^2_{rc}	S^2_{ec}	$100 * (S^2_{ec}/S^2_{rc})$	95%CI	Differences between subgroups
Age								
a) Younger than 7	15	17922	.74*	.0021	.0002	9.73%	.65,.83	a > f, g
b) Between 7 and 8[2]	31	4667	.83*	.1024	.0016	12.96%	.62,1.0	b > f, g
c) Between 8 and 9	27	4802	.74*	.0241	.0018	7.78%	.44,1.0	c > f, g
d) Between 9 and 10	25	10982	.86*	.0314	.0004	1.27%	.52,1.0	d > g
e) Between 10 and 12	20	2245	.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	4086	.41*	.0371	.0054	18.22%	.03,.78	
Type of reader								
a) Poor decoders	22	3127	.64*	.0663	.0036	6.02%	.13,1.0	
b) Unselected	99	37430	.76*	.0340	.0007	2.54%	.40,1.0	
c) Average decoders	11	548	.60*	.0405	.0125	27.71%	.20,.99	
Hypothetical continuous moderators	k^1	n	R^2	*Beta*	95%CI			
Age	158	70483	.25*	-.50	-.02,-.01			
Listening comprehension level	10	1140	.40*	-.63	-.02,.00			
Vocabulary level	20	3701	.20	-.44	-.01,.00			
Method used to assess decoding and reading comprehension								
Hypothetical categorical moderators	k^1	n	$\bar{r}_c$	S^2_{rc}	S^2_{ec}	$100 * (S^2_{ec}/S^2_{rc})$	95%CI	Differences between subgroups
Decoding measure								
a) Accuracy of word reading (in a list)	53	13720	.86*	.0249	.0037	14.52%	.55,1.0	**a > d, i**
b) Speed of word reading (in a list)	8	1217	.65*	.0141	.0036	24.11%	.42,.89	**b > i**

c) Accuracy of word reading in context	18	1410	.62*	.1012	.0085	9.99%	-.01,1.0	**d > i**
d) Speed of word reading in context	20	1917	.48*	.0489	.0075	16.25%	.05,.91	**e > i**
e) Accuracy of single word reading (fixed time)	47	7912	.69*	.0557	.0023	4.64%	.23,1.0	**f > g, i**
								g > i
f) Accuracy of word reading in context (fixed time)	34	21960	.79*	.0087	.0004	4.25%	.61,.97	**h > i**
g) Accuracy of pseudoword reading	63	7537	.56*	.0412	.0048	12.58%	.16,.96	
h) Accuracy of pseudoword reading (fixed time)	24	20722	.66*	.0143	.0005	4.19%	.42,.89	
i) Lexical decision	16	2515	.39	.0661	.0055	10.26%	-.11,.90	
Reading comprehension test								
a) Gates-MacGinitie Reading Tests	18	1862	.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	8688	.96*	.0156	.0001	1.17%	.71,1.0	e > b, d
d) Nelson–Denny Reading Test	8	1953	.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
								i > d
f) Stanford Achievement Test	6	16810	.75*	.0027	.0001	4.93%	.65,.85	j > b, d
g) Spache Diagnostic Reading Scales	4	460	.62*	.0413	.0036	8.74%	.22,1.0	
h) Wechsler Individual Achievement Test	13	2843	.73*	.0163	.0013	8.59%	.48,.98	
i) Woodcock-Johnson	11	2938	.72*	.0389	.0012	3.59%	.34,1.0	
j) Woodcock Reading Mastery Test	32	3376	.77*	.0270	.0025	9.80%	.45,1.0	
Genre of the material								
a) Narrative	17	1313	.63*	.0311	.0064	18.94%	.29,.98	**a > b**
b) Expository	13	2217	.30	.0287	.0052	20.08%	-.03,.64	**c > b**
c) Narrative and expository	80	22056	.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	6042	.74*	.0339	.0022	7.14%	.38,1.0	
c) Paragraphs or passages	97	35782	.75*	.0380	.0008	2.63%	.37,1.0	
Type of reading comprehension task								
a) Multiple choice task	66	26034	.70*	.0321	.0010	3.87%	.35,1.0	
b) Cloze task	34	3736	.76*	.0275	.0026	9.96%	.43,1.0	
c) Open-ended questions	42	12788	.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	4808	.73*	.0364	.0035	10.03%	.35,1.0	
b) Inferential	15	3517	.80*	.0374	.0015	4.26%	.42,1.0	
c) Literal and inferential	91	35148	.76*	.0381	.0008	2.50%	.38,1.0	
Help provided with decoding the reading comprehension material								
a) Yes	17	8748	.95*	.0172	.0002	1.25%	.69,1.0	
b) No	121	32698	.69*	.0294	.0014	5.42%	.36,1.0	
Time limit								
a) Yes	49	9482	.63*	.0553	.0027	6.08%	.17,1.0	
b) No	83	23936	.71*	.0174	.0011	7.22%	.45,.97	
Option of re-reading								
a) Yes	92	35676	.76*	.0371	.0008	2.48%	.38,1.0	
b) No	48	5953	.69*	.0405	.0031	8.32%	.30,1.0	
Reading aloud								
a) Yes	10	858	.37*	.0299	.0021	24.03%	.05,.72	b > a
b) No	104	29447	.70*	.0293	.0014	5.28%	.36,1.0	
Participant reads test items (e.g. questions)								
a) Yes	80	10109	.63*	.0675	.0040	6.86%	.13,1.0	
b) No	16	1418	.63*	.0305	.0052	16.03%	.29,.97	

	k^1	n	$\bar{r}_c$	S^2_{rc}	S^2_{ec}	$100*$ (S^2_{ec}/S^2_{rc})	95%CI	Differences between subgroups
Interaction between reader age and method used to assess decoding and reading comprehension								
Average corrected correlations								
a) Younger (up to 10)	87	36361	.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 x hypothetical categorical moderators	k^1	n	$\bar{r}_c$	S^2_{rc}	S^2_{ec}	$100*$ (S^2_{ec}/S^2_{rc})	95%CI	**Differences between subgroups**
Age x Decoding measure								
a) Younger: Accuracy of word reading (in a list)	32	11510	.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	2210	.62*	.0224	.0045	19.09%	.33,.92	**b** > o, **q**
c) Younger: Speed of word reading (in a list)	7	1004	.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**
g) Older: Speed of word reading in context	11	1010	.35*	.0253	.0083	29.62%	.04,.66	**h** > **q**
h) Younger: Accuracy of single word reading (fixed time)	29	5677	.75*	.0528	.0016	3.33%	.30,1.0	**i** > **q**
i) Older: Accuracy of single word reading (fixed time)	16	2419	.57*	.0380	.0035	9.77%	.19,.96	**j** > b, e, f, **g**, i, k, **m**, **o**, p, **q**
j) Younger: Accuracy of word reading	24	19990	.80*	.0053	.0003	4.95%	.66,.95	**k** > g, m, **o**, **q**
								l > **q**
								m > **q**
								n > e, g, m, **o**, **q**
								p > o, **q**

in context (fixed time)								
k) Older: Accuracy of word reading in context (fixed time)	10	1970	.61*	.0048	.0027	27.46%	.47,.75	
l) Younger: Accuracy of pseudoword reading	35	4813	.65*	.0341	.0034	10.76%	.29,1.0	
m) Older: Accuracy of pseudoword reading	28	2724	.41*	.0113	.0077	45.39%	.20,.62	
n) Younger: Accuracy of pseudoword reading (fixed time)	15	19079	.68*	.0037	.0003	8.59%	.56,.80	
o) Older: Accuracy of pseudoword reading (fixed time)	9	1643	.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	1915	.34	.0631	.0040	8.40%	-.15,.84	
Age x 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	2061	.27*	.0213	.0048	22.89%	-.01,.56	
d) Younger: Narrative and expository	57	19711	.85*	.0241	-.0003	-1.74%	.54,1.0	
e) Older: Narrative and expository	23	2345	.46*	.0179	.0065	28.91%	.19,.72	
Age x 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	4810	.82*	.0116	.0012	10.44%	.61,1.0	d > a, c, e
c) Older: Sentences and paragraphs	18	1751	.54*	.0208	.0063	27.12%	.25,.82	
d) Younger: Paragraphs or passages	57	31084	.80*	.0152	.0004	2.98%	.55,1.0	
e) Older: Paragraphs or passages	41	4738	.42*	.0417	.0065	17.04%	.02,.82	
Age x Type of reading comprehension task								
a) Younger: Multiple choice task	35	21419	.75*	.0076	.0005	6.58%	.58,.92	a > b, f
b) Older: Multiple choice task	31	4615	.40*	.0312	.0052	17.90%	.05,.74	c > b, d, f

	k	N	r			%	CI	Contrast
c) Younger: Cloze task	23	3083	.82*	.0093	.0015	15.53%	.64,1.0	e > b, d, f
d) Older: Cloze task	14	1172	.60*	.0216	.0063	26.67%	.31,.89	
e) Younger: Open-ended questions	29	11920	.90*	.0190	.0004	1.76%	.62,1.0	
f) Older: Open-ended questions	13	868	.45*	.0280	.0094	27.72%	.12,.78	
Age x Information assessed								
a) Younger: Literal	30	3747	.80*	.0150	.0020	13.13%	.56,1.0	a > d, f
b) Older: Literal	22	1580	.58*	.0386	.0077	19.93%	.20,.97	c > b, d, f
c) Younger: Inferential	11	2675	.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	30687	.80*	.0148	.0004	2.82%	.56,1.0	
f) Older: Literal and inferential	38	4501	.41*	.0365	.0065	19.26%	.04,.79	
Age x Help provided with decoding the reading comprehension material								a > b, c, d
a) Younger: With help	13	8560	.97*	.0097	.0001	1.59%	.77,1.0	c > b, d
b) Older: With help	4	188	.49*	.0454	.0084	18.84%	.07,.90	
c) Younger: Without help	71	26972	.75*	.0082	.0008	9.25%	.57,.92	
d) Older: Without help	53	6245	.44*	.0390	.0061	16.43%	.06,.84	
Age x Time limit								
a) Younger: Time limit	28	6495	.73*	.0165	.0016	9.77%	.48,.98	a > b
b) Older: Time limit	21	2987	.37*	.0348	.0057	17.76%	.01,.74	c > b, d
c) Younger: No time limit	50	20931	.74*	.0065	.0006	10.47%	.59,.90	
d) Older: No time limit	36	3524	.52*	.0314	.0064	19.90%	.17,.87	
Age x Option of re-reading								
a) Younger: Option of re-reading	54	30771	.80*	.0157	.0004	2.90%	.56,1.0	a > b, d
b) Older: Option of re-reading	38	4905	.42*	.0348	.0057	17.15%	.05,.79	c > b
c) Younger: No option of re-reading	30	4859	.77*	.0178	.0018	10.36%	.50,1.0	
d) Older: No option of re-reading	21	1613	.51*	.0427	.0085	20.06%	.10,.91	
Age x 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	24100	.75*	.0072	.0007	9.14%	.58,.92
d) Older: No reading aloud	50	5866	.45*	.0377	.0061	17.12%	.07,.84
Age x Participant reads test items (e.g. questions)								a > b
a) Younger: Reading test items	46	6796	.76*	.0274	.0022	8.55%	.44,1.0	c > b, d
b) Older: Reading test items	37	3832	.42*	.0469	.0074	17.07%	-.00,.84
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

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

[1] K: number of independent correlations included to calculate each combined correlation.

[2] 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.

Online supplemental table 1. Some of the factors might influence the strength of the relation between decoding and reading comprehension and the predicted relationship

Potential moderators	Predicted influence of each moderator on the decoding and reading comprehension relationship	
	Weaker relationship	*Stronger relationship*
Reader characteristics		
Age	Old readers	Young readers
Decoding competence	Good readers	Poor readers
Listening comprehension and vocabulary	Good level of listening comprehension and vocabulary	Poor level of listening comprehension and vocabulary
Methods used to assess decoding and reading comprehension		
Decoding		
	Measures with low semantic content (e.g. pseudowords reading)	Measures with high semantic content (e.g. text reading)
Comprehension		
Genre of the material	Expository	Narrative
Format of the material	Paragraphs or passages	Sentences
Type of task	Multiple-choice tasks, cued recall, open ended questions	Sentence cloze, free recall
Nature of information assessed	Inferential	Literal
Help provided with decoding	Examiner corrects decoding mistakes	Examiner does not correct decoding mistakes
Time limit	No time limit	Time limit
Option of reviewing	Can review text	Cannot review text
Reading aloud	No	Yes
Participant reads test items	No	Yes

Online supplemental table 2. Coding system for individual studies

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Reader characteristics

1.1) Age (average in years in the decimal system: e.g. 8.70)

1.2) Type of reader according to their word reading skill
   a) Poor decoders
   b) Unselected
   c) Average decoders

1.3) Listening comprehension level (percentage of success on the listening comprehension task, where available. If more than one task was used the average percentage was obtained and coded, where available).

1.4) Vocabulary level (percentage of success in the vocabulary knowledge task, where available employed).

Method used to assess decoding and reading comprehension

2.1) Decoding measure
   a) Accuracy of word reading (in a list)
   b) Speed of word reading (in a list)
   c) Accuracy of word reading in context
   d) Speed of word reading in context
   e) Accuracy of single word reading (fixed time)
   f) Accuracy of word reading in context (fixed time)
   g) Accuracy of pseudoword reading
   h) Accuracy of pseudoword reading (fixed time)
   i) Lexical decision

2.2) Genre of the material to be understood
   a) Narrative
   b) Expository
   c) Narrative and expository

2.3) Format of the material to be understood
   a) Single sentences
   b) Sentences and paragraphs (in different items of the test)
   c) Paragraphs or passages

2.4) Type of reading comprehension task
   a) Multiple choice task
   b) Cloze task
   c) Open-ended questions
   d) Picture matching (response requires reader to choose a picture from set of options that
   best matches the meaning of a sentence).

2.5) Type of information assessed
   a) Literal
   b) Inferential
   c) Literal and inferential

2.6) Help provided with decoding
   a) Yes

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b) No

2.7) Time limit for the reading comprehension task
   a) Yes
   b) No

2.8) Option of re-reading the material to be understood
   a) Yes
   b) No

2.9) Reading aloud of the comprehension material
   a) Yes (reader reads the material aloud)
   b) No (silent reading)

2.10) Reading of the reading comprehension items (e.g. questions)
   a) Yes (participant reads the items)
   b) No (examiner reads the items)

Note: Genre was not coded when the format of the material to be understood was single sentences because more than one sentence is necessary to determine the structure and genre of a discourse.

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Online supplemental table 3. Summary of studies included in the meta-analysis

Study First author (Year)		n	Age	Type of reader	Reading comprehension measure	Correlation between reading comprehension and each decoding measure								
						AWR	SWR	AWRC	SWRC	APR	AWRT	AWRCT	LD	O
Aaron (1991)		30	9.2	Unselected	Woodcock Reading Mastery Test					.36				
		30	10.1	Unselected	Woodcock Reading Mastery Test					.37				
		30	11.1	Unselected	Woodcock Reading Mastery Test					.30				
		30	12.1	Unselected	Woodcock Reading Mastery Test					.34				
		30	12.9	Unselected	Woodcock Reading Mastery Test					.34				
		30	14.6	Unselected	Woodcock Reading Mastery Test					.21				
Abbott (2010)*	Cohort 1	128	6.89	Unselected	Wechsler Individual Achievement Test	.85								
		124	7.89			.84								
	Cohort 1 & 2	235	8.89	Unselected	Wechsler Individual Achievement Test	.67								
		229	9.89			.56								
		220	10.89			.56								
	Cohort 2	106	11.83	Unselected	Wechsler Individual Achievement Test	.65								
		99	12.83			.57								
Acheson (2008)		99	Adults[1]	Unselected	Scholastic Achievement Test					.31				
					Experimental					.16				
Arnell (2009)		64	22.5	Unselected	Nelson-Denny Reading Test					.53				
Ashbaker (1996)		30	14.1	Low general achieving readers	Multiple Skill Series	.58								
		30	14.1	Average	Multiple Skill Series	.43								

Study	n	Age	Sample	Measure						
			decoders							
Bell (1994)	29	Adults[1]	Heterogeneous	Experimental 1 Experimental 2 Experimental 3 Jackson-McClelland				.03 .26 .46 .42		
Benjamin (2010)	90	8.16	Unselected	Wechsler Individual Achievement Test			.74			
Berninger (2006)	96	6.6	Poor decoders	Learner Test Battery for Reading and Writing	.14 .25	.28 .39 .34 .39		.15 .14	.19 .31 .30 .27	.06 .09
				Woodcock Reading Mastery Test	.58 .74	.54 .63 .71 .58		.49 .51	.84 .66 .78 .64	.33 .45
				Qualitative Reading Inventory	.30 .21	.19 .23 .24 .41		.02 .08	.22 .24 .29 .35	.01 .09
				Gray Oral Reading Test (GORT)	.51 .46	.50 .51 .43 .40		.25 .29	.50 .48 .49 .42	.24 .33
				Wechsler Individual Achievement Test	.63 .71	.73 .65 .73 .57		.36 .48	.76 .67 .71 .69	.29 .51
Best (2008)	61	9.1	Unselected	Experimental 1 Experimental 2	.21 .48 .21 .65 .63 .64					
Betourne (2003)	17	10.4	Poor decoders	Woodcock Reading Mastery Test				.69	.83	
Blakmore (1997)	34	5.9	Unselected	Interactive Reading Assessment System	.76			.81		
Braze (2007)	44	20.6	Average decoders	Gray Oral Reading Test (GORT)	.62		.39		.45	.24

Study	N	Age	Selection	Test								
								.48				
				Peabody Individual Achievement Test (Peabody)	.77		.55	.44				.27
								.36				
				GORT + Peabody				.49				
Burgoyne (2011)*	39	7.91	Unselected	Neale		.84						
	39	8.91				.76						
	167	7.89	Unselected	Woodcock Reading Mastery Test						.69		
Burke (2009)*												
Burt (2000)	100	19.9	Unselected	Nelson-Denny Reading Test		.20	.26					
Byrne (2007)	638	7.1	Unselected	Woodcock Reading Mastery Test						.83		.77
										.84		.75
Cain (2007)	49	7.8	Average decoders	Neale		.71						
	50	9.8	Average decoders	Neale		.56						
Cain (2004),	102	7.5	Average	Neale		.14	.12					
Oakhill (2003)	92	8.62	decoders			.40	.23					
& Cain (2011)*	80	10.64				.19						
	52	14		Edinburgh Reading Test							-.11	
	40	16									.25	
Carlisle (2000)	34	8.9	Unselected	Comprehension Testing Program	.61							
	25	10.8	Unselected	Comprehension Testing Program	.39							
Cartwright (2007)	88	19.4	Unselected	Woodcock Reading Mastery Test				.16	.57			
Chen (1997) & Vellutino (2007)	163(a)	7.9	Unselected	Spache Diagnostic Reading Scales	.86			.71				
	131(b)	8.9	Unselected	Spache Diagnostic Reading Scales	.73			.62				
	297 (a+b)	8.5	Unselected	Spache Diagnostic Reading Scales	.80							
	129c	11.9	Unselected	Spache Diagnostic Reading	.46			.34				

Study	N	Age	Selection	Test								
				Scales								
	37d	12.9	Unselected	Spache Diagnostic Reading Scales	.27			0				
	171 (c+d)	12.4	Unselected	Spache Diagnostic Reading Scales	.43							
Compton (2008)*	177	6.89	Poor decoders	Woodcock Reading Mastery Test					.61			
	177	7.89							.82			
									.69			
	177	9.89							.53			
									.75			
									.60			
Conners (2009)	67	8.6	Unselected	Peabody Individual Achievement Test (Peabody)	.71			.55				
Cromley (2011)				Experimental						.34		
	185	21.1	Unselected	Stanford Achievement Test (SAT)						.29		
Deacon (2004)*				Woodcock Reading Mastery Test								
	103	7.4	Unselected	Test				.85	.92			
	103	8.4	Unselected	Woodcock Reading Mastery Test				.81	.90			
	103	9.4	Unselected	Woodcock Reading Mastery Test				.76	.85			
	103	10.3	Unselected	Woodcock Reading Mastery Test				.74	.81			
Dreyer (1992)	137	8.6	Unselected	Educational Records Bureau Comprehensive Testing Program	.62							
Elleman (2011)	99	8.25	Unselected	Woodcock Reading Mastery Test					.84			
Fien (2010)	3506	6.89	Unselected	Stanford Achievement Test (SAT)					.62	.79		
Fraser (2008)	71	10.1	Unselected	Wechsler Objective Reading Dimensions	.40				.21			.22
Geva (2012)*	149	10.66	Average decoders	Gates MacGinitie Reading Tests	.56					.52		.38
Greenberg (2009)	67	30.70	Poor decoders	Gray Oral Reading Test (GORT)		.10	.07	.06	.11		.05	.22
						.19	.14	.15	.15		.10	.04
	130	30.70	Poor decoders	Gray Oral Reading Test (GORT)		.10	.07					
						.19	.14					
Guthrie (2009)	156	10	Unselected	Gates MacGinitie Reading Tests Experimental								.87
												.79

Study	N	Age	Group	Test								
					.56							
Hansen (1994)	68	7.3	Unselected	Woodcock Reading Mastery Test				.76	.90			
Hatcher (1999)	124	7.5	Poor decoders	Neale	.61		.71					
					.56							
Hudson (2012)	198	8.41	Unselected	Gray Oral Reading Test (GORT)					.32	.37		.25
									.29	.36		.33
										.36		.34
										.40		.29
												.27
Jarmulowicz (2008)	76	8.8	Unselected	Woodcock Reading Mastery Test				.59				
Jenkins (1993)	47	6.9	Unselected	Gates MacGinitie Reading Tests						.86		
				Metropolitan Achievement Tests						.84		
	50	7.9	Unselected	Gates MacGinitie Reading Tests						.82		
				Metropolitan Achievement Tests						.67		
	66	8.9	Unselected	Gates MacGinitie Reading Tests						.86		
				Metropolitan Achievement Tests						.82		
	47	9.9	Unselected	Gates MacGinitie Reading Tests						.68		
				Metropolitan Achievement Tests						.64		
	125	10.9	Unselected	Gates MacGinitie Reading Tests						.63		
				Metropolitan Achievement Tests						.58		
Jenkins (2003)	113	9.6	Unselected	Iowa Test of Basic Skills		.53		.61		.50		
						.71	.83	.60				
Joshi (2000)	40	7.9	Unselected	Gates MacGinitie Reading Tests				.59				
Katz (2012)	99	21.50	Poor decoders	Gray Oral Reading Test (GORT)		.57	.60	.25	.04			.21
				Woodcock-Johnson		.41	.40	.43	.25			.24
Katzir (2006)	17	8.3	Poor decoders	Woodcock Reading Mastery Test				.79	.96		.83	.71
									.93			
	17	7.5	Average decoders	Woodcock Reading Mastery Test				.85	.95		.96	.80
									.95			
Kendeou (2009)	103	6	Unselected	Dynamic Indicators of Basic Early Literacy Skills						.54		.48
Kershaw (2012)	215	8.9	Unselected	Florida Comprehensive Assessment Test				.64		.73		.62
										.76		
										.73		
										.73		
										.74		

				Stanford Achievement Test	.65	.72 .71 .75 .72 .72 .76 .74 .71 .72 .72 .72 .76 .73	.62
	188	12.9	Unselected	Florida Comprehensive Assessment Test	.41	.63 .63 .65 .66 .61 .64 .63	.47
Kershaw (2012)	188	12.9	Unselected	Florida Comprehensive Assessment Test Stanford Achievement Test	.47	.64 .68 .66 .62 .62 .65 .61 .67 .65 .65 .67	.49
	180	14.9	Unselected	Florida Comprehensive Assessment Test	.43	.58 .59 .59 .64 .52 .61 .56 .56 .60	.41

Study	N	Grade	Group	Measure					
				Stanford Achievement Test			.41	.53	.38
								.56	
								.56	
								.54	
								.50	
								.52	
								.51	
								.47	
								.49	
Kershner (1991)	30	11.3	Poor decoders	Woodcock Reading Mastery Test	.61	.15			
	30	7.8	Average decoders	Woodcock Reading Mastery Test	.69	.53			
Kim (2010)*	12536	6	Unselected	Stanford Achievement Test				.73	.60
		7						.63	.48
		8						.10	
Kim (2011)	242	5.83	Unselected	Woodcock-Johnson			.87		.79
							.85		
Kim (2011) & Kim (2012)*	316	7.08	Unselected	Experimental 1			.37	.39	
							.40	.39	
								.37	
				Experimental 2			.62	.64	
							.64	.63	
								.62	
				Woodcock-Johnson			.84	.84	
							.83	.83	
								.83	
				Woodcock Reading Mastery Test			.86	.84	
							.85	.83	
								.83	
	270	8.08	Unselected	Experimental 1			.41	.47	
							.39	.44	
								.48	
				Experimental 2			.25	.34	
							.23	.31	
								.30	
				Woodcock-Johnson			.64	.75	
							.63	.71	
								.72	
				Woodcock Reading Mastery			.61	.69	

Study	N	Age	Group	Test							
				Test					.59	.65 .66	
Kirby (2011) & Kirby (2012)*	117	8.08	Heterogeneous	Woodcock Reading Mastery Test	.76			.70	.77	.71	
Kitz (1992)	63	20	Poor decoders	Stanford Diagnostic Reading Test			.58				
Klauda (2008)	278	9.9	Unselected	Gates MacGinitie Reading Tests		.65					
Kuperman (2011)	71	20.80	Unselected	Peabody Individual Achievement Test	.96			.83			
				Stanford Diagnostic Reading Test	.94			.84			
Landi (2010)	928	20.17	Unselected	Nelson-Denny Reading Test							.09
Leather (1994)	71	7.4	Unselected	Neale			.81				
Lee (2011)*	1071	8.08	Unselected	Woodcock-Johnson				.67			
Lesaux (2006)	480	9.8	Unselected	Stanford Diagnostic Reading Test	.46 .33			.30	.19		
MacArthur (2010)	486	35	Low reading comprehension	Nelson-Denny Reading Test	.45			.28 .36	.46	.52	.24
Manis (1999)*	67	7.8	Unselected	Silveroli Classroom Reading Inventory				.60	.76	.47 .37	
	67	8.8			.77			.66	.79	.56 .62	
Martino (2002)	26	19	Unselected	The American College Testing				.43	.66		
McCutchen (2009) & McCutchen (2011)	88	10.83	Unselected	Gates MacGinitie Reading Tests	.51						
	74	13.83	Unselected	Gates MacGinitie Reading Tests	.51						
Meisinger (2009)	521	8.16	Unselected	Wechsler Individual Achievement Test						.72	
	347	9.33	Unselected	Wechsler Individual Achievement Test						.59	
	110	9.33	Unselected	Wechsler Individual Achievement Test						.65	
	92	11.33	Unselected	Wechsler Individual Achievement Test						.51	
Mellard (2010)	174	32	Low general achieving readers	Woodcock Reading Mastery Test	.53			.51		.66	
Mellard (2012)	296	Adults[1]	Low general	Comprehensive Adult Student				.45		.55	.53

Study	N	Age	achieving readers	Assessment System									
Messer (2004)	20	7.2	Poor decoders	Word Reading Comprehension Test	.87								.86
Miller (2008)*	92	9.16	Unselected	Wechsler Individual Achievement Test							.52		
Muter (2004)	90	6.7	Unselected	Neale	.72 .75		.91						
Nagy (2003)	98	7.9	Poor decoders	Gates MacGinitie Reading Tests	.62 .57	.40 .17			.42	.48		.33 .43	.43
	97	9.9	Poor decoders	Gates MacGinitie Reading Tests	.49 .59	.56 .55			.59 .50	.61		.27 .48	.47
Neuhaus (2006)	122	8.7	Unselected	Stanford Achievement Test (SAT)		.26			.32				
Noble (2006)	150	6.9	Unselected	Woodcock-Johnson	.85				.73				
Nunes (2012)*	7648	9.83	Unselected	Neale	.88								
Ouellette (2010)	67	6.67	Unselected	Woodcock Reading Mastery Test	.76								
	56	11.95	Unselected	Woodcock Reading Mastery Test	.47				.35				.15
Pritchard (2000)	235	19	Unselected	Nelson-Denny Reading Test				.31					
Ricketts (2007)	81	9.2	Unselected	Neale	.34 .52		.45		.17 .21				
Ricketts (2011)	88	8.24	Unselected	Neale			.59			.45			.46
Rupley (1997)	300	6.5	Unselected	K-ABC	.89								
	400	9	Unselected	K-ABC	.91								
	400	11.3	Unselected	K-ABC	.79								
Sabatini (2002)	95	34.5	Unselected	Experimental	.51 .48	.31 .68			.61 .53 .55 .64 .61 .57				.16 .34 .59 .61 .48 -.06
				Wechsler Individual Achievement Test	.55	.59			.49				.40
									.49				.61
									.59				.31

Study	N	Age	Group	Test								
Sabatini (2010)	476	36.90	Poor decoders	Woodcock-Johnson				.35	.47		.26	
									.49			
Savage (2001)	14	15.5	Poor decoders	Neale		.57	.07	.46				
Savage (2007)	60	25	Heterogeneous	Nelson-Denny Reading Test	.36			.34				
Shinn (1992)	114	7.9	Unselected	Experimental				.59	.55	.49		
								.60	.63	.60		
								.75				
								.79				
				Stanford Diagnostic Reading Test				.58	.67	.55		
								.60	.63	.52		
								.57				
								.58				
	124	9.9	Unselected	Experimental				.38	.27	.31		
								.40	.45	.53		
								.62				
								.63				
				Stanford Diagnostic Reading Test				.55	.30	.40		
								.54	.34	.44		
								.60				
								.62				
Spear-Swerling (2004)	95	9.7	Unselected	Degrees of Reading Power from the Connecticut Mastery Test	.71	.46		.63			.72	
				Reading Comprehension from the Connecticut Mastery Test	.63	.42		.46			.58	
Spedding (1993)	55	10.2	Unselected	Progressive Achievement Test in Reading Comprehension							.75	.54
Speece (2010)	230	9.45	Unselected	Gates MacGinitie Reading Tests				.49	.61		.55	.51
								.49	.45		.45	
									.44			
				Experimental					.74		.44	.58
									.60		.66	
									.58			
Spooner (2004)	114	10.8	Unselected	Neale			.59					
				Experimental			.60					

Study	Subgroup	N	Age	Sample	Measure					
Stuart (2004)		12	7.4	Unselected	Neale		.93			
Swanson (1995)		36	7.9	Average decoders	Peabody Individual Achievement Test	.88				
		33	13.3	Average decoders	Peabody Individual Achievement Test	.61				
		22	13.4	Low reading comprehension	Peabody Individual Achievement Test	.84				
Taft (2001)		53	19	Unselected	Test based on the Cooperative Reading Comprehension Test					.41
										.52
Taylor (2008)		83	8	Unselected	Woodcock-Johnson	.84				
		155	8	Unselected	Woodcock-Johnson	.88				
Taylor (2012)		82	35	Poor decoders	Woodcock-Johnson			.29		
Tilstra (2009)		89	9.91	Unselected	Gates MacGinitie Reading Tests			.66	.80	
		89	13	Unselected	Gates MacGinitie Reading Tests			.37	.62	
		93	14.91	Unselected	Gates MacGinitie Reading Tests			.40	.67	
Torgesen (1997) & Hecht (2000)[*]	Cohort 1	215	7.7	Unselected	Woodcock Reading Mastery Test			.76	.90	
		197	8.7					.74	.85	
		215	10.1				.59	.76	.82	.59
								.76	.85	.58
	Cohort 2	201	8.7	Unselected	Woodcock Reading Mastery Test		.63	.74	.85	
		201	11.1				.59	.72	.76	.40
									.81	.38
										.39
										.44
Tunmer (2012)		122	7.50	Unselected	Neale	.81		.74		
						.79				
Vadasy (2008)		32	Young[1]	Poor decoders	Woodcock Reading Mastery Test					.50
		54	Young[1]	Poor decoders	Woodcock Reading Mastery Test					.47
Valencia (2010)		93	7.91	Unselected	Experimental					.24
					Iowa Test of Basic Skills Battery			.54		.37
								.51		.43
										.55

Study	N	Grade/Age	Selection	Test								
										.52		
	91	9.91	Unselected	Experimental						.29		
				Iowa Test of Basic Skills Battery			.47			.35		
							.46			.42		
										.48		
										.49		
	95	11.91	Unselected	Experimental						.12		
				Iowa Test of Basic Skills Battery			.47			.24		
							.50			.24		
										.48		
										.50		
Weems (2004)	60	Adults[1]	Unselected	Nelson-Denny Reading Test						.22		
										.34		
										.25		
										.41		
										.30		
										.01		
										.30		
										.09		
Welcome (2009)	16	Adults[1]	Average decoders	Woodcock Reading Mastery Test				.44				
	25	Adults[1]	Poor decoders	Woodcock Reading Mastery Test				-.17				
Welcome (2012)	20	29.70	Unselected	Nelson-Denny Reading Test					.44			.08
Whalley (2006)	84	9.3	Unselected	Neale		.62	.23	.29	.46			
Wise (2007)	279	7.4	Poor decoders	Woodcock Reading Mastery Test	.63			.75				
								.80				
Wise (2010)	949	7.58	Poor decoders	Wechsler Individual Achievement Test				.83	.80		.73	
	146	7.69	Poor decoders	Wechsler Individual Achievement Test				.57	.45		.45	
Wood (1994)	204	6.9	Unselected	Woodcok-Johnson				.78				
	60	8.9	Poor decoders	Woodcok-Johnson				.20				
Wood (2009)*	74	8.60	Unselected	Colorado Student Assessment Program	.60			.51	.54		.39	
	74	9.60							.68			
Zinar (2000)	96	9.7	Unselected	Nelson Reading Skills Test	.68							
Zipke (2009)	46	8.58	Unselected	Gates MacGinitie Reading Tests	.72			.51				
				Woodcock Reading Mastery	.80			.65				

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6   Test
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8   AWR: Accuracy of word reading; SWR: Speed of word reading; AWRC: Accuracy of word reading in context; SWRC: Speed of word reading in context; APR: Accuracy of pseudoword
9   reading; AWRT: Accuracy of single word reading (fixed time); AWRCT: Accuracy of word reading in context (fixed time); LD: Lexical decision; O: Others measures
10   * Longitudinal studies
11   [1] Exact age or grade is not provided
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