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Running Title: PREDICTORS OF READING DEVELOPMENT

## **Revisiting the causal effects of phonemic awareness on reading acquisition: insights from a systematic review and a large-scale longitudinal study**

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## Abstract

Phoneme awareness (PA) is undoubtedly the most important and well-studied predictor of reading development. Yet, 20 years ago, Castles and Coltheart made the provocative claim that there was no convincing evidence for the causal role of phoneme awareness (PA) in learning-to-read because previous studies had failed to control for pre-reading skills, such as letter knowledge. In the present study, we first wanted to know whether studies published after Castles and Coltheart's seminal article had adequately controlled for pre-reading skills. The results of our systematic review clearly show that this is not the case. Thus, the evidence in favor of a direct causal role of PA in learning-to-read is not stronger today than it was 20 years ago. Given the absence of any conclusive data, we thus analyzed the results of a large-scale longitudinal investigation on predictors of reading development that has been conducted nation-wide on all first graders in France (i.e., N = 810,328 children). We estimated not only the effect of PA on reading fluency measured one year later but also the interaction effects with letter-knowledge (LK), knowledge of the alphabetic principle (KAP) and oral comprehension. The results clearly showed that when interaction effects are integrated into the statistical models, PA is no longer a good predictor of reading development, while LK and KAP remain strong individual predictors. These results have important consequences for our understanding of early predictors of reading development, educational policy recommendations, and early intervention strategies.

Key words: Phoneme awareness, knowledge of the alphabetic principle, phonics, decoding, reading

Research on reading development has clearly established that variations in phonological skills are the major cause of variations in how well children are able to learn to read (Goswami & Bryant, 1990; Melby-Lervåg et al., 2012; Snowling & Melby-Lervåg et al., 2016; Ziegler & Goswami, 2005). Among phonological skills, Melby-Lervåg et al. (2012) highlighted the “pivotal role of phonemic awareness” (p. 322), which reflects the ability to recognize, identify, or manipulate speech sounds at the phonemic level. The results of Melby-Lervåg et al.’s (2012) meta-analysis converged to suggest that phoneme awareness (PA) yielded the strongest correlation with individual differences in word reading ability across all alphabetic languages, regardless of cross-linguistic differences in orthographic transparency (see also Landerl et al., 2013; Ziegler et al., 2010). PA is thought to be such an important variable in learning-to-read alphabetic scripts because the awareness of phonemes facilitates the development of a basic decoding network (i.e., grapheme-phoneme correspondences), which is the fundamental self-teaching mechanism at the heart of learning-to-read alphabetic scripts (Share, 1995; Ziegler & Goswami, 2005; Ziegler et al., 2014).

In their seminal article, Castles and Coltheart (2004) challenged the dominant view about the causal role of PA on reading skills. They examined more than forty articles and showed that none of them had properly controlled for pre-reading skills. They argued that pre-reading skills could concurrently affect PA and later reading ability without a direct causal relationship between PA and reading ability. Hence, Castles and Coltheart (2004) concluded that “no single study has conclusively established that phonemic awareness training assists reading or spelling acquisition.” (p. 101). In the present article, we first present the results of a systematic review aiming to investigate whether studies on the role of PA in reading

development published after Castles and Coltheart's (2004) important article took their criticism at heart and concurrently controlled for pre-reading skills and their interactions with PA. Second, we present the results of a longitudinal study of unprecedented scale on the predictors of reading skills based on data from the French national evaluations in first and second grade (N = 810,328 children), which measured PA, oral comprehension, letter knowledge and knowledge of the alphabetic principle concurrently and thus made it possible to investigate the interaction between these variables in predicting subsequent reading fluency.

### **On the need of reassessing PA's role in learning to read**

Castles and Coltheart's criticism was not totally new because many researchers before them claimed that PA may very well be a consequence of literacy rather than its cause (Ehri, 1989; Morais et al., 1979, 1986; Share, 1995). These studies typically showed that PA was dependent on some level of alphabetical knowledge (e.g., letter or letter-sound knowledge). For example, in their seminal article, Morais et al. (1979) showed that illiterates, who had no alphabetic knowledge at all, were unable to perform a basic phoneme deletion task. Similarly, Mann and Wimmer (2002) showed that German kindergartners were much worse than their English counterparts in PA tasks presumably because they were not taught any letters or letter sounds prior to schooling. Yet, once formal schooling has started, they quickly caught up and outperformed their English counterparts in PA and decoding because of systematic grapheme-phoneme teaching and the transparency of the writing system, which led the authors to suggest that "phoneme awareness develops primarily as a product of literacy exposure" (p. 653). These studies suggest that for PA to emerge children need to know some letters, that is, have a minimum level of alphabetic knowledge. What is more, Byrne and Fielding-Barnsley

(1989) showed that once this minimum level of alphabetic knowledge is reached (some letters), it is possible to independently increase PA (without increasing letter knowledge) or to increase letter knowledge (without increasing PA). This is an important finding because if PA and letter knowledge were completely dependent, one could not study them separately.

Hypothetically, there are three ways in which PA might have an effect on learning-to-read. First, PA could have a causal effect on future reading skills *before* the presence of any pre-reading skills (e.g., letter knowledge and basic knowledge of the alphabetic principle). This is the hypothesis that Castles and Coltheart (2004) were mainly concerned with. Second, PA could also have a causal effect on future reading skills *while* pre-reading skills are already present. In this case, PA would have a direct causal effect on reading development independent of the level of pre-reading skills (i.e., regardless of whether these skills are strong, average or modest). Finally, the effect of PA on reading skills could be *dependent on* some level of pre-reading skills. For example, PA might have an effect on subsequent reading skills if pre-reading skills were good but not if pre-reading skills were weak. In that case, there would be an interaction between the effects of PA and pre-reading skills. To tease apart these different explanations, it is therefore important to control for pre-reading skills and their interaction effects (see also Hulme et al., 2005). Without doing so, one might attribute the effect of one variable (e.g., letter knowledge) to the other variable (e.g., PA), which could result in an “omitted variable bias”.

### **Pre-reading skills and the missing role of alphabetic knowledge**

Pre-reading skills constitute undoubtedly the most powerful predictor of later readings skills (Piquard-Kipffer & Sprenger-Charolles, 2013). How could it be otherwise because one is

explaining future reading skills with already existent/past reading skills. Thus, precise definitions of the pre-reading skills are necessary especially because some variables are highly intertwined and others might be missing. In Figure 1, we make a clear proposition regarding the pre-reading variables that should be looked at. We make the radical claim that knowledge of the alphabetic principle (KAP) is a key variable that is often missed or encapsulated in other variables. We argue that KAP needs to be measured independently of the other variables and should take a central place between other pre-reading skills and decoding.

**Insert Figure 1 about here**

Most studies that investigated the causal role of PA on reading include letter knowledge (LK) and vocabulary. Note, however, that LK is measured in inconstant ways across the vast literature: Some use the names of letters (9 articles in the systematic review), while others use the names and sounds of letters (5 articles) or just the sounds of letters (5 articles). It is thus quite important to be very clear about what exactly is being measured. Vocabulary is less problematic as there are many standardized tests for vocabulary knowledge and there are no conceptual confounds with other pre-reading measures.

We argue that knowledge of alphabetic principle (KAP) is the black sheep amongst the pre-reading variables. Although it is considered by many scholars as a key stage in the “foundation of literacy” (Byrne, 1998; Castles & Coltheart, 2004; Ehri, 2015; Ehri & Soffer, 1999; Morais, 1994, 2016), it is often “stuck” in between abilities that precede it (e.g., PA) and ones that encapsulate it (e.g., decoding). KAP is defined as the ability to understand that “letters represent the phonemes in speech” (Ehri, 2015, p. 312). Remarkably, all authors use more or

less the same wording to define it: “discovering”, “mastering”, “grasping” the alphabetic principle (e.g., Byrne, 1998, p. 20 or Castles & Coltheart, 2004, p. 91). Calling it a “principle” has undoubtedly had the negative effect of suggesting that knowledge of the alphabetic principle would be all-or-none. However, as clearly pointed out by Byrne (1998, p. 127), there are “individual differences in alphabetic mastery” (Byrne 1998, p. 127) and “for some children (...) alphabetic insight might be partial” (Byrne & Fielding-Barnsley, 1991, p. 320).

In sum, although almost all scholars agree that KAP is a crucial step towards decoding, surprisingly none of them made the effort to actually estimate its effect on reading development. Indeed, some authors used decoding as a measure of KAP (e.g., Goigoux, 2016). Certainly, decoding encapsulates the alphabetic principle because decoding requires an understanding that graphemes transcribe phonemes. However, obviously, decoding skills go way beyond that understanding. In Byrne and Fielding-Barnsley’s (1991) experiments, a child might have grasped the alphabetic principle while being unable to entirely read a single word. At the same time, KAP partially encapsulates PA because understanding that phonemes in speech are represented by graphemes obviously requires some degree of PA. In the same way, it also partially encapsulates letter-sound knowledge because to understand the alphabetic principle, one needs to know at least some letter-sound correspondences. It nevertheless goes beyond in both cases. As Byrne and Fielding-Barnsley showed in their experiments, there are some children who had strong PA and LK who did not necessarily grasp the alphabetic principle. Thus, in part 2 of this article, we will estimate the effect of KAP on reading development in addition to other pre-reading variables and their interactions.



## Part 1: Systematic Review

This systematic review aims to address the question as to whether studies on the role of PA in reading development published after Castles and Coltheart (2004) have controlled for pre-reading skills? First, have they measured PA *before* the emergence of other pre-reading skills? Second, have they systematically controlled for both letter knowledge and grapheme-phoneme skills? Third, have they consistently controlled for letter knowledge and grapheme-phoneme skills while investigating their possible interactions with PA so as to ensure they were no omitted variables in the estimation of their effects on learning to read? Finally, have they consistently defined (i.e., with constant, clear cut and hermetic measurements) letter knowledge and grapheme-phoneme skills when analyzing PA's effect on future reading skills?

### Methods

#### Search Strategy and Inclusion Criteria

Figure 2 summarizes the method and the criteria that were used to search and select the articles.

1. We searched for articles in *ProQuest* and *PsychNet* databases using the following keywords: “decoding” + “phon\* awareness” and “reading” + “phon\* awareness”.
2. We included all articles of the meta-analyses that were published after Castles and Coltheart's (2004) article (i.e., Al Otaiba et al., 2009; Galuschka et al., 2014; Hall et al., 2023; Melby-Lervåg et al., 2012; Míguez-Álvarez et al., 2022; Suggate, 2016).
3. We looked for articles in *Google Scholar* that cited Castles and Coltheart's (2004) article.

4. We hand-searched the following specialized journals: Journal of Research in Reading, Scientific Studies in Reading, Reading and Writing, Journal of Educational Psychology, Journal of Learning Disabilities, The Journal of Educational Research.

After the removal of duplicates, these search criteria resulted in a collection of more than 1000 articles (577 with ProQuest and PsychNet).

**Insert Figure 2 about here**

### **Selection and exclusion criteria**

1. We selected only articles published after Castles and Coltheart's (2004) article.
2. We restricted the systematic review to the strongest causal evidence, that is intervention or longitudinal studies without interventions. We did not include cross-sectional studies.
3. Among the longitudinal studies, we only selected studies in which the first points of observations preceded formal literacy education.
4. We only included studies that measured phonemic awareness with the following tasks: phoneme identification, phoneme isolation, phoneme elision and/or phoneme blending (see Justi et al., 2021; Papadopoulos et al., 2012; Vloedgraven & Verhoeven, 2009).
5. When the same datasets (or samples) were published in several articles, we only kept the major study for each sample as all articles based on the same sample would share the same methodological properties.

6. As concerns intervention studies, we excluded intervention studies that did not focus on PA teaching, such as general phonological intervention programs.
7. We did not exclude studies, in which PA was not the main variable of interest but rather a control variable. However, we only kept the ones that draw conclusions on the role of PA as an isolated predictor (i.e., having a partial effect on reading skills).
8. We excluded studies investigating predictors of non-alphabetic languages (apart from two studies that included both alphabetic and non-alphabetic languages – Hmong and Cantonese – but studied them separately). We included one study investigating predictors of Arabic because, during the first years of literacy learning, it is taught as an alphabetic language. The final literature review therefore included only alphabetic languages with variable levels of transparency: Arabic, Czech, Dutch, English, Finnish, French, German, Greek, Hangul, Norwegian, Portuguese, Slovak, Spanish, and Swedish.
9. We did not exclude non-English articles published in non-Q1 journals because journal rankings depend on citation numbers and non-English articles tend to be less cited. Besides English, the literature review includes articles written in French and Spanish.

The selection procedure resulted in 47 articles published after the article by Castles and Coltheart (2004). All included articles are presented in Appendix 1.

### **Coding system**

To address our main questions, we first developed a coding system that allowed us to classify studies according to the extent to which they controlled for letter knowledge (LK),

decoding skills and their interactions with PA. The coding system was based on a 7-point scale going from complete control (C1) to no control (C7). In C1 (complete control), we included studies that did not accept any decoding skills and that controlled for LK and its interaction with PA. In C2, we included studies that did not accept any decoding skills and that controlled for LK but not for its interaction with PA. In C3, we included studies that did not accept any children who could read real words but that accepted that children could decode a few syllables (and not more than that). Also, LK was controlled but without any interaction with PA. In C4, we included studies that controlled for LK and basic decoding but without interactions with PA. In C5, we included studies that controlled for basic decoding but neither LK nor its interaction with PA. In C6, we included studies that controlled for LK but neither basic decoding nor its interaction with PA. In C7 (no control), we included studies that did not control for either LK or basic decoding. The coding was performed by two independent raters (i.e., first and third author). The intercoder reliability was 1 (perfect agreement).

### **Openness and Transparency**

We adhered to the PRISMA 2020 guidelines for systematic reviews (Page et al., 2021). This review project was not preregistered. The systematic review does not contain any statistical analyses apart from percentages per category. The relevant information for the systematic review is summarized for each article in Appendix 1.

### **Results**

The results of the systematic review are presented in Figure 3. The results show that most studies in the systematic review did not control for LK and decoding skills within the same study

(C7, 16 articles). Some studies controlled for LK but not decoding skills (C6, 14 articles), while others controlled for decoding skills but not LK (C5, 3 articles). Thus, in 70% of the studies ( $C5+C6+C7=33/47$ ), decoding skills and LK were not concurrently controlled.

### **Insert Figure 3 about here**

As argued above, controlling concurrently PA and pre-reading skills (decoding, LK) is not sufficient to avoid biased estimations since there might be interactive effects between them. As shown in Figure 3, among the 14 studies (30%) that controlled for both decoding skills and LK (C1 to C4), none of them controlled for the interactions between them. Interestingly, only one of the studies (C2) has restricted the sample to children who did not have any decoding skills (i.e., who could not decode any two-letter syllable). Thus, we cannot rule out that, in the vast majority of studies, the effect of PA on reading skills might have been mediated by decoding skills and/or letter knowledge. We should also notice that none of the studies measured KAP independently of decoding or LK.

One of the reasons why interaction terms might not have been included in these studies is that their estimation is “costly” because the number of coefficients can become quite large, which requires a fairly large sample size for robust parameter estimation. In fact, the study by Carlson et al. (2013) had the biggest sample size ( $N = 3,104$  children), which would have been big enough to study interactions. However, the study did not control for either LK or decoding skills (C7).

The second result concerns the question whether studies have consistently defined letter knowledge and grapheme-phoneme skills when analyzing PA’s effect on future reading

skills (i.e., with constant, clear cut and hermetic measurements). As far as letter knowledge is concerned, the results show that it has been measured in four different ways across the studies: names of letters (9 articles in the systematic review), names or sounds of letters (6 articles), names and sounds of letters (5 articles) and sounds of letters (5 articles). Additionally, a minority of studies either measure it along with decoding skills in a synthetic variable (2 articles) or do not specify its definition (1 article). This is a rather serious problem. Since PA and LK are closely intertwined and since LK can be measured in many ways, measuring LK with variable levels of difficulty and strictness will automatically influence the estimation of PA's coefficients in the same regression. Previous meta-analyses have not required LK to be measured with the exact same measure.

In sum, the present metanalysis does not provide convincing evidence for a direct causal effect of PA on future reading skills. Given that the interactions between PA and pre-reading variables (see Figure 1) were not included in any of the previous studies, it is difficult to estimate the extent to which the effect of PA is mediated by other pre-reading variables. This will be addressed in the analysis of the large-scale longitudinal study below.

## **Part 2: Empirical evidence from a large-scale longitudinal study**

The present analysis used longitudinal data from the French national evaluations in first and second grade. Conducted exhaustively in the whole country (N = 810 328 children), these data represent a unique opportunity to study predictors of reading and their interactions with hitherto unseen scales, that is, a whole population and not a sample. This makes it possible to investigate the effect of PA on future reading skills *in interaction* with other pre-reading skills. It

also allows us to estimate the effect of one variable in the absence of the others and determine the extent to which its effect is mediated by the presence of other variables. Furthermore, it will put the debate to rest as to whether PA is a good predictor of ulterior reading skills or whether its effect is dependent upon other predictors.

## Methods

### Design and procedure

The present analysis was based on the French national and exhaustive evaluations in first and second grade (N = 810,328 children, mean age during the first week of first grade = 6.3 years), which have been conducted each year since 2018-2019. The tests are conducted exhaustively in France<sup>1</sup> in order to give teachers standardized evaluations of their pupils. Children were tested on three occasions across the two years: at the entrance of first grade in September (during the 3<sup>rd</sup> and 4<sup>th</sup> week of the 36-week school year), then midway through the year in January (17<sup>th</sup> and 18<sup>th</sup> week) and, lastly, at the entrance of second grade (also during the 3<sup>rd</sup> and 4<sup>th</sup> week).

The evaluations are conceived by the “Direction of evaluation, foresight and performance” (*Direction de l'évaluation, de la prospective et de la performance* - DEPP) and they comprise a number of tests in French language and mathematics. Teachers must follow standardized guidelines for the administration of the tests (timing of the exercises, separation of their pupils...). The evaluations are conducted collectively (i.e., with the whole class) for all

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<sup>1</sup> The evaluations do not take place in fully private schools but only 0.8% of the children are enrolled in private schools.

exercises except for reading fluency tests, which are administered individually by the teacher with one child at a time. Apart from these individual reading tests, each pupil is given a notebook in which they have to provide the answers.

### **Transparency and openness**

The data used in this large-scale analysis come from statistical evaluations conducted by the French Ministry of National Education. The collection and storage of the data comply with the GDPR (General Data Protection Regulation). Access to the data was granted through a research agreement signed between [blinded], the French Ministry of National Education, and the researchers. The data cannot be made publicly available. If necessary, the data can be made accessible through a specific license to be established with the Direction of Evaluation, Foresight and Performance (DEEP) of the French Ministry of National Education. All statistical analyses were done in R. The study analysis code can be provided upon request.

The study protocol has been approved by the Data Protection Office (DPO) of [blinded]. The office is in charge of enforcing the principles of the GDPR during the collection, processing, and storage of personal data, especially in the context of scientific research.

### **Participants**

Attrition from first grade to second grade was 6.5% of the children evaluated in first grade (i.e., 52 955 pupils). It was mainly due to children who left the public educational system or were absent during the tests. Children with learning difficulties were not excluded from the data.



Importantly, we made the decision to exclude pre-readers, that is, pupils who already had strong decoding skills upon entering first grade. Since there is no word or pseudoword reading test at the first stage of the national evaluations (3<sup>rd</sup> week of grade 1), we relied on the results of a very large and representative French study (N = 2,507 children in 131 classes) by Goigoux (2015) who found that about 20% to 30% of French children entering first grade are able to decode syllables with no more than two letters, while another 20% are able to decode syllables with more than two letters. To make sure that we did not include any pre-readers in our regression analyses, we excluded the data of 33% of the pupils who obtained the highest scores on the subtest that assessed knowledge of the alphabetic principle (see *Tests*). One-third corresponds to the proportion of children who answered correctly to all the items of the subtest.

## **Tests and materials**

### ***Phoneme awareness (early first grade)***

There were two subtests that measured PA in the first stage of the national evaluation (early first grade). In the first subtest, children were first asked to select words that started with the same sound (at the phonemic level) as a target word. In the second subtest, they were asked to select words that ended with the same sound as target words (also at the phonemic level). The four response options were provided in a booklet using drawings. Children had to circle the correct responses in the booklet. The target words and the four response options were read out loud by the teachers. The PA test of the initial phoneme was composed of 8

items while the PA test based on the last phoneme consisted of 7 items. Each subtest started with a training item.

The scores of the two subsets were summed to create a single PA measure (see Table 1 for descriptive data). Since there were 15 items in total and 4 possible answers for each of them, the chance score was just below 4 correctly answered items.

### ***Oral comprehension (early first grade)***

The oral comprehension test is an adaptation of the TROG (*Test for Reception of Grammar*, Bishop, 2003) and its French equivalent ECOSSE (*Épreuve de compréhension syntaxico-sémantique*, Lecocq 1996). In this test, the teacher read out loud a sentence and children had to circle in their booklet the corresponding picture out of four response options. Each of the four response options were close to the actual meaning of the sentence so that pupils could not easily rule out the wrong answers without having understood the whole sentence. The test started with a training item (*L'enfant jette la pomme* [*The child throws the apple*]). There were 14 items in the test. The chance score is 3.5 correct answers.

### ***Knowledge of the alphabetic principle (early first grade)***

This subtest focused on knowledge of the alphabetic principle (KAP). In this test, a series of 5 letters was presented in the booklet (e.g., m, n, b, d, f). Teachers said out loud a target word and the children had to circle the letter that corresponded to the initial phoneme of the target word.

It is important to note that all target words started with consonants. It is therefore more difficult for children to rely on the name of the letter to find the correct grapheme because the names of consonants in French (contrary to vowels) do not provide much information regarding their phonemic correspondents. The test is composed of 10 trials (10 target words). Since there are 5 possible answers for each item, the chance score is 2 out of 10.

In order to succeed in this test, children do not only have to know the association between the letters and their phonemic correspondents but they also need to know that words are made of letters that code for phonemes and they need to be able to isolate the phonemes in a spoken word and find the corresponding letter. This test is therefore quite innovative because it measures a knowledge that lies in between letter knowledge and basic decoding skills. One could argue that it is a test of the degree to which children master the alphabetic principle. Despite the reference to the mastery of a principle, we have conceived it as a continuous variable rather than an all-or-none measure.

### ***Socio-economic status***

The socio-economic status (SES) of the pupils was estimated through the Social Position Index (*Indice de Position Sociale* or IPS), which is based on the socio-professional category distribution of the families in each school (for more information regarding the index construction, see Rocher, 2016). The greater the number of socially-advantaged families in a given school, the higher the index (and vice versa). The index essentially ranges from 50 to 150. It is computed every year by the statistics department of the ministry of education (DEPP).

Using this index in our regression analyses allowed us to partially control for the effect of socio-economic background on general academic performance and reading, in particular.

### ***Reading fluency (early second grade)***

In this test, students were presented with a 103-word text and they were asked to read the text out loud. The dependent variable was the number of correctly read words in one minute. The test was administered individually by teachers with each pupil. Children were told that they will be stopped at one minute. Many students did not manage to reach the end of the text. For them, teachers reported the number of correctly read words in one minute. For the ones who managed to read the whole text in less than a minute, teachers divided the number of words by the number of seconds it took students to read the text and multiplied it by 60 to obtain the number of words read per minute.

### **Analysis methods**

As argued above, pre-reading skills need to be apprehended as a continuum of partially overlapping and intertwined variables. Since they are partially dependent and because they partially and reciprocally influence each other, modeling their effects on reading skills needs to be done allowing interactions between these variables. We therefore decided to use classic multiple regression analysis to investigate the effects of PA, oral comprehension (OC) and knowledge of the alphabetic principle (KAP) and their interactions on subsequent reading fluency. At this stage, we did not include letter knowledge (LK) in the core regression models but we provide additional analysis that include LK in the second part of the analyses. All pre-

reading skills (PA, OC, KAP and LK) were measured in the first weeks of grade 1, while reading fluency was measured one year later in the first weeks of grade 2.

The two statistical models are specified below. Both models are composed of the same dependent and independent variables. However, the first model (1) contained only main effects, while the second model (2) included the interactions between the dependent variables. Both models also controlled socioeconomic status (SES).

$$(1) \text{ Reading fluency}_i = \beta_0 + \beta_1 \text{SES}_i + \beta_2 \text{PA}_i + \beta_3 \text{OC}_i + \beta_4 \text{KAP}_i + e_i$$

$$(2) \text{ Reading fluency}_j = \beta_0 + \beta_1 \text{SES}_j + \beta_2 \text{PA}_j + \beta_3 \text{OC}_j + \beta_4 \text{KAP}_j + \beta_5 \text{PA}_j * \text{OC}_j + \beta_6 \text{PA}_j * \text{KAP}_j +$$

$$\beta_7 \text{OC}_j * \text{KAP}_j + \beta_8 \text{PA}_j * \text{OC}_j * \text{KAP}_j + e_i$$

## Results

### Descriptive statistics

The descriptive statistics and distributions of the predictor variables measured at the beginning of grade 1 and the outcome variable (reading fluency) measured at the beginning of grade 2 are presented in Table 1. We will comment on these results below.

### Insert Table 1 about there

Regarding oral comprehension (14 items), French pupils enter first grade with overall strong oral comprehension skills. The test creates a saturated distribution with the vast majority of pupils obtaining high scores. More than 50% of them obtain 13 or 14 and more than 90% obtain

at least 9 correct responses. This very high success rate generates a small variance for that variable.

Regarding phoneme awareness (15 items), the distribution shows that the test is well calibrated for children entering first grade. Half the children pass half the items, and scores decline in a linear way across deciles: 14 (9<sup>st</sup> decile), 12 (8<sup>nd</sup> decile), 11 (7<sup>rd</sup> decile), 10 (6<sup>th</sup> decile), 9 (5<sup>th</sup> decile), 8 (4<sup>th</sup> decile), 7 (3<sup>th</sup> decile), 6 (2<sup>th</sup> decile) and 4 (1<sup>th</sup> decile). Between 20% and 30% of French children entering first grade obtained less than 7 and could therefore be considered as having modest to weak PA.

Regarding knowledge of the alphabetic principle (KAP – 10 items), more than half of French children enter first grade with very high KAP. Nevertheless, the distribution is not saturated with the first deciles obtaining low scores in the task, that is, between 20% and 30% of the pupils who enter first grade can indeed be considered to have modest to weak KAP (scoring 5 or less).

Regarding reading fluency in early second grade, the results show that many French pupils are slow readers. Indeed, according to the French Ministry of Education, at the end of first grade, pupils should be able to read at least 50 words per minute (French Ministry of National Education, 2019). This is in line with Morais (2016) who argued that pupils at the end of first grade should be able to read a text at a pace of 55 words per minute. As can be seen in Table 1, half of the French students at the beginning of grade 2 did not reach the official objective of 50 words per minute that they were supposed to have reached a couple of months

before, at the end of first grade. If one follows Morais' (2016) recommendation, almost 60% of French pupils do not attain the proficiency threshold of 55 words per minute.

The correlations between the four variables are presented in Table 2. OC is positively correlated with PA ( $r = 0.43$ ) and KAP ( $r = 0.39$ ) but is less correlated with reading fluency measured one year later (0.23). This is in line with other studies (e.g., Fricke et al., 2016). PA is indeed strongly correlated with KAP (0.59) and with reading fluency measured one year later (0.36). Interestingly, the correlation with fluency is exactly the same for KAP and PA (0.36). It is also close to the coefficients found in the literature for the correlation between letter knowledge and decoding skills (Melby-Lervåg et al., 2012, p. 325).

**Insert Table 2 about there**

### **Regression analyses**

The two core models are specified above (see Analysis methods). Table 3 The results of the simple effect model (1) and the model with interactions between PA, OC and GPK (2) are presented in Table 3.

**Insert Table 3 about there**

A F-test model comparison showed that the interaction terms were statistically significant ( $p < .0001$ ). In the main effect model (1), PA and KAP came out as very strong predictors. The effect of PA on ulterior reading skills was very close to the one found in the literature. Regarding KAP, it should be noted that this effect has never been measured in the literature but our results showed that it was as strong as a predictor as PA. The results

drastically change when incorporating interactions in the second model (2). In the model with interactions, the main effect of PA on reading fluency was no longer significant. Furthermore, with the exception of the triple interaction between PA, OC and KAP, none of the coefficients that include PA were statistically significant, while all the ones that did not include PA were significant. In sum, in the second model, PA was almost never significant, and its effect was entirely contingent upon and mediated by OC and KAP. To further illustrate the nature of the interactions between PA, OC and KAP, we present the fitted values of the two models in Figures 4 and 5.

**Insert Figure 4 about here**

The results presented in Figure 4 can be interpreted as follows: PA did have a positive effect on reading fluency one year later, but its effect was entirely mediated and conditional upon strong scores in OC and KAP. When OC and KAP were low, the fluency curves as a function of PA were almost flat. Even in the case where KAP was low and OC was perfect, PA did not produce big gains in reading fluency. For example, when KAP was at chance (2/10) and OC was at ceiling (14/14), moving PA from 3/15 (chance score) to 15/15 did not increase reading fluency much (from 25.4 to 34.5 words per minute). In Figure 5, the same interaction is presented as a function of KAP.

**Insert Figure 5 about here**

Figure 5 shows that KAP had a strong positive effect on reading fluency one year later and its effect was less affected by the two other variables (here, PA and OC) than was the case for PA (OC and KAP), as displayed in Figure 4. Even though only a strong KAP guaranteed high



reading fluency, the results showed that it is a continuous rather than a binary ability. Its effect on ulterior reading levels was linear: each additional point on the test substantially improved future reading fluency.

### **Additional Analyses**

In this section, we will present a number of additional analyses (models) that further confirm the robustness of the results. In particular, we added three more predictor variables to the regressions: letter knowledge (LK), classroom and age (in months). Indeed, we had not used LK in the core regressions above (i.e., Table 3) because LK is closely intertwined with PA and KAP. We added a classroom fixed effect (one dummy variable per classroom minus the reference one) to account for teacher/class effects (model 5 and 6). We also added age as it accounts for quite a large amount of variance (model 4, 5 and 6). Because some configurations would have been nonsensical (e.g., a child with perfect KAP but no letter knowledge), we additionally ran the regressions on a sub-sample from which we excluded pupils with limited LK (model 6). Finally, in one of the models (model 3), we recoded reading fluency as a dichotomous variable with 50 words per minute as the cut-off point. We used a linear probability model for this analysis. The models are presented below.

$$(3) \text{ Reading fluency(dichotomous)}_j = \text{Model (2)} + e_j$$

$$(4) \text{ Reading fluency}_j = \text{Model (2)} + \beta_{9-19} \text{ Age}_j + \beta_{20} \text{ LK}_j + e_j$$

$$(5) \text{ Reading fluency}_j = \text{Model (2)} + \beta_{9-19} \text{ Age}_j + \beta_{20} \text{ LK}_j + \alpha \text{ classroom}_j + e_j$$

- For the whole population of pupils without pre-readers and only for pupils with good letter knowledge:

$$(6) \text{ Reading fluency}_j = \text{Model (2)} + \beta_{9-19} \text{ Age}_j + \beta_{20} \text{ LK}_j + \alpha \text{ classroom}_j + \epsilon_j$$

LK in early first grade was assessed in the national evaluations by presenting pupils a letter name and a series of different letters written in three formats in their test booklets (cursive, capital and print). Teachers said out loud the name of the letter and children were asked to circle all the instances of the same letter. Each series contained 18 letters and there were 3 instances of the correct letter, one for each writing (cursive, capital and print). This test was originally meant to assess alphabetic character knowledge. Since we were interested in letter knowledge rather than script knowledge, we recoded the test as following: pupils were given one point if they correctly circled at least one of the three correct answers while circling no wrong answer. The test was composed of 7 items (3 vowels and 4 consonants) and chance level was therefore below 1. The results are presented in Table 4.

**Insert Table 4 about here**

The results presented in Table 4 confirm that controlling for LK, classroom (teacher effects) and age, all of which had a positive and significant effect on reading fluency, did not change any of the results presented above (i.e., Table 3). That is, the effects of PA were not statistically significant and remained mediated by KAP and OC. KAP was the main predictor of subsequent reading skills.

## Discussion

The results of the present study show that PA has a significant positive main effect when KAP and OC are concurrently controlled (main effect model). However, the introduction of interaction terms in the present analyses considering the interactive and reciprocal effects of PA with KAP and OC tells a different story. That is, when interactions are taken into account, PA and OC alone are no longer good predictors of subsequent reading skills. They are both necessary but insufficient because they fail to guarantee good reading levels for the majority of pupils entering first grade when PA and OC are high but KAP is low. In this configuration, almost half of these pupils indeed experience great reading difficulties one year later.

On the contrary, KAP is by far the strongest predictor of later reading skills. Even though KAP partially encapsulates PA and is empirically also linked to OC, it does not need high levels of PA or OC to guarantee good reading levels of beginning readers. Almost all students (80%), who entered first grade with strong KAP, reached an acceptable reading level one year later even if they had fairly modest PA. Our results further suggest that KAP is best considered as a continuous rather than a binary ability contrary to what the literature on the “alphabetic principle” has suggested so far (e.g., Ehri & Soffer, 1999).



## General Discussion

Phonemic awareness (PA) is considered by many researchers to be one of the most – if not the most – powerful predictor of ulterior reading skills (e.g., Melby-Lervåg et al., 2012). In their influential article, Castles and Coltheart (2004) challenged this claim by arguing that no study had convincingly demonstrated a causal role of PA in learning-to-read because pre-reading skills had not been sufficiently controlled in these studies. In the first part of our article, we re-assessed Castles and Coltheart's (2004) claim in a new systematic review that investigated whether articles on the role of PA in learning-to-read published after 2004 controlled for pre-reading skills and potential interaction between these skills and PA. The results of the systematic review show that no single study published after 2004 has concurrently controlled for LK, decoding skills and their interactions with PA. Thus, it seems that there is no stronger evidence today than there was in 2004 for the claim that PA has a causal effect on ulterior reading skills.

In the second part of the article, we used longitudinal data from the French national and exhaustive evaluations in first and second grade (N = 810,328 children) to provide a more definite answer on the causal role of PA while controlling for various pre-reading skills and their interactions with PA. We investigated letter name knowledge (LK), oral comprehension (OC), and knowledge of the alphabetic principle (KAP). The results from several mixed-effect analyses show that although PA has a positive main effect on subsequent reading fluency, the causal effect of PA on later reading vanished when interactions between other pre-reading variables were considered. This finding is extremely robust as it was replicated in several additional

analyses controlling for classroom, age, and LK. Together, our results seem to suggest that PA is a less good predictor of subsequent reading fluency than is KAP.

Of course, one might argue that KAP is such a powerful predictor because it encapsulates PA, OC and LK. That is, to succeed in the KAP test, a child needs to isolate the first phoneme of a spoken word and needs to know the letter-sound correspondences that map onto this phoneme. However, as shown above, PA and KAP are not identical. There are readers with modest PA that become excellent readers one year later because they have high KAP, and there are readers with high PA and high OC that become poor readers one year later because they have low KAP.

These results are far from trivial as they force us to reconsider and redefine the concept of KAP. First, our results indicate that KAP should be considered a continuous rather than a binary ability contrary to what has been implied in the literature on reading development (e.g., Byrne, 1998, p. 20 or Castles & Coltheart, 2004, p. 91). Each additional point on the KAP scale is associated with a better reading score one year later. We propose the following stages for the development of KAP and its effect on learning-to-read. First (and consecutively to possible pre-alphabetic phases), the child understands that the oral language is graphically transcribed, that words are comprised of letters which code for speech sounds at the phonemic level. This comprehension does not require the child to know all letter-sound correspondences but each one of them deepens KAP and anchors the cognitive predispositions and ramifications based on it (such as decoding). Additionally, this comprehension does not entail that the child is able to associate letters and decode any two-letter syllable. Second, as KAP continues to deepen, the child understands that letters can be associated and read together (as two or three-letter

syllables) and that letter-sound correspondences vary depending on surrounding letters (digraphs and trigrams). This understanding is the basis of decoding, which in turn is crucial for bootstrapping lexical development.

The importance of KAP is consistent with the computational model by Ziegler et al. (2014, 2020) that simulates learning-to-read through decoding and self-teaching (i.e., Share, 1995). In this model, the grapheme-phoneme decoding network is at the heart of learning-to-read. In the initial phase, the network is trained explicitly on a small set of grapheme-phoneme correspondences (GPCs) using supervised learning that mimics the explicit teaching of GPCs in first weeks of primary school. Of course, hypothetically, the higher PA, the easier it should be to learn the rudimentary GPCs but this process is actually not implemented in the model, thus, it is not needed to obtain successful simulations of interindividual differences in learning to read (Perry et al., 2019; Ziegler et al., 2014, 2020). Once the explicit learning phase of GPCs is stopped, the model enters a self-teaching cycle, in which its rudimentary decoding network will allow the model to read aloud words it has never seen before. For any decoded phoneme string, it will search whether there is a corresponding word in the phonological lexicon. Whenever the network finds a phonological entry that matches the semantic context, self-teaching happens, that is, the correctly decoded word serves a non-supervised teaching signal that improves the very same process that generated the successful decoding response, that is the KAP network. In this process, good OC matters because if there are no phonological entries in the phonological lexicon, self-teaching will not occur. Importantly, the powerful self-teaching mechanism does not directly affect PA but it does very quickly affect the quality and efficiency of the grapheme-phoneme decoding network (for simulations, see Ziegler et al., 2014).

The results of the present article do not contradict the hypothesis according to which phonological deficits are the main pathway that leads to dyslexia (Hulme et al., 2015; Snowling & Melby-Lervåg, 2016). PA is necessary (even though children do not need high levels of PA to reach good levels of KAP and, consequently, of reading skills). Yet, it is insufficient: children entering first grade with high levels of PA and low levels of KAP are on average slow readers one year later. Low levels of PA might therefore help identifying children at risk, but high PA levels are not sufficient to predict good reading skills.

Our results indeed suggest that there is little to no beneficial effect of training PA by itself, which challenges an apparent consensus in the literature. To understand why, it should be kept in mind that for PA to emerge a child needs some minimum LK (let us call this the floor). Yet, the effect of PA on reading skills is statistically significant only when OC and KAP are strong (let us call this the roof). Thus, the margin, that is the space between the floor and the roof, to beneficially train PA in isolation seems very thin. Even if we cannot dismiss the possibility that there is a small benefit of training PA in isolation prior to any pre-reading skills, our results seem to suggest that good PA alone is not a strong predictor of success in reading unless KAP is good as well. These results suggest that we need to rethink about educational policy recommendations that encourage to exclusively train PA without a systematic link to its graphemic correspondences.

In conclusion, we would suggest that teachers need to be aware of the fact that our alphabetic systems are grapho-phonemic coding systems. They need to understand that KAP is a powerful predictor of later reading ability that can be easily assessed and systematically



taught. We are confident that a clear and unbiased understanding of these notions should yield rich rewards.

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## Tables

**Table 1. Descriptive statistics of predictor and outcome variables**

<b>Variables</b>		<b>n</b>	<b>mean</b>	<b>SD</b>	<b>Range</b>
Oral comprehension	Whole population	795 650	12.1	2.4	0-14
	Population without pre-readers	532 260	11.7	2.6	
Phoneme awareness	Whole population	796 967	8.9	3.6	0-15
	Population without pre-readers	538 719	7.8	3.4	
Knowledge of the alphabetic principle	Whole population	796 520	7.5	2.7	0-10
	Population without pre-readers	539 940	6.3	2.6	
Reading fluency	Population without pre-readers	757 373	54.2	43.1	0-300
	Population without pre-readers	501 258	45.0	30.5	

**Table 2. Correlation matrix between the predictor and outcome variables**

	Oral comprehension (early 1st grade)	Phonemic awareness (early 1st grade)	Knowledge of the alphabetic principle (early 1st grade)	Reading fluency (early 2nd grade)
Oral comprehension (early 1st grade)	1			
Phonemic awareness (early 1st grade)	0.43	1		
Knowledge of the alphabetic principle (early 1st grade)	0.39	0.59	1	
Reading fluency (early 2nd grade)	0.23	0.36	0.36	1

**Table 3. Results of the linear regression analysis using a model without interactions (main effect model) and a model with interactions.**

	<i>Whole population without pre-readers</i>			
	(1)		(2)	
	Main effects model		Model with interactions	
	Coefficient	p-value	Coefficient	p-value
(Intercept)	-16.135***	0.000	-5.780***	0.000
Phonemic awareness	1.737***	0.000	0.112	0.475
Oral comprehension	0.980***	0.000	0.883***	0.000
Knowledge of the alphabetic principle	2.681***	0.000	2.545***	0.000
Socio-economic status	0.185***	0.000	0.182***	0.000
PA*OC			0.009	0.513
PA*KAP			-0.029	0.243
OC*KAP			-0.110***	0.000
PA*OC*KAP			0.021***	0.000
Number of observations:	466 752		466 752	
R <sup>2</sup> :	0,128		0.132	
<i>Dependent variable:</i>	Reading fluency, i.e. number of words read per minute			
Significance levels: 0 '***' 0.001 '**' 0.01 '*' 0.05 '' 0.1 ' ' 1				

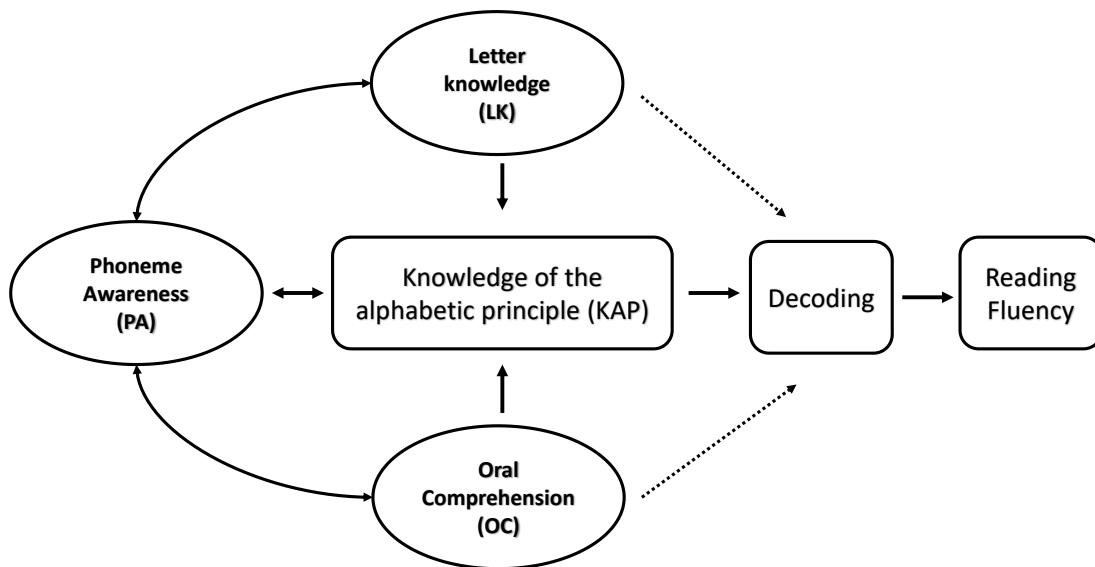
**Table 4. Additional analyses including age (in months), letter knowledge (LK) and classroom as fixed effects.**

	Whole population without pre-readers						Whole population without pre-readers & only for pupils with good letter knowledge	
	(3)		(4)		(5)		(6)	
	Linear probability model		Linear model		Linear model with classroom fixed effects		Linear model with classroom fixed effects	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
(Intercept)	-0.116***	0.010	-8.859***	0.000	<i>ref</i>		<i>ref</i>	
[Born in Jan.]			<i>ref</i>		<i>ref</i>		<i>ref</i>	
Born in Feb.			0.239	0.263	0.400'	0.062	0.487*	0.041
Born in Mar.			-0.308	0.139	-0.081	0.698	-0.014	0.953
Born in Apr.			-0.454*	0.031	-0.101	0.633	-0.088	0.709
Born in May			-0.606**	0.003	-0.156	0.450	-0.085	0.714
Born in Jun.			-1.162***	0.000	-0.733***	0.000	-0.697**	0.003
Born in Jul.			-1.054***	0.000	-0.444*	0.028	-0.301	0.186
Born in Aug.			-1.256***	0.000	-0.664**	0.001	-0.635***	0.005
Born in Sep.			-1.287***	0.000	-0.532**	0.008	-0.343	0.131
Born in Oct.			-1.559***	0.000	-0.629**	0.002	-0.628**	0.006
Born in Nov.			-1.946***	0.000	-0.945***	0.000	-0.943***	0.000
Born in Dec.			-2.138***	0.000	-0.979***	0.000	-0.803***	0.000
Letter knowledge			2.536***	0.000	2.540***	0.000	2.848***	0.000
Socio-economic status	0.002***	0.000	0.182***	0.000				
Phonemic awareness	-0.009***	0.002	-0.392**	0.002	-0.461***	0.000	0.208	0.316
Oral comprehension	0.002*	0.001	0.343***	0.000	0.016	0.781	0.564***	0.000
Knowledge of the alphabetic principle	0.013***	0.002	1.56***	0.000	1.310***	0.000	2.261***	0.000
PA*OC	0.001***	0.000	0.037***	0.001	0.071***	0.000	0.007	0.692
PA*KAP	0.001***	0.000	0.026	0.209	0.086***	0.000	-0.016	0.609
OC*KAP	0.000	0.000	-0.053***	0.000	-0.034**	0.004	-0.122***	0.000
PA*OC*KAP	0.000***	0.000	0.016***	0.000	0.012***	0.000	0.022***	0.000
Number of observations:	466 752		444 475		444 475		369 360	
R <sup>2</sup> =	0.118		0.205		0.377		0.363	
<i>Dependent variable:</i>	Reading fluency, i.e. number of words read per minute.				Dummy variable = 1 when pupils read at a 50-word pace per minute or more; = 0 otherwise.		Reading fluency, i.e. number of words read per minute.	

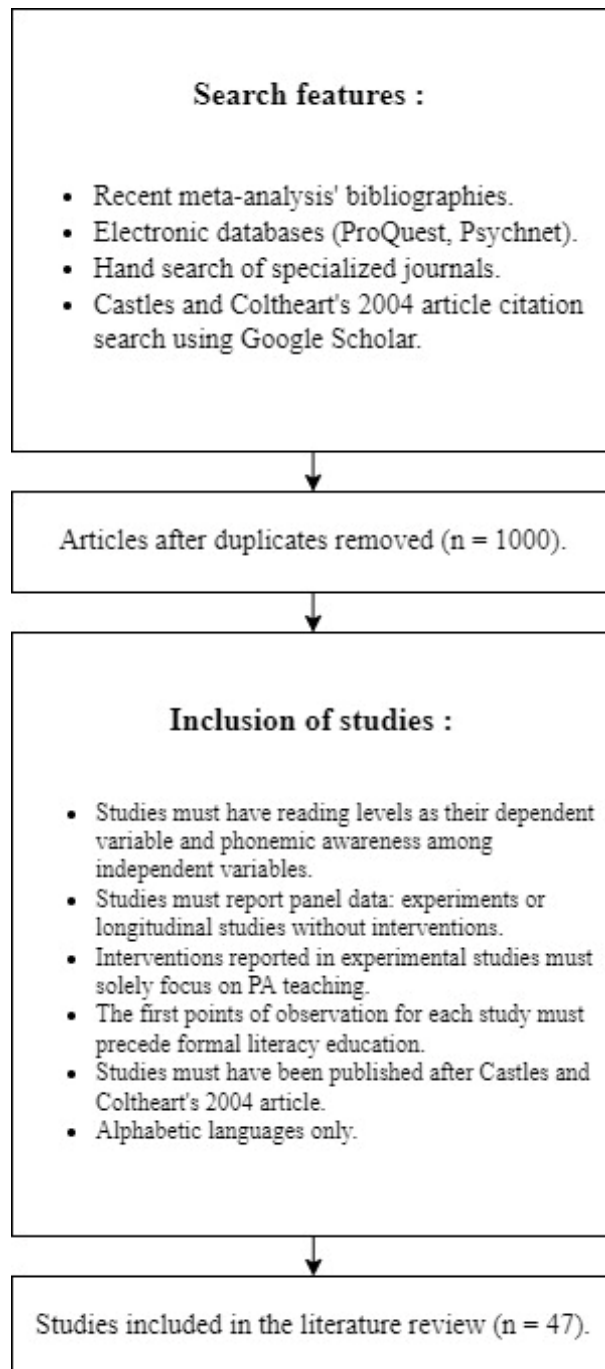
Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

## Figures

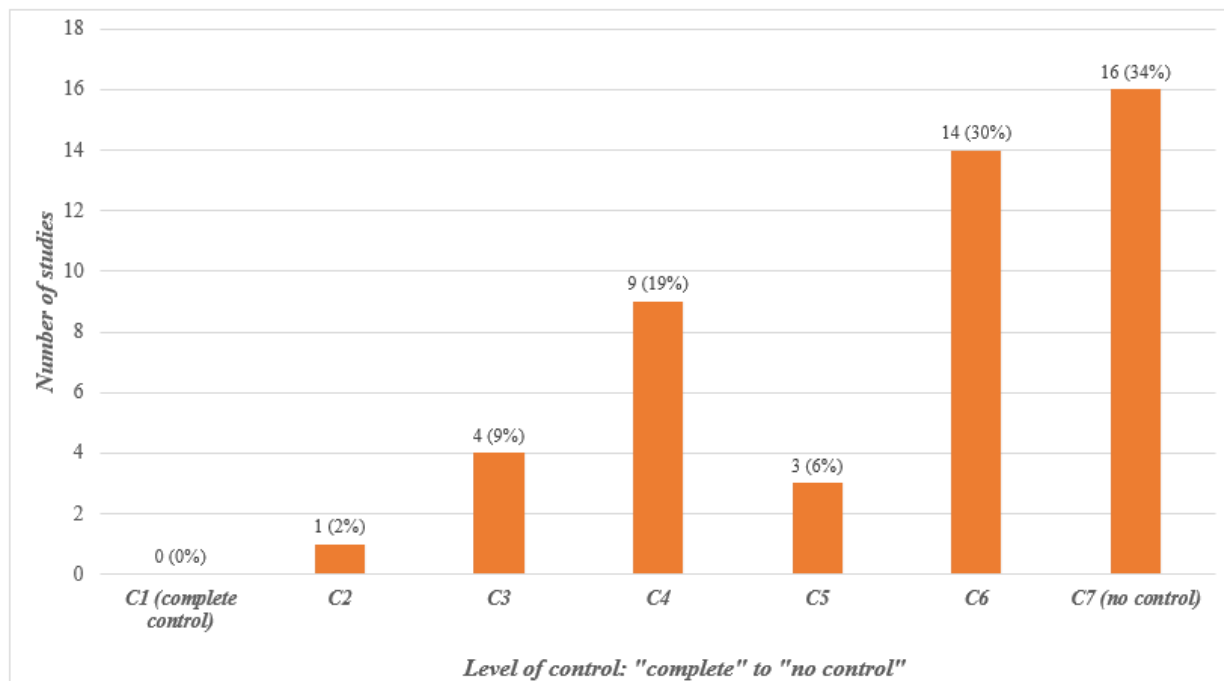
**Figure 1. Theoretical model on the relation between pre-reading variables and their role on decoding and reading fluency. In this model, knowledge of the alphabetic principle plays a central role for predicting decoding and ultimately reading fluency.**



**Figure 2. Flow Diagram for the Search and Inclusion Criteria of Studies in the Systematic Review**



**Figure 3. Decoding Skills and Letter Knowledge Control Types in the Systematic Review (N = 47 articles)**



Complete control ↑

Control strictness

No control

**C1** : No decoding skills accepted. LK controlled in interaction with PA.

**C2** : No decoding skills accepted. LK controlled but without any interaction with PA.

**C3** : Children cannot read words but might be able to decode some syllables.  
LK controlled but without any interaction with PA.

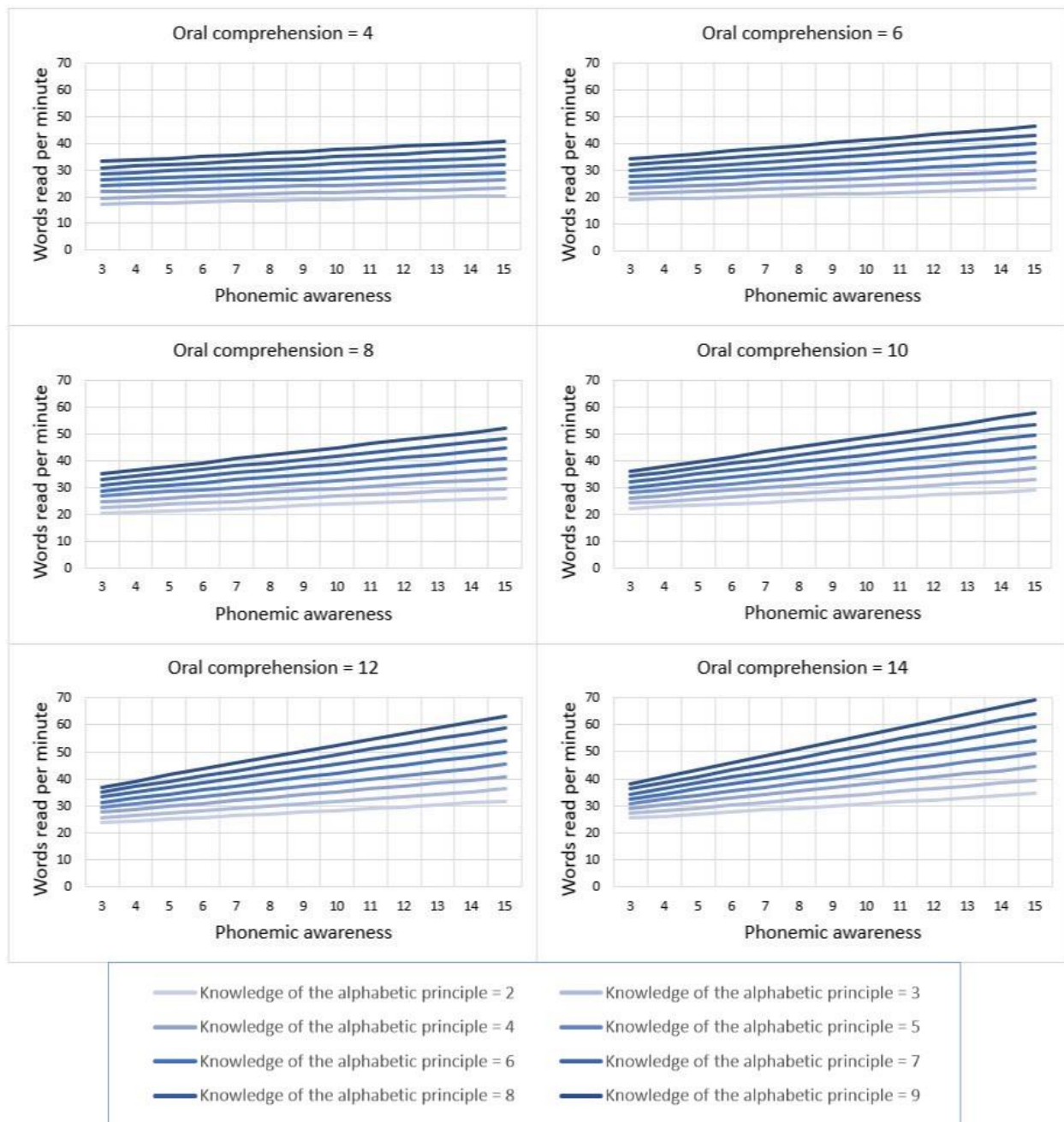
**C4** : Decoding skills and LK controlled but without any interaction with PA.

**C5** : Decoding skills controlled but without any interaction with PA. LK not controlled.

**C6** : Decoding skills not controlled. LK controlled but without any interaction with PA.

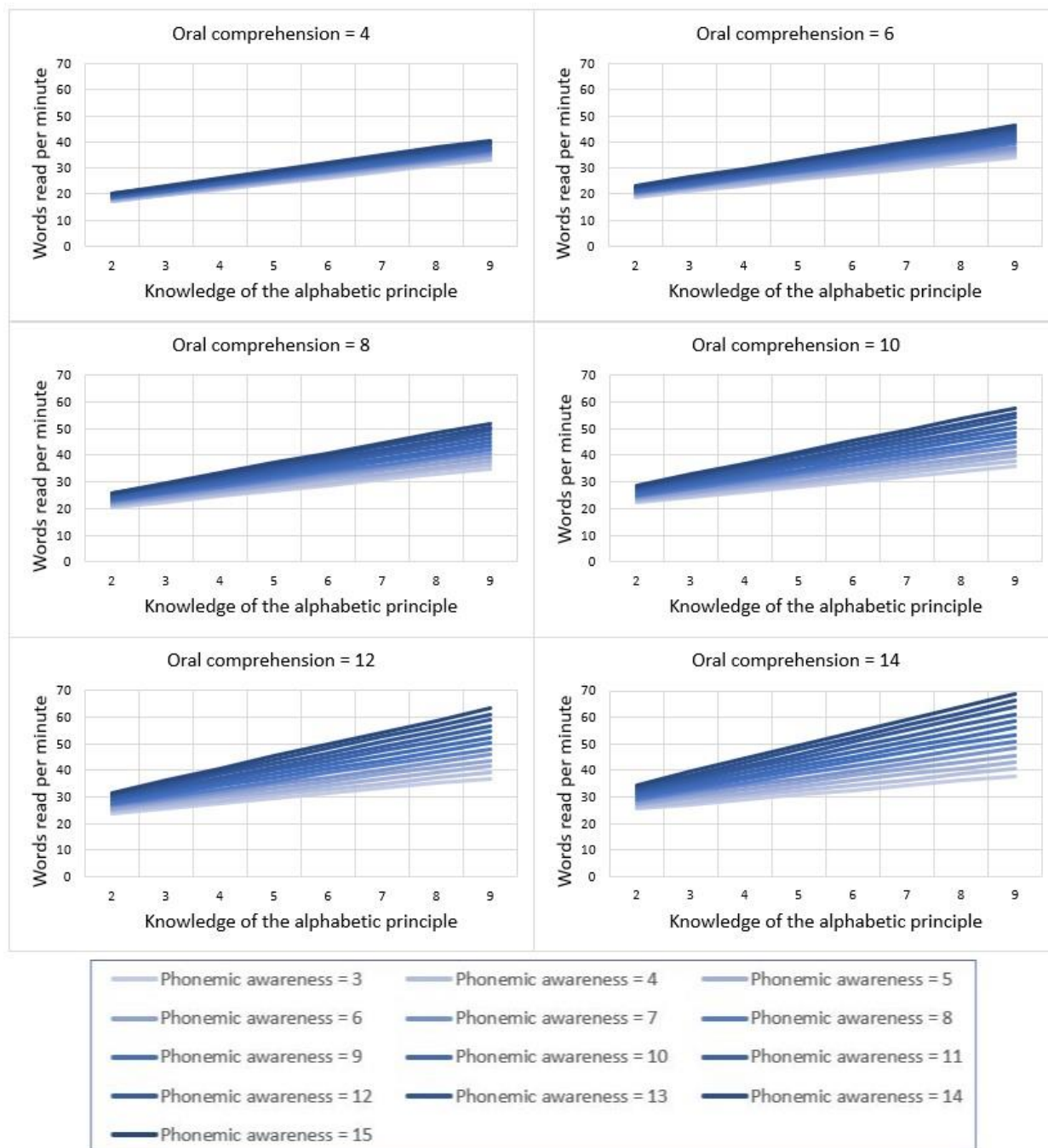
**C7** : Decoding skills not controlled. Letter knowledge not controlled.

**Figure 4. Predicted reading fluency (words per minute) for the interaction model as a function of PA (on the abscissa) and various levels of oral comprehension (OC) and different levels of knowledge of the alphabetic principle, KAP (i.e., the different lines)**





**Figure 5. Predicted reading fluency (words per minute) for the interaction model as a function of knowledge of the alphabetic principle (on the abscissa) and various levels of oral comprehension and different levels of PA (different lines)**



### Appendix 1: Studies included in the systematic review

Bianco, M., Pellenq, C., Lambert, E., Bressoux, P., Lima, L., & Doyen, A.-L. (2011). Impact of early code-skill and oral-comprehension training on reading achievement in first grade.

- Intervention.
- N = 687 children.
- C7: Regressions. Decoding skills not controlled. LK not controlled.

Bravo, M. V., Etchevers, E. O., & Valdivieso, L. B. (2006). Diferencias en la Predictividad de la Lectura Entre Primer Año y Cuarto Año Básicos.

- Longitudinal (no intervention).
- N = 227 children.
- C6: Regressions. Decoding skills not controlled. LK (names or sounds) controlled but without any interaction with PA.

Caravolas, M., Lervåg, A., Mousikou, P., Efrim, C., Litavsky, M., Onochie-Quintanilla, E., et al. (2012). Common patterns of prediction of literacy development in different alphabetic orthographies.

- Longitudinal (no intervention).
- N = 735 children.
- C4: Regressions. Decoding skills and LK (names and sounds) controlled but without any interaction with PA.

Carlson, E., Jenkins, F., Li, T., & Brownell, M. (2013). The Interactions of Vocabulary, Phonemic

Awareness, Decoding, and Reading Comprehension.

- Longitudinal (no intervention).
- N = 3104 children.
- C7: Regressions. Decoding skills not controlled. LK not controlled.

Casalis, S., & Colé, P. (2009). On the relationship between morphological and phonological awareness:

Effects of training in kindergarten and in first-grade reading.

- Intervention.
- N = 90 children.
- C3: Regressions. Readers were excluded from the study (“reader” criteria not specified). Letter-knowledge (the authors do not specify whether the variable measures knowledge of names and/or sounds) controlled but without any interaction with PA.

Casillas, Á., & Goikoetxea, E. (2007). Syllable, onset-rhyme, and phoneme as predictors of early reading and spelling.

- Longitudinal (no intervention).
- N = 48 children.
- C3: Regressions. Children could not read any pseudoword. Letter-knowledge (names or sounds) controlled but without any interaction with PA.

Chiappe, P., Glaeser, B., & Ferko, D. (2007). Speech Perception, Vocabulary, and the Development of Reading Skills in English among Korean- and English-Speaking Children.

- Longitudinal (no intervention).
- N = 50 children.

- C4: Regressions. Decoding skills and LK (both in a unique synthetic variable) controlled but without any interaction with PA.

Clayton, F. J., West, G., Sears, C., Hulme, C., & Lervåg, A. (2020). A Longitudinal Study of Early Reading Development: Letter-Sound Knowledge, Phoneme Awareness and RAN, but Not Letter-Sound Integration, Predict Variations in Reading Development.

- Longitudinal (no intervention).
- N = 191 children.
- C6: Regressions. Decoding skills not controlled. LK (sounds) controlled but without any interaction with PA.

Dally, K. (2006). The influence of phonological processing and inattentive behavior on reading acquisition. *Journal of Educational Psychology, 98*, 420–437.

- Longitudinal (no intervention).
- N = 132 children.
- C4: Regressions. Decoding skills and LK (names and sounds) controlled but without any interaction with PA.

Deacon, H., Wade-Woolley, L., & Kirby, J. (2007). Crossover: The role of morphological awareness in French Immersion children's reading.

- Longitudinal (no intervention).
- N = 76 children.
- C7: Regressions. Decoding skills not controlled. LK not controlled.

Fricke, S., Szczerbinski, M., Fox-Boyer, A., & Stackhouse, J. (2016). Preschool Predictors of Early

Literacy Acquisition in German-Speaking Children.

- Longitudinal (no intervention).
- N = 78 children.
- C6: Regressions. Decoding skills not controlled. LK (names or sounds) controlled but without any interaction with PA.

Fumagalli, J., Barreyro, J. P., & Jaichenco, V. (2014). Syllabic awareness and phonemic awareness:

Which is the best reading predictor?

- Longitudinal (no intervention).
- N = 70 children.
- C7: Regressions. Decoding skills and LK not controlled.

Furnes, B., & Samuelsson, S. (2011). Phonological Awareness and Rapid Automatized Naming

Predicting Early Development in Reading and Spelling: Results from a Cross-Linguistic Longitudinal Study.

- Longitudinal (no intervention).
- N = 980 children.
- C4: Regressions. Decoding skills and LK (names) controlled but without any interaction with PA.

Gottardo, A., Pasquarella, A., Chen, X., & Ramirez, G. (2016). The impact of language on the relationships between phonological awareness and word reading in different orthographies: A test of the psycholinguistic grain size theory in bilinguals.

- Longitudinal (no intervention).

- N = 252 children.
- C7: Regressions. Decoding skills and LK not controlled.

Jared, D., Cormier, P., Levy, B. A., & Wade-Woolley, L. (2011). Early predictors of biliteracy development in children in French immersion: A 4-year longitudinal study.

- Longitudinal (no intervention).
- N = 140 children.
- 5<sup>th</sup> and C6: Regressions. Different models estimated including decoding skills and LK (sounds) but never simultaneously (in the same one) and without any interaction with PA.

Kelley, M. F., Roe, M., Blanchard, J., & Atwill, K. (2015). The influence of Spanish vocabulary and phonemic awareness on beginning English reading development: A three-year (K–2nd) longitudinal study.

- Longitudinal (no intervention).
- N = 80 children.
- C7: Regressions. Decoding skills and LK not controlled.

Kim, Y.-S., & Pallante, D. (2012). Predictors of reading skills for kindergartners and first grade students in Spanish: A longitudinal study.

- Longitudinal (no intervention).
- N = 468 children.
- C4: Regressions. Decoding skills and LK (names) controlled but without any interaction with PA.

Kjeldsen, A.-C., Educ, L., Saarento-Zaprudin, S., & Niemi, P. (2019). Kindergarten Training in

Phonological Awareness: Fluency and Comprehension Gains Are Greatest for Readers at Risk in Grades 1 Through 9.

- Intervention.
- N = 209 children.
- C6: Regressions. Decoding skills not controlled. LK (names) controlled but without any interaction with PA.

Koponen, T., Salmi, P., Eklund, K., & Aro, T. (2013). Counting and RAN: Predictors of Arithmetic Calculation and Reading Fluency.

- Longitudinal (no intervention).
- N = 200 children.
- C7: Regressions. Decoding skills and LK not controlled.

Krenca, K., Segers, E., Chen, X., Shakory, S., Steele, J., & Verhoeven, L. (2020). Phonological specificity relates to phonological awareness and reading ability in English–French bilingual children.

- Longitudinal (no intervention).
- N = 62 children.
- C4: Regressions. Decoding skills and LK (both in a unique synthetic variable) controlled but without any interaction with PA.

Landerl, K., & Wimmer, H. (2008). Development of Word Reading Fluency and Spelling in a Consistent Orthography: An 8-Year Follow-Up.

- Longitudinal (no intervention).
- N = 115 children.

- C6: Regressions. Decoding skills not controlled. LK (names or sounds) controlled but without any interaction with PA.

Landerl, K., Freudenthaler, H. H., Heene, M., De Jong, P. F., Desrochers, A., Manolitsis, G., et al. (2019). Phonological Awareness and Rapid Automatized Naming as Longitudinal Predictors of Reading in Five Alphabetic Orthographies with Varying Degrees of Consistency.

- Longitudinal (no intervention).
- N = 1120 children.
- C5: Regressions. Decoding skills controlled but without any interaction with PA. LK not controlled.

Lervåg, A., Bråten, I., & Hulme, C. (2009). The cognitive and linguistic foundations of early reading development: A Norwegian latent variable longitudinal study.

- Longitudinal (no intervention).
- N = 228 children.
- C6: Regressions. Decoding skills not controlled. LK (names and sounds) controlled but without any interaction with PA.

Lesaux, N., Rupp, A., & Siegel, L. (2007). Growth in Reading Skills of Children From Diverse Linguistic Backgrounds: Findings From a 5-Year Longitudinal Study.

- Longitudinal (no intervention).
- N = 824 children.
- C6: Regressions. Decoding skills not controlled. LK (names) controlled but without any interaction with PA.



Lundetræ, K., & Thomson, J. M. (2018). Rhythm production at school entry as a predictor of poor reading and spelling at the end of first grade.

- Longitudinal (no intervention).
- N = 479 children.
- C6: Regressions. Decoding skills not controlled. LK (sounds) controlled but without any interaction with PA.

Mansour-Adwan, J., Asadi, I. A., & Khateb, A. (2020). Phonological task comparability in Arabic and relation to reading: a longitudinal assessment in kindergarten and first grade.

- Longitudinal (no intervention).
- N = 32 children.
- C7: Analysis of correlations. Decoding skills not controlled. LK not controlled.

Muter, V., Hulme, C., Snowling, M. J., & Stevenson, J. (2004). Phonemes, Rimes, Vocabulary, and Grammatical Skills as Foundations of Early Reading Development: Evidence From a Longitudinal Study.

- Longitudinal (no intervention).
- N = 90 children.
- C4: Regressions. Decoding skills and LK (names or sounds) controlled but without any interaction with PA.

Nancollis, A., Lawrie, B.-A., & Dodd, B. (2005). Phonological Awareness Intervention and the Acquisition of Literacy Skills in Children From Deprived Social Backgrounds.

- Longitudinal (no intervention).
- N = 213 children.

- C7: Group comparison. Decoding skills not controlled. LK not controlled.

O'Brien, B. A., Mohamed, M. B. H., Yussof, N. T., & Ng, S. C. (2019). The phonological awareness relation to early reading in English for three groups of simultaneous bilingual children.

- Longitudinal (no intervention).
- N = 612 children.
- C7: Regressions. Decoding skills not controlled. LK not controlled.

Parrila, R., Kirby, J. R., & McQuarrie, L. (2004). Articulation rate, naming speed, verbal short-term memory, and phonological awareness: Longitudinal predictors of early reading development?

- Longitudinal (no intervention).
- N = 161 children.
- C5 and C6: Regressions. Different models estimated including decoding skills and LK (sounds) but never simultaneously (in the same one) and without any interaction with PA.

Piquard-Kipffer, A., & Sprenger-Charolles, L. (2013). Early predictors of future reading skills: A follow-up of French-speaking children from the beginning of kindergarten to the end of the second grade (age 5 to 8).

- Longitudinal (no intervention).
- N = 85 children.
- C2: no single blend accepted. LK (names) controlled but without any interaction with PA.

Powell, D., & Atkinson, L. (2021). Unraveling the links between rapid automatized naming (RAN), phonological awareness, and reading.

- Longitudinal (no intervention).

- N = 91 children.
- C3: Regressions. Children could not read any word. Letter-knowledge (names or sounds) controlled but without any interaction with PA.

Roberts, T. A. (2005). Articulation Accuracy and Vocabulary Size Contributions to Phonemic Awareness and Word Reading in English Language Learners.

- Longitudinal (no intervention).
- N = 45 children.
- C7: Regressions. Decoding skills not controlled. LK not controlled.

Rodríguez, T. C. (2011). Conciencia Fonológica como predictor de la lectura al inicio de la escolaridad en contextos de pobreza.

- Longitudinal (no intervention).
- N = 100 children.
- C7: Regressions. Decoding skills not controlled. LK not controlled.

Sanchez, M., Magnan, A., & Ecalle, J. (2012). Knowledge about word structure in beginning readers: what specific links are there with word reading and spelling?

- Longitudinal (no intervention).
- N = 123 children.
- C6: Regressions. Decoding skills not controlled. LK (names) controlled but without any interaction with PA.

Schatschneider, C., Fletcher, J. M., Francis, D. J., Carlson, C. D., & Foorman, B. R. (2004). Kindergarten Prediction of Reading Skills: A Longitudinal Comparative Analysis.

- Longitudinal (no intervention).
- N = 945 children.
- C6: Regressions. Decoding skills not controlled. LK (names and sounds) controlled but without any interaction with PA.

Sénéchal, M. (2017). Testing a nested skills model of the relations among invented spelling, accurate spelling, and word reading, from kindergarten to grade 1.

- Longitudinal (no intervention).
- N = 107 children.
- C4: Regressions. Decoding skills and LK (names) controlled but without any interaction with PA.

Silvén, M., Poskiparta, E., Niemi, P., & Voeten, R. (2007). Precursors of Reading Skill From Infancy to First Grade in Finnish: Continuity and Change in a Highly Inflected Language.

- Longitudinal (no intervention).
- N = 56 children.
- C5: Regressions. Decoding skills controlled but without any interaction with PA. LK not controlled.

Suárez-Coalla, P., García-de-Castro, M., & Cuetos, F. (2013). Predictors of reading and writing in Spanish.

- Longitudinal (no intervention).
- N = 50 children.
- C7: Regressions. Decoding skills not controlled. LK not controlled.

Suggate, S., Reese, E., Lenhard, W., & Schneider, W. (2014). The relative contributions of vocabulary, decoding, and phonemic awareness to word reading in English versus German.

- Longitudinal (no intervention).
- N = 133 children.
- C5: Regressions. Decoding skills controlled but without any interaction with PA. LK not controlled.

Vander Stappen, C., & Van Reybroeck, M. (2022). Relating Phonological Awareness and Rapid Automated Naming to Phonological and Orthographic Processing of Written Words: Cross-sequential Evidence from French.

- Longitudinal (no intervention).
- N = 153 children.
- C7: Regressions. Decoding skills not controlled. LK not controlled.

Vergara, D., Strasser, K., & Del Río, F. (2016). Beyond words per minute: The other skills that influence comprehension in first grade.

- Longitudinal (no intervention).
- N = 202 children.
- C4: Regressions. Decoding skills and LK (names) controlled but without any interaction with PA.

Villagrán, A. M., Guzmán, N. J. I., Jiménez M., I., Cuevas, A. C., Consejero, M. E., & Olivier, R. P. (2010). Naming speed and phonological awareness in early reading learning.

- Longitudinal (no intervention).

- N = 85 children.
- C6: Regressions. Decoding skills not controlled. LK (names) controlled but without any interaction with PA.

Wheldall, R., Glenn, K., Arakelian, S., Madelaine, A., Reynolds, M., & Wheldall, K. (2016). Efficacy of an evidence-based literacy preparation program for young children beginning school.

- Intervention.
- N = 240 children.
- C6: Regressions. Decoding skills not controlled. LK (sounds) controlled but without any interaction with PA.

Wolff, U., & Gustafsson, J.-E. (2022). Early phonological training preceding kindergarten training: effects on reading and spelling.

- Intervention.
- N = 364 children.
- C7: Regressions. Decoding skills not controlled. LK not controlled.

Zhao, J., Dixon, L. Q., Quiroz, B., & Chen, S. (2017). The Relationship Between Vocabulary and Word Reading Among Head Start Spanish–English Bilingual Children.

- Longitudinal (no intervention).
- N = 117 children.
- C7: Regressions. Decoding skills not controlled. LK not controlled.

Zugarramurdi, C., Fernández, L., Lallier, M., Valle-Lisboa, J. C., & Carreiras, M. (2022). Mind the orthography: Revisiting the contribution of prereading phonological awareness to reading acquisition.

- Longitudinal (no intervention).
- N = 616 children.
- C3: Regressions. Children could not read any pseudoword. Letter-knowledge (names and sounds) controlled but without any interaction with PA.