



Phonological development in relation to native language and literacy: Variations on a theme in six alphabetic orthographies



Lynne G. Duncan^{a,*}, São Luís Castro^b, Sylvia Defior^c, Philip H.K. Seymour^a, Sheila Baillie^a, Jacqueline Leybaert^d, Philippe Mousty^d, Nathalie Genard^d, Menelaos Sarris^e, Costas D. Porpodas^e, Rannveig Lund^f, Baldur Sigurðsson^g, Anna S. Þráinsdóttir^g, Ana Sucena^b, Francisca Serrano^c

^a School of Psychology, University of Dundee, Dundee DD1 4HN, United Kingdom

^b Centro de Psicologia, Faculdade de Psicologia e Ciências da Educação, Universidade do Porto, 4200-135 Porto, Portugal

^c Faculty of Psychology, Universidad de Granada, 18071 Granada, Spain

^d Centre for Research in Cognition & Neuroscience, Laboratoire Cognition Langage & Développement, Université libre de Bruxelles, B-1050 Brussels, Belgium

^e Section of Psychology, Department of Education, Faculty of Humanities and Social Sciences, University of Patras, 26504 Patras, Greece

^f Reykjavik Academy, 107 Reykjavik, Iceland

^g School of Education, University of Iceland, 105 Reykjavik, Iceland

ARTICLE INFO

Article history:

Received 29 July 2010

Revised 11 February 2013

Accepted 16 February 2013

Keywords:

Phonological awareness

Orthographic depth

Speech rhythm

Cross-linguistic

Reading development

Phonics instruction

ABSTRACT

Phonological development was assessed in six alphabetic orthographies (English, French, Greek, Icelandic, Portuguese and Spanish) at the beginning and end of the first year of reading instruction. The aim was to explore contrasting theoretical views regarding: the question of the availability of phonology at the outset of learning to read (Study 1); the influence of orthographic depth on the pace of phonological development during the transition to literacy (Study 2); and the impact of literacy instruction (Study 3). Results from 242 children did not reveal a consistent sequence of development as performance varied according to task demands and language. Phonics instruction appeared more influential than orthographic depth in the emergence of an early meta-phonological capacity to manipulate phonemes, and preliminary indications were that cross-linguistic variation was associated with speech rhythm more than factors such as syllable complexity. The implications of the outcome for current models of phonological development are discussed.

© 2013 Elsevier B.V. All rights reserved.

1. Introduction

While the impact of variation between languages on orthographic development has been documented in several large-scale studies (Caravolas et al., 2012; Ellis et al., 2004; Seymour et al., 2003; Ziegler et al., 2010), phonolog-

ical development has yet to receive the same degree of attention in cross-linguistic research. One consequence of this is that understanding of phonological development in relation to early reading is informed by a predominantly English-language literature with all the disadvantages entailed by over-reliance on what is acknowledged to be an atypical orthography (Share, 2008). Of course, many notable studies on languages other than English exist; indeed, seminal work on phonological awareness was conducted using the Germanic languages of Scandinavia (Lundberg, Frost, & Petersen, 1988; Lundberg, Olofsson, & Wall,

* Corresponding author. Address: School of Psychology, University of Dundee, Dundee DD1 4HN, United Kingdom. Tel.: +44 (0)1382 384629; fax: +44 (0)1382 229993.

E-mail address: l.g.duncan@dundee.ac.uk (L.G. Duncan).

1980). Nevertheless, few studies have systematically compared phonological development between two languages in order to understand the interaction between native language and progress, and none to our knowledge have made observations cross-linguistically and longitudinally from the point when spoken language determines phonological awareness until increasing experience of the written orthography begins to influence further development. Thus, the present study is unusual in both scale and duration, as it encompasses six European languages with alphabetic orthographies and uses a carefully-matched methodology to compare phonological development during the first year of reading acquisition.

A detailed review of the literature follows this section. The theoretical questions under investigation concern competing views about the nature of phonological development. From one perspective, development is seen as a universal sequence of increasing sensitivity to smaller units of sound as a result of the changing organisation of speech representations during language acquisition. However, other views predict more variability in the sequence of development according to the characteristics of the specific language context and whether implicit or explicit learning about sound is examined. The questions are timely, having important implications not only for understanding the development of the phonological system but also for modelling early visual word recognition (Grainger, Lété, Bertrand, Dufau, & Ziegler, 2012; Ziegler & Goswami, 2005), where the phonological lexicon is regarded as integral to the orthographic learning process.

The data will show that the idea of a universal fixed sequence of development is an unnecessary constraint on thinking in this area. Instead, our experiments will reveal a dynamic process that responds to the influences of native language, task demands and instructional context. Surprisingly, the phonological awareness literature has not always embraced such factors perhaps due to the combination of an anglocentric bias and a strong theoretical focus on the size of the sounds that are important in early reading.

1.1. Competing views of preschool phonological development

The relation between phonology and orthography in reading development is most likely bi-directional (e.g., Perfetti, Beck, Bell, & Hughes, 1987; Wagner, Torgesen, & Rashotte, 1994). A necessary first step in uncovering the fine details of this relationship between phonology and orthography then is to describe the availability of sound as reading acquisition begins and whether this differs notably between languages. What would be considered “atypical” is particularly important since delay or impairment to the availability of early phonological skills is detrimental to subsequent reading progress (Carroll & Snowling, 2004).

Phonological development is characterised as a large-to-small sequence in the *Lexical Restructuring* (LR) model (Metsala & Walley, 1998; Walley, 1993). The basis of this model is that the need to distinguish an increasing variety of words in the developing lexicon causes recursive change, known as *lexical restructuring*, in the early organisation of the speech system. Spoken words are initially

represented as unanalysed wholes with the result that attributes such as global acoustic or prosodic structure are used for recognition. As the lexicon begins to expand significantly with the vocabulary growth spurt around the age of 18 months, there is an increased need for more fine-grained sub-lexical representations to facilitate discrimination between similar lexical entries. Lexical representations, initially based around syllables, are gradually overlaid with segmental information and cross-referenced with existing members of similarity neighbourhoods to produce efficiencies in storage and recognition. Nevertheless, children’s speech processing is thought to remain more holistic than that of adults throughout middle childhood in spite of the increasingly segmental organisation in long-term memory. For example, children aged between 4 and 5 years still make syllable similarity classifications based on global similarity rather than using phonemic similarity as favoured by adults (Treiman & Baron, 1981; Treiman & Breaux, 1982).

Thus, the LR model gives rise to several key claims: (1) lexical restructuring alters the structure of speech representations from a holistic to a segmental format (i.e. a large-to-small sequence); (2) lexical restructuring is vocabulary-driven and occurs first for items that are acquired early, are high in frequency and are from dense neighbourhoods; (3) early (implicit) sensitivity to phonemes in spoken word recognition is the product of this process of segmental restructuring; (4) emerging phoneme awareness, an explicit ability, depends on this aspect of “language development specifically, rather than on general metacognitive ability or reading experience” (Metsala & Walley, 1998, p. 108); and therefore, (5) implicit and explicit performance will be related for specific items.

Some variants of the LR view exist with several authors specifying that large-to-small restructuring follows the proposed hierarchical internal structure of the syllable (Selkirk, 1982). Instead of the syllable-to-phoneme sequence envisaged in the LR model, this would create a path from a syllabic to an intermediate level of organisation, which emphasises the onset (i.e. the initial consonant(s)) and the rime (the vowel plus any following consonants), before finally settling at the phonemic level (e.g., Ferguson & Farwell, 1975; Jusczyk, 1986). The *Psycholinguistic Grain Size* (PGS) model of reading development (Ziegler & Goswami, 2005; Ziegler, Perry, Jacobs, & Braun, 2001) predicts that preschool restructuring will only create a progression from syllable to onset-rime awareness and that further progression to the phoneme level will not occur until reading begins (see also Goswami (2002)). Finally, while the LR model portrays the restructuring sequence as universal, the PGS model acknowledges the possibility of cross-language variation on the basis of the characteristics of spoken language such as the prevalence of phonological rime neighbourhoods. Variation is limited at present to differing rates of phonological development among European languages as opposed to the possibility of differing sequences of development (see also Anthony & Francis, 2005).

An alternative account contained within a more general model of *meta-linguistic* (ML) development, referred to here as the ML model, contrasts with this position in a number of ways (Gombert, 1992; Karmiloff-Smith, 1986).

Firstly, the impetus for change is not vocabulary growth alone but rather a wider interaction with the linguistic environment. Secondly, lexical information, initially stored in an instance-bound format, is gradually reorganised to allow representation of more abstract, system-wide knowledge about the system of language sounds. This offers some degree of elementary (*epi-linguistic*) control, although the information is still inaccessible to conscious awareness. This phase is necessary for the development of conscious (*meta-linguistic*) control but it is not sufficient, as only the presence of a specific meta-cognitive demand in the external language environment leads to the ability to manipulate sound consciously. Thirdly, meta-phonological development proceeds independently for each unit of sound, leaving open the possibility that a child could be in the more explicit *meta-phase* for phonemes but remain in the implicit *epi-phase* for larger rime units. Finally, the overt dependence of the model on the language environment creates the potential for alternative routes in phonological development according to the characteristics of native language.

Evidence relating to these points of contrast between the models will be reviewed in the remainder of this section.

1.1.1. Influence of vocabulary growth

Vocabulary-driven restructuring, as described in the LR model, is supported by developmental evidence that low frequency words are more likely to be represented in greater phonological detail if they are from dense than sparse phonological neighbourhoods (Metsala, 1997, 1999). Nevertheless, the observation that this frequency by neighbourhood density interaction is displayed to the same extent by literate and illiterate adult populations in gating and identification in noise tasks (Ventura, Kolinsky, Fernandes, Querido, & Morais, 2007a), raises issues about the relationship between restructuring and vocabulary growth since vocabulary tends to be smaller in illiterate than literate groups (Morais & Kolinsky, 2002). One possibility is that segmental restructuring occurs after a certain threshold of vocabulary is acquired and so the process would be complete by adulthood regardless of literacy (Metsala, Stavrinos, & Walley, 2009; Ventura et al., 2007a), but this would need to be reconciled with evidence that segmental organisation and vocabulary are related within both child and adult populations (Foy & Mann, 2009). Another possibility suggested by studies of young word learners is that vocabulary size is not a direct factor since segmental representations may be present earlier than previously thought, although access to these may be difficult and dependent on familiarity (Ballem & Plunkett, 2005).

Evidence of a relation between vocabulary and later phonological awareness is also somewhat mixed. While receptive vocabulary is a strong correlate of phonological awareness in some studies (McBride-Chang, Wagner, & Chang, 1997; Metsala, 1999), others have failed to find such a relationship (Elbro, Borstrom, & Petersen, 1998; Garlock, Walley, & Metsala, 2001). In yet other studies, facility at recognising spoken words from sparse neighbourhoods emerged as a predictor (Garlock et al., 2001;

Metsala et al., 2009). Although this latter finding does not appear consistent with LR predictions, it could be that this measure acts as an index of the quality of the underlying speech representations that may underpin both vocabulary acquisition and phonological awareness (e.g., Boada & Pennington, 2006; Elbro et al., 1998).

1.1.2. A large-to-small sequence in phonological development

One important but unanswered question is whether the view that early lexical representations become increasingly segmental is best characterised as a large-to-small (syllable-to-phoneme) sequence as implied in the LR model, or whether restructuring might be progressive in the sense that there is an intermediate onset-rime level of representation as suggested in the PGS model.

Preschool sensitivity to syllables and rimes in phonological awareness tasks is well documented (Goswami & Bryant, 1990) but reports of the relative salience of these units vary. Carroll, Snowling, Hulme, and Stevenson (2003) found no preschool difference in syllable and rime matching where word pairs containing shared sounds had to be discriminated from those with no sounds in common. In contrast, Anthony, Lonigan, Driscoll, Phillips, and Burgess (2003) observed an overall advantage for syllables over rimes in tasks requiring sound blending to form words or sound deletion from words. Much may depend on unit size since syllables (e.g., window, table) are not necessarily larger than rimes (e.g., tent, ghost), and indeed, when Treiman and Zukowski (1991) equated unit size within words, kindergartners showed no matching advantage for syllables over rimes. Similarly, Savage, Blair, and Rvachew (2006) found equivalent matching for rimes (“bag-rag”) and similarly-sized *head* (onset + vowel) units (“dog-doll”) among pre-readers.

Awareness of onsets and rimes seems reliably stronger than phoneme awareness prior to school entry (see Goswami and Bryant (1990) for a review). However, similar issues relating to unit size arise and comparisons frequently contain not just a contrast in sound (rimes vs. phonemes) but also a contrast in task (e.g., oddity vs. deletion). Oddity tasks require detection of the “odd word out” from a sequence of words in which all but one share the same sounds (e.g., cat, hat, leg). The meta-cognitive demands of deletion tasks are higher as these involve the removal of one sound from a word or nonword and pronunciation of the remainder (e.g., “Say card without the /d/ sound”).

When each sound is measured via the same task, accuracy can sometimes be higher for phonemes than rimes (Anthony et al., 2003; Seymour & Evans, 1994). Phonemes appear most accessible when they correspond to word onsets as Kirtley, Bryant, Maclean, and Bradley (1989) found pre-schoolers to be better at oddity detection for sequences of words sharing (initial phoneme) onsets (e.g., doll–deaf–can) or rimes (e.g., top–rail–hop) than final phonemes (e.g., mop, lead, whip).

Several authors have argued that consideration of task demands is fundamental to the understanding of phonological development (e.g., Bertelson & de Gelder, 1989, 1991; Morais, 1991; Morais, Alegria, & Content, 1987a). Such work contrasts a holistic or *implicit* sensitivity to

sound similarity, sufficient for tasks such as oddity and matching, with more analytic or *explicit* skills that may be required for deletion or word segmentation. Rather confusingly, disparities in terminology exist between the phonological development models: the LR model regards the online use of phonological representations in spoken word recognition as implicit processing but phonological awareness tasks as explicit; whereas, the ML distinction between epi- and meta-linguistic control is similar to that outlined above in suggesting that phonological awareness tasks themselves can be implicit or explicit in nature according to their demands.

Observations support this latter distinction since children can show an advantage for rimes over phonemes in implicit oddity tasks and yet be unable to identify the rime shared by pairs like “boat-goat” in a more explicit common unit identification task (Duncan, Seymour, & Hill, 1997). This pattern is similar to the illiterate Brazilian poet (Bertelson & de Gelder, 1989), who composed poetry based on rhyme and showed perfect accuracy at implicit rhyme judgements and rhyme production but was unable to isolate the shared parts of word-pairs which he had identified as rhyming or to explain why words rhyme (see also Morris et al., 1987a). Among beginning readers, this pattern of poor explicit rime awareness has been observed in spite of excellent awareness of the shared phoneme in pairs like “face-food” (Duncan & Seymour, 2000; Duncan et al., 1997; Goswami & East, 2000; Seymour, Duncan, & Bolik, 1999). An advantage for larger over smaller units in matching tasks but a small-unit advantage in common unit identification has also been observed among pre-readers (Savage et al., 2006). Thus, the evidence implies that phonological development may at times follow a small-to-large rather than a large-to-small path, depending on the nature of the phonological task and the spoken or written language demands placed upon the child. There is no provision for this in the LR model, although it could be accommodated within the ML model.

1.1.3. A universal sequence of phonological development

A large-to small progression has also been reported in languages other than English. For example, kindergarteners show better syllable than phoneme awareness in French, Greek, Italian and Turkish, (e.g., Cossu, Shankweiler, Liberman, Katz, & Tola, 1988; Demont & Gombert, 1996; Durgunoğlu & Öney, 1999; Harris & Giannouli, 1999), leading to claims that a large-to-small sequence is universal in European languages (Anthony & Francis, 2005; Goswami, 2002).

However, there are indications from Dutch that task demands and unit size may exert an effect on performance. Rimes show an intermediate status between syllables and phonemes in oddity tasks (de Jong & van der Leij, 2003) but seem less salient in more explicit tasks (e.g., Geudens & Sandra, 2003; Geudens, Sandra, & Van den Broeck, 2004). Further, Bertelson, de Gelder, and van Zon (1997) observed that phonemes corresponding to the onsets of words with a Consonant–Vowel–Consonant–Consonant (CVCC) structure were no more salient in a matching task than those that split the onset (CCVC), reinforcing the importance of unit size in such tasks; nevertheless, initial

phoneme deletion, a more explicit task, was easier from the CVCC structures. In Spanish, the large-to-small sequence in matching becomes more evident the more that syllables and rimes differ in size and duration (Goikoetxea, 2005).

Cross-linguistic variation has also been noted (Caravolas & Bruck, 1993; Cossu et al., 1988; Durgunoğlu & Öney, 1999), raising questions about the idea of a universal developmental sequence (Defior, 2004). Higher levels of syllable awareness in Turkish, Italian, and also Greek, have been linked to their simple syllable structures and limited vowel repertoires compared to languages like English and French (Anthony & Francis, 2005; Ziegler & Goswami, 2005). Phoneme awareness may be accelerated in languages where complex consonant structures are more frequent (Caravolas & Bruck, 1993; Caravolas & Landerl, 2010). According to the PGS model, phoneme awareness emerges faster in simple syllable languages because onset-rime and phoneme levels coincide within CV syllables.

Exactly how cross-linguistic variation might be explained within the LR model has yet to be clarified. One possibility is that restructuring is determined by the density of the phonological neighbourhoods present in vocabulary, a factor that has been discussed in relation to the timing of restructuring during childhood (Storkel, 2004), but which may also lead to cross-linguistic variation in the speed of restructuring (Vicente, Castro, & Walley, 2003). A feature of languages containing simple syllable structures is the large number of polysyllabic words, whereas languages with more complex syllables do not need to rely on syllable combination for lexical variety, as variety can also exist via changes in syllable structure (Fenk-Oczlon & Fenk, 1999). Vicente et al. (2003) examined this in relation to Portuguese which permits only CC clusters in the onset position and single C codas. As Portuguese vocabulary expands, more and more polysyllabic words are added to the lexicon; however, the majority of these words occupy sparse phonological neighbourhoods. Vocabulary growth in English consists of the acquisition of shorter words with complex syllable structures many of which occupy relatively dense neighbourhoods. Thus, any pressure for lexical restructuring may vary between languages and might be regarded as greater in English, leading to faster restructuring than in languages with simpler syllable structures like Portuguese, Turkish or Italian (Vicente et al., 2003).

Alternatively, cross-linguistic variation might be sufficient to influence the *sequence* of phonological development. The *first linguistic skills* phase of the ML model shapes subsequent development through the influence of native language on the early organisation of the linguistic system. Gombert (1992) reviews illustrative evidence that infants become adept at native phonetic distinctions but lose the ability to discriminate non-native contrasts. Evidence that speech perception and production mechanisms come to vary between languages from different speech rhythm categories will be explored here as an analogous instance of first linguistic skills. Syllable structure together with patterns of vowel reduction and lexical stress form the basis of several metrics of speech rhythm (Dauer, 1983; Grabe & Low, 2002; Ramus, Nespor, & Mehler,

1999), which can distinguish prototypical stress-timed languages like English, German and Dutch from syllable-timed languages like French, Italian and Spanish. The former differ from the latter in the tendency for lexical stress to be *contrastive*; that is, the level of emphasis given to each syllable in polysyllabic words is critical for word meaning (e.g. stress position distinguishes the noun (initial stress) and verb (final stress) forms of the English word “abstract”). Lexical stress appears to contribute more to spoken word recognition for contrastive than for *fixed* stress languages in which the position of lexical stress is uniform and not indicative of word meaning (Cutler, 2005). Stress-timed languages often also show vowel reduction in unstressed syllables and are characterised by greater syllable complexity than syllable-timed languages. Table 1 tabulates these factors for the languages in the present study.

Nevertheless, controversy exists over the precise definition of speech rhythm (e.g., Arvaniti, 2007; Dauer, 1983; Kohler, 2009), with alternative suggestions being that prosodic properties may underpin the rhythmic continuum (e.g., Arvaniti, 2007; Dauer, 1983; Prieto, del Mar Vanrell, Astruc, Payne, & Post, 2012), or that rhythm may involve perceptual grouping on the part of the listener (e.g., Arvaniti, 1994; Dauer, 1983; Lee & Todd, 2004; Lehiste, 1977). Notwithstanding this controversy, the evidence is considerable that infant speech perception quickly tunes into the rhythm of native language and that such effects persist in adult speech perception (e.g., Kim, Davis, & Cutler, 2008; Mehler, Dommergues, Frauenfelder, & Seguí, 1981; Nazzi, Bertoncini, & Mehler, 1998; Nazzi, Iakimova, Bertoncini, Fredonie, & Alcantara, 2006).

Sensitivity to rhythm in speech has recently been identified as a significant predictor of later reading success (e.g., Goswami et al., 2002; Gutierrez-Palma & Palma-Reyes, 2008; Holliman, Wood, & Sheehy, 2010). Syllable awareness is one aspect of preschool phonological development that may show evidence of differences in speech rhythm. In stress-timed English, syllable boundaries appear to lack clarity resulting in evidence of ambisyllabicity in syllabifications by adult and child native speakers (Treiman, Bowey, & Bourassa, 2002). Data already exist to show differences in syllable awareness between English and syllable-timed French, with syllables appearing more salient in the latter (Cutler, Mehler, Norris, & Seguí, 1986; Duncan,

Cole, Seymour, & Magnan, 2006). Thus, speech rhythm might be one aspect of the early language environment emphasised by the ML model that has the potential to produce variation in phonological development.

1.2. The influence of orthography

A new system of interactive links between phonology and orthography is thought to be initiated by learning to read (e.g., Ehri, 1992; Perfetti et al., 1987). This informs not only the reading but also the speech processing of adults and children (Pattamadilok, Perre, & Ziegler, 2011; Ventura, Morais, & Kolinsky, 2007b; Ziegler & Ferrand, 1998). Of interest in the present context is the prospect that differences between orthographies can lead to cross-linguistic variation in the ease and speed of further phonological development (Cossu et al., 1988).

The concept of *orthographic depth* distinguishes alphabetic orthographies according to the complexity of their letter-sound correspondences (Frost, Katz, & Bentin, 1987). In a *shallow orthography*, a direct 1:1 relation exists between spoken sounds and the graphemes that represent those sounds, whereas, in a *deep orthography*, the relation between spoken and written language is more opaque. Niessen, Frith, Reitsma, and Öhngren (2000) classified European languages according to orthographic depth (see Fig. 1), identifying the shallower orthographies as Finnish, Greek, Spanish, Icelandic, Norwegian and Swedish, the intermediate group as Portuguese and French, and the deepest orthographies as Danish and English. Subsequent work has broadly supported this classification except to suggest that French may be a deeper orthography than Portuguese, and that Swedish may be deeper than Icelandic and Norwegian (Borgwaldt, Hellwig, & de Groot, 2005; Serrano et al., 2010; Seymour et al., 2003).

In the LR model, early phoneme awareness depends entirely on preschool restructuring. The PGS model instead predicts that restructuring only creates a progression from syllable to rime awareness and that further progression to the phoneme level does not occur until reading begins (Ziegler & Goswami, 2005). A further claim is that this process will be slower in deeper orthographies due to the inconsistency of grapheme-to-phoneme links (e.g., Goswami, Porpodas, & Wheelwright, 1997; Goswami, Ziegler, Dalton, & Schneider, 2001). The ML model makes no direct

Table 1

Language characteristics indicating type of lexical stress (contrastive, fixed), occurrence of vowel reduction and syllable structure (number of consonants permitted in onset and coda positions) and the percentage of open syllables.

Language	Stress	Vowel reduction	Syllable structure		
			Onset	Coda	% Open syllables
English	Contrastive	Yes	CCC	CCCC	44 ^a
Icelandic	Fixed	No	CCCC	CCC	Not available
Greek	Contrastive	Yes ^b	CCC	C ^c	69 ^d
Portuguese	Contrastive	Yes	CC	C	81 ^e
Spanish	Contrastive	No	CC	CC	70 ^a
French	Fixed	No	CCC	CC	74 ^a

^a Dauer (1983).

^b Arvaniti (2007).

^c Mennen and Okalidou (2006).

^d Dauer (1980).

^e Frota and Vigário (2001).

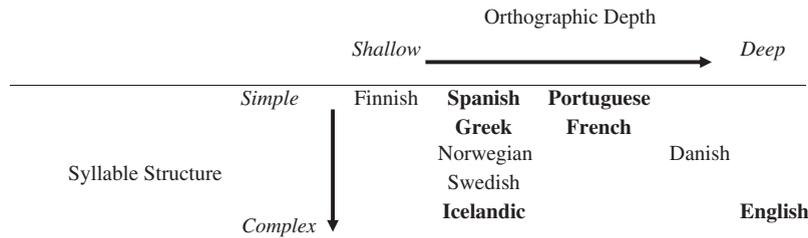


Fig. 1. Classification of languages in terms of orthographic depth and syllable structure (Niessen et al., 2000). The languages included in the present study are highlighted in bold.

predictions about the influence of orthographic depth but a central claim is that explicit awareness results from the external demand imposed by learning to read, which might be interpreted as encompassing orthographic depth.

Mann and Wimmer (2002) reported that German kindergartners were at chance even at implicit phoneme matching (cf. the LR model), whereas English-speaking kindergartners, who are taught letters at kindergarten, showed implicit and explicit phoneme awareness. Once German children also began to learn about letters at school, phoneme awareness was observed to emerge at a faster rate than in English perhaps due to the greater transparency of the German orthography (PGS model), although an alternative explanation was that the pace of the phonics reading instruction was more intensive in German than English (see Duncan et al. (2006) for a similar result from a comparison of French and English).

In spite of instruction having been shown to influence phonological awareness (e.g., Alegria, Pignot, & Morais, 1982; Mann, 1986; Read, Zhang, Nie, & Ding, 1986), instruction plays a relatively minor role in the PGS model, being limited to initiating completion of the segmental restructuring process. Instruction is more central to the ML model where it triggers the emergence and automation of explicit awareness of sounds that receive teaching emphasis. Therefore, instructional differences might create variation in the imperative for intentional control over particular sounds.

1.3. The present study

The research to be presented here is a longitudinal study of phonological development in six European languages with alphabetic orthographies. Our investigation starts on school entry (Time 1) and follows the children until the end of the first year of literacy acquisition (Time 2). At each point, two phonological tasks with differing demands are administered to assess awareness of syllable, rime and phoneme units. The aim is to explore: the question of the *availability* of phonology in the six languages at the outset of learning to read (Study 1); the influence of orthographic depth on the pace of phonological development during the transition to literacy (Study 2); and the impact of literacy instruction on the sequence of phonological development (Study 3).

2. Study 1: Availability of phonology at Time 1

Study 1 assesses the LR model prediction that phonological development follows a large-to-small sequence

with the result that there should be a universal advantage for syllables over phonemes at the outset of reading. Onsets and rimes may occupy an intermediate phase, in which case, phonemes (which are also onsets) and rimes should be equally salient (PGS model). Thus, in contrast to the ML model which does not predict a fixed sequence, the LR model predicts a consistent effect of unit size (large > small) in phonological tasks.

If, on the other hand, spoken language characteristics affect phonological development then unit size will interact with language, and differing patterns of unit salience may be observed among the language groups. According to the PGS model, development may progress more quickly in languages with simple syllables (see also Anthony & Francis, 2005), and onset-rime awareness may be accelerated when phonological rime neighbourhood density is high.¹ Differences in the sequence rather than rate of development could be encompassed within the ML model, which emphasises the role of native language in shaping phonological development. Speech rhythm will be considered here as one linguistic characteristic that might create variation. The existing literature consistently distinguishes syllable-timed French and Spanish from stress-timed English (e.g., Dauer, 1983; Prieto et al., 2012; Ramus et al., 1999) and most often places European Portuguese and Greek in an intermediate category (Dauer, 1983; Frota & Vigário, 2001; Grabe & Low, 2002). Icelandic has not yet been classified, and while its Germanic origin and complex syllables suggest stress-timing, the absence of vowel reduction plus fixed lexical stress contribute to a mixed profile (Table 1).

Comparison of within-language unit salience effects is the most rigorous evidence that we can offer on the question of cross-language variation. Our rich data set also allows awareness of each unit to be contrasted across languages but despite our efforts to match stimuli and participants, it cannot be established unequivocally that these are comparable (Share, 2008). Nevertheless, exploratory analyses will be presented to provide preliminary data about whether any such language differences appear most consistent with an effect of syllable complexity (English, Icelandic > French, Greek > Spanish, Portuguese) or speech rhythm (English vs. (Icelandic, Greek, Portuguese) vs. French, Spanish).

¹ Note that this latter argument, based on a similar numerical advantage for rime neighbours across English, French, German and Dutch, needs to be reconciled with evidence of low rime salience in Dutch (e.g., Geudens & Sandra, 2003).

2.1. Method

2.1.1. Participants

A total of 242 primary school entrants took part from schools with equivalent class sizes and middle-class catchment areas in similar small European towns to enable comparison of the following languages: English, Greek, Icelandic, Portuguese, Spanish and (Belgian) French. As part of a larger longitudinal study of reading development, the phonological assessments together with background and reading measures were administered at the beginning of the first school year (Time 1) and after 10 months of schooling (Time 2).²

Appropriate informed consent procedures were followed in each country. While UK children were 5 years old at Time 1 due to the earlier commencement of schooling in the UK, all other language groups were aged 6 years. A teacher questionnaire³ confirmed that reading instruction followed a phonics programme in each country, which meant that in addition to word reading activities children encountered letters and learned their sounds early in the school year and completed phonics exercise to practice letter-sound decoding.

2.2. Materials and procedure

2.2.1. Phonological tasks

Same-different matching (*implicit* sensitivity to phonological similarity) was contrasted with common unit identification (*explicit* manipulation of sound). All phonological units were located in the initial syllable of disyllabic words as only disyllables are typical across all languages in our study. Our predictions are unaffected by this since all syllables are thought to have a hierarchical structure with *each* syllable in a word being most easily divisible into onsets and rimes and only then into phonemes (Selkirk, 1982; Treiman, 1992). The most typical stress pattern was used in each language (e.g., English, Greek, Icelandic, Spanish and Portuguese: initial stress; French: final stress). Three sets of 8 word-pairs were constructed according to the (only) shared sound: syllable, rime or phoneme (see Table 2). Each set contained an equal number of CV (open) and CVC (closed) initial syllables according to the maximal onset principle of syllabification (Pulgram, 1970). This choice of syllable structures meant that shared phonemes were also word onsets and that the shared rimes in CV syllables were also phonemes. The CVC condition proved difficult to form in Greek and Icelandic. Only two CVC items were included for each sound in Greek and three CVC items for syllables and phonemes in Icelandic with accuracy calculated as a proportion of these items.

As part of the wider longitudinal study, the school reading books that were available to children from the first to the fourth year of schooling were scanned to compile a simple printed word database in each country. All words were selected to be either in the school reading books or oral vocabularies of the beginning readers and, in lan-

guages where a psycholinguistic database was available, target frequency was matched between conditions (e.g., English items were matched using CPWD (Stuart, Dixon, Masterson, & Gray, 2003): Unit, $F(2,42) = 1.16$, $p > .05$; Structure, $F < 1$; and Unit by Structure, $F(2,42) = 1.34$, $p > .05$).

Target pairs were used in both tasks (see Table A1). The matching task additionally had 24 foil pairs with no sounds in common (e.g., fountain-shoulder [faʊn][tɪn]-[ʃəʊl][dəʃ(r)], mummy-parrot [mʌ][mi]-[pæ][rət]). The items for each task were blocked by condition, each in a separate testing session. Condition order was counterbalanced over participants in each country with the proviso that all matching conditions were presented before common unit conditions to avoid artificially drawing children's attention to segments of sound in the matching task.

2.2.1.1. Matching task procedure. A demonstration item introduced a puppet who liked word-pairs that sound the same. On subsequent trials, after repetition of each item by both child and experimenter, the child chose either a picture of a happy or sad face according to whether the puppet liked the words. Corrective feedback was only given on two practice items when the shared sound was emphasised orally but not segmented. Accuracy was analysed after applying a simple correction for guessing (*hits-false alarms*).

2.2.1.2. Common unit identification task procedure. A demonstration item introduced a different puppet who liked to say the little bits of words that sound the same. On each trial, after repetition of the word-pair, the child "helped" the puppet to answer the question: "Which bit sounds the same in...?" Corrective feedback which isolated the shared sound was only given on the two practice items.

2.2.2. Literacy tasks

Tests of letter knowledge, word reading and nonword naming were administered at Times 1 and 2. Cognitive Workshop software developed at the Universities of Dundee in the United Kingdom and Jyväskylä in Finland was used to run the experiments in each country. The procedure was the same for each task: stimuli in 48 point Times New Roman font were presented centrally, preceded by a 1000 ms central fixation and a 1000 ms blank screen, and remained on the screen until a vocal response was made, or for 10,000 ms.

2.2.2.1. Letter knowledge. Upper and lower-case letter-sound knowledge was assessed. The number of letters in each alphabet varied: English = 26; Greek = 24; Icelandic = 32; Portuguese = 31; Spanish = 27; and French = 26. Letter-sounds or letter-names were accepted as correct in Greek and Icelandic.

2.2.2.2. Simple word reading. Words were high in school reading book database frequency and had a consistent 1:1 relationship between spelling and sound (e.g., dog, sun, dragon), in line with the predominant letter-sound correspondences taught via phonics reading instruction. English, Icelandic and French words had 1 or 2 syllables,

² The first testing point was delayed by approximately 2 weeks in Belgium.

³ Available on request from the authors.

Table 2
English examples showing the structure of the target stimuli used in the matching and common unit tasks.

Shared sound ^a	Target word-pair	
	CVC initial syllables	CV initial syllables
Syllable	window-winter[wɪn][dʊ]-[wɪn][tə(r)]	letter-lemon[lɛ][tə(r)]-[lɛ][mən]
Rime	panther-bandage[pæn][ə(r)]-[bænd][ɪdʒ]	comic-poppy[ko][mɪk]-[pɒ][pi]
Phoneme	penguin-padlock[pɛŋ][gɪn]-[pæd]-[lɒk]	wallet-woman[wɒ][lɪt]-[wʊ][mən]

^a Shared sounds occur in the initial syllable.

and Greek, Portuguese and Spanish words had 2 or 3 syllables. There were 4 short words and 2 long words at Time 1, and 8 short words and 4 long words at Time 2. Content and function words were evenly distributed at each length.

2.2.2.3. Monosyllabic nonword naming. Nonwords had a CV, VC or CVC structure. Participants saw two examples of each structure at Time 1 and four examples of each at Time 2.

2.3. Results

Data were converted to proportions due to small differences in the number of items between languages in some of the tests (e.g. alphabetic letters; CVC phonological items in Greek) and hence, these analyses were conducted on arcsine transformed data. After the usual screening procedures, some additional checks were made for outliers. No obviously aberrant cases were identified but inevitably children were progressing at different rates. To establish whether cases at the edge of the distribution were distorting results, phonological task analyses were re-run after trimming the data to remove the highest- and lowest-scoring child in each language. As this made no appreciable difference, only the analyses of the full dataset are reported in the text to provide the most accurate reflection of the range of performance within each classroom.

2.3.1. Literacy tasks

Table 3 contains mean percentage accuracy for letter identification and reading. For letters, languages differed significantly in one-way ANOVAs for upper-case, $F(5, 236) = 5.64, p < .001, \eta_p^2 = .11$, and lower-case, $F(5, 236) = 5.41, p < .001, \eta_p^2 = .10$. Tukey HSD tests ($\alpha < .05$) were used for post hoc analyses. The pattern was similar for both letter-cases, with lowest scores in Portuguese. Greek overlapped with Portuguese and with all other groups except Icelandic, the most accurate group. English-speakers were not disadvantaged by being a year younger as they were high performers, knowing 50–60% of letters at the outset of schooling.

Significant group differences emerged in word, $F(5, 236) = 3.27, p < .01, \eta_p^2 = .07$, and nonword reading, $F(5, 236) = 7.89, p < .001, \eta_p^2 = .14$. Word reading was similar across groups with only high-scoring Icelandic being distinguishable from low-scoring Portuguese children. A similar pattern emerged for nonword naming (Portuguese, English, Greek < Spanish, Icelandic), with French forming an intermediate group that overlapped with all but the most accurate Icelandic children.

2.3.2. Matching task

A three-way ANOVA on accuracy data (Table 4) with between-participants factor, language (English, Greek, Icelandic,

Portuguese, Spanish, French) and within-participants factors, unit (syllable, rime, phoneme) and structure (CVC, CV) showed all main effects to be significant (language: $F(5, 236) = 9.21, p < .001, \eta_p^2 = .16$; unit: $F(2, 472) = 109.60, p < .001, \eta_p^2 = .32$; structure: $F(1, 236) = 16.19, p < .001, \eta_p^2 = .06$). The interaction structure by language was not significant, $F(5, 236) = 1.98, p = .08$, but the other two-way interactions were (unit by language: $F(10, 472) = 3.26, p < .001, \eta_p^2 = .07$; unit by structure: $F(2, 472) = 13.07, p < .001, \eta_p^2 = .05$), as was the three-way interaction unit by structure by language, $F(10, 472) = 3.03, p < .001, \eta_p^2 = .06$.

Sounds were more salient in CVC structures where syllables and rimes were larger according to simple effects for the three-way interaction: this applied to all units in Greek, $F(1, 49) = 13.40, p < .01$, but just to rimes in Portuguese, $F(2, 42) = 6.20, p < .01$, Spanish, $F(2, 122) = 10.95, p < .001$, and marginally so in French, $F(2, 38) = 3.18, p = .05$. The Spanish group showed a significant effect of structure for phonemes (CV > CVC), and the French group showed a similar but marginal effect. The effect of structure was marginal in Icelandic, $F(1, 32) = 3.83, p = .06$, and non-significant in English.

Simple effects for the theoretically important unit by language interaction revealed significant effects of unit for all languages (English: $F(2, 108) = 17.10, p < .001$; Greek: $F(2, 98) = 34.16, p < .001$; Icelandic: $F(2, 64) = 11.76, p < .001$; Portuguese: $F(2, 42) = 16.27, p < .001$; Spanish: $F(2, 122) = 41.70, p < .001$; French: $F(2, 38) = 30.92, p < .001$). English and Greek showed a similar pattern: syllables > phonemes > rimes; whereas for Icelandic, Portuguese, Spanish and French the pattern was: syllables > rimes = phonemes (Fig. 2a).

On syllables, English performance was significantly worse than Spanish, Icelandic and French (all three equal), with Greek and Portuguese overlapping each grouping, $F(5, 236) = 5.24, p < .001$. On rimes, English and Greek performance was equivalent and significantly worse than all the other languages, $F(5, 236) = 21.33, p < .001$. A different pattern emerged for phonemes with the only significant difference between French (low) and Icelandic (high), $F(5, 236) = 2.92, p < .05$.

2.3.3. Common unit identification

Despite the tendency to floor effects for CVC rime accuracy (Table 5), an ANOVA was conducted with between-participants factor, language (English, Greek, Icelandic, Portuguese, Spanish, French) and within-participants factors, unit (syllable, rime, phoneme) and structure (CVC, CV). All main effects were significant: language ($F(5, 236) = 15.27, p < .001, \eta_p^2 = .24$); unit

Table 3

Chronological age in months and mean percentage accuracy for upper- and lower-case letter knowledge, simple word reading and monosyllabic nonword naming for each language at Time 1 (standard deviations in parentheses).

Language	N	CA months	Letter knowledge		Reading	
			Upper case	Lower case	Simple words	Monosyllabic nonwords
English	55	63.78 (3.11)	54.96 (31.51)	51.19 (31.39)	9.09 (19.20)	5.76 (16.11)
Greek	50	74.52(3.60)	39.75 (33.36)	37.58 (33.18)	6.67 (23.33)	7.00 (22.36)
Icelandic	33	73.82(3.40)	63.73 (27.16)	56.82 (29.74)	21.72 (32.14)	30.30 (36.91)
Portuguese	22	75.45(3.79)	31.82 (33.09)	24.11 (18.19)	0.76 (3.55)	3.03 (11.07)
Spanish	62	74.50 (3.45)	61.65 (26.21)	51.08 (23.27)	15.05 (28.74)	23.66 (32.02)
French	20	77.75(4.42)	56.40 (35.25)	44.26 (23.84)	7.50 (19.62)	11.67 (28.66)

Table 4

Mean percentage accuracy for matching in each language at Time 1 (standard deviations in parentheses).

Unit	Structure	Language						Total (n = 242)
		English (n = 55)	French (n = 20)	Greek (n = 50)	Icelandic (n = 33)	Portuguese (n = 22)	Spanish (n = 62)	
Syllable	CVC	46.36 (40.66)	76.23 (37.59)	61.00 (44.37)	75.76 (32.57)	65.91 (36.63)	70.97 (33.02)	63.94 (39.15)
	CV	41.36 (41.17)	76.19 (28.67)	47.00 (40.92)	66.67 (35.17)	67.05 (37.31)	68.55 (33.25)	58.16 (38.89)
Rime	CVC	12.73 (17.26)	48.63 (34.88)	20.00 (28.57)	41.92 (30.93)	55.68 (30.79)	49.60 (34.32)	34.53 (33.35)
	CV	13.64 (20.31)	29.88 (20.81)	9.33 (17.87)	38.64 (30.03)	21.59 (24.76)	28.63 (25.14)	22.06 (25.06)
Phoneme	CVC	29.55 (40.28)	21.19 (28.39)	37.00 (37.54)	50.51 (32.87)	30.68 (34.44)	39.92 (30.52)	36.01 (35.49)
	CV	31.82 (40.38)	33.70 (35.60)	31.00 (35.32)	50.76 (37.23)	31.82 (31.98)	50.81 (28.62)	39.25 (35.86)

($F(2, 472) = 58.59, p < .001, \eta_p^2 = .20$); and structure ($F(1, 236) = 137.77, p < .001, \eta_p^2 = .37$). All two- and three-way interactions were significant (unit by language: $F(10, 472) = 17.10, p < .001, \eta_p^2 = .27$; structure by language: $F(5, 236) = 31.85, p < .001, \eta_p^2 = .40$; unit by structure: $F(2, 472) = 57.89, p < .001, \eta_p^2 = .20$; language by unit by structure, $F(10, 472) = 9.21, p < .001, \eta_p^2 = .16$).

Exploration of the three way interaction confirmed the greater ease of not only rime but also syllable identification in small CV structures (Icelandic: $F(2, 64) = 8.73, p < .001$; Portuguese: $F(2, 42) = 3.98, p < .05$; Spanish: $F(2, 122) = 44.78, p < .001$; French: $F(2, 38) = 18.92, p < .001$). This only applied to syllables in Greek, $F(2, 98) = 13.00, p < .001$, and no effect was

observed in English. Phoneme identification was not affected by structure in English, Icelandic and Portuguese but was easier in CVC structures for Greek and French (marginal), and in CV structures for Spanish.

Combining over structures ameliorated the floor effect to allow investigation of the important unit by language interaction via simple effects. Unit was significant in all languages (English: $F(2, 108) = 85.37, p < .001$; Greek: $F(2, 98) = 14.83, p < .001$; Icelandic: $F(2, 64) = 48.49, p < .001$; Spanish: $F(2, 122) = 19.73, p < .001$; French: $F(2, 38) = 9.53, p < .001$; and marginal in Portuguese: $F(2, 42) = 2.87, p = .07$). Phonemes were more salient than syllables and rimes in English, Greek and Icelandic. Syllables were better than rimes in Greek and Icelandic (and Portuguese). Sylla-

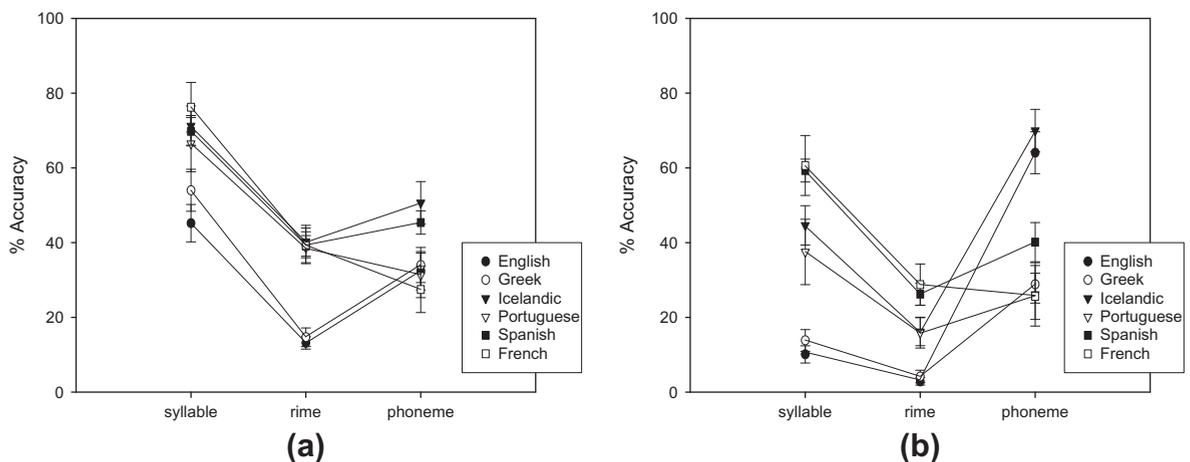


Fig. 2. Percentage accuracy in phonological awareness tasks for each language group at Time 1: (a) matching task; (b) common unit task.

Table 5

Mean percentage accuracy for common unit identification in each language at Time 1 (standard deviations in parentheses).

Unit	Structure	Language						Total (n = 242)
		English (n = 55)	French (n = 20)	Greek (n = 50)	Icelandic (n = 33)	Portuguese (n = 22)	Spanish (n = 62)	
Syllable	CVC	9.55 (20.12)	52.50 (38.81)	5.00 (20.82)	32.42 (29.34)	29.55 (39.82)	29.03 (38.73)	22.09 (33.69)
	CV	9.55 (18.31)	68.75 (39.63)	22.67 (32.25)	56.82 (37.64)	45.45 (47.33)	89.52 (20.52)	47.35 (43.14)
Rime	CVC	2.73 (11.46)	5.00 (13.08)	3.00 (11.99)	8.84 (17.67)	4.55 (9.87)	8.06 (19.61)	5.34 (15.03)
	CV	2.73 (7.87)	52.50 (42.07)	5.33 (14.85)	23.48 (33.04)	27.27 (34.42)	44.35 (36.33)	23.11 (33.62)
Phoneme	CVC	64.09 (43.50)	30.00 (28.79)	33.00 (39.91)	71.72 (34.48)	26.14 (40.44)	37.10 (42.64)	45.52 (43.03)
	CV	61.36 (43.52)	21.25 (29.55)	24.67 (34.87)	68.18 (34.95)	26.14 (39.70)	43.15 (41.78)	43.53 (42.19)

bles were easiest in Spanish and French, and phonemes were easier than rimes in Spanish but not French.

Clear accuracy differences were observed between English and Greek (low) and Spanish and French (high) in relation to syllables, $F(5,236) = 31.54$, $p < .001$, and rimes, $F(5,236) = 16.10$, $p < .001$. Icelandic and Portuguese were intermediate for syllables and rimes, with Icelandic overlapping with Spanish and French for syllables, and both Icelandic and Portuguese overlapping with the high and low groupings for rimes (see Fig. 2b). The outcome differed noticeably for phonemes, $F(5,236) = 9.05$, $p < .001$: highest accuracy in Icelandic and English, and lowest in Portuguese, French and Greek, with Spanish overlapping each set.

2.4. Summary discussion

2.4.1. Literacy

Across languages, children were in the earliest phases of literacy acquisition, recognising on average 12 letters but being generally unable to read even one frequent word or monosyllabic nonword. Icelandic children had made most progress in literacy and Portuguese children the least but considerable overlap in speed of acquisition was observed.

2.4.2. Matching

Syllables were more salient than phonemes in every language as per LR predictions. Rimes and phonemes were equally salient in Icelandic, Portuguese, Spanish and French, consistent with onset-rime equivalence in the PGS model, but phonemes proved easier than rimes in English and Greek. English tended to be less accurate than Spanish, Icelandic and French for syllable and rime matching but, for phoneme matching, accuracy was lowest in French and highest in Icelandic.

2.4.3. Common unit identification

Instead of a large-to-small sequence, three contrasting patterns were observed: (1) English, Greek and Icelandic – phonemes > syllables; (2) Portuguese – phonemes = syllables; and (3) French and Spanish – syllables > phonemes. Rime identification was uniformly poor, either equivalent to phonemes (Portuguese, French) or worse than phonemes (English, Greek, Icelandic, Spanish). On syllable and rime identification, Spanish and French were consistently most accurate with English and Greek least accurate but, for phoneme identification, English and Icelandic were more accurate than Portuguese, French and Greek.

Although matching broadly followed the LR model large-to-small sequence, this effect of unit size was not consistent across phonological tasks. Further, unit size interacted with language. Neither syllable matching nor identification was consistent with the syllable complexity hypothesis but instead fitted better with the speech rhythm explanation. The pattern for phoneme awareness was different again with accuracy highest in Icelandic, English and Spanish. Literacy and phonological task performance differed, suggesting that these tasks are tapping specific abilities rather than fixed effects of age or ability.

One limitation of our study was the absence of a comparable vocabulary measure across languages to test the LR prediction of vocabulary-driven segmental restructuring. Nevertheless, the English-speakers, who were a year younger, would be predicted by the LR model to be at an earlier point in phonological development given age-appropriate but lower vocabulary skills. This should delay the emergence of phoneme awareness but, in the event, English common phoneme identification was among the most accurate.

3. Study 2: The influence of orthographic depth on phonological awareness at Time 2

The idea of an interactive relationship between phonology and orthography in early reading (e.g., Perfetti et al., 1987) is the product of two hypotheses: (a) phonological awareness is a critical precursor to learning links between letters and sounds; and (b) the process of learning about letters and word spellings itself enhances phonological awareness (Castles & Coltheart, 2004).

While Study 1 assessed hypothesis (a), Study 2 provides an opportunity to investigate hypothesis (b) after 10 months' exposure to reading instruction. The written symbols of all six alphabetic orthographies correspond to the phonemes of spoken language but the orthographies differ in depth due to variation in correspondence consistency (Fig. 1). Although orthographic depth is known to influence the rate of reading acquisition (e.g., Seymour et al., 2003; Ziegler et al., 2010), no large-scale study has yet examined the effect of orthographic depth on phonological development.

The LR model predicts an effect of unit size (large > small) regardless of language, task and reading experience, although segmental restructuring should have advanced

since Study 1. The ML model claims that the meta-cognitive demands of phonics instruction should trigger a differential increase in *explicit* awareness of phonemes across languages. Any interaction between unit size and language could be consistent with either: (1) spoken language influence – as discussed in Study 1, (a) syllable complexity (PGS model); or (b) speech rhythm (ML model); or (2) written language influence – orthographic depth (PGS model – reading acquisition initiates phoneme awareness more quickly in shallow than deep orthographies: Greek, Spanish, Icelandic > Portuguese > French > English).

3.1. Method

3.1.1. Participants, materials and procedure

As described for Study 1. Additional Time 2 assessments: WISC-R Digit Span (forwards and backwards); Raven's Progressive Coloured Matrices.

3.2. Results

3.2.1. Literacy and background measures

Mean (and standard deviation) scores are in Table 6. Letter knowledge (upper- and lower-case) was approaching ceiling in all groups. The Greek and Spanish groups also showed ceiling effects in reading both words and nonwords, and the French-speakers for nonwords only. One-way ANOVAs investigating language effects for the remaining groups were significant for words, $F(3, 126) = 13.93$, $p < .001$, $\eta_p^2 = .25$, and nonwords, $F(2, 107) = 4.60$, $p = .01$, $\eta_p^2 = .08$. For words, English-speakers performed least well with the three remaining groups overlapping. For nonwords, English-speakers were again the worst, Icelandic was the best and the Portuguese group was intermediate overlapping with both. Ravens Matrices raw scores differed by language, $F(5, 234) = 19.09$, $p < .001$, $\eta_p^2 = .29$, with Icelandic and French performing more accurately than the other groups. French-speakers had the highest Digit Span raw scores and the youngest English-speakers the lowest, with the remaining groups in the middle of the distribution, although Portuguese was lower than Greek, $F(5, 233) = 24.37$, $p < .001$, $\eta_p^2 = .34$.

3.2.2. Matching task

Although French syllable matching was at ceiling (Table 7), an exploratory three-way ANOVA was attempted to fully examine the results. There was one between-participants factor, language (English, Greek, Icelandic, Portuguese, Spanish, French), and two within-participants factors, unit (syllable, rime, phoneme) and structure (CVC, CV). All main effects, and two- and three-way interactions were significant (language: $F(5, 236) = 16.23$, $p < .001$, $\eta_p^2 = .26$; unit: $F(2, 472) = 147.15$, $p < .001$, $\eta_p^2 = .38$; structure: $F(1, 236) = 36.29$, $p < .001$, $\eta_p^2 = .13$; unit by language: $F(10, 472) = 4.89$, $p < .001$, $\eta_p^2 = .09$; unit by structure: $F(2, 472) = 21.24$, $p < .001$, $\eta_p^2 = .08$; unit by structure by language: $F(10, 472) = 4.70$, $p < .001$, $\eta_p^2 = .09$), except structure by language, $F(5, 236) = 1.20$, $p > .05$. An analysis without the French results produced exactly the same pattern of significant effects (language: $F(4, 217) = 17.11$, $p < .001$, $\eta_p^2 = .24$; unit: $F(2, 434) = 134.58$, $p < .001$, $\eta_p^2 = .38$; structure: $F(1, 217) = 32.88$, $p < .001$, $\eta_p^2 = .13$; unit by language: $F(8, 434) = 5.89$, $p < .001$, $\eta_p^2 = .10$; unit by structure: $F(2, 434) = 22.77$, $p < .001$, $\eta_p^2 = .10$; structure by language: $F(4, 217) = 1.44$, $p = .22$; unit by structure by language: $F(8, 434) = 5.31$, $p < .001$, $\eta_p^2 = .09$).

English performance tended to be better with CVC structures where syllables and rimes were larger, $F(1, 54) = 3.89$, $p = .05$. For other languages, unit and structure interacted (Greek: $F(2, 98) = 4.33$, $p < .05$; Icelandic: $F(2, 64) = 4.87$, $p < .05$; Portuguese: $F(2, 42) = 9.62$, $p < .001$; Spanish: $F(2, 122) = 22.21$, $p < .001$; and marginally in French: $F(2, 38) = 3.14$, $p = .06$). Greek showed a CVC advantage for syllables, whereas, the CVC advantage for Icelandic, Portuguese and Spanish (and French) was restricted to rimes. Only Portuguese and Spanish showed a structure effect for phonemes (CV advantage).

For the unit by language interaction, all languages except Portuguese showed simple effects of unit (English: $F(2, 108) = 71.57$, $p < .001$; Greek: $F(2, 98) = 55.99$, $p < .001$; Icelandic: $F(2, 64) = 19.62$, $p < .001$; Spanish: $F(2, 122) = 54.01$, $p < .001$; French: $F(2, 38) = 22.70$, $p < .001$). Rime matching was least accurate across languages. Greek, Icelandic and French showed no difference between syllables and phonemes, but matching was better for syllables than phonemes in English and Spanish (see Fig. 3a).

Languages differed in syllable matching, $F(5, 236) = 6.17$, $p < .001$, with English and Portuguese worse than

Table 6

Mean chronological age (months), raw score for Raven's Progressive Matrices and WISC-R Digit Span, and percentage accuracy for letter knowledge, simple word and monosyllabic nonword reading for each language at Time 2 (standard deviations in parentheses).

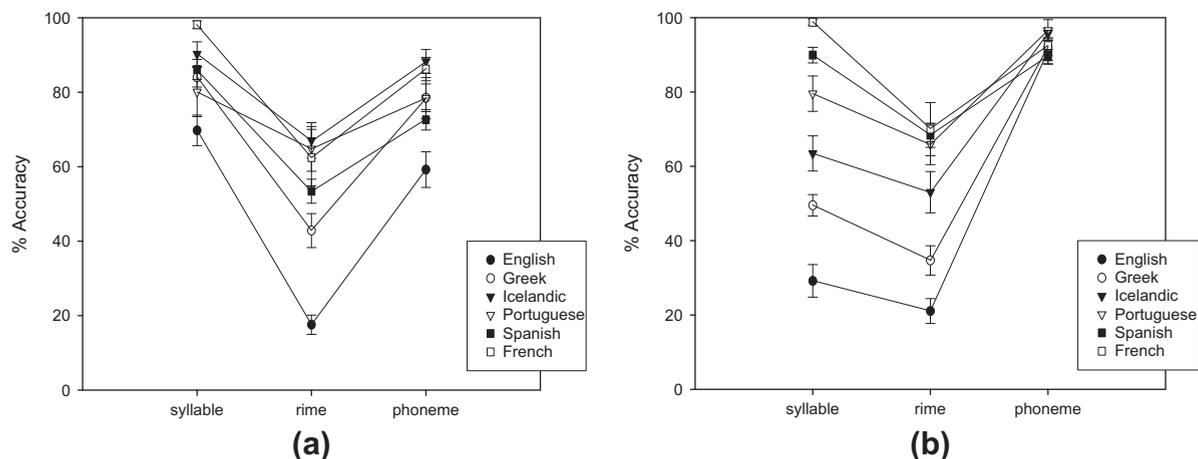
Language	N	CA months	Ravens raw score	Digit Span raw score	Letter knowledge%		Reading%	
					Upper	Lower	Simple words	Monosyllabic nonwords
English	55	71.41 (3.13)	18.00 (3.94)	6.56 (1.71)	94.73 (8.72)	92.17 (9.85)	56.21 (25.97)	60.91 (31.13)
Greek	50	82.46 (3.64)	18.46 (4.56)	9.24 (1.61)	98.92 (2.20)	99.25 (1.62)	96.00 (5.39)	98.00 (4.31)
Icelandic	33	81.33 (3.44)	26.10 (4.70)	9.19 ^a (1.83)	97.63 (4.94)	96.31 (9.74)	81.82 (20.78)	78.03 (22.61)
Portuguese	22	83.45 (3.79)	18.23 (4.72)	8.00 (1.31)	87.17 (5.11)	88.91 (5.31)	78.16 (19.37)	68.94 (26.25)
Spanish	62	82.47 (3.48)	21.23 (4.71)	8.02 (1.65)	95.68 ^a (6.18)	91.79 (7.72)	91.25 ^a (13.67)	91.53 ^a (15.98)
French	20	84.75 (4.42)	24.65 (5.58)	10.84 ^a (2.46)	92.20 (12.48)	88.08 (10.13)	86.56 (16.00)	94.58 (13.32)

^a The Icelandic mean Digit Span score was based on 31 participants, the Spanish letter knowledge and reading percentages on 60 participants and the French Digit Span scores on 19 participants.

Table 7

Mean percentage accuracy for matching in each language at Time 2 (standard deviations in parentheses).

Unit	Structure	Language						Total (n = 242)
		English (n = 55)	French (n = 20)	Greek (n = 50)	Icelandic (n = 33)	Portuguese (n = 22)	Spanish (n = 62)	
Syllable	CVC	73.64 (29.82)	98.75 (5.59)	94.00 (19.27)	91.92 (18.69)	81.82 (31.98)	87.90 (23.41)	86.81 (24.90)
	CV	68.18 (35.50)	97.49 (7.73)	74.00 (26.55)	88.64 (22.61)	78.41 (32.09)	84.27 (23.62)	79.65 (28.44)
Rime	CVC	21.36 (27.39)	71.24 (36.52)	47.00 (40.92)	78.03 (27.07)	77.27 (26.62)	69.76 (31.08)	55.99 (38.52)
	CV	13.64 (21.42)	53.64 (35.61)	38.67 (33.41)	56.06 (36.45)	52.27 (40.02)	37.10 (34.69)	37.42 (35.63)
Phoneme	CVC	59.09 (38.30)	88.74 (15.13)	80.00 (33.50)	89.39 (18.90)	73.86 (29.36)	66.13 (29.37)	73.14 (32.24)
	CV	58.64 (39.45)	83.68 (18.74)	77.00 (28.35)	87.12 (24.30)	82.95 (28.23)	79.03 (27.61)	75.82 (31.27)

**Fig. 3.** Percentage accuracy in phonological awareness tasks for each language group at Time 2: (a) matching task; (b) common unit task.

French. English was also worse than Icelandic, and the remaining languages overlapped with these groups. For rimes, English performance was weakest followed by Greek. Spanish and French overlapped with Greek and the remaining set of high performers (Portuguese, Icelandic), $F(5,236) = 19.94, p < .001$. For phonemes, English was weakest, and Spanish and Portuguese were intermediate, overlapping with English and the remaining languages ($F(5,236) = 6.68, p = .001$).

3.2.3. Common unit identification

All groups scored at ceiling in the phoneme condition of the common unit task (Fig. 3b, Table 8). Despite the proximity to ceiling of French and Spanish syllable identification, an exploratory analysis was conducted on the syllable and rime data because of the interest in the comparison between all six languages. The three-way ANOVA had one between-participants factor, language (English, Greek, Icelandic, Portuguese, Spanish, French), and two within-participants factors, unit (syllable, rime) and structure (CVC, CV). All effects were significant (language: $F(5,236) = 58.44, p < .001, \eta_p^2 = .55$; unit: $F(1,236) = 61.53, p < .001, \eta_p^2 = .21$; structure: $F(1,236) = 273.12, p < .001, \eta_p^2 = .54$; structure and language: $F(5,236) = 13.72, p < .001, \eta_p^2 = .23$; unit and language: $F(5,236) = 2.35, p < .05, \eta_p^2 = .05$; unit and structure and language: $F(5,236) = 8.71, p < .001, \eta_p^2 = .16$), except for the interaction between unit and structure, $F(1,236) = 3.11, p = .08$. An analysis without the French and Spanish results

produced exactly the same pattern except that the unit and language interaction was non-significant as this reflected the ceiling effects in the full analysis (language: $F(3,156) = 33.12, p < .001, \eta_p^2 = .39$; unit: $F(1,156) = 20.84, p < .001, \eta_p^2 = .12$; structure: $F(1,156) = 211.99, p < .001, \eta_p^2 = .58$; unit and structure: $F < 1$; structure and language: $F(3,156) = 14.94, p < .001, \eta_p^2 = .22$; unit and language: $F < 1$; unit and structure and language: $F(3,156) = 5.69, p = .001, \eta_p^2 = .10$).

In the three-way interaction, simple effects showed a CV advantage for syllables and rimes in all languages.⁴ This was more pronounced for syllables than rimes in Greek and Icelandic, but the reverse was true for Spanish and French since performance was at ceiling for syllables (Greek: $F(1,49) = 10.68, p < .01$; Icelandic: $F(1,32) = 4.19, p < .05$; Spanish, $F(1,61) = 25.07, p < .001$; French: $F(1,19) = 13.74, p < .01$).

The unit by language interaction revealed simple effects of unit (syllables > rimes) for Greek, $F(1,49) = 14.79, p < .001$, Portuguese, $F(1,21) = 4.65, p < .05$; Spanish, $F(1,61) = 41.71, p < .001$, French, $F(1,19) = 16.81, p < .01$, and marginally for English, $F(1,54) = 3.71, p = .06$, and Icelandic, $F(1,32) = 3.91, p = .06$. Syllable, $F(5,236) = 56.17, p < .001$, and rime identification, $F(5,236) = 27.25, p < .001$, differed across languages. For syllables, accuracy was lowest in English, followed by Greek, and highest in

⁴ Note that the rime unit in CV structures corresponds to the vowel and, therefore, is also a single phoneme.

Table 8

Mean percentage accuracy for common unit identification in each language at Time 2 (standard deviations in parentheses).

Unit	Structure	Language						Total (n = 242)
		English (n = 55)	French (n = 20)	Greek (n = 50)	Icelandic (n = 33)	Portuguese (n = 22)	Spanish (n = 62)	
Syllable	CVC	20.91 (31.09)	97.50 (7.69)	15.00 (29.01)	39.65 (39.69)	67.05 (37.31)	83.47 (29.32)	48.79 (43.62)
	CV	34.09 (40.64)	100.00 (0.00)	84.00 (25.19)	87.27 (28.94)	92.05 (14.20)	96.37 (8.88)	78.33 (35.38)
Rime	CVC	6.82 (17.65)	55.00 (41.04)	12.00 (27.77)	36.36 (33.13)	48.86 (44.64)	49.19 (35.05)	30.58 (36.93)
	CV	31.82 (39.22)	85.00 (31.83)	57.33 (42.21)	69.70 (38.91)	82.95 (33.08)	87.50 (23.41)	65.56 (41.00)
Phoneme	CVC	89.55 (26.65)	92.50 (18.32)	90.00 (26.73)	92.93 (13.84)	96.59 (11.69)	85.08 (22.84)	89.84 (22.63)
	CV	91.82 (23.10)	92.50 (20.03)	94.33 (13.30)	98.48 (6.06)	96.59 (15.99)	93.95 (14.09)	94.28 (16.41)

Spanish and French. Icelandic and Portuguese were intermediate with Icelandic overlapping with Greek, and Portuguese with Spanish. For rimes, there were two groups: English and Greek (low) vs. the remaining languages (high).

3.3. Summary discussion

3.3.1. Literacy and background measures

Letter knowledge was generally excellent but only some groups were at ceiling in reading (Spanish, Greek). Lowest reading accuracy occurred among English-speakers who read just over half of the words and nonwords. Icelandic was slightly worse than predicted overall and the French group slightly better than expected with respect to nonword reading only. Icelandic and French children had the highest non-verbal IQ, with the latter also having the best phonological short-term memory. The remaining groups overlapped except the (youngest) English-speakers who had the lowest raw short-term memory scores, followed by the Portuguese.

3.3.2. Matching

There were two patterns, broadly consistent with the LR model: (a) syllables = phonemes (Greek, Icelandic, French); and (b) syllables > phonemes (English, Spanish). Rimes proved most difficult, even more difficult than phonemes, in all languages except Portuguese, where performance was equivalent for all sounds. Syllables were most accurate in French and least accurate in English and Portuguese. Rimes were most accurate in Portuguese and Icelandic, and least accurate in English. Phonemes were least accurate in English, followed by Spanish and Portuguese. The younger English group proved poor at matching relative to the older children.

3.3.3. Common unit identification

Phoneme identification was at ceiling in every language in contrast to syllable and rime identification. Syllables were better than rimes in Greek, Portuguese, Spanish and French. Syllables were most accurate in Spanish and French and least accurate in English, and rimes were least accurate in English and Greek.

Matching performance conformed to LR predictions (syllables \geq phonemes). Common unit performance was consistent instead with the ML model as ceiling performance was evident for explicit awareness of phonemes but not syllables for all but the syllable-timed

languages, Spanish and French who were at ceiling in both conditions. Letter knowledge was complete in all languages and the effect of orthographic depth on reading progress was clear with Spanish and Greek the best and English the worst. Nevertheless, no variance in due to orthographic depth was discernible in phoneme awareness. While orthographic depth may have exerted an earlier effect, the Time 1 findings give no indication of a strong relationship with orthographic depth since phoneme identification was equally accurate in English (deep) as in Icelandic and Spanish (shallow).

4. Study 3: The impact of literacy instruction on phonological awareness

The role of instruction in promoting phonological development has been rather overlooked in spite of longstanding evidence that alphabetic reading instruction promotes phoneme awareness (e.g., [Alegria et al., 1982](#); [Read et al., 1986](#)). The PGS model acknowledges the influence of instruction about letter-sounds but differences in the implementation of such instruction are considered to have relatively low impact (cf. [Johnston & Watson, 2004](#)). Instead, the model places an emphasis on the effect of orthographic depth since letter-sound instruction is predicted to work better in shallow than deep orthographies. The ML model, on the other hand, highlights the meta-cognitive demands imposed by the method of reading instruction, predicting that instruction will promote explicit awareness of whichever sounds receive this type of emphasis.

In each language under investigation here, reading was taught via phonics instruction, in which letter-sounds were introduced early in the first year together with phonics exercises for practising decoding. The objective in Study 3 is to consider each of these two factors in turn: in the first part, the influence of letter knowledge is examined and in the second part, a manipulation of instruction method is presented to examine the effect of a meta-cognitive focus on phonemes. This will test our assumption that the Time 2 ceiling effects in explicit phoneme awareness were largely due to the phonics instruction that the children had received.

4.1. Letter knowledge

[Fig. 4](#) helps to conceptualise the influence of letter knowledge on phoneme awareness and reading at Time

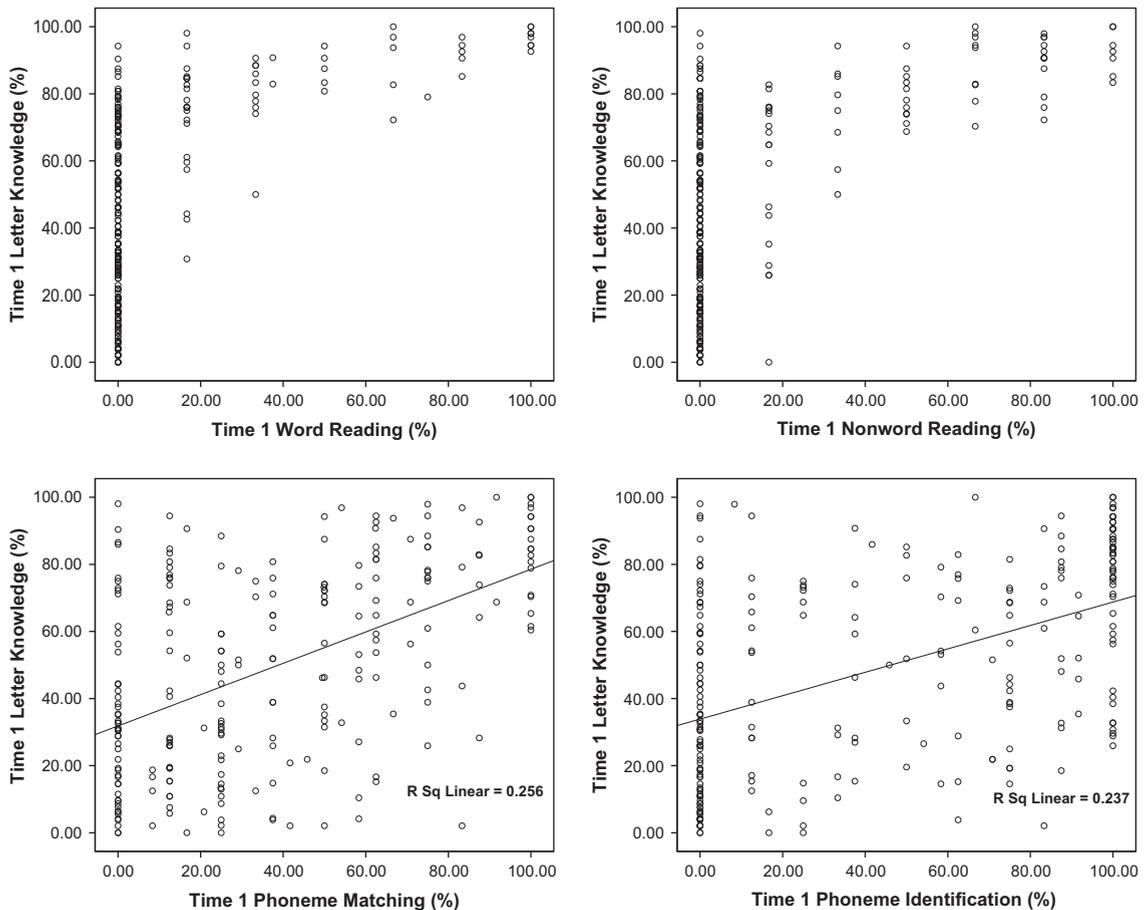


Fig. 4. Time 1 scatterplots plotting percentage accuracy scores for letter knowledge against word and nonword reading (upper graphs) and against phoneme matching and phoneme common unit identification (lower graphs). All individual participants are included.

1. The data are combined across language groups. The upper graphs show that the limited reading of words and nonwords is highly dependent on letter knowledge, with knowledge of approximately 80% of letters required before reading advances. This is similar to previous findings from English-speaking phonics classrooms (Duncan & Seymour, 2000; Seymour & Duncan, 2001). In the lower graphs, letter knowledge explains approximately 25% of the variance in simple regressions against phoneme matching and identification. The relationship between letter knowledge and phoneme awareness is much less restrictive than the one depicted in the upper graphs, adding support from a classroom setting to experimental evidence that item-specific letter knowledge is not required for the emergence of phoneme awareness (Castles, Wilson, & Coltheart, 2011; Hulme, Caravolas, Malkova, & Brigstocke, 2005).

4.2. Literacy instruction

Given that letter knowledge provides only a partial account of phoneme awareness at Time 1, the effect of other aspects of reading instruction was examined; in particular, whether phonics exercises for practicing decoding were related to the rapid development of explicit phoneme awareness across languages. An innovative aspect

of the Belgian (French) study, directed by Jacqueline Leybaert, Philippe Mousty, and Nathalie Genard, was the inclusion of groups receiving contrasting methods of instruction. The Belgian French-speakers in Studies 1 and 2 received phonics instruction but an additional sample was taught via a whole-word method that adopted a look-and-say approach to reading by encouraging children to practice whole-word identification using techniques such as flash cards. Alegria et al. (1982) compared similar groups, finding that phonics instruction conferred an advantage in phoneme but not syllable reversal.

The LR model does not predict any instructional effects on the large-to-small sequence but the ML model predicts that phonics instruction should specifically promote the emergence of explicit phoneme awareness. According to the PGS model, depending on whether letter-sound knowledge is being acquired, phonological development should proceed similarly since both groups are learning to read the same (French) orthography.

4.2.1. Method

4.2.1.1. Participants. The phonics group are the French-speaking children in Studies 1 and 2. The new whole-word group were also (Belgian) French-speaking and comprised

Table 9

Mean chronological age (months), raw score for Raven's Progressive Matrices and WISC-R Digit Span, and percentage accuracy for letter knowledge and monosyllabic nonword decoding in the phonics and whole-word instructional groups according to time of testing (standard deviations in parentheses).

Instruction method	N	CA months		Ravens raw score	Digit Span raw score	Letter Knowledge%		Nonword decoding %	
		Time 1	Time 2			Time 1	Time 2	Time 1	Time 2
Phonics	20	77.75 (4.42)	24.65 (5.58)	10.84 ^a (2.46)	50.34 (28.79)	90.14 (9.99)	11.67 (28.66)	94.58 (13.32)	
Whole- Word	15	78.00 (3.48)	24.50 (5.29)	10.54 (2.33)	44.66 (39.01)	62.96 (35.64)	24.44 (37.20)	37.22 (46.06)	

^a The phonics group's mean Digit Span score was based on 19 participants.

15 children. *Materials and Procedure* are as described in Studies 1 and 2.

4.2.1.2. Results.

4.2.1.2.1. Literacy and background measures. The two instructional groups were matched on age, Raven's Matrices and Digit Span, all $F_s < 1$ (see Table 9 for means). For both letter knowledge (upper- and lower-case) and nonword decoding, interactions indicated that groups were equivalent at Time 1 but differed by Time 2, $F(1, 33) = 8.69, p < .01, \eta_p^2 = .21$ and $F(1, 33) = 28.30, p < .001, \eta_p^2 = .46$, respectively. Letter knowledge had improved in both groups by Time 2 but nonword decoding only improved after exposure to phonics instruction.

4.2.1.2.2. Phonological tasks. Fig. 5 illustrates phonological task performance at Times 1 and 2. Note that Time 2 French syllable awareness is approaching ceiling regardless of instruction method. For matching, a mixed ANOVA using within-participants factors, time (Time 1, Time 2), unit (syllable, rime, phoneme) and structure (CVC, CV) and the between-participants factor, instruction (whole-word, phonics) revealed that the only significant effect involving instruction was the interaction with time, $F(1, 32) = 7.70, p < .01, \eta_p^2 = .20$. The groups performed similarly at Time 1, $F < 1$, and differed marginally by Time 2, $F(1, 32) = 3.58, p = .07$. While the phonics group showed a tendency for stronger improvement over time, the *pattern* of improvement was similar in both groups: the smaller the unit, the greater the improvement. In the common unit task, time and instruction interacted, $F(1, 32) = 35.76, p < .001, \eta_p^2 = .53$, with the groups matched at Time 1, $F(1, 32) = 2.06, p > .05$, but differing by Time 2, $F(1, 32) = 10.90, p < .01$. However, these factors also interacted with unit and structure in a four-way interaction, $F(2, 64) = 4.54, p < .05, \eta_p^2 = .12$, indicating group differences in the pattern of improvement. The whole-word group did not improve for any unit over time (syllable: $F(1, 13) = 1.81, p > .05$; rime: $F(1, 13) = 1.34, p > .05$; phoneme: $F(1, 13) = 3.60, p > .05$), whereas the phonics group showed improvement for syllables, $F(1, 19) = 26.81, p < .001$, rimes, $F(1, 19) = 21.67, p < .001$, and especially, phonemes, $F(1, 19) = 90.57, p < .001$. Structure modified the picture: the phonics advantage at Time 2 tended to be restricted to CV structures for syllable and rime identification but to be significant across structures for phoneme identification. The CV advantage for rime identification may reflect the *single phoneme* rime unit in these items.

4.3. Summary discussion

The instructional manipulation was confirmed by a phonics group advantage in letter knowledge and nonword reading at Time 2, even though groups were matched at Time 1. Although letter knowledge improved in both groups across the year, the two instruction methods were associated with different patterns of phonological performance. Whole-word instruction improved implicit matching but not explicit common unit identification despite the gains in letter knowledge among this group. Phonics instruction conferred advantages in both phonological tasks. Aspects of the findings are consistent with each model: emerging letter knowledge appeared sufficient to stimulate (implicit) awareness of smaller units (PGS model) but the demand imposed by phonics exercises seemed necessary for explicit awareness of phonemes (ML model). Nevertheless, contrary to the ML model, phonics instruction also increased explicit syllable and rime awareness, albeit to a lesser extent than for phonemes.

5. General discussion

Our study provides a rare opportunity to observe phonological development in six alphabetic orthographies as children begin to read under comparable teaching regimes. Progress was monitored from the beginning of the first year of reading (Time 1) until the end of this school year (Time 2). The two leading models of phonological development offer contrasting views about the likely outcome of such a study. The LR model anticipates a universal large-to-small sequence of sensitivity to speech sounds that is dependent on preschool segmental restructuring of speech representations driven by item familiarity and neighbourhood density. The ML model offers no fixed order but emphasises the influence of native language and distinguishes different levels of awareness, proposing that explicit awareness of any sound is dependent on prior implicit awareness and the presence of an external demand for meta-linguistic control over that particular sound. Key phases of phonological development were examined to shed light on these competing claims, namely: the question of the *availability* of phonology in the six languages at the outset of learning to read (Study 1); the influence of orthographic depth on the pace of phonological development during the transition to literacy (Study 2); and the impact of literacy instruction on the sequence of phonological development (Study 3). The outcome did not support either model in its entirety and the resulting implications

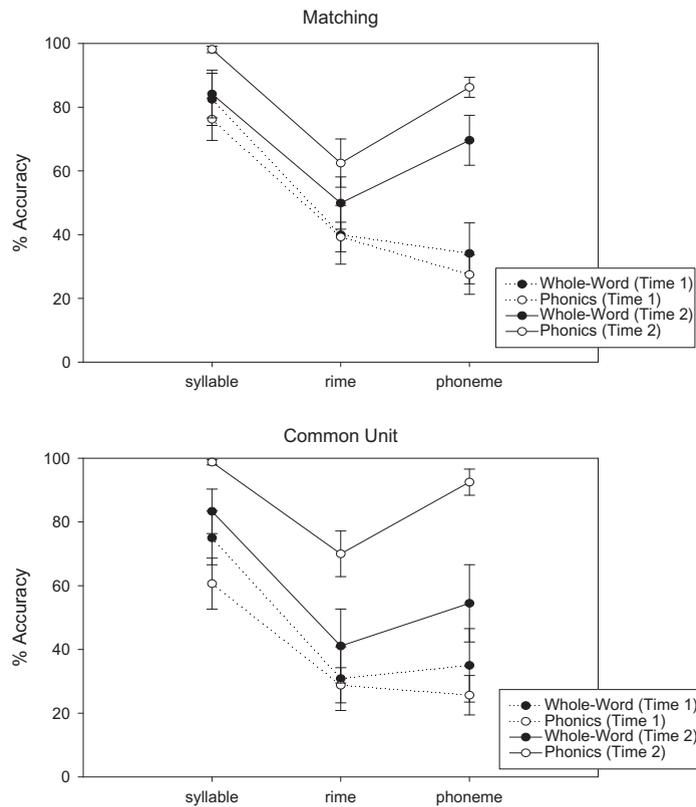


Fig. 5. Mean percentage accuracy for each instruction group in the matching and common unit tasks at Times 1 and 2.

for understanding phonological development are explored in the sections to follow.

5.1. Availability of phonology

Consistent with the LR model large-to-small sequence, syllables were most salient in the matching task for every language at Time 1. The status of onset-rime awareness was less clear. Phonemes that are also word onsets should have equal salience to rimes and in some languages phoneme and rime matching were developing at a similar pace (Icelandic, Portuguese, Spanish, French) but, in others, phonemes were already more salient than rimes (English, Greek). This strongly implies that initial phonemes may have a different status from rimes in the latter languages, and further, that awareness of larger rime units is not necessary for awareness of smaller phonemes to emerge.

Processing in the common unit task did not follow the same pattern since syllables were not always the easiest sounds to identify across all languages. Instead, three response profiles were observed: (1) phonemes > syllables (English, Greek, Icelandic); (2) syllables = phonemes (Portuguese); and (3) syllables > phonemes (French, Spanish). Rime identification was uniformly poor, either equivalent to phonemes (Portuguese, French) or worse than phonemes (English, Greek, Icelandic, Spanish). These results contradict LR claims that there should be a relation across tasks for specific items (Metsala & Walley, 1998, p. 102),

since our implicit and explicit tasks used the same stimuli to control for item frequency and neighbourhood density effects. The outcome was also inconsistent with the ML prediction that implicit sensitivity to any sound is necessary for explicit awareness of that sound. This latter prediction worked best for syllables, where implicit performance tended to be better or similar to explicit performance, and for rimes, where performance levels were equivalent. However, implicit abilities were relatively poor compared to explicit skills for phonemes, especially by Time 2.

The contrasting outcomes link to proposals that different phonological tasks may assess differing levels of awareness (e.g., Morais, 1991). Savage et al. (2006) observed a similar large-unit advantage in matching and a small-unit advantage in common unit identification among pre-school English-speakers. They concluded that implicit matching may be related to the quality of acoustic-phonetic representations and that explicit common-unit identification may relate to the quality of articulatory-phonetic representations. While this proposal awaits confirmation, it is at least consistent with the present evidence. Implicit (or holistic) sensitivity appeared sufficient for matching as larger units of sound were most salient, in keeping with the relevance of unit size rather than linguistic status (Treiman & Zukowski, 1996), and cross-linguistic variation was relatively small as might be expected when precision in identification or articulation is not required. In contrast, the analysis demanded by common unit identification ex-

posed considerable cross-linguistic variation in skill at isolating specific units of sound.

The presence of cross-linguistic variation challenges the existence of a universal sequence of phonological development. In the syllable tasks, the results contradict a syllable complexity explanation which would favour Spanish and Portuguese over English and Icelandic. Instead, speech rhythm offers a better account since syllable processing was strongest in syllable-timed French and Spanish and weakest in stress-timed English (and in Greek).

The low levels of rime awareness observed here contrast with the wealth of evidence that onset-rime structure is salient from preschool onwards (e.g., Kirtley et al., 1989; Treiman, 1985). Rime awareness was often higher in CV syllables where rime units correspond to phonemes, and also higher in French than English, arguing against the influence of phonological rime neighbourhood density which is similar in these languages (Ziegler & Goswami, 2005). Nevertheless, previous work has concentrated on English monosyllabic stimuli, raising questions about how well findings translate to the multisyllabic context more typical of other European languages, and which was, by necessity, the focus for the present study. An exploration of this question by Duncan, Seymour, and Bolik (2007) found that English-speakers favoured division of disyllabic words like “rocket” into an onset plus superrime structure (/r/-/ɒkt/) rather than an organisation in which the onset and rime within each syllable was salient ([/r/-/ɒ/]-[/k/-/ɪt/], Selkirk, 1982). The current data confirm that the rime of the first syllable is also low in salience in other languages.

5.2. Influence of orthographic depth

Common syllable and rime identification improved during the first school year but the relative position of the language groups remained much the same, suggesting that orthographic depth was not exerting a differential effect on performance; syllable identification remained most accurate in Spanish and French and least accurate in English, consistent with the speech rhythm hypothesis.

The PGS model predicts that phoneme awareness should be accelerated in shallow relative to deep orthographies (Greek, Spanish, Icelandic > Portuguese > French > English). The best fit came from phoneme matching at Time 1 where Icelandic (shallow) was better than French (intermediate) but by Time 2, English (deep) did not differ from Spanish (shallow) or Portuguese (intermediate). In the common unit task, the two most advanced groups at Time 1 phoneme identification were the readers of the English (deep) and Icelandic (shallow) orthographies, and by Time 2, ceiling-level phoneme identification was exhibited by all language groups.

In contrast to the phonological tasks, Time 2 word and nonword reading broadly confirmed the influence of orthographic depth on literacy acquisition (e.g., Seymour et al., 2003), although Icelandic performance was slightly worse and French performance slightly better than expected (Table 6). The lack of a consistent effect of orthographic depth on phonological development made it seem possible that instruction might be having a strong impact on phoneme awareness and, most especially, on the emergence of *expli-*

cit awareness of phonemes where variation by the end of the year was minimal.

5.3. Impact of literacy instruction

Phonics was the common instructional method across languages in our main study of phonological development. As well as conferring letter-sound knowledge, phonics instruction offers insight into the small phonemic sounds that are contained within spoken words and which can be used via their associations with letters to decode written words. This contrasts with a whole-word technique that teaches visual recognition of words as wholes. In a comparison of these methods in French, the phonics group developed more accurate letter knowledge and nonword decoding than the whole-word group by Time 2. Matching in both groups improved during this time with the phonics group displaying only a marginal accuracy advantage but not one that was specific to any unit. This contrasted with the outcome in the common unit task where the whole-word group's letter knowledge (63%) and reading experience failed to improve identification performance by Time 2. The phonics group, on the other hand, showed significant improvement across all units, although most strongly for phonemes.

Although the ML model predicts that phonics instruction will trigger explicit phoneme awareness due to the meta-cognitive demand for conscious manipulation of phonemes imposed by the phonics exercises, the concomitant effects on syllable and rime awareness are not predicted. One possibility is that this generalisation to larger units can be traced to the well-documented interaction between phonology and orthography, consistent with the phonics group's Time 2 advantage in nonword decoding. Alternatively, learning to read via phonics instruction may give rise to an attention mechanism which increases capacity to focus on the sound structure of speech (Morais, Castro, Scliar-Cabral, Kolinsky, & Content, 1987b; Morais & Kolinsky, 2002).

5.4. Overview

Our longitudinal study of phonological development revealed shared themes as well as cross-linguistic variation in the processing of spoken and written language. Although the findings are consistent with the idea of a reciprocal relationship between phonological awareness and learning to read (e.g., Perfetti et al., 1987), the outcome offers a greater precision about the changes that occur in phonological awareness over the first year of reading acquisition.

An argument has been made in this article that the processing demands of phonological tasks need to be taken into account in describing children's awareness of sound. The tasks chosen for our study, matching and common unit identification, were carefully equated in terms of memory load and structure so that the focus was on the different levels of awareness being assessed. Moreover, the items were identical between tasks to control for the influence of frequency and neighbourhood density. In spite of these measures, performance was neither stable between tasks

nor consistently more accurate for syllables than phonemes, contrary to the predictions of the LR model. Matching provoked more large-unit processing, especially at Time 1, seemingly due to the requirement for a global judgement about sound similarity. By Time 2, the large-unit advantage had diminished despite several language groups not having achieved ceiling performance at syllable matching. This contrasted markedly with the pattern observed in the common unit task where accuracy was higher for small than large units in several languages from Time 1, and all languages showed ceiling effects for small-units (although not necessarily for large units) by Time 2. Thus, these findings conflict with the view of phonological development as a universal large-to-small sequence.

It will be important to move towards a classification of task differences if the relationship between phonological development and later reading is to be better understood. Previous distinctions between *implicit* sensitivity to sound similarity and a more *explicit* capacity to manipulate individual sounds (e.g., *Morais, 1991*) correspond broadly with the task analyses presented here but exactly how these terms relate to the processing in any phonological task is not well understood. When a larger battery of phonological tasks is included, it becomes much more difficult to order tasks along the hypothesised implicit-explicit continuum. This problem has challenged researchers for some time but no consistent classification system has emerged. For example, *Yopp (1988)* identified three independent processing demands: (a) comparison or discrimination; (b) individual sound manipulation; and (c) phonological memory.⁵ More recently, *Roberts and McDougall (2003)* distinguished slightly different categories, namely: implicit awareness (e.g., matching); production and discrimination (e.g., oddity, similarity detection); and manipulation (e.g., segmentation, blending). Yet another way of conceiving of the processing demands has been to treat the status of phonological speech representations separately from the meta-cognitive task demands such as short-term memory or conscious awareness that might be involved in accessing such representations (*Ramus & Szenkovits, 2008*). This acknowledges that even implicit phonological awareness tasks do not reflect speech representations as directly as online measures of speech processing since meta-cognitive processing is required and is likely to become increasingly involved with age and reading experience.

The present study demonstrated that the training provided by phonics instruction, rather than learning to read per se, appeared sufficient to trigger excellent explicit sensitivity to phonemes across languages by the end of the first school year. Indeed, the children who were not exposed to phonics instruction (whole-word group, Study 3) were the only group in our study not to show a ceiling effect in common *phoneme* identification by Time 2. A meta-cognitive ability to manipulate sound explicitly appears deeply intertwined with what children have to do with sound in decoding novel words (*Duncan, Seymour, & Hill, 2000; Duncan et al., 1997*). Pinpointing the source

of this effect will be important for understanding the direction of the association between phonological awareness and reading progress. There is long-standing evidence that meta-cognitive training benefits performance in both phoneme awareness and reading (*Cunningham, 1990*), which implies that strategies learned during reading acquisition might usefully be extended to solve phonological tasks.

Alternatively, the emerging linkage between phonology and orthography that features in many models of reading development (e.g., *Grainger et al., 2012*) may strengthen phonological task performance. Phonological perceptions are known to become coloured by orthographic knowledge once reading begins, as children are more likely to judge that a word like 'pitch' contains more phonemes than 'rich' when they know how to spell these phonemically identical words (*Ehri & Wilce, 1980*). Nevertheless, phonological representations may also be directly impacted by learning to read in a manner independent of these newly acquired links to orthography. It remains an empirical question as to which explanation is most likely but emerging fMRI evidence from adults and older children offers support for age-related increases in the recruitment of orthographic processing in rhyming tasks even when, as in the present study, these tasks are delivered exclusively in the auditory modality (*Booth et al., 2004*). Among adults, *Pattamadilok et al. (2011)* found two ERP components associated with orthographic activation in auditory rhyme judgement: the first occurred during phonological segmentation, and the second, during the task decision process. Exactly how these processes are formed among beginning readers or indeed, why they might fail to be formed in the case of reading disability, requires further study.

A notable strength of our study is that it provides the opportunity to compare six language groups, which reinforces the generalizability of the present findings by replication across a series of alphabetic languages. It also sets up the possibility of cross-linguistic comparisons, although this raises inevitable questions about item and participant comparability across groups (*Share, 2008*). As these comparisons are of considerable theoretical interest, we have presented the outcome throughout but acknowledge the limitations inherent in this design even when careful attempts are made to match groups and stimuli.

Phonological awareness differed between languages at Time 1. Variation in syllable awareness, especially syllable *identification*, appeared associated with speech rhythm, which replicates and extends existing cross-linguistic work on this topic (e.g., *Duncan et al., 2006*). As outlined in the introduction, an exact definition of speech rhythm remains elusive but consistent differences in word segmentation from fluent speech emerge among infants from prototypical syllable-timed vs. stress-timed linguistic environments (*Nazzi et al., 1998, 2006*). Future work is needed to analyse the association between phonological awareness and speech rhythm more closely. At present, sensitivity to speech rhythm is increasingly being linked to reading progress (e.g., *Goswami et al., 2002; Gutierrez-Palma & Palma-Reyes, 2008; Holliman et al., 2010*). Developmental dyslexics appear less sensitive to the amplitude modulation of the auditory signal at frequencies which, in speech,

⁵ Note that in this study the sound unit under investigation is confounded with task.

correspond with aspects of syllable processing. These experimental techniques have recently been used to identify auditory processing differences between young speakers of English and, syllable-timed, Hungarian (Surányi et al., 2009). Thus, the typical rhythm of native language may normally be encoded in lexical representations from the earliest phases of development (see also Curtin, Mintz, and Christiansen (2005)), which strengthens support for the ML model emphasis on the role of the early linguistic environment in shaping the developing phonological system.

Expanding orthographic knowledge and instruction exerted a powerful influence on the course of phonological

development in all six of our alphabetic orthographies. While the lack of a clear effect of orthographic depth was surprising (cf. PGS model), orthographic depth was associated with the implementation of the alphabetic principle in reading here as in previous work (e.g., Seymour et al., 2003). Possibilities for future investigation are that orthographic depth may shape the development of phoneme awareness more strongly in the absence of phonics instruction, or that a meta-cognitive ability to focus on sub-lexical sounds may emerge relatively rapidly via instruction but differential effects of spelling-sound correspondence consistency may emerge over a longer time span via statistical learning.

Table A1
Stimuli for the matching and common unit tasks in each language^a.

Language	Target sound and initial syllable structure					
English	Syllable	Structure	Rime	Structure	Phoneme	Structure
	curtain–curly	cvc	gamble–hamster	cvc	penguin–padlock	cvc
	marble–market	cvc	panther–bandage	cvc	corner–camping	cvc
	parcel–party	cvc	purple–burden	cvc	garden–guilty	cvc
	window–winter	cvc	cobweb–lobster	cvc	dolphin–darker	cvc
	button–bubble	cv	comic–poppy	cv	kettle–curry	cv
	letter–lemon	cv	melon–better	cv	rummage–rabbit	cv
	woman–woolly	cv	puppy–rubbish	cv	garage–going	cv
	carrot–camel	cv	hammer–saddle	cv	wallet–woman	cv
Greek	Syllable	Structure	Rime	Structure	Phoneme	Structure
	πάρκο–πάρτι	CVC	φόρμα–πόρτες	CVC	κάρτα–κόλπο	CVC
	δέρνω–δέρμα	CVC	τέρμα–πέρσι	CVC	βάλτοι–βέργες	CVC
	νύφες–νύχτα	CV	βόλοι–γόμα	CV	γέλα–γίνω	CV
	μέρα–μέλι	CV	ρίζα–μύτες	CV	κήπος–κούτα	CV
	κάνω–κάτσε	CV	βάφω–χάνει	CV	λέπι–λάμπα	CV
	γίδες–γύρο	CV	σέλα–γέρο	CV	μόδα–μούσι	CV
	πάχος–πάλη	CV	λίρα–βίδες	CV	πέτρες–πείνα	CV
	θέση–θέμα	CV	φούστες–γούνα	CV	νέος–νίκη	CV
Icelandic	Syllable	Structure	Rime	Structure	Phoneme	Structure
	borði–borga	cvc	kexið–sexan	cvc	vindur–vökvað	cvc
	tálga–tálmi	cvc	heflað–gefnir	cvc	tefli–tíska	cvc
	veðmál–veðbók	cvc	veskið–hespan	cvc	regla–rosti	cvc
	dúfan–dúkur	cv	þurrka–burtu	cvc	sófi–sumar	cv
	hátíð–hávær	cv	gusa–funi	cv	fífa–foli	cv
	hótel–hópur	cv	lína–sími	cv	líta–leki	cv
	pefi–pera	cv	kátur–málað	cv	hamar–höfuð	cv
	tími–týra	cv	vinur–litað	cv	kútur–kominn	cv
Portuguese	Syllable	Structure	Rime	Structure	Phoneme	Structure
	balça–balde	cvc	silva–filme	cvc	mosca–março	cvc
	cisma–cisne	cvc	bolso–polpa	cvc	perna–polvo	cvc
	farda–farto	cvc	poste–costa	cvc	relva–risco	cvc
	melga–melro	cvc	curva–furto	cvc	sarda–silvo	cvc
	vinda–vinco	cv	fuga–gume	cv	baba–beco	cv
	rude–rumo	cv	lama–cano	cv	caco–cola	cv
	povo–poça	cv	mito–tira	cv	dedo–dica	cv
	pêlo–pêra	cv	toga–colo	cv	fera–figo	cv
Spanish	Syllable	Structure	Rime	Structure	Phoneme	Structure
	pinza–pintor	cvc	casco–raspa	cvc	balsa–bingo	cvc
	palco–palpar	cvc	lapsó–raptar	cvc	caldó–curva	cvc
	censo–central	cvc	campo–gamba	cvc	falda–firme	cvc
	manta–mango	cvc	acné–tacto	cvc	munto–manta	cvc
	mesa–metro	cv	taco–nata	cv	pata–pelo	cv
	caja–cable	cv	nube–duna	cv	gota–gallo	cv
	dado–dama	cv	teja–velo	cv	faro–fuga	cv
	solo–sopa	cv	risa–pico	cv	mago–muro	cv

^a For the matching task, the items shown are targets which were administered together with an equal number of foils of similar structure. Foils for the matching task and French items for both tasks can be obtained on request from L. Duncan and J. Leybaert, respectively.

Therefore, to conclude, the outcome of our study suggests that it is no longer helpful to characterise phonological development in terms of a fixed sequence because this type of generalisation obscures important variation that occurs in response to the demands of the assessment task, the type of instruction taking place in the classroom and the nature of the spoken and written languages under investigation.

Acknowledgements

The research presented in this article was supported by grants from the Economic and Social Research Council (R000239151), the Economic and Social Research Council/European Science Foundation EUROCORES scheme (R000223737), The Leverhulme Trust (F/00143/B), the Portuguese Foundation for Science and Technology (CPSY50/Language Group), The Spanish Ministry of Science and Innovation (SEJ2010-21983-C02-01/PSIC) and the Junta de Andalucía (HUM-820), the Fonds de la Recherche Fondamentale Collective (8.4.503.03 F (2)), and RANNIS - The Icelandic Centre for Research (021330002,3,4). We would like to thank Jane Erskine and Leila Kalliokoski for their research assistance and three anonymous reviewers for their valuable comments.

Appendix A. Phonological stimuli

See Table A1.

References

- Alegria, J., Pignot, E., & Morais, J. (1982). Phonetic analysis of speech and memory codes in beginning readers. *Memory & Cognition*, 10, 451–456.
- Anthony, J. L., & Francis, D. J. (2005). Development of phonological awareness. *Current Directions in Psychological Science*, 14, 255–259.
- Anthony, J. L., Lonigan, C. J., Driscoll, K., Phillips, B. M., & Burgess, S. R. (2003). Phonological sensitivity: A quasi-parallel progression of word structure units and cognitive operations. *Reading Research Quarterly*, 38, 470–487.
- Arvaniti, A. (1994). Acoustic features of Greek rhythmic structure. *Journal of Phonetics*, 22, 239–268.
- Arvaniti, A. (2007). Greek phonetics: The state of the art. *Journal of Greek Linguistics*, 8, 97–208.
- Ballem, K. D., & Plunkett, K. (2005). Phonological specificity in children at 1; 2. *Journal of Child Language*, 32, 159–173.
- Bertelson, P., & de Gelder, B. (1991). The emergence of phonological awareness: Comparative approaches. In I. G. Mattingly, & M. Studdert-Kennedy (Eds.), *Modularity and the motor theory of speech perception* (pp. 393–412). Hillsdale, NJ: Erlbaum.
- Bertelson, P., & de Gelder, B. (1989). Learning about reading from illiterates. In A. M. Galaburda (Ed.), *From reading to neurons* (pp. 1–25). Cambridge, MA: M.I.T. Press.
- Bertelson, P., de Gelder, B., & van Zon, M. (1997). Explicit speech segmentation and syllabic onset structure: Developmental trends. *Psychological Research*, 60, 183–191.
- Boada, R., & Pennington, B. F. (2006). Deficient implicit phonological representations in children with dyslexia. *Journal of Experimental Child Psychology*, 95, 153–193.
- Booth, J. R., Burman, D. D., Meyer, J. R., Gitelman, D. R., Parrish, T. B., & Mesulam, M. M. (2004). Development of brain mechanisms for processing orthographic and phonologic representations. *Journal of Cognitive Neuroscience*, 16, 1234–1249.
- Borgwaldt, S. R., Hellwig, F. M., & de Groot, A. M. B. (2005). Onset entropy matters – Letter-to-phoneme mappings in seven languages. *Reading and Writing*, 18, 211–229.
- Caravolas, M., & Bruck, M. (1993). The effect of oral and written language input on children's phonological awareness – A cross-linguistic study. *Journal of Experimental Child Psychology*, 55, 1–30.
- Caravolas, M., & Landerl, K. (2010). The influences of syllable structure and reading ability on the development of phoneme awareness: A longitudinal cross-linguistic study. *Scientific Studies of Reading*, 14, 464–484.
- Caravolas, M., Lervåg, A., Mousikou, P., Efrim, C., Litavský, M., Onochie-Quintanilla, E., et al. (2012). Common patterns of prediction of literacy development in different alphabetic orthographies. *Psychological Science*, 23, 678–686.
- Carroll, J. M., & Snowling, M. J. (2004). Language and phonological skills in children at high risk of reading difficulties. *Journal of Child Psychology and Psychiatry*, 45, 631–640.
- Carroll, J. M., Snowling, M. J., Hulme, C., & Stevenson, J. (2003). The development of phonological awareness in preschool children. *Developmental Psychology*, 39, 913–923.
- Castles, A., & Coltheart, M. (2004). Is there a causal link from phonological awareness to success in learning to read? *Cognition*, 91, 77–111.
- Castles, A., Wilson, K., & Coltheart, M. (2011). Early orthographic influences on phonemic awareness tasks: Evidence from a preschool training study. *Journal of Experimental Child Psychology*, 108, 203–210.
- Cossu, G., Shankweiler, D., Liberman, I. Y., Katz, L., & Tola, G. (1988). Awareness of phonological segments and reading ability in Italian children. *Applied Psycholinguistics*, 9, 1–16.
- Cunningham, A. E. (1990). Explicit versus implicit instruction in phonemic awareness. *Journal of Experimental Child Psychology*, 50, 429–444.
- Curtin, S., Mintz, T. H., & Christiansen, M. H. (2005). Stress changes the representational landscape: Evidence from word segmentation. *Cognition*, 96, 233–262.
- Cutler, A., Mehler, J., Norris, D., & Seguí, J. (1986). The syllable's differing role in the segmentation of French and English. *Journal of Memory and Language*, 25, 385–400.
- Cutler, A. (2005). Lexical stress. In D. B. Pisoni & R. E. Remez (Eds.), *The handbook of speech perception* (pp. 264–289). Oxford: Blackwell.
- Dauer, R. M. (1980). *Stress and rhythm in modern Greek*. Doctoral dissertation. University of Edinburgh.
- Dauer, R. M. (1983). Stress-timing and syllable-timing reanalyzed. *Journal of Phonetics*, 11, 51–62.
- De Jong, P. F., & Van der Leij, A. (2003). Developmental changes in the manifestation of a phonological deficit in dyslexic children learning to read a regular orthography. *Journal of Educational Psychology*, 95, 22–40.
- Defior, S. (2004). Phonological awareness and learning to read: A cross-linguistic perspective. In T. Nunes & P. Bryant (Eds.), *Handbook of children's literacy* (pp. 631–649). Dordrecht: Kluwer.
- Demont, E., & Gombert, J. E. (1996). Phonological awareness as a predictor of recoding skills and syntactic awareness as a predictor of comprehension skills. *British Journal of Educational Psychology*, 66, 315–332.
- Duncan, L. G., Colé, P., Seymour, P. H. K., & Magnan, A. (2006). Differing sequences of metaphonological development in French and English. *Journal of Child Language*, 33, 369–399.
- Duncan, L. G., & Seymour, P. H. K. (2000). Socio-economic differences in foundation-level literacy. *British Journal of Psychology*, 91, 145–166.
- Duncan, L. G., Seymour, P. H. K., & Bolik, F. (2007). Rimes and superrimes: An exploration of children's disyllabic rhyming skills. *British Journal of Psychology*, 98, 199–221.
- Duncan, L. G., Seymour, P. H. K., & Hill, S. (1997). How important are rhyme and analogy in beginning reading? *Cognition*, 63, 171–208.
- Duncan, L. G., Seymour, P. H. K., & Hill, S. (2000). A small-to-large unit progression in metaphonological awareness and reading? *Quarterly Journal of Experimental Psychology*, 53A, 1081–1104.
- Durgunoğlu, A. Y., & Öney, B. (1999). A cross-linguistic comparison of phonological awareness and word recognition. *Reading and Writing*, 11, 281–299.
- Ehri, L. C. (1992). Reconceptualizing the development of sight word reading and its relationship to recoding. In P. Gough, L. C. Ehri, & R. Treiman (Eds.), *Reading acquisition* (pp. 107–143). Hillsdale, NJ: Erlbaum.
- Ehri, L. C., & Wilce, L. S. (1980). The influence of orthography on readers' conceptualization of the phonemic structure of words. *Applied Psycholinguistics*, 1, 371–385.
- Elbro, C., Borstrom, I., & Petersen, D. K. (1998). Predicting dyslexia from kindergarten: The importance of distinctness of phonological representations of lexical items. *Reading Research Quarterly*, 33, 36–60.
- Ellis, N. C., Natsume, M., Stavropoulou, K., Hoxhallari, L., Van Daal, V. H. P., Polyzoe, N., et al. (2004). The effects of orthographic depth on learning

- to read alphabetic, syllabic, and logographic scripts. *Reading Research Quarterly*, 39, 438–468.
- Fenk-Oczlon, G., & Fenk, A. (1999). Cognition, quantitative linguistics, and systemic typology. *Linguistic Typology*, 3, 151–177.
- Ferguson, C. A., & Farwell, C. B. (1975). Words and sounds in early language acquisition. *Language*, 51, 419–439.
- Foy, J. G., & Mann, V. A. (2009). Effects of onset density in preschool children: Implications for development of phonological awareness and phonological representation. *Applied Psycholinguistics*, 30, 339–361.
- Frost, R., Katz, L., & Bentin, S. (1987). Strategies for visual word recognition and orthographical depth: A multilingual comparison. *Journal of Experimental Psychology*, 13, 104–115.
- Frota, S., & Vigário, M. (2001). On the correlates of rhythmic distinctions: The European/Brazilian Portuguese case. *Probus*, 13, 247–275.
- Garlock, V. M., Walley, A. C., & Metsala, J. L. (2001). Age-of-acquisition, word frequency, and neighborhood density effects on spoken word recognition by children and adults. *Journal of Memory and Language*, 45, 468–492.
- Geudens, A., & Sandra, D. (2003). Beyond implicit phonological knowledge: No support for an onset-rime structure in children's explicit phonological awareness. *Journal of Memory and Language*, 49, 157–182.
- Geudens, A., Sandra, D., & Van den Broeck, W. (2004). Segmenting two-phoneme syllables: Developmental differences in relation with early reading skills. *Brain and Language*, 90, 338–352.
- Goikoetxea, E. (2005). Levels of phonological awareness in preliterate and literate Spanish-speaking children. *Reading and Writing*, 18, 51–79.
- Gombert, J. E. (1992). *Metalinguistic development*. New York: Harvester Wheatsheaf.
- Goswami, U. (2002). Phonology, reading development, and dyslexia: A cross-linguistic perspective. *Annals of Dyslexia*, 52, 141–163.
- Goswami, U., & Bryant, P. E. (1990). *Phonological skills and learning to read*. Hillsdale, NJ: Erlbaum.
- Goswami, U., & East, M. (2000). Rhyme and analogy in beginning reading: Conceptual and methodological issues. *Applied Psycholinguistics*, 21, 63–93.
- Goswami, U., Porpodas, C., & Wheelwright, S. (1997). Children's orthographic representations in English and Greek. *European Journal of Psychology of Education*, 12, 273–292.
- Goswami, U., Thomson, J., Richardson, U., Stainthorpe, R., Hughes, D., Rosen, S., et al. (2002). Amplitude envelope onsets and developmental dyslexia: A new hypothesis. *Proceedings of the National Academy of Sciences of the United States of America*, 99, 10911–10916.
- Goswami, U., Ziegler, J. C., Dalton, L., & Schneider, W. (2001). Pseudohomophone effects and phonological recoding procedures in reading development in English and German. *Journal of Memory and Language*, 45, 648–664.
- Grabe, E., & Low, E. L. (2002). Durational variability in speech and the rhythm class hypothesis. In C. Gussenhoven & N. Warner (Eds.), *Laboratory phonology VII* (pp. 515–546). Berlin: Mouton de Gruyter.
- Grainger, J., Lété, B., Bertrand, D., Dufau, S., & Ziegler, J. C. (2012). Evidence for multiple routes in learning to read. *Cognition*, 123, 280–292.
- Gutiérrez-Palma, N., & Palma-Reyes, A. (2008). On the use of lexical stress in reading Spanish. *Reading and Writing*, 21, 645–660.
- Harris, M., & Giannouli, V. (1999). Learning to read and spell in Greek: The importance of letter knowledge and morphological awareness. In M. Harris & G. Hatano (Eds.), *Learning to read and write: A cross-linguistic perspective* (pp. 51–70). Cambridge: Cambridge University Press.
- Holliman, A. J., Wood, C., & Sheehy, K. (2010). Does speech rhythm sensitivity predict children's reading ability 1 year later? *Journal of Educational Psychology*, 102, 356–366.
- Hulme, C., Caravolas, M., Malkova, G., & Brigstocke, S. (2005). Phoneme isolation ability is not simply a consequence of letter-sound knowledge. *Cognition*, 97, B1–B11.
- Johnston, R. S., & Watson, J. (2004). Accelerating the development of reading, spelling and phonemic awareness. *Reading and Writing*, 17, 327–357.
- Jusczyk, P. W. (1986). Toward a model of the development of speech perception. In J. S. Perkell & D. H. Klatt (Eds.), *Invariance and variability in speech processes* (pp. 1–19). Hillsdale, NJ: Erlbaum.
- Karmiloff-Smith, A. (1986). From meta-processes to conscious access – Evidence from children's metalinguistic and repair data. *Cognition*, 23, 95–147.
- Kim, J., Davis, C., & Cutler, A. (2008). Perceptual tests of rhythmic similarity: II. Syllable rhythm. *Language and Speech*, 51, 343–359.
- Kirtley, C., Bryant, P., Maclean, M., & Bradley, L. (1989). Rhyme, rime, and the onset of reading. *Journal of Experimental Child Psychology*, 48, 224–245.
- Kohler, K. J. (2009). Whither speech rhythm research? *Phonetica*, 66, 5–14.
- Lee, C. S., & Todd, N. P. M. (2004). Towards an auditory account of speech rhythm: Application of a model of the auditory 'primal sketch' to two multi-language corpora. *Cognition*, 93, 225–254.
- Lehiste, I. (1977). Isochrony reconsidered. *Journal of Phonetics*, 5, 253–263.
- Lundberg, I., Frost, J., & Petersen, O. P. (1988). Effects of an extensive program for stimulating phonological awareness in preschool children. *Reading Research Quarterly*, 23, 263–284.
- Lundberg, I., Olofsson, A., & Wall, S. (1980). Reading and spelling skills in the 1st school years predicted from phonemic awareness skills in kindergarten. *Scandinavian Journal of Psychology*, 21, 159–173.
- Mann, V. A. (1986). Phonological awareness: The role of reading experience. *Cognition*, 24, 65–92.
- Mann, V., & Wimmer, H. (2002). Phoneme awareness and pathways into literacy: A comparison of German and American children. *Reading and Writing*, 15, 653–682.
- McBride-Chang, C., Wagner, R. K., & Chang, L. (1997). Growth modelling of phonological awareness. *Journal of Educational Psychology*, 89, 621–630.
- Mehler, J., Dommergues, J. Y., Frauenfelder, U., & Segui, J. (1981). The syllable's role in speech segmentation. *Journal of Verbal Learning and Verbal Behavior*, 20, 298–305.
- Mennen, I., & Okalidou, A. (2006). Acquisition of Greek phonology: An overview. *QMUC Speech Science Research Centre working papers*, WP-11.
- Metsala, J. L. (1997). An examination of word frequency and neighborhood density in the development of spoken-word recognition. *Memory & Cognition*, 25, 47–56.
- Metsala, J. L. (1999). Young children's phonological awareness and nonword repetition as a function of vocabulary development. *Journal of Educational Psychology*, 91, 3–19.
- Metsala, J. L., Stavrinou, D., & Walley, A. C. (2009). Children's spoken word recognition and contributions to phonological awareness and nonword repetition: A 1-year follow-up. *Applied Psycholinguistics*, 30, 101–121.
- Metsala, J. L., & Walley, A. C. (1998). Spoken vocabulary growth and the segmental restructuring of lexical representations: Precursors to phonemic awareness and early reading ability. In J. L. Metsala & L. C. Ehri (Eds.), *Word recognition in beginning literacy* (pp. 89–120). Mahwah, NJ: Erlbaum.
- Morais, J., Alegria, J., & Content, A. (1987a). The relationships between segmental analysis and alphabetic literacy: An interactive view. *Cahiers de psychologie cognitive/European bulletin of psychology*, 7, 415–438.
- Morais, J. (1991). Constraints on the development of phonemic awareness. In S. A. Brady & D. P. Shankweiler (Eds.), *Phonological processes in literacy* (pp. 5–27). Hillsdale, NJ: Erlbaum.
- Morais, J., Castro, S. L., Sciarra-Cabral, L., Kolinsky, R., & Content, A. (1987b). The effects of literacy on the recognition of dichotic words. *Quarterly Journal of Experimental Psychology*, 39A, 451–465.
- Morais, J., & Kolinsky, R. (2002). Literacy effects on language and cognition. In L. Bäckman & C. von Hofsten (Eds.), *Psychology at the turn of the millennium* (Vol. 1, pp. 507–530). Hove: Psychology Press.
- Nazzi, T., Bertoncini, J., & Mehler, J. (1998). Language discrimination by newborns: Toward an understanding of the role of rhythm. *Journal of Experimental Psychology-Human Perception and Performance*, 24, 756–766.
- Nazzi, T., Iakimova, G., Bertoncini, J., Fredonie, S., & Alcantara, C. (2006). Early segmentation of fluent speech by infants acquiring French: Emerging evidence for crosslinguistic differences. *Journal of Memory and Language*, 54, 283–299.
- Niessen, M., Frith, U., Reitsma, P., & Öhngren, B. (2000). *Learning disorders as a barrier to human development 1995–1999*. Evaluation report. Technical Committee COST Social Sciences.
- Pattamadilok, C., Perre, L., & Ziegler, J. C. (2011). Beyond rhyme or reason: ERPs reveal task-specific activation of orthography on spoken language. *Brain & Language*, 116, 116–124.
- Perfetti, C. A., Beck, I., Bell, L. C., & Hughes, C. (1987). Phonemic knowledge and learning to read are reciprocal – A longitudinal study of 1st-grade children. *Merrill-Palmer Quarterly*, 33, 283–319.
- Prieto, P., del Mar Vanrell, M., Astruc, L., Payne, E., & Post, B. (2012). Phonotactic and phrasal properties of speech rhythm. Evidence from Catalan, English, and Spanish. *Speech Communication*, 54, 681–702.
- Pulgram, E. (1970). *Syllable, word, nexus, cursus*. The Hague: Mouton.
- Ramus, F., Nespor, M., & Mehler, J. (1999). Correlates of linguistic rhythm in the speech signal. *Cognition*, 73, 265–292.
- Ramus, F., & Szenkovičs, G. (2008). What phonological deficit? *Quarterly Journal of Experimental Psychology*, 61, 129–141.

- Read, C., Zhang, Y. F., Nie, H. Y., & Ding, B. Q. (1986). The ability to manipulate speech sounds depends on knowing alphabetic writing. *Cognition*, 24, 31–44.
- Roberts, L., & McDougall, S. (2003). What do children do in the rime-analogy task? An examination of the skills and strategies used by early readers. *Journal of Experimental Child Psychology*, 84, 310–337.
- Savage, R., Blair, R., & Rvachew, S. (2006). Rimes are not necessarily favored by prereaders: Evidence from meta- and epi-linguistic phonological tasks. *Journal of Experimental Child Psychology*, 94, 183–205.
- Selkirk, E. O. (1982). The syllable. In H. Van der Hulst & N. Smith (Eds.), *The structure of phonological representations (Part II)*. Dordrecht, Holland: Foris.
- Serrano, F., Genard, N., Sucena, A., Defior, S., Alegria, J., Mousty, P., et al. (2010). Variations in reading and spelling acquisition in Portuguese, French and Spanish: A cross-linguistic comparison. In S. L. Castro, & J. Morais (Eds.), *Special issue: Lexical processing: Phonetic, prosodic and morphological aspects*. *Journal of Portuguese Linguistics*, 9–10, 183–205.
- Seymour, P. H. K., Aro, M., Erskine, J. M., Wimmer, H., Leybaert, J., Elbro, C., et al. (2003). Foundation literacy acquisition in European orthographies. *British Journal of Psychology*, 94, 143–174.
- Seymour, P. H. K., & Duncan, L. G. (2001). Learning to read in English. Ψ YXOΛOΓIA (*Psychology*), 8, 281–299.
- Seymour, P. H. K., Duncan, L. G., & Bolik, F. M. (1999). Rhymes and phonemes in the common unit task: Replications and implications for beginning reading. *Journal of Research in Reading*, 22, 113–130.
- Seymour, P. H. K., & Evans, H. M. (1994). Levels of phonological awareness and learning to read. *Reading and Writing*, 6, 221–250.
- Share, D. L. (2008). On the anglocentricities of current reading research and practice: The perils of overreliance on an “Outlier” orthography. *Psychological Bulletin*, 134, 584–615.
- Storkel, H. L. (2004). Do children acquire dense neighborhoods? An investigation of similarity neighborhoods in lexical acquisition. *Applied Psycholinguistics*, 25, 201–221.
- Stuart, M., Dixon, M., Masterson, J., & Gray, B. (2003). Children’s early reading vocabulary: Description and word frequency lists. *British Journal of Educational Psychology*, 73, 585–598.
- Surányi, Z., Csépe, V., Richardson, U., Thomson, J. M., Honbolygó, F., & Goswami, U. (2009). Sensitivity to rhythmic parameters in dyslexic children: A comparison of Hungarian and English. *Reading and Writing*, 22, 41–56.
- Treiman, R. (1985). Onsets and rimes as units of spoken syllables – Evidence from children. *Journal of Experimental Child Psychology*, 39, 161–181.
- Treiman, R., & Baron, J. (1981). Segmental analysis ability: Development and relation to reading ability. In G. E. MacKinnon & T. G. Waller (Eds.), *Reading research: Advances in theory and practice* (pp. 159–197). New York: Academic Press.
- Treiman, R., Bowey, J. A., & Bourassa, D. (2002). Segmentation of spoken words into syllables by English-speaking children as compared to adults. *Journal of Experimental Child Psychology*, 83, 213–238.
- Treiman, R., & Breaux, A. M. (1982). Common phoneme and overall similarity relations among spoken word syllables: Their use by children and adults. *Journal of Psycholinguistic Research*, 11, 569–598.
- Treiman, R. (1992). The role of intrasyllabic units in learning to read and spell. In P. B. Gough, L. C. Ehri, & R. Treiman (Eds.), *Reading acquisition* (pp. 1–70). Hillsdale, NJ: Erlbaum.
- Treiman, R., & Zukowski, A. (1996). Children’s sensitivity to syllables, onsets, rimes and phonemes. *Journal of Experimental Child Psychology*, 61, 193–215.
- Treiman, R., & Zukowski, A. (1991). Levels of phonological awareness. In S. A. Brady & D. P. Shankweiler (Eds.), *Phonological processes in literacy: A tribute to Isabelle Y Liberman* (pp. 67–83). Hillsdale, NJ: Erlbaum.
- Ventura, P., Kolinsky, R., Fernandes, S., Querido, L., & Morais, J. (2007a). Lexical restructuring in the absence of literacy. *Cognition*, 105, 334–361.
- Ventura, P., Morais, J., & Kolinsky, R. (2007b). The development of the orthographic consistency effect in speech recognition: From sublexical to lexical involvement. *Cognition*, 105, 547–576.
- Vicente, S., Castro, S. L., & Walley, A. (2003). A developmental analysis of similarity neighborhoods in European Portuguese. *Journal of Portuguese Linguistics*, 2, 93–114.
- Wagner, R. K., Torgesen, J. K., & Rashotte, C. A. (1994). Development of reading-related phonological processing abilities – New evidence of bidirectional causality from a latent variable longitudinal study. *Developmental Psychology*, 30, 73–87.
- Walley, A. C. (1993). The role of vocabulary development in children’s spoken word recognition and segmentation ability. *Developmental Review*, 13, 286–350.
- Yopp, H. K. (1988). The validity and reliability of phonemic awareness tests. *Reading Research Quarterly*, 23, 159–177.
- Ziegler, J. C., Bertrand, D., Toth, D., Csepe, V., Reis, A., Faisca, L., et al. (2010). Orthographic depth and its impact on universal predictors of reading: A cross-language investigation. *Psychological Science*, 21, 551–559.
- Ziegler, J. C., & Ferrand, L. (1998). Orthography shapes the perception of speech: The consistency effect in auditory word recognition. *Psychonomic Bulletin & Review*, 5, 683–689.
- Ziegler, J. C., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: A psycholinguistic grain size theory. *Psychological Bulletin*, 131, 3–29.
- Ziegler, J. C., Perry, C., Jacobs, A. M., & Braun, M. (2001). Identical words are read differently in different languages. *Psychological Science*, 12, 379–384.