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The cognitive foundations of learning to read: a framework for preventing and remediating reading difficulties

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ABSTRACT
This article presents an overview of a conceptual framework designed to help reading professionals better understand what their students are facing as they learn to read in alphabetic writing systems. The US National Reading Panel (NRP) recommended five instructional components for improving reading outcomes but presented these instructional components as a list without explicitly addressing their interrelations, either in terms of instruction or cognitive development. In contrast, the Cognitive Foundations Framework offers a description of the major cognitive capacities underlying learning to read and specifies the relationships between them. The central claim of this article is that what is needed to help intervention specialists achieve better outcomes is a clearly specified conceptual framework of the cognitive capacities underlying learning to read that provides the basis for an assessment framework that is linked to evidence-based instructional strategies for addressing the individual literacy learning needs of students.

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In this article, we provide an overview of a conceptual framework designed to help reading professionals better understand what their students are facing as they learn to read in alphabetic writing systems. The Cognitive Foundations Framework achieves this aim by supporting critical thinking about reading, its assessment, and its teaching. A book we have prepared for publication provides more detailed information about the Framework and its applications, as well as an extensive discussion of the theoretical arguments and empirical evidence in support of the model (Hoover & Tunmer, 2019).

Effective beginning reading teachers and intervention specialists possess three competencies that enable them to answer two key questions about their practice: what are you doing and why are you doing it? First, they have a broad understanding of the cognitive capacities involved in learning to read, including familiarity with the typical developmental patterns that exist within each. Second, they can determine what beginning or struggling readers know and what they still need to know to become skilled readers. These understandings are critical in guiding the many instructional decisions that reading teachers and specialists must make each day. And third, they can provide their students with targeted, evidence-based instruction

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that directly addresses their individual literacy learning needs. This includes monitoring their students' responses to instruction and adjusting appropriately when necessary.

What is needed, then, to assist all reading professionals develop these competencies is a clearly specified conceptual framework of the cognitive capacities underlying learning to read that provides the basis for an assessment framework that is linked to evidence-based instructional strategies for addressing the individual literacy learning needs of students. By focusing on the cognitive structures underlying learning to read, the Cognitive Foundations Framework can play an important role in helping professionals think about reading difficulties and interventions for addressing them. They can use the Framework as an effective guide in determining where the source of the difficulty might be for students struggling with reading, what assessment data can be used to better understand where their students are developmentally, and where to focus instructional time.

As a consequence of the important work of the National Reading Panel (NRP) in the United States, increasing attention has focused on five instructional components for improving reading outcomes: (1) phonemic awareness, (2) phonics, (3) fluency, (4) vocabulary, and (5) comprehension (National Institute of Child Health and Human Development, 2000). While the NRP made positive recommendations for instruction within each of these five domains based on a review of available research, it did not elaborate on how or when these "big five" instructional components impacted the cognitive capacities underlying learning to read. Rather, the NRP presented these instructional components as a list without explicitly addressing their interrelations, either in terms of instruction or cognitive development. In contrast, the Cognitive Foundations Framework offers a description of the major cognitive capacities underlying learning to read and, importantly, specifies the relationships between them.

The Cognitive Foundations Framework

Figure 1 presents the overall Cognitive Foundations Framework. In presenting the Framework, we need to note two restrictions. First, the Framework is concerned with

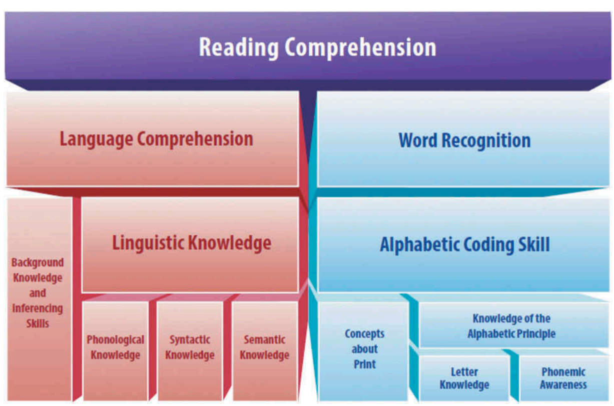

Figure 1. The cognitive foundations framework.
Source. Graphic from Hoover and Tunmer (2019).

the cognitive foundations underlying learning to read. As such, it does not deal with other important factors that may indirectly impact reading acquisition. These include psychological factors such as motivation to learn to read, interest in reading, and self-efficacy, and ecological factors such as richness of the home literacy environment and quality of classroom literacy instruction (Aaron, Joshi, Gooden, & Bentum, 2008). All of these (distal) factors can impact reading development indirectly through the cognitive domain, which includes elements that have a more direct (proximal) influence on reading development (Tunmer & Chapman, 2012b).

Second, the hierarchical structure of the Framework is not intended to suggest that the development of the higher-order cognitive elements cannot occur until *all* of the lower-order elements are *fully* developed, although it does assume that some level of mastery is needed. Typically, once a critical level is attained in a given element, it tends to develop concurrently with those immediately above and below, in a reciprocally facilitating manner. This suggests that the elements should not be taught in isolation from each other but rather in a more integrated manner. Beginning readers should be given plenty of opportunities to practice and receive feedback on applying their newly acquired skills while engaged in performing the more advanced cognitive functions specified in the Framework. However, the Framework will help the practitioner understand that some capacities must be developed to fairly sophisticated levels before others can be acquired. This is critical, for trying to facilitate the development of higher-order skills when the lower-order skills upon which they are based are weak will likely be ineffective, as those students being so instructed will not be able to take full advantage of the supports being provided, given their level of development.

At the top of the Framework is *reading comprehension*, which is defined as the ability to extract and construct linguistically based meaning, both literal and inferred, from written text. Note that this definition makes reference to *linguistically based* meaning. Knowledge of the language being read is central to the reading process and without that knowledge reading could not take place. For typical children learning to read in their native language, the reading process is grafted onto the listening process. From this perspective, reading is the ability to convert language represented in print to a representation from which the child can already derive meaning, namely, one based in the child's spoken language. That is, if a child can successfully identify written words and thereby gain access to their appropriate meanings, which are already in place by virtue of having learned the language, the child can use their language system to construct the meanings of sentences and discourses, thereby allowing successful reading at the level of their spoken language comprehension. Although there are certainly some differences between spoken and written language (Catts & Kamhi, 2005), comprehending language in text requires the full set of linguistic skills needed to comprehend spoken language. These include locating individual words in lexical memory, determining the intended meaning of individual words (many of which have multiple meanings), assigning appropriate syntactic structures to sentences, deriving meaning from individually structured sentences, and building meaningful discourse from the meanings assigned to individual sentences.

This conceptualization of reading suggests that the child's fundamental task in learning to read is to discover how print maps onto their existing spoken language. In comprehending spoken language, words are built up from speech sounds, sentences are built up from words, and sets of interrelated propositions are built up from the propositions underlying

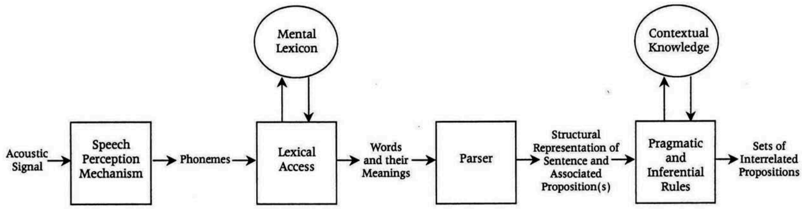

Figure 2. Model of processes and products involved in spoken language comprehension.

individual sentences and additional propositions derived from background knowledge and inferencing skills. As shown in Figure 2, the process of converting sound to meaning can be represented in terms of a cognitive model that specifies a set of interacting processors (i.e. mental mechanisms) in which the output of each becomes the input to the next. The task confronting the non-reader is to figure out how print, which initially appears as a series of mysterious squiggles, provides access to this spoken language system.

Given the nature of the task confronting the beginning reader, the process of learning to derive meaning from print can be adversely affected in one, or both, of two ways: the child's spoken language system may be underdeveloped in various ways or the process by which print is connected to the child's spoken language system may be less than optimal. Stated simply, the ability to read age-appropriate material will be impaired if the child has difficulty understanding the language being read or recognizing the words of text, or both. These basic ideas are represented in the Simple View of Reading (SVR), which constitutes the top section of the Cognitive Foundations Framework (Gough & Tunmer, 1986; Hoover & Gough, 1990; Hoover & Tunmer, 2018; Tunmer & Chapman, 2012b).

The SVR holds that at the broadest level of analysis, the ability to gain meaning from print is dependent on two necessary and equally important cognitive capacities, *language comprehension* and *word recognition* (see Figure 1). Language comprehension is the ability to extract and construct literal and inferred meaning from linguistic discourse represented in speech, and word recognition is the ability to derive accurately and quickly a representation from printed input that allows access to the appropriate word meaning contained in the internal mental lexicon. The SVR is therefore a model of the directly linked causes of individual differences in reading comprehension performance that provides an explanation for why some beginning readers perform well on reading comprehension measures while other children perform less well. Research reported in the scientific literature has provided strong evidence in support of the SVR (e.g. Language and Reading Research Consortium & Chiu, Y. D, 2018; Lonigan, Burgess, & Schatschneider, 2018).

Two key aspects of the SVR model need to be emphasized. First, the SVR does not claim that reading is simple. Both language comprehension and word recognition are highly complex, and because of that, reading is complex. The SVR simply separates that complexity into two component parts to provide the big picture of reading. Language comprehension and word recognition can each be analyzed into component processes (Kirby & Savage, 2008), and the development of each is influenced directly and indirectly by several other factors (e.g. Vellutino, Tunmer, Jaccard, & Chen, 2007).

Second, reading comprehension and language comprehension are defined in a parallel fashion in the SVR model because both engage the same cognitive processes save the different points of access, one through print and the other through speech. The SVR predicts that if the reading and language constructs in the model are defined and assessed comparably, reading comprehension will be a function of the product of word recognition and language comprehension. However, this draws attention to the importance of distinguishing between conceptual issues and measurement issues. Research indicates that commonly used reading comprehension tests vary in the relative amounts of variance contributed by word recognition and oral language comprehension (Keenan, Betjemann, & Olson, 2008) and make differential demands on two aspects of oral language comprehension: vocabulary knowledge and sentence-processing abilities (Cutting & Scarborough, 2006). On the basis of their findings, Keenan et al. drew the following conclusions that apply to both oral language and reading comprehension tests:

> Comprehension is a complex cognitive construct, consisting of multiple component skills. Even though this complexity is recognized theoretically, when it comes to assessment, there is a tendency to ignore it and treat tests as if they are measuring the same "thing". (p. 294)

These findings underscore the importance of using parallel forms of oral language and reading comprehension tests that are well-matched in linguistic complexity to obtain a reasonable estimate of the contribution of language comprehension to reading comprehension (Hoover & Tunmer, 2018). For example, if narrative material is used in assessing language comprehension, then narrative, as opposed to expository, material should also be used in assessing reading comprehension, as narrative and expository material typically differ on several linguistic parameters (word frequency, rarity of word meaning, syntactic complexity, specification of content, cohesion, semantic explicitness, etc.). Related to these considerations, the background knowledge required to understand the written and spoken samples of language should be kept as similar as possible in the parallel forms to avoid introducing possible confounding variables, such as would occur if a passage concerned with baseball was used to assess spoken language comprehension at a particular level whereas reading comprehension was assessed at the same level using a passage about the game of cricket.

The failure to fully appreciate the importance of distinguishing between conceptual and measurement issues in evaluating the validity of the SVR has, in our view, led to unfair criticisms of the model (Catts, 2018; Nation, 2019; Snow, 2018). Catts (2018), for example, argued that, "One false impression that I believe the SVR has contributed to is the notion that comprehension, both language comprehension and RC [reading comprehension], is unidimensional and not nearly as complex as it really is" (p. 320). However, language and reading comprehension are *hypothetical constructs* in the SVR model, with each defined in very general terms. Reading comprehension is defined as the ability to extract and construct meaning from linguistic discourse represented in print, and language comprehension is defined as the ability to extract and construct meaning from linguistic discourse represented in speech. The key point is that these two parallel constructs can be *operationalized* in a variety of ways, which could, for example, include a focus on "deep comprehension". The latter includes skills in academic language, perspective taking, and argumentation, all of which require analysis, synthesis, and critique (Snow, 2018). We have no objection to such an approach and in fact support it, especially with older readers. However, this approach does not draw into question or point to inadequacies in the SVR model, which predicts that, if the hypothetical constructs of language and reading comprehension are operationalized in a similar fashion (e.g. if both are assessed by tests requiring skills in academic language, perspective taking, and critical analysis), reading comprehension will be a function of the product of word recognition and language comprehension.

Another criticism of the SVR is that it gives rise to a false impression about the separability of the two components of the model, word recognition and language comprehension, because several studies of the SVR have reported a substantial amount of shared variance between these two components (Catts, 2018; Nation, 2019). Lonigan et al. (2018), for example, suggested that the large amount of shared variance between word recognition and language comprehension reported in their study may reflect more general linguistic or cognitive skills that drive the development of both components. Such general skills could provide substantial obstacles to improving reading comprehension (Catts, 2018; Lonigan et al., 2018). However, we think there is another explanation that could account for much of the shared variance, one based on Matthew effects (Stanovich, 1986) that could be easier to address through early interventions focused on the underlying cognitive capacities specified in the Cognitive Foundations Framework.

As noted earlier, a given element in the Framework tends to develop concurrently with those immediately above and below in a reciprocally facilitating manner. This is true for reading itself, where growth in reading comprehension produces growth in the two constituent components of reading – language comprehension and word recognition. According to the Framework, word recognition and language comprehension skills are themselves each dependent on the development of several other cognitive elements (see Figure 1). Consider children who do not possess sufficient levels of mastery of these foundational skills during the early stages of learning to read and who are not provided with explicit instruction where needed to develop them, especially those pertaining to the development of word recognition skills. Such children will be forced to rely increasingly on ineffective literacy learning strategies to identify unfamiliar words in text, such as using picture cues, partial visual cues, and contextual guessing. The continued use of such ineffective compensatory strategies will inevitably lead to literacy learning difficulties and downstream Matthew effects (i.e. rich-get-richer and poor-get-poorer effects). Poor readers not only receive less practice in reading – because they read less, read less successfully, and read more slowly – but soon also begin to confront materials that are too difficult for them. This typically results in avoidance of reading, inattentive behavior, low expectations of success, and withdrawal from literacy learning tasks (i.e. negative Matthew effects). As a consequence, such children are prevented from taking advantage of the reciprocally

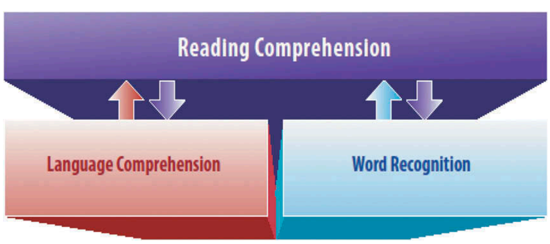

Figure 3. Reciprocally facilitating positive Matthew effects between reading comprehension and both word recognition and language comprehension.
Source. Graphic from Hoover and Tunmer (2019).

facilitating positive Matthew effects between growth in reading comprehension and growth in the two constituent components of reading, as shown in Figure 3.

As children become better readers, both the amount and difficulty of the material they read increases. These additional practice opportunities help children improve word recognition skill by strengthening fluency and facilitating implicit learning of more complex letter-sound patterns (as discussed in greater detail below). Exposure to more advanced texts also helps children to build skills in language comprehension by further developing knowledge of vocabulary, more complex syntactic structures, more diverse and complex text genres, and richer and more elaborate knowledge bases. These improvements in word recognition and language comprehension skills then promote further growth in reading comprehension by enabling children to cope with even more difficult materials.

We are not implying that word recognition and language comprehension are *based on* reading comprehension. The SVR holds that word recognition and language comprehension are the proximal causes of individual differences in reading comprehension at any given point in time. The dual arrows shown in Figure 3 indicate that from a developmental perspective across time, not only will reading comprehension grow as word recognition and language comprehension grow, but also that growth in reading comprehension will advance word recognition and language comprehension. Given the nature of Matthew effects in reading, which are particularly marked in New Zealand (Tunmer & Chapman, 2015), beginning literacy instruction that focuses on helping struggling readers to overcome weaknesses in the essential cognitive elements represented in the Cognitive Foundations Framework is a more effective teaching strategy than delaying action until substantial evidence of literacy learning difficulties has accumulated, an intervention strategy called "wait to fail". The longer the delay in providing targeted, needs-based assistance, the greater the likelihood that reading problems will become severe and difficult to ameliorate.

Cognitive capacities underlying language comprehension

As shown in Figure 1, underpinning language comprehension are two sets of cognitive capacities: (1) *linguistic knowledge* and (2) *background knowledge and inferencing skills*. The first set represents the internalized formal system that underlies knowledge of a language and includes knowledge from three distinct domains (Moats, 2000): *phonological knowledge* (or phonology), *semantic knowledge* (or semantics), and *syntactic knowledge* (or syntax). Linguistic knowledge provides the basis for deriving the literal meaning of sentences. However, language comprehension is more that just literal meaning. It is the combination of literal comprehension based on linguistic knowledge and inferential understanding based on background knowledge.

In describing how language comprehension is carried out, we use the model of spoken language comprehension shown in Figure 2 and then relate that process model to the knowledge skill sets that are depicted in the Cognitive Foundations Framework. The spoken language comprehension process begins with the acoustic signal, the sound waves produced by speech that arrive at the ear. The signal is converted into a sequence of discrete abstract units, called *phonemes*, through the process of speech perception. Phonemes represent the basic units in a language that mark differences in meaning, as shown by the distinctly different meanings of the spoken words *bad* and *pad*, which differ only in their initial phonemes.

The speech perception process is highly complex, largely because there is no one-to-one correspondence between segments of the acoustic signal and the information in the signal required to identify individual phonemes; the information necessary for identifying a particular phoneme overlaps with that of another phoneme. As we will discuss in more detail below, this feature of speech perception can represent a major obstacle to mastering the skills that allow letter sequences to be related to phonological sequences, an essential process in the development of word recognition. The main difficulty is that information about the phonemic content of speech is transmitted in parallel because the articulators – the tongue, lips, teeth, and throat – used to generate speech move dynamically from one structural target (i.e. one configuration of the articulators) to the next. It is possible to get a sense of this overlaying of information by noting the difference in the position of the lips when preparing to say *tea* or *two*, or the position of the outer articulators when preparing to say *hit* or *pit*. To comprehend spoken language, then, children must possess phonological knowledge; they must be able to derive from speech input the abstract phonemic units that make up the language.

As shown in Figure 2, the speech perception mechanism produces as output a sequence of distinct phonemes that serve as input to a processor that groups the phonemes and searches a phonemically accessible mental lexicon to find the meanings of the words contained in the utterance. Thus, the accurate identification of the individual phonemes in spoken words is essential because the misclassification of a single phoneme could result in retrieving lexical information that is different in both meaning and syntactic category from the target (e.g. *ran*, a verb, versus *man*, a noun).

The output of the lexical access mechanism shown in Figure 2 not only contains information about the objects, ideas, properties, and actions to which words refer, but also information about how words can be combined with other words to form larger units of meaning. This information includes rules that govern the syntactic structures into which a word can enter. For example, *The boy slept the bed* is not a grammatically acceptable sentence but *The boy broke the bed* is acceptable, the difference residing in the properties of the verbs contained in the sentences, which constrain what can serve as an object of their respective actions. Information in the mental lexicon also includes rules that place constraints on how words of different syntactic categories can be combined. For example, *The cage creaked* and *The child cried* are acceptable whereas *The cage cried* is not, due to constraints on the types of nouns and verbs that can be combined (inanimate versus animate in this case). The meanings of some words, especially the function words of English, such as *the, a*, and *on*, are expressed entirely in terms of rules specifying how the words can be combined with other words to form larger units of meaning. For example, speakers of English know that the phrases *the ball* and *a ball* each mean something different.

Although the meaning of an utterance clearly depends on the meanings of the words it contains, it also depends on how the words are hierarchically arranged, or parsed. This point can be demonstrated by going to the end of the next paragraph of this article and reading the words in reverse order. While it is possible to assign meanings to most of the individual words, the paragraph makes little or no sense because the order in which words appear is clearly important. Not only is word order essential for comprehending language, but so is how the words are hierarchically grouped. Another processor in the information processing model – the *parser* – takes the words and related information retrieved from the mental lexicon and builds a structural representation of the utterance that allows the utterance's literal meaning to be derived (see Figure 2). For example, the sentence *Flying hang gliders can be dangerous* has two entirely different meanings depending on how the words of the sentence are hierarchically organized (Moats, 2000). One structural representation conveys the idea that the act of flying hang gliders as carried out by an unspecified person can be dangerous to that person, whereas the other represents the idea that the physical objects themselves when in flight (i.e. flying hang gliders) can be dangerous to innocent bystanders. In linguistics, the knowledge represented in the parser that assigns such structural representations to utterances is *syntactic knowledge*.

The output of the lexical access mechanism that becomes the input to the parser (i.e. words and their meanings) is placed in a temporary storage system called *verbal working memory*. Verbal working memory is often described as the bottleneck in the language processing system because the information that can be held in working memory is limited in both duration and capacity. Without active rehearsal (i.e. saying words repeatedly) only a limited number of ungrouped (i.e. not hierarchically organized) words can be retained in working memory (typically fewer than 10 words) and for only a brief period of time. Because of these limitations, the parser immediately attempts to build a structural representation of a new sentence as soon as word meanings retrieved from lexical memory arrive as input. This is demonstrated by sentences like *The large man weighed two thousand grapes* and *The shooting of the prince shocked his wife, since she thought he was a good marksman*. The element of surprise or confusion experienced by many readers when they reached the end of these "garden path" sentences occurred because the parser immediately began assigning a structural representation to each sentence that seemed probable given the content at the beginning of the sentence. However, the predicted structural representations turned out to be inconsistent with the content found toward the end of the sentences, thus requiring the creation of different structures to make the sentences comprehensible.

The processing limitations of verbal working memory have important implications for reading development. Word recognition processes that are inefficient and capacity draining make understanding text much more difficult for children. Readers with slow, non-automatic word recognition processes often forget the words they read at the beginning of a sentence by the time they reach the end. This makes it difficult, if not impossible, for them to determine the overall meaning of the sentence being read, as well as the developing meaning of the discourse, for two reasons. First, the earlier recognized words are no longer available due to working memory limitations, and second, inadequate cognitive resources are available for successful sentence comprehension and text integration processes due to the heavy expenditure of resources on word recognition.

Taken together, the phonology, semantics, and syntax of a language represents linguistic knowledge (see Figure 1). Such knowledge provides the basis for determining the literal meaning of sentences and passages. However, more is needed to achieve full comprehension and use of language. One's linguistic knowledge must interact with what one knows about the world.

As indicated in Figure 2, the propositions underlying individual sentences normally do not stand in isolation but are integrated into larger sets of interrelated propositions through the application of inferential and pragmatic rules. Such rules combine new information derived from the meaning of the sentence just processed with previously existing information, which includes one's knowledge of the world, the preceding discourse, and the situational context. For example, most listeners would not fully understand the sentence *The cloth ripped but the haystack saved her*, unless they knew it was about a woman parachuting from an airplane; that is, unless they had comprehended the preceding discourse and made inferences that went beyond an interpretation of this sentence based solely on linguistic knowledge. Similarly, inferences based on pragmatic rules for using language in social contexts enable listeners to understand the intended (as opposed to just the literal) meaning of utterances. For example, if a parent said to their child *The garbage is beginning to stink*, the child would infer from the situational context (which includes knowledge about the household distribution of responsibilities) that the parent means more than that a particular state of affairs exists in the world at a particular place and point in time!

Background knowledge is the generic term used to refer to knowledge of the preceding discourse, prior knowledge activated by the developing meaning of the discourse, and knowledge of the situational context. To comprehend spoken language, children must have and use background knowledge that is relevant to what they are trying to understand. To understand spoken (or written) stories, they must have background knowledge that is related to the topic of the story. For example, children raised in Australia or New Zealand would more likely find it easier to understand a story about cricket than a story about baseball, whereas the opposite would be true of children raised in the United States. Understanding will also vary as a function of the cultural experiences children have had, both prior to school entry and while attending school. It is for these reasons that when teachers ask children to listen to or read material, they can improve their students' understanding of the material by providing or activating relevant background knowledge at the beginning of the lesson.

To briefly summarize, the language comprehension part of the Cognitive Foundations Framework draws from the description of the cognitive processes involved in deriving meaning from speech. Accordingly, language comprehension is seen as the articulation of background knowledge and inferencing skills operating in conjunction with literal meaning provided through linguistic knowledge, the latter representing the articulation of phonological, syntactic, and semantic knowledge.

Most children acquire much of their native language with relative ease through little more than exposure to an engaging, active speech community during their first years of life. However, many children come from impoverished linguistic environments with limited pre-school exposure to the kinds of verbal interactions and language play activities that promote the development of more advanced language skills, such as the ability to deal with the more formal, decontextualized, academic language used in classrooms. For these children, both exposure to rich language environments as well as explicit classroom instruction aimed at developing language skills are needed.

As noted previously, learning to read requires the full set of linguistic skills involved in understanding spoken language. Weaknesses in the different components of language functioning as represented in Figure 2 would therefore be expected to result in different kinds of literacy learning difficulties. These include the following:

- Children who have problems discriminating between different speech sounds because of a high-frequency hearing loss or deficits in auditory acuity due to *otitis media* (or *glue ear*), will encounter difficulty in analyzing speech and relating it to print.
- Children with limited understanding of the meanings of the words of spoken language will be impaired in their ability to derive meaning from text, even for words they have correctly identified. Such children will also have trouble identifying previously unseen printed words, especially partially decoded or irregularly spelled words, if the corresponding spoken words are not in their vocabulary. This in turn can limit the development of their alphabetic coding skills, as additional letter-sound relationships can be induced from the words that have been correctly identified (Tunmer & Chapman, 2012a), as discussed in greater detail in the following section.
- Children with weaknesses in syntactic knowledge (i.e. the implicit knowledge of rules that specify structural relationships within sentences) will have difficulty understanding written sentences, which will diminish any potential use of the structural constraints of sentential context as a learning aid in identifying partially decoded words.
- Children who have problems in relating the meaning of each new sentence in spoken discourse to the meanings of the sentences that preceded it (i.e. discourse processing) will have difficulty comprehending and recalling written stories and passages.

It is little wonder, then, that children who begin school with weaknesses in one or more of the subsystems of spoken language comprehension are much more likely to encounter problems in learning to read than children with age-appropriate oral language skills (Catts & Kamhi, 2005). Differences in language exposure during early childhood, which result in individual differences in vocabulary and syntactic development as well as knowledge of the world, can be very large (Hart & Risley, 1995). Given the structure of reading, such a difference in opportunity of exposure to expand language comprehension could have a substantial impact on reading comprehension. This may be particularly true at later stages of learning to read after children have begun to master basic word identification skills and the reading materials to which they are exposed have become more advanced in vocabulary, syntax, and discourse structure.

Cognitive capacities underlying word recognition

The Cognitive Foundations Framework defines word recognition as the ability to read words accurately and quickly; it is the ability to derive automatically a representation from printed input that allows access to the appropriate entry in the mental lexicon. Accuracy in word recognition is important because the meaning of text depends on the meanings of the words it contains. An incorrect identification of a word (e.g. mistakenly identifying *not* as *hot*) can result in very divergent renderings of a sentence's meaning (e.g. compare *John was not on the boat* with *John was hot on the boat*). Recognizing words quickly is important because, as noted previously, word recognition processes that are inefficient and capacity draining hinder text understanding by reducing the cognitive resources available for sentence comprehension and text integration processes. Slow, non-automatic word recognition processes in alphabetic orthographies typically occur when children attempt to identify most of the words they encounter by painstakingly sounding out and blending the constituent letter sounds, or by laboriously using sentence context cues to guess word identity.

To develop automaticity in word recognition, beginning readers *must* acquire *alphabetic coding skill* (also called *phonological decoding skill*), which is the cognitive ability to map letters and letter patterns onto phonological forms (Shankweiler & Fowler, 2004). Alphabetic coding skill includes not only knowledge of correspondences between single letters or digraphs (e.g. *f, b, sh, oa*) and single phonemes (e.g. /f/, /b/, /sh/, /o/), correspondences between groups of letters (e.g. *tion*) and groups of phonemes (e.g. /*shun*/), and polyphonic spelling patterns (e.g. *ear* as in *bear* and *hear; own* as in *clown* and *flown*), but also knowledge of more complex conditional rules. These are rules whose application depends on position-specific constraints (e.g. the digraph *gh* at the beginning of words corresponds to /g/ as in *gherkin, ghetto, ghost*, and *ghastly*) or the presence of "marker" letters (e.g. the letter *e* indicates that the pronunciation of a vowel is long rather than short, as in *hop* versus *hope; tap* versus *tape; cut* versus *cute; bit* versus *bite*). The sounds of some letters are highly context-sensitive. For example, the letter *y* signifies one sound in final position of two-syllable words (e.g. *baby, happy*), another sound at the beginning of words (e.g. *yes, yell, yogurt*), and yet another sound in single open syllable words (e.g. *by, my, cry*). Alphabetic coding skill also draws upon morphophonemic rules that speakers of English know implicitly through language acquisition, for example, that the morpheme for regular noun plural inflection (represented by the letter *s* in English orthography) is realized as /s/ when it follows an unvoiced consonant, as in *sacks*, and as /z/ when it follows a voiced consonant, as in *sags*. Readers with advanced alphabetic coding skill can rapidly and easily pronounce non-words like *jit, med, dut, prew, thrain*, and *fruice* (Tunmer & Nicholson, 2011).

Making use of known relationships between letters and phonological units to identify unfamiliar written words is the basic mechanism for acquiring word-specific knowledge, including knowledge of irregularly spelled words (Ehri, 2005, 2014; Snow & Juel, 2005; Tunmer & Nicholson, 2011). Each successful identification of a word strengthens the word-specific, sub-lexical connections between its constituent letter sequence and corresponding phonological sequence in lexical memory. This process provides the basis for constructing the detailed orthographic representations required for the automatization of word recognition, which Ehri (2005, 2014) calls "sight word" knowledge. Correctly identifying words on the basis of letter-phoneme correspondences just a few times ultimately establishes their orthographic representations firmly in lexical memory, from which additional letter-sound patterns can be induced without explicit instruction (Share, 1995, 2004). Using the cognitive process model of listening comprehension presented earlier, Figure 4 depicts the transition from analytic word recognition that relies solely on the use of alphabetic coding skills, to automatic word recognition that relies on the establishment of word-specific, sub-lexical connections.

For beginning readers who continue to rely mostly on partial visual cues supported by contextual guessing at the expense of phonological information, there is little interaction between the subcomponents of written and spoken words. The word recognition skills of these children will remain relatively weak because they do not develop as rich a network of sub-lexical connections between orthographic and phonological representations in lexical memory as normally developing readers do. Because of their inefficient and capacity draining word recognition skills, children who do not make use of letter-sound relationships

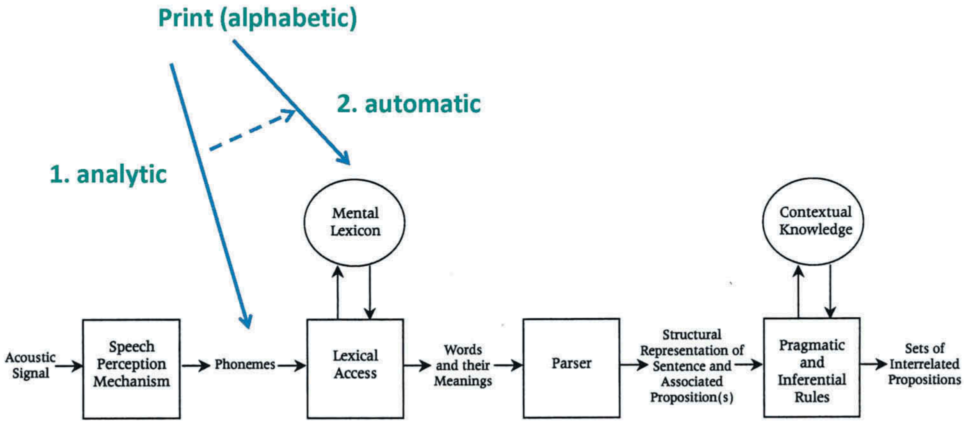

Figure 4. The transition from analytic to automatic processing of words in text as represented in the listening comprehension process model presented earlier.

in word learning will experience progressive deterioration in their rate of reading comprehension development as they grow older (Tunmer & Nicholson, 2011).

Traditional phonics programs have been used to explicitly teach alphabetic coding skills to beginning readers. However, these programs generally suffer from two major shortcomings. First, they tend to be strongly teacher-centered and have curricula that are rigid, fixed, and lock-step, with the same skill-and-drill lesson given to every child in the same sequence. Such an approach to teaching beginning reading conflicts with the basic principles of differentiated instruction because it fails to recognize that the individual literary learning needs of children vary greatly depending on their specific levels of development across the set of reading component skills shown in Figure 1. Second, most phonics programs incorrectly assume that children can only acquire knowledge of letter-sound patterns through direct instruction in which the teaching of letter-sound correspondences is explicit and systematic. The difficulty with this assumption, however, is that there are simply too many letter-sound relationships in English orthography for children to acquire by direct instruction, probably between 300 and 400 (Gough & Hillinger, 1980).

Much, if not most, of what children learning to read in English come to know about its written orthography is acquired through implicit learning, especially knowledge of context sensitive letter-sound correspondences that depend on position-specific constraints or the presence of other letters (Bryant, 2002; Tunmer & Nicholson, 2011; Venezky, 1999). In contrast, letter-sound correspondences acquired by direct phonics instruction are fewer in number and are largely context free, involving one-to-one correspondences between single letters or digraphs and single phonemes. As the reading attempts of beginning readers who have acquired basic alphabetic coding skills become more successful, the orthographic representations of more words become established in lexical memory from which additional spelling-sound relationships can be induced without explicit instruction. As children continue to develop in reading, they begin making greater independent use of letter-sound information to identify novel printed words in text. Once this point is reached, the most effective way that children can achieve further progress in learning to read is through print exposure, as reading itself can provide practice opportunities for building fluency and for facilitating implicit learning of additional letter-sound patterns (Tunmer & Nicholson, 2011).

Although children must rely increasingly on induction to acquire the letter-sound relationships necessary for learning to read, explicit phonics instruction plays an important role in helping to "kick start" the process by which beginning readers acquire untaught letter-sound relationships through implicit learning. Phonics instruction is therefore best thought of as a means to an end and not an end itself (Venezky, 1999). By adopting a "set for diversity", children learn to use their knowledge of letter-sound relationships acquired through phonics instruction to produce partial phonological representations for unfamiliar words encountered in print, especially those containing irregular, polyphonic, or orthographically complex spelling patterns. These approximate phonological representations provide the basis for generating alternative pronunciations of target words until one is produced that matches a word in the child's lexical memory and makes sense in the context in which it appears. Additional letter-sound relationships, especially context-sensitive patterns, can then be induced from the stored orthographic representations of words that have been correctly identified (Tunmer & Chapman, 2012a).

Thus, phonics instruction is useful not because of the specific letter-sound correspondences taught (which are limited in number), but because it instils in beginning readers a firm grasp of the alphabetic principle and gives them practice in looking closely at word spellings (Snow & Juel, 2005). Some explicit phonics instruction may therefore go a long way in facilitating the process by which children induce untaught spelling-sound relationships (Juel, 1991). However, the amount of explicit instruction in alphabetic coding skills needed to initiate the process of inducing letter-sound relationships varies considerably across children. Some beginning readers seem to grasp the idea after having had only a few spelling-sound correspondences explicitly taught to them, whereas other children require a fairly structured and teacher-supported introduction to reading (Connor, Morrison, & Katch, 2004; Juel & Minden-Cupp, 2000; Snow & Juel, 2005; Tunmer & Nicholson, 2011). For children encountering difficulty in developing the ability to perceive intuitively the redundant patterns and connections between speech and print, explicit instruction in alphabetic coding skills is likely to be crucial, especially for those children with limited reading-related knowledge, skills, and experiences at school entry (Prochnow, Tunmer, & Arrow, 2015).

In support of these claims is a large body of research indicating that explicit, systematic instruction in the code relating spellings to pronunciations positively influences reading achievement, especially during the early stages of learning to read (Brady, 2011; Hattie, 2009; National Institute of Child Health and Human Development, 2000; Snow & Juel, 2005; Tunmer & Arrow, 2013). From an examination of findings from a range of sources that included studies of reading development, specific instructional practices, and effective teachers and schools, Snow and Juel (2005) concluded that explicit attention to alphabetic coding skills in early reading instruction is helpful for all children and crucial for some.

Two knowledge sets must be acquired by beginning readers to develop analytic links between print and phonology (see Figure 1). These are *concepts about print* and *knowledge of the alphabetic principle*. Concepts about print refer to the conventions used in print to represent linguistic discourse, such as that printed text carries a linguistic meaning, that there is correspondence between printed and spoken words, that spaces mark word boundaries, that words in sentences are arranged left-to-right and top-to-bottom on a page, and that successive book pages are ordered left-to-right and turned right-to-left.

Learning these concepts early is critical for advancing word recognition skills as they allow the child to pair printed and spoken words, thus expanding the opportunities to learn the connections between orthography and phonology. While these concepts about print are clearly necessary for successful reading and must become known early in the process of learning to read, their acquisition does not appear to represent major difficulties for children (Tunmer, Herriman, & Nesdale, 1988).

The second critical knowledge set that must be acquired in order to learn the analytic links between print and speech is knowledge of the alphabetic principle – the conscious awareness that letters and letter combinations are used to represent the phonemes of spoken words. The child who writes the word *color* as KLR clearly grasps the alphabetic principle. Without this insight, instruction designed to help students learn the relationships between the units of print and speech, such as phonics, will only lead to frustration, because the unaware child will not understand the relationships being targeted.

Knowledge of the alphabetic principle in turns depends on two additional knowledge sets, *letter knowledge* and *phonemic awareness* (see Figure 1). These are the knowledge sets about the units that are to be connected under the alphabetic principle – the letters and phonemes. Letter knowledge is the ability to recognize and manipulate the letters of the alphabet, including letters in different fonts and cases. Children must be able to differentiate each letter of the alphabet from all of the others, a skill usually acquired by learning letter names (Adams, 1990). Familiarity with the letters of the alphabet is essential for developing alphabetic coding skill, where individual letters and letter patterns are mapped onto phonological forms in the language. Letter-name knowledge also contributes to the development of reading ability in three other ways (Foulin, 2005). First, letter-name knowledge serves as a bridge toward understanding the alphabetic principle, as reflected in children's invented spellings (e.g. *da* for *day* and *bl* for *bell*), in which the names of letters are used to represent speech sounds in words. Second, letter-name knowledge can act as a precursor to alphabetic coding skill because the names of *most* letters contain the phoneme to which the letter normally refers. For example, /b/ is the first phoneme (of two) in the name of the letter *b*; but there is no /w/ in the name for *w*. Third, letter-name knowledge can facilitate the development of phonemic awareness, especially when children are exposed to alphabet books and games that increase knowledge of letter names and their relation to speech sounds in words (e.g. *s* is for *snake*).

Phonemic awareness is the conscious ability to recognize and manipulate the phonemic units of spoken words. The child with phonemic awareness knows that the spoken word *feet*, for example, has three phonemic units, that the word *eat* is what remains when the first phoneme (i.e. /f/) of *feet* is deleted, and that *fee* is what remains when the final phoneme (i.e. /t/) is deleted. Children who experience ongoing difficulties in analyzing spoken words into their constituent phonemic elements will not be able to fully grasp the alphabetic principle and discover spelling-to-sound relationships (Shankweiler & Fowler, 2004). Without specific intervention, the development of word recognition skills in these children will be impeded (Stanovich, 1986).

Many children enter school with little or no phonemic awareness because it is not a cognitive capacity that is needed for either language learning or using language. Using a phonemic contrast to signal a meaning difference, such as saying *pig* rather than *big* when referring to the farm animal, is done intuitively and at a subconscious level; it is not the same as consciously reflecting on and manipulating the phonemic elements of speech. Gaining conscious access to phonemic segments is much more difficult for children because, as noted previously, there is no simple physical basis for recognizing phonemes in speech. Rather, phonemic awareness is a more demanding *metalinguistic* skill (Tunmer et al., 1988) that requires the ability to perform higher-order cognitive operations on the products of the speech perception mechanism responsible for converting the speech signal into a sequence of abstract phonemic units (see Figure 2). Fortunately, for beginning readers experiencing difficulty in gaining conscious access to phonemic units, there are several teaching programs available for promoting the development of phonemic awareness that have been shown to be effective, especially those that combine phonemic awareness training with letter-sound training (Blachman, 2000; Gillon, 2018).

Implications for practice

We conclude by focusing on the broad implications of the Cognitive Foundations Framework for educational practice. The Framework assumes that learning to read follows developmental progressions from pre-reader to skilled reader. These progressions are based on development that varies within the two main cognitive components underlying reading comprehension, as well as within their respective subcomponents. The literacy learning needs of beginning readers necessarily vary because they differ in the amount of reading-related knowledge, skills, and experiences they bring to the classroom, in the explicitness and intensity of instruction they need to acquire knowledge and skills for identifying words and comprehending text, and in their location along the overall developmental progression from pre-reader to skilled reader.

These considerations underscore the importance of *differentiated instruction* (Arrow, Chapman, & Greaney, 2015), where reading teachers and intervention specialists use evidence-based assessment procedures and instructional strategies to address the different literacy learning needs of beginning readers from the outset of schooling, as opposed to relying on wait-to-fail reading interventions like Reading Recovery (Chapman & Tunmer, 2018). Teachers can use the structure of the Cognitive Foundations Framework as the basis for diagnostic reading assessment and the determination of instructional options that best meet the needs of struggling readers. If beginning readers are not progressing satisfactorily (i.e. at rates similar to their peers) in reading comprehension, is it because they are having problems recognizing printed words, problems understanding the language being read, or both? Weakness in word recognition skill may stem from a lack of automaticity or weak alphabetic coding skills, or the difficulty might lie with inadequate knowledge of the alphabetic principle, weak letter knowledge, weak phonemic awareness skills, or a failure to appreciate how print operates.

Reading professionals can adopt a similar strategy in identifying possible weaknesses in aspects of language comprehension. Children having difficulty understanding sentences may have weaknesses in vocabulary or syntactic knowledge, or perhaps weaknesses in phonological knowledge that prevent them from hearing the differences between words with different meanings (e.g. *thin* and *fin*). Children having difficulty understanding stories and passages or making inferences may have weak background knowledge, difficulties in activating relevant knowledge, or weak understanding of the structures used in integrating meaning across sentence boundaries. Any of these circumstances could lead to specialized instructional activities that target the underlying cognitive skills. As we noted earlier, the longer the delay in providing targeted, needs-based assistance to struggling readers, the greater the likelihood that their reading problems will become severe and difficult to ameliorate.

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