Cognitive processing deficits associated with low literacy: Differences between adult- and child-focused models

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Abstract

In this chapter, we examine adult- and child-focused models of reading with respect to cognitive processing deficits associated with low literacy. We examine influential integrative models of reading and reading comprehension. We then review the empirical literature on components of reading ability, subdivided into three categories: language general, print reading specific, and non-specific cognitive. We find that most deficits discussed in the child-focused literature are also found in studies of adults with low literacy. We conclude with a discussion of implications for adult literacy research and practice.

In this chapter, we examine differences between adult- and child-focused models with respect to cognitive processing deficits associated with low literacy. We view cognitive deficits as any knowledge, skills, or dispositions that have been identified as disruptive in the acquisition of proficiency in reading literacy. We are agnostic as to whether said deficits are congenital, acquired, or stem from the absence of learning opportunities. Adults with low literacy have varied histories that are not typically easy to reconstruct (Fowler & Scarborough, 1993), so we have taken as broad a perspective as possible in understanding which and whether the assumptions underlying children's models are similar or different to adults with low literacy.

The Oxford English dictionary defines the term 'deficit' as a 'deficiency or failing, especially in a neurological or psychological function' (Deficit, n.d.). For many, this negatively worded definition connotes that the condition is permanent, insurmountable or unfixable, and perhaps even a flaw in the individual who suffers the deficit. We would ask the reader to consider the terms *challenges* and *obstacles*, as these terms have a more productive connotation. A challenge is something that one might overcome. An obstacle is something one may need to work around. This is not to deny the existence of individual differences in cognition, some sufficiently severe as to make it all but impossible to achieve high levels of reading proficiency absent herculean feats of learning effort and time. Rather, it is an acknowledgment that deficits are typically measured as continuous variables with ranges from mild to severe, not all or none. The severity of a deficit defines the challenge level; mild may be a challenge that can be overcome with the investment of practice and time learning in an intervention program; severe may represent an obstacle best worked around or compensated for with assistive devices or perhaps more simply, by executing reading strategies that circumvent the deficit. Also, there are numerous routes to learning, such that with the investment of learner time and effort, significant, meaningful gains in proficiency can be made along alternate learning pathways.

We examine both integrative models and componential approaches to cognitive processing deficits most frequently researched in the study of children. We will present three broad categories of components: language general, reading/print specific, and non-specific cognitive. Language general knowledge and skills can be accessed or expressed in four modalities: speaking and listening, as well as reading and writing. The underlying cognitive-linguistic resources include phonology, vocabulary, morphology, syntax, semantics, discourse, and pragmatics.

Reading/print specific resources include those that are unique to the visual processing of print including not only phonological decoding of print orthography, visual word recognition, and spelling, but also knowledge of punctuation, typographic conventions (e.g., *italics*), tables, charts, spatial navigation of documents whether paper-based, digital, or other media (e.g., road signs or graffiti). Most of the empirical literature on reading has focused on the first set of reading specific resources (i.e., visual word recognition and decoding), so the latter set are mentioned here for completeness and as areas for future research. The adaptation of cognition to the complex information processing demands of the digital age have yet to be explored, and thus we do not know how individual differences may surface as barriers to achieving proficiency.

We then discuss factors that interfere with the learning trajectory to proficient reading. We sequence the topics roughly from bottom up to top down processing. We begin with perceptual processing (vision and hearing), then cognitive capacities (working memory and attention). Finally, we discuss general intelligence as it relates to comprehension proficiency.

Who are adult learners with low literacy?

An estimated 17.5 % of adults in the United States demonstrate Literacy Proficiency at or below Level 1 and another 33% at Level 2 based on the results of the Program for International Assessment of Adult Competencies (PIAAC: OECD, 2013). The majority of adults at Level 2 would be considered below college and career readiness, while adults at Level 1 or below would possess even more limited reading literacy skills. Sec. 203(1) of AEFLA (Adult Education and Family Literacy Act) defines “adult education” as “services or instruction below the postsecondary level for individuals (A) who have attained 16 years of age; (B) who are not enrolled or required to be enrolled in secondary school under State law; and (C) who (i) lack sufficient mastery of basic educational skills to enable the individuals to function effectively in society; (ii) do not have a secondary school diploma or its recognized equivalent, and have not achieved an equivalent level of education; or (iii) are unable to speak, read, or write the English language.” (U.S. Department of Education, 2015). Who are adult in adult education programs? In enrollment year 2011-12, there were 39% Hispanic, 26% white, 22% black or African American, 8% Asian, 2% multiple, 1% , and 1% Pacific Islander, 1% American Indian/Native Alaskan (U.S. Department of Education 2015).

Integrated Reading Models

Integrated reading models are multivariate descriptions of components or elements of reading, coupled with explanations of how they are interrelated or integrated functionally. In developing an integrated or theoretical model, researchers typically first model processing of the skilled reader, then use the model to explore or explain the impact of component deficits (e.g., Plaut, McClelland, Seidenberg, & Patterson, 1996). Developmental models take into consideration changes or skill growth over time, and can focus on any developmental period, from pre-reading through adulthood, though historically the first few years of reading from preK to grade 3-4 have been the focus of the most complete child-focused models (Chall, 1983; Ehri, 2004).

No single, unified theory of reading or comprehension has emerged from the literature (Cain & Parrila, 2014; Perfetti & Stafura, 2014). There is, however, widespread overlap in some cognitive and linguistic components discussed and researched, and some highly influential models that serve as the basis for a large proportion of the empirical studies conducted on reading proficiency, disability, and low literacy. Reading has often been distinguished from reading (or listening) comprehension in the literature, with the former primarily referring to word recognition processes, and the latter referring to all subsequent processing that culminates in understanding the text message. Until recently, the vast majority of research on deficits or disabilities in reading has focused on word recognition in adults and children variously labelled as struggling, disabled, or dyslexic (Klein and McMullen, 2001).

While seminal, comprehensive treatments of reading and comprehension stand out (notably Kintsch, 1998; Perfetti, 1985), the psychological research on comprehension processes and their integration with word recognition processes may still be characterized as under-developed, in part, because of this bias of treating the components unique to reading - decoding and word recognition – as entirely separate from language and comprehension. But there is an alternate perspective that considers reading (and writing) as modalities or subcomponents of language and comprehension. This position is articulated succinctly by Vellutino, Tunmer, Jaccard, & Chen (2007) who state that learning to read in English “entails visual recoding of language in the form of alphabetic characters representing speech segments,” (p. 7). In other words, word recognition is primarily a language skill. Research on the language basis of dyslexia and reading disability stemming from the Simple View (discussed later) are consistent with this position (Catts, Adlof, Weismer, & Ellis, 2006; Catts, Fey, Zhang, & Tomblin, 1999).

Given a goal of helping adults with low literacy to strive towards reading comprehension proficiency, we seek to identify all deficits that interfere with reaching that goal. Not all low literate adults may become skilled, proficient readers, but starting with a description of proficiency may help us understand the distance they need to traverse and better define realistic milestones along the path. With this in mind, we begin by briefly describing what we mean by a skilled, proficient reader.

The skilled, proficient reader

In the past 500 years or so, spanning the invention of the printing press to the information age, print reading has become one of the most important cognitive skills an individual acquires (Klein and McMullen, 2001). This cognitive accomplishment is most profound. Skilled readers processes about four words per second. The eyes jump from word to word, fixating for about 200-300 milliseconds, before moving (called a saccade) to the next fixation point with an average of 1.1 word per fixation. In that fixation time, the spelling of the word is converted to a phonological code and the meaning of the word is accessed in one’s mental lexicon (Rayner, 1997). If the word is novel (no meaning or sound pattern has ever been experienced prior by the reader), then a provisional sound and meaning inference is generated – the learning of a new word has been initiated. The processing of text by the skilled reader involves a complex orchestration of bottom-up and top-down, cascading interactions that go into processing spelling, sound, and meaning patterns (Rumelhart & McClelland, 1982).

In the 250 to 400 words per minute rate of text processing of a skilled adult reader, multiple levels of comprehension are simultaneously accomplished. Syntax is parsed, propositions of meaning are formed into coherent, text-based representations of global and local meaning, and mental memory situation models that combine background knowledge (both from prior experience and from prior text one is reading) with the reader’s purpose-driven goals are formed (Kintsch, 1998).

The skilled reader’s word recognition processes operate on an English lexicon of at least 250,000 unique words, most with morphological variants, that are inflectional (e.g., plurals, tenses) or derivational (affixes, roots, combining forms) (Nagy & Anderson, 1984; Nagy, Berninger, & Abbott, 2006). Many words are polysemous, indicating they have multiple meanings. To complicate the processing of such polysemous words, English spelling or pronunciation does not necessarily change when meaning changes, though sometimes spelling, but not pronunciation changes (i.e., homonyms like bear, bare), and sometimes spelling remains the same, but pronunciation changes (e.g., minute; bass) (Venezky, 1999). The lexicon of word meanings should also account for a) English idioms – a ball park estimate for those is 25,000; b) noun and verb phrases, i.e., combinations of words that make a new meaning different from the either word alone such as hot dog; and c) proper nouns such as people, places, and consumer products.

How is this lexicon of recognizable word meanings accumulated in memory? Through repeated exposure and experience reading (and listening) across the life-span, starting in childhood (Stanovich & Cunningham, 1993). An average skilled adult reader likely reads several million words per year. At the same time, across development from childhood through adulthood, individuals are learning and comprehending spoken language (words, phrases, idioms, complex syntactic structures, knowledge), accumulated language resources (knowledge and skills) via ear to be part of the intellectual knowledge-base that is accessible when reading print for understanding.

The *Modern Reader* comprehends not only oral language and the written word, but does so in a literacy context that includes and therefore requires extensive visio-graphic information processing and integration (e.g., tables, charts, figures, maps, photos, illustrations, animations, videos), as well as search, navigation, and multiple source synthesis – wrought by a digital age of devices (e.g., smart phones, tablets, laptops, etc.) that access literacy content (web, internet, search engines, apps, emails, social media sites, etc.) (Magliano, McCrudden, Rouet, & Sabatini, 2016; PIAAC Literacy Expert Group, 2009).

All of this complexity of word and meaning processing begins humbly with the learning of an arbitrary set of 26 visual symbols that signify sounds (though not a one-to-one mapping to the sounds of English), and some basic rules for combining them to make sound patterns (more like guidelines, as the rules only work some of the time in some contexts). Given the miraculous accomplishment that is skilled adult reading, it is perhaps unfair to term any one of the multiple ways this developmental trajectory can go awry as a cognitive-deficit, though the pathway to helping adults with inadequate reading literacy proficiency requires we understand the challenges and obstacles they might encounter.

Since we must be selective because of length constraints, we will describe three influential models of integrated reading in some detail, as these, in our judgment, are helpful in analogic reasoning about adults with low literacy. In describing each, however, we do provide some citations of other related or alternative models that the reader may wish to review as well.

Simple View

Unavoidable in a discussion of reading models is the Simple View of reading (SVR). The simple view hypothesizes two primary components of reading – word recognition (or decoding) and language comprehension. Together, these components predict reading comprehension. In this model, reading comprehension cannot occur if decoding or linguistic comprehension are missing, making both skills necessary, but not sufficient for comprehension (Gough & Tunmer, 1986; Hoover & Gough, 1990). Studies of the model have been conducted with normally developing, struggling readers, or those with diagnosed disabilities at elementary (Johnston & Kirby, 2006; Chen & Velluntino, 1997; Dermont & Gomeber, 1996), middle (Catts & Weismer, 2006), secondary (Tilstra et al., 2009; Savage, 2006), and adult learner levels (Sabatini, Sawaki, Shore & Scarborough, 2010; Savage & Wolforth, 2007). Though some studies have looked at expanding the model beyond the two components to include skills such as vocabulary, decoding ability, syntax, phonemic awareness, or fluency (Adlof, Catts, and Little, 2006; Kirby and Savage, 2008; Ouellette and Beers, 2010), most have decided to "keep it simple", and collapse the multiple components into the original two of the SVR model.

As an extension of the Simple View, Vellutino, Tunmer, Jaccard, & Chen (2007) describe the *Convergent Skills Model*, in which several additional language antecedents give added structure to the two Simple View categories. They also added a developmental dimension, by providing evidence that word recognition/decoding measures are more predictive of reading comprehension in younger learners (grades 2-3), whereas measures of language comprehension are more predictive in older readers (grades 6-7). This result has been replicated by others with younger students (e.g., Catts & Weismer, 2006; Gough, Hoover, & Peterson, 1996).

Child versus adult deficits. The patterns of correlations in SVR models is often sample specific in adults due to the relative smaller number of studies and wider variation in age and experience of adults. . For example, in a sample of adults with word recognition variability between first to seventh grade equivalency, Sabatini, Sawaki, Shore & Scarborough, (2010) reported essentially equivalent word recognition and language comprehension coefficients in the .5 range. Other studies with different sampling criteria show varying patterns and strengths of relations among components skills (MacArthur, Konold, Glutting, & Alamprese, 2010; Marcuso & Shankweiler, 2010; Mellard, Fall, & Woods, 2010; Nanda, Greenberg, & Morris, 2010). While the SVR model has been helpful as a heuristic in organizing component studies of word recognition and language in relation to reading comprehension, more sophisticated process models that allow for more nuanced predictions are available and future research may profit from using them as a basis for empirical investigations. We review two influential models next.

Perfetti and colleagues: Model of Linguistic and Writing System, Verbal Efficiency, and the Lexical Quality Hypothesis

Perfetti and colleagues have been developing integrative models of reading ability since the 1970s (Lesgold & Perfetti, 1978). The early research culminated with the publication of Perfetti's seminal book, *Reading Ability* in 1985, which laid the foundation for *verbal efficiency theory* (Perfetti, 1985). In recent years, a componential information processing model reminiscent, but more complex than the Simple View, was proposed (Perfetti & Adlof, 2012; Perfetti, Landi, & Oakhill, 2005). According to this model, reading comprehension mainly involves two systems: 1) an orthographic system that processes visual input, mapping spelling patterns onto phonology (and vice versa), and 2) a linguistic system that processes the phonology, syntax and morphology of the language for comprehension. The orthographic system develops into a functional network of connections for mapping visual input into orthographic and phonological units used for accessing the lexicon (Harm, McCandliss, & Seidenberg, 2003; Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001). These processes are interactive culminating in word recognition when all three units (orthographic, phonological and lexical) converge on a known word. The linguistic system contains the lexicon (meaning, morphology and syntax) and it also performs comprehension processes, including extracting word meanings, parsing word strings into syntactic and propositional constituents, and generating inferences for the integration of these constituents.

The role that word identification plays in this framework is supported by empirical studies examining the relation between word reading ability and reading comprehension. Numerous studies have found strong correlations between word reading ability and reading comprehension in students ranging from primary school (e.g. Adlof, Catts, & Little, 2006; Perfetti, 1985), middle school (e.g. Grade 8, Adlof et al., 2006), and adults (Bell & Perfetti, 1994; Braze, Tabor, Shankweiler, & Mencl, 2007; Perfetti, 1985; Sabatini, 2002; Sabatini, 2003). These studies confirmed that word identification is an important factor in reading, but not the only factor. The failure to develop a robust, automatic, and rapid word recognition network of connections is the lead symptom and cause of dyslexia and reading disability in children (Rayner et al., 2001) and adults (Taymans et al., 2009).

Other studies have often identified readers who had problems in reading comprehension but appeared to be relatively unimpaired in their word reading (Catts & Weismer, 2006; Landi, 2010; Nation & Snowling, 1999). These readers seemed to have specific comprehension difficulties (SCD) (Perfetti & Adlof, 2012), though the specification remains a debated topic (Spencer, Quinn, & Wagner, 2014). Elementary school children with SCD showed difficulties in inference making (Cain & Oakhill, 1999; Cain, Oakhill, Barnes, & Bryant, 2001; Oakhill, 1984) and comprehension monitoring (Oakhill, Hartt, & Samols, 2005).

Verbal efficiency theory an expansion of Perfetti's earlier work, described how impaired or inefficient word identification processes may impact higher-level processing in reading (Perfetti & Hart, 2001). According to theory, cognitive resources (e.g., attention and working memory) for comprehension are limited (LaBerge & Samuels, 1974). As a result, inefficient word identification consumes the cognitive resources that would otherwise be available for higher-level processing, such as inference making and comprehension monitoring, and this negatively impacts reading comprehension. Readers who have lower verbal efficiency may show adequate performance in recognizing words, but still show problems in comprehension, because they do not have sufficient cognitive resources to be allocated for complex, higher-level processing.

The nature of the word identification to linguistic processing was elaborated in the *lexical quality hypothesis* (Perfetti & Hart, 2002), which posits that "successful comprehension depends on accessible, well specified and flexible knowledge of word forms and meanings" (Perfetti & Adlof, 2012, pp 9-10). According to this hypothesis, not only the ability to recognize a word on a surface level, but also the quality of the memory representation of the word affect comprehension. Following this logic, readers with SCD may have lower quality lexical representations despite normal performance in word reading. Indeed, several experimental studies have identified differences in the cognitive processing of words in readers with SCD. For example, Nation and Snowling (1999) compared good and poor comprehension readers (average 10 years old) who were matched on decoding skill on a semantic priming task, and found that poor readers only showed priming when two words were strongly associated, whereas good readers also showed priming when two words were only weakly associated.

Child versus adult deficits. Evidence from adult readers also supports the lexical quality hypothesis with studies using behavioral, eye-tracking and ERP measures. Poor and skilled adult readers showed electrophysiological (ERP) differences in a semantic processing task (Landi & Perfetti, 2007). Future research could investigate more closely how deficits in verbal efficiency and lexical quality influence adult reading development.

Kintsch and the Construction Integration model

The Simple View and Perfetti's models of reading cover elements of both component reading skills and some aspects of reading comprehension. The perhaps most prominent and widely acknowledge model of reading comprehension is the *Construction Integration* model or CI model (Kintsch, 1988; 1998; Kintsch & van Dijk, 1978). Although, the CI model acknowledges the importance of reading components and print processing, it is primarily a cognitive model of comprehension, in reading or listening modalities. According to the CI model, people process and store textual information into three levels of understanding: the surface code, the textbase and the situation model.

The surface code preserves the exact wording of the text in verbatim format. In general, the surface code is transient and the details are lost not long after reading the text. A more stable and durable form of representation is called the textbase. The textbase level of understanding contains the basic meaning of the text encoded into propositions or idea units. The propositions, preserves the key ideas, relations among ideas and basic text structure, while the exact wording of the original text is lost. In essence, the textbase is a slightly condensed version of what the text explicitly states.

However, texts are often incomplete as the author assumes that readers have some background knowledge on the topic of the text. Adding in all the necessary background knowledge to the text would make it unnecessarily long. However, because the text is incomplete, the reader must infer unstated information. In order to process text deeply, readers need to form a more complete representation of text called the situation model. The situation model takes into account the reader goals, the key information stated in the text, as well as the reader's background knowledge. More explicitly, the situation model contains the integration between the text and the reader background knowledge as it relates to the reader's purpose for reading. This representation allows the reader to make knowledge-based inferences and resulting in a deeper, more coherent and goal relevant level of understanding.

The situation model is not limited to the text and the reader's background knowledge; it contains information from a variety of modalities including, visual, action and emotive elements. These features also add to, and strengthen, the mental representation as compared to the textbase. However, this depth may come at a cost: Kintsch notes that the process of constructing a situation model is effortful and strategic, and without this extra effort, a student's model of text can be superficial. The effort not only involves the active integration of background knowledge and cross modality information, but also accurate comprehension and repair strategies. Skilled readers recognize when they don't understand text and take actions to resolve inconsistencies and to actively fill in gaps in their understanding (Short & Ryan, 1984).

Unfortunately by default, students may only put in enough effort to draw the most basic inferences required to create a textbase (McKoon & Ratcliff, 1992). Fortunately, however readers can draw inferences when prompted and under certain conditions (Graesser, 1981; Graesser, Singer, & Trabasso, 1994). The trick is to find ways to encourage students to engage in more active processing rather than defaulting to a minimalist strategy when a deeper understanding is required.

On balance, the CI model has been very influential and has resulted in the widely accepted view that readers form a mental model of the text contents while reading. This basic idea converges with other discourse processing theories such as the Landscape model (van den Broek, Young, Tzeng, & Linderholm 1999), the Event Indexing model (Zwaan, Langston, & Graesser 1995; Zwaan & Radvansky 1998), the Constructionist model (Graesser, Singer, & Trabasso,1994), the Resonance model (Myers & O'Brien, 1998), the Minimalist hypothesis (McKoon & Ratcliff, 1992) and the Structure Building Framework (Gernsbacher 1997).

In short, these discourse processing models suggest that the text activates concepts in the readers mind, and the reader builds up a representation of text as new information is encountered. There may be passive or bottom up processing as well as active and top down processing that may facilitate the formation of the text model. In any event, the key idea to be taken from this literature is that text meaning is created by an interaction between the quality of the text, the reader's background knowledge, and the reader's goals.

Purpose, background knowledge, and metacognition in discourse comprehension models. It is important to note that all readers, from young children to adults, form situation models (Kintsch, 1998; 2012). In fact the multiple levels of processing occur simultaneously. They apply knowledge of text structures (e.g., narrative story, explanatory or persuasive essay) to understand the macrostructure of a text (e.g., story elements of character roles and plot) (Wijekumar, Meyer, & Lei, 2012). The purpose a reader adopts may initiate situation model formation (McCrudden & Schraw, 2007), even before the reader lays eyes on a text perhaps by activating relevant background knowledge (Rowe & Rayford, 1987).

Herein lays a source of challenge to achieving proficiency. Inadequate knowledge (O'Reilly & McNamara, 2007) of text structures (Hebert, Bohaty, Nelson, & Brown, 2016) or how to identify a structure from text cues can interfere with understanding. Lacking background knowledge needed to make knowledge-based inferences is another barrier (McNamara, Kintsch, Songer, & Kintsch 1996), as authors presume their readers have adequate knowledge of the topic (Beck, McKeown, & Gromoll, 1989; Beck, McKeown, Sinatra, & Loxterman, 1991; Chi et al., 1994; Wilson & Anderson, 1986), and may leave information to be inferred by the target reader (McNamara et al., 1996; McNamara & O'Reilly, 2009; Oakhill, 1984). Not knowing when one does or does not have adequate knowledge – a failure of self-monitoring (or metacognition) - is another factor related to reading comprehension failure (Cromley, 2005; Nejadihassan & Arabmofrad, 2016). Readers need to know when they do not understand and take appropriate action to resolve inconsistencies, gaps or misconceptions in text.

Child versus adult deficits. Discourse processing models have been extensively researched with children and skilled adult readers (McNamara & Magliano, 2009), however, we were unable to find specific applications of these discourse processing models in studies of low literate adults. While most multivariate studies of adults with low literacy reviewed in this chapter have measured vocabulary knowledge, and some have measured general knowledge (e.g., Mellard et al. 2012) or metacognitive strategies (see Cromley, 2005), we could not find any studies of adults that targeted the specific relations between background knowledge, reading comprehension, and metacognition (Cain, Oakhill, Barnes, & Bryant, 2001). In what follows, we review key, research based components associated with reading proficiency that could be mediators or causes of individual differences that result in low literacy in adults.

Language general deficits and factors

In this section, we discuss the emergence of language ability and language difficulties or disorders. We examine deficits or factors that emerge in childhood, and summarize the literature that demonstrate that deficits persist into adulthood.

Emergent literacy skills (in the digital age)

There are emergent literacy skills that we take for granted in literate societies that children typically master at the beginning of formal schooling (Crone & Whitehurst, 1999), but may not be taken for granted in adults, especially those from other countries or cultures. Emergent skills include knowledge of the alphabet, and knowledge of print conventions (e.g., a book has title and author, English text is read left to right, from top to bottom, and pages are turned counter-clockwise). Literacy practices differ across the globe, for example, Hebrew and Arabic are read right to left. Thus, adults from other cultures may need to learn or relearn skills to learn to read in English.

The type and nature of emergent literacy skills has been complicated by the digital age, when turning a page may require pressing a keypad, dragging a mouse to a scrollbar, or swiping a tablet screen left or right (with one, two, or three fingers) (Leu et al., 2015). Coordination of perceptual, motor, and cognitive sequences must be learned, then procedurally encoded for automatic application when reading with paper-based or digital devices, thus, cognitive learning deficits can interfere with these basic operational fluencies, interfering with reading growth, though we know of no studies yet examining deficits in adapting to digital literacy explicitly.

Phonological Processing, phonemic awareness, decoding, and word recognition

The foundation of all alphabetic spoken languages are phonemes, the smallest unit of sound. The English language has forty four different phonemes, yet only 26 letters. This mismatch occurs because several letters in the English language have more than one pronunciation, and combinations of letters, such as “ch”, have an entirely different sound than the individual letters themselves. The recognition of this “sound to letter” correspondence is called phonemic awareness. Those who have phonemic awareness are able to recognize that words are made up a sequence of sounds and can blend and manipulate those sounds (even without knowing a visual alphabet of symbols representing those sounds). Phonemic Awareness is critical for learning to spell and word recognition in an alphabetic writing system; it also is a significant correlate of word reading ability (Melby-Lervåg, Lyster, & Hulme, 2012). For children with reading disabilities, deficits in cognitive- linguistic measures, like phonemic awareness, are significantly related to lower reading ability several years later (Scarborough, 1998). More specifically, phonemic awareness is the core deficit in children with dyslexia comparison to typically developing children (Melby-Lervåg, Lyster, & Hulme, 2012). Phonological processing and phonemic awareness develop in tandem during the early years of life. Around age 2, children begin to show awareness of the sounds of their native language (Swingley &Ashlin, 2000). By the age of 5, typically developing children have acquired a nearly complete understanding of the sounds of language. This knowledge provides the basis for developing foundational decoding skills during 1st and 2nd grade.

Early skills in reading, including ***phonemic awareness*** and decoding, are significantly correlated to reading ability later on. When a deficit occurs early on, it impacts the individual's reading ability years later (Melby-Lervåg, Lyster, & Hulme, 2012). Phonoemic awareness is also a strong predictor of reading ability past 3rd grade (Pratt & Brady, 1998). However, phonological awareness in adults is not as strong a predictor as decoding or sight word recognition, making it difficult to parse out phonological awareness from sight word memory (Bus & van Ijzendoorn, 1999).

Decoding is considered the fundamental word learning mechanism in alphabetic languages and the loci of dyslexia (Share, 1997), but many still think of it as an uncomplicated skill of sounding out words, mastered by most children in first or second grade. In fact, mature decoding in English is a computationally complex, neurological network system that develops across the life-span (Rayner et al., 2007). The complexity is driven by the highly irregular sight–sound correspondence patterns of the English language, the influence on pronunciation of different stress patterns in multisyllabic words (Venezky, 1995, 1999), and the ongoing creation of novel words in added to the English lexicon, such as product (Advil) or place (Bombai) names.

Finally, (***sight) word recognition*** are occurs when the visual form of the word has been stored as a memory representation that allows it to be identified automatically, without the conscious effort of sounding it out, using minimal cognitive resources which can then be invested in comprehension (Ehri, 2005; Perfetti, 1985; Rayner et al., 2007; Reynolds, 2000). Verbal efficiency theory explains how impairments in rapid, automatic, visual word recognition skills can interfere with reading comprehension (Abadzi, 2003; Ehri, 2005; Perfetti, 1985; Verhoeven & Perfetti, 2011).

Deficits in phonological awareness that are identified early in children, followed by intensive interventions that include phonics instruction, result in increased success in reading later (Glauschka, 2014). In children, when phonemic awareness training or fluency training was the only intervention, no significant changes were found in children's reading ability. However, when used together, school aged children and adolescents with reading disabilities, show improvements in spelling and reading suggesting that phonemic awareness or fluency are not sufficient for effective interventions in children (Scammacca et al., 2007).

Child versus adult deficits. Deficits in all of the elements of language-based, word processing have been demonstrably and repeatedly found in integrated models and component studies of adult learners and adults identified with dyslexia including phonemic awareness, phonological processing, decoding, and sight word recognition accuracy and efficiency adulthood (Baer, Kutner, & Sabatini, 2009; Curtis & Kruidenier, 2005; Kruidenier, MacArthur, & Wrigley, 2010; Sabatini, 2002, 2003, 2011, 2015; Tighe & Schatschneider, 2014). Nanda, Greenberg, & Morris (2010) and Sabatini et al. (2010) both showed relative effectiveness with intervention programs that varied the mixture of decoding and fluency instruction, leaving this an open question for future research to explore with adults.

The lexicon and semantic knowledge: vocabulary and morphology.

Semantic knowledge is not restricted to words or language; visual imagery, musical melodies, faces, or procedural sequences are just some of the types of non-language based knowledge that can be associated with verbal conceptual labels. Regardless of modality of input or nature of cognitive coding, the accumulation of lexical knowledge (the meaning associated to words or morphemes) is central to language processing in print and in listening. Neither vocabulary nor morphology knowledge are restricted to print; in fact, some of the sight to sound irregularity of English serves as additional cueing in when words are encountered by ear versus eye (Venezky, 1999). Next we review these two constructs frequently researched in relation to developing reading proficiency.

Vocabulary. Skilled readers have breadth and depth of lexical knowledge (Beck & McKeown, 1991; Cunningham & Stanovich, 1997; Hirsch, 2003). Correlations between vocabulary and reading comprehension assessments ranging from .6 to .7 (Anderson & Freebody, 1981). Individual differences in vocabulary knowledge emerge as early as preschool, and these differences tend to grow over time (Graves & Slater, 1987; Hart & Risley, 1995). The accumulation of word meanings is a critical part of learning to read well and appears to be a significant aspect of the gap between competent and struggling readers. The *lexical quality hypothesis* signals a warning that learning word meanings is not entirely distinct from learning their spellings and pronunciations (Perfetti and Hart, 2001). Word knowledge as a complex assemblage of representations that vary both in the information they contain and in the degree to which they have been fully specified (i.e., in terms of orthographic, phonemic, syntactic, and semantic quality).

One can distinguish broad classes or tiers of words into basic conversational, general purpose academic (e.g., hypothesis, model), or content-specific or specialized (hydrogen) (Beck, McKeown, and Kucan, 2002, 2008). One challenge in accumulating depth and breadth of lexical knowledge is the prevalence of polysemous words in English, that is, words with more than one meaning. Research shows that learners may make inferences based on a common meaning of a word leading to misconceptions when using that meaning to infer the more specific content meaning (e.g., *prime* meaning “high quality” versus referring to prime numbers in mathematics) (McNamara & McDaniel, 2004). This interferes with word learning and comprehension. Individual differences in recognizing polysemy may impede accumulation of word meanings.

Morphology. Morphemes are the basic building blocks of meaning in the language. More than half of English words may be morphologically complex (Anglin, 1993; Nagy and

Anderson, 1984). Morphological awareness is the extent to which an individual recognizes the role that morphemes play in words—both in a semantic and syntactic sense. Nagy, Berninger, and Abbott (2006) concluded that there are computational interactions among phonological, morphological, and orthographic word forms and their parts. Research has also linked morphological awareness to reading comprehension (e.g., Carlisle, 2000; Carlisle & Stone, 2003; Fowler & Lieberman, 1995; Kuo & Anderson, 2006; Tong, Deacon, Kirby, Cain, & Parrila, 2011).

Weak morphological awareness is associated with reading comprehension difficulties among native (Berninger, Abbott, Nagy, & Carlisle, 2010; Carlisle, 2000; Deacon & Kirby, 2004; Nagy et al., 2006; Stahl & Nagy, 2006) and non-native English speakers (Carlo et al., 2004; Kieffer & Lesaux, 2007, 2008). Morphological structure can be taught and results in enhanced vocabulary and comprehension, especially with English language learners (Carlo et al., 2004; Kieffer & Lesaux, 2007; Lesaux, Kieffer, Faller, & Kelley, 2010; Proctor et al., 2011). Most of this research involved young children learning English, with a focus on inflectional morphology (e.g., plurals, tenses). In late elementary to early adolescents, acquiring knowledge and skill in processing derivational morphology (prefixes, suffixes, roots, and combining forms) becomes a core skill word learning and comprehension. The suffixes of words are especially important in syntactic processing.

Child versus adult deficits. Deficits in vocabulary have been demonstrably and repeatedly found in integrated models and component skills studies of adult learners and adults identified with dyslexia (Braze et al., 2007; Curtis & Kruidenier, 2005; Hall, Greenberg, Laures-Gore, & Pae, 2014; Kruidenier, MacArthur, & Wrigley, 2010; To, Tighe & Binder, 2015), though there are less studies that specifically target morphology or morphological awareness (Tighe & Schatschneider, 2014). For example, in a group of young adults (age 14-24 years) who were seeking high school level education, Braze et al. (2007) found that receptive and expressive vocabulary provided additional prediction to their reading ability after controlling for decoding and listening comprehension. Future research on adults would benefit from a continued focus on morphology, the quality of measures (Hall et al., 2014), and difference in real world vocabulary versus school-based academic words as pertains to comprehension (Sticht, 1976).

Grammar, syntax, and sentence processing

The sentence is a natural chunk cue when the reading of continuous text (Kintsch, 1998). A skilled reader will generally pause at the end of each sentence to encode the propositions of the sentence, make anaphoric inferences, relate meaning units to background knowledge and to previous memory of the passage as it unfolds, and decide which meaning elements to hold in working memory. The grammar of written texts does diverge from typical conversational speech (Biber, 1992) including more use of nominalized noun forms of verbs (representation vs. represent) and passive voice. The consequence is often longer sentences with a greater density of propositional chunks of information. Skilled readers handle the added informational demands by orchestrating their resources (memory and attention) and strategic processes (metacognition and self-regulation) to enhance comprehension.

Carlisle and Rice (2002) noted several ways in which compound and complex sentences may pose difficulty for low literacy readers. Perhaps most obviously, complex sentences are often longer, and this places increased demands on working memory. Also, complex sentences often have multiple embedded phrases and clauses that increase the distance between subjects and predicates, a feature known to increase processing demands (e.g., Mann, Shankweiler, &

Smith, 1984). One strategic skills of relational connectors can be used to overcome knowledge or resource limitations when processing complex sentences. Connectors signal temporal (e.g., before), causal (e.g., because), adversative (e.g., although), or conditional (e.g., if) relations. Empirical studies find that struggling learners often inadequately process these kinds of relations (e.g., McClure & Steffensen, 1985).

Child versus adult deficits. Deficits in grammar, syntax, and sentence processing have also been found in some studies of adult learners and adults identified with dyslexia (Curtis & Kruidenier, 2005; Kruidenier, MacArthur, & Wrigley, 2010; Sabatini, 2015; Taylor, Greenberg, Laures-Gore, & Wise, 2012; Tighe & Schatschneider, 2014), though there are less studies that specifically target these processes directly with explicit measures (Tighe & Schatschneider, 2014). This is a topic that may warrant more research both with children and adults.

Reading Fluency

Skilled reading is rapid, efficient, and fluent (silent or aloud). Reading fluency has been most often defined and operationalized by some combination of automatized word recognition (LaBerge & Samuels, 1974; Torgesen, Wagner, & Rashotte, 1999), along with aspects related to continuous text reading such as prosody or expression (Daane, Campbell, Grigg, Goodman, & Oranje, 2005; Fuchs, Fuchs, Hosp, & Jenkins, 2001; Klauda & Guthrie, 2008; Samuels, 2006). Reading fluency can be measured by having individuals read aloud, so that accuracy, speed, and prosody can be observed and scored. It can also be measured during silent reading using cloze techniques. Silent reading fluency on such tasks show a stronger correlation to reading comprehension than oral reading after grade four (Wayman, Wallace, Wiley, Ticha, & Espin, 2007). The shared variance between oral and silent fluency is generally high however (Eason, Sabatini, Goldberg, Bruce, & Cutting, 2013). Reading fluency can be considered an indicator of consolidation and integration of the orthographic and linguistic systems in Perfetti’s model of the Linguistic and Writing System, and measures of oral and silent reading may be useful diagnostically (and instructionally), depending on one’s diagnostic/learning goals.

Child versus adult deficits. Deficits in reading fluency, whether measured in oral or silent reading, have been definitively found in integrated models and component skill studies of adult learners and adults identified with dyslexia (Baer, Kutner, & Sabatini, 2008; Curtis & Kruidenier, 2005; Kruidenier, MacArthur, & Wrigley, 2010; Sabatini, 2011, 2015; Tighe & Schatschneider, 2014). Often, these measures have been interpreted as part of the word recognition component of the SVR model (Mellard, Woods, & Desa, 2012). As noted, fluency interventions have shown some success with low literate adults (e.g., Shore et al., 2015).

Non-native and non-standard speakers of English

The language processing of non-native or bilingual speakers of English, as well as speakers of non-standard English – which may include pidgin, creole, dialects, accents, African-American Vernacular English – can add additional variance between the sight and sound correspondence signals, as well as between the reception and production of speech codes. Consider that the same simple words (e.g., Boston, chowder) can have dozens of variant pronunciations one might here systematically varying by geographic or community setting. Spelling what one hears is an uncertain science, as is pronouncing a novel written word. Of course, non-native English learners may also have to learn all the components of the English language, including vocabulary, syntax, and grammar. When testing or instructing individuals with diverse language backgrounds, it is important to consider how their observable behaviors (speech patterns and rates), and underlying English and native language resources may interact with inferences about deficits, challenges and obstacles. Though it is beyond the scope of this chapter to address this topic adequately, some key resources include (August & Shanahan, 2006).

Child versus adult deficits. Individual differences related to differences in language learners and language minorities have been found in studies of adult learners (Baer, Kutner, & Sabatini, 2008; Curtis & Kruidenier, 2005; National Research Council, 2012; Sabatini, 2011, 2015; Tighe & Schatschneider, 2014). A significant proportion of adults with low literacy are immigrants or non-native speakers of English, and they show both component accuracy and rate deficits when compared to other low literate adults (Sabatini, 2015). However, it remains unclear how to distinguish a specific deficit from a lack of sufficient opportunity to learn the English language (Durgunoğlu, Nagy, & Hancin-Bhatt, 1993; Shore & Sabatini, 2009; Wrigley, Chen, White, & Soroui, 2009).

Non-specific cognitive knowledge and skills deficits

In this section, we discuss deficits or factors that interfere with the learning trajectory to proficient reading. We sequence the topics roughly from bottom up to top down processing. We begin with perceptual processing (vision and hearing) and cognitive capacities (working memory and attention). We then discuss general intelligence (knowledge, intellectual ability).

Perceptual and General Cognitive Processing Deficits

Visual Acuity. Uncorrected vision or visual impairment are deficits that can interfere with reading development. A reader of any proficiency will experience increased difficulty when reading without corrected vision, or even in poor lighting conditions. The impact on reading development is likely significant, decreasing the quality of letter and spelling pattern recognition, while increasing visual and mental fatigue.

One of the most controversial and least understood areas of reading related cognitive deficits surrounds visual processing. For the non-expert, dyslexia is about visual reversals, like seeing the symbol ‘b’ and calling mapping it to the sound /d/. Evidence for this specific type of perceptual-cognitive distortion is not easily found. A phonological deficit will surely make such phonemic discriminations more uncertain and error prone, though errors on single consonants (b versus d) are far less prevalent than with vowels or consonant clusters. A visual processing deficit may be related to temporal processing and resolution of letters rapidly enough to enable rapid, automatic, and fluent word processing (Chase, 1996). This type of deficit is reviewed in section below with respect to rapid automatized naming (RAN).

Hearing. Analogously, hearing impairment or uncorrected hearing could interfere with reading development. Anyone who has tried to understand speech in a crowded, noisy room understands the extra effort required. A hearing impairment would impact language development or diminish accumulation of language knowledge and skills over time. The quality of the speech code signal impacts encoding of phonemic and phonological distinctions and subsequently learning vocabulary. It may also impact executive function and working memory, as more processing resources need to be devoted to initial word and syntactic processing.

Rapid Automatized Naming (RAN). A considerable body of evidence identifies naming-speed deficits in disabled readers, which, when combined with phonological deficits creates a double-deficit (Wolf, 1997; Wolf & Bowers, 1999). Considerable research and theorizing has been conducted to understand RAN behavior (Booth, Perfetti, MacWhinney, & Hunt, 2000; Denckla & Rudel, 1976; Farmer & Klein, 1995; Klein & Farmer, 1995; Rayner, Pollatsek, & Bilsky, 1995; Tallal, Miller, Jenkins, & Merzenich, 1997; Wolf, Bowers, & Biddle, 2000), but parsing RAN tasks is complicated as performance involves attention, visual recognition, access to phonological codes, articulation, and temporal processing—all important for normal reading development.

Attention. Reading requires readers' sustained attention to the text (Rayner, 2009). Studies have found that primary school students' performance on tasks that required sustained attention positively predicted their reading achievement, and so did teachers' rating of students' classroom behavior (Lam & Beale, 1991). Attention problems pose difficulties to the development of reading skills. In a longitudinal study, Rabiner, Coie, and Group (2000) followed a group of children from kindergarten to Grade 5 and found that children's attentional problems predicted future reading difficulties. For example, Rabiner et al. (2000) found that children who had normal reading, but attentional problems at Grade 1, had much higher risk of developing reading difficulties later. Additionally, children's attention problems also moderate the effect of intervention programs. Rabiner, Malone, and Group (2004) found that Grade 1 children who were attentive showed much larger benefit in reading achievement than inattentive children during a one-year behavioral intervention.

Compared to studies of children, studies focused on the relation between attentional problems and reading difficulties in adults are difficult to find. A reasonable extrapolation from child studies would be that attentional problems also positively predict reading problems in adults. However, it is possible that adults with attentional problems may develop strategies to compensate for their inattention, making the relationship less clear.

Working Memory. There are issues in operationalizing working memory due to the range of models and measures used to test the construct. Of the numerous theories, the most influential is the Baddeley (2003) and colleagues model of working memory (Gathercole et al., 2004; Jarvis & Gathercole 2003). The model includes a central executive that supervises the flow of information through the three other components that interpret visual and linguistic input. Baddeley (2003) describes working memory as "temporary storage and manipulation of information that is assumed to be necessary for a wide range of complex cognitive activities". Working memory typically emerges at age 6, and increases sharply, with the quickest acquisition between ages 11-14. However, near the end of adolescence, working memory growth plateaus and remains at that level until around the age of 35, when it then begins to decline for the rest of the lifespan (Fry & Hale, 2000).

One of the most complex functions of working memory is processing language. Individual differences in working memory may be related to varying levels of processing speeds and language skill. Working memory in adults is significantly correlated to reading ability and, reciprocally, word knowledge can affect performance on a measure of verbal working memory (Daneman & Merikle, 1996; De Beni & Palladino, 2000; Dixon, LeFevre, & Twilley, 1988; Just & Carpenter, 1992). Individual neurological differences have been found between those with high and low working memory capacity. Individuals with high capacity are able to suppress irrelevant information, compared to low capacity individuals who inefficiently process irrelevant information. The ability to pass over irrelevant knowledge is critical for reading in the digital age. Furthermore, an individual's working memory capacity can also affect writing ability. Skilled writers can create sentences fluently, which reduces the load put on working memory, suggesting that barriers to working memory can decrease writing ability (McCutchen, 1994). In fact, learning disabled children, specifically those with reading disabilities, have poorer working memory ability compared to normally achieving children (Siegel & Ryan, 1989; Wolf et al., 2002).

Working memory is primarily measured in studies by adaptations of word span and digit span tasks. The most popular among these is the WAIS (Wechsler Adult Intelligence Scale) digit span task, and the Brown- Peterson task. However, there is disagreement that word and digit span tasks measure the actual working memory construct. Though they have been shown to be reliable measures, the tasks do not necessarily capture working memory itself (Turner & Engle, 1989). Thus far, attempts to train working memory have been unsuccessful. Working memory training produces short-term specific training effects that do not generalize beyond working memory. Specific training of verbal working memory was not sustained and did not translate to other skills such as decoding (Melby-Lervåg & Hulme, 2013)

Child versus adult deficits. With the exception of studies of attention deficits, deficits in perceptual and basic cognitive processes identified in children have been definitively found in studies of adult learners and adults identified with dyslexia (Baer, Kutner, & Sabatini, 2008; Curtis & Kruidenier, 2005; National Research Council, 2012; Sabatini, 2002, 2003, 2011, 2015; Taymans et al., 2009; Tighe & Schatschneider, 2014); however, it is often difficult to tease apart cause and effect when such deficits are only first measured or diagnosed when the individual is already an adult with low literacy.

General Intellectual Ability, Knowledge, and Comprehension Proficiency

Research supports a distinction between two highly correlated, but nonetheless separate and distinguishable types of intelligence – fluid and crystallized (Cattell, 1963; Cattell & Horn, 1978). Fluid intelligence includes inductive and deductive reasoning, pattern recognition and abstract thinking, and is applied whenever solving complex, novel tasks. Crystallized intelligence includes language development, verbal and reading comprehension, lexical and foreign language knowledge and is applied whenever accumulated knowledge and skill from education or experience is called upon (Carroll, 1993). Individual differences in fluid intelligence can be explained in part by differences in working memory. The two factors are highly correlated, as most complex reasoning and problem solving tasks used to measure fluid intelligence require adequate levels of working memory to solve. Fluid intelligence shows a decline with age, peaking at around 20 (Hunt, 2011); whereas crystallized can continue to grow for as long as an individual is learning new skills and knowledge. To the extent that fluid intelligence enables and supports learning, it can be thought of us foundational to the acquisition of crystallized intelligence. As Cattell (1963, p. 2) states: “skilled judgments have become crystallized due to schooling or prior learning experienced.”

By this conceptualization, reading comprehension and verbal ability are facets of crystallized intelligence. The failure to acquire fluent reading ability or the failure to read and learn from texts across one’s lifetime impact the accumulation of the knowledge and skills comprising crystallized intelligence; in this sense, vocabulary tests are often cross-classified as tests of verbal intelligence or general knowledge. Modern conceptions of the reading comprehension construct also include critical thinking, reasoning, and problem solving as part proficiency (LaRusso et al., 2016; OECD, 2015; Sabatini, O’Reilly, & Deane, 2013); thus, implying an overlap with fluid intelligence as well (Fry & Hale, 2000). Thus, it may be redundant to consider general intelligence as separate from proficiency in reading comprehension – the two constructs are fundamentally confounded. Only clinically extreme deficits in measured intelligence would seem to be relevant to achieving reading proficiency, because they interfere with learning more generally.

Prior to the 1990s, dyslexia or specific reading disabilities used to be diagnosed as a discrepancy between ones general intelligence quotient (IQ) and reading achievement, assuming average instructional opportunity to learn to read. The logic was that if one had unexpectedly lower reading achievement than predicted by one’s general intelligence score, then there must be an underlying cognitive deficit specific to reading. Empirical evidence did not uphold this logic or methodology for several reasons: 1) individuals with low IQ nonetheless could learn to read fluently with basic understanding; and 2) the intelligence tests were biased because low SES and other disadvantaged groups often show lower scores on IQ tests (Siegel, 2003; see also Taymans et al., 2009).

Child versus adult deficits. Studies that include measures of general intelligence of adults with low literacy are less common, unless the studies are targeting specific learning disabilities or as a covariate (Mellard & Patterson, 2008; Taymans et al., 2009). Mellard and Fall (2009) only found a small amount of variance (between 1 and 7 percent) accounted for by the general intelligence measures they used. Given the history of misuse of intelligence measures, both in the IQ-Discrepancy criteria for reading disability and more generally in the population (Gould, 1996), perhaps this remains a best practice for future research. However, we note that there is considerable overlap between modern conceptions of reading comprehension proficiency and conceptualizations of fluid and crystallized intelligence. Both are viewed now as malleable factors that change across the lifespan. Reading comprehension is related to and supported by knowledge, which is a facet of the crystallized intelligence. Reading comprehension requires critical thinking and problem solving, which are facets of fluid intelligence. Thus, it seems unnecessary to measure intelligence separately from comprehension, unless there is reason to suspect clinically extreme specific learning disability.

What are the differences between adults versus children focused models of cognitive deficits?

Conclusions and Implications

In the 1980s, researchers often used a study design in which they would compare skilled readers of a certain age/grade, struggling or disabled readers at that age, and younger, normally developing children (whose skill levels were matched to the delayed/struggling older readers) (Backman, Mamen, & Ferguson, 1984; Jackson, & Biemiller, 1985; Jackson, & Butterfield, 1989; Stanovich, Nathan, & Zolman, 1988; Treiman & Hirsh-Pasek, 1985). Researchers matched reading level and chronological age in order to attempt to distinguish between delay versus deficit. If the older, struggling readers had the same skill profile across multiple components of reading, then they were lagged or delayed, but otherwise normal. However, if the pattern of skills reflected other differences from younger children, then a deficit could be hypothesized. Unfortunately, this design results in ambiguous findings under certain conditions; if there are no differences between chronological age matched readers or if there is a difference between reading level matches, no conclusions can be made with certainty (Bryant & Goswami, 1986; Goswami & Bryant, 1989). Due to this limitation, the combined reading level and chronological age matched design was discontinued in the past two decades in favor of longitudinal studies, making it more challenging to make direct comparisons between younger and older readers with respect to lag or deficit.

Several studies have used the ability match design in comparing adults with ability matched children (Greenberg, Ehri, & Perin, 1997, 2002; Thompkins, & Binder, 2003) producing interesting, though complex results. The studies have led to a closer examination of the validity of inferences about low literate adults that are derived from measures primarily norm referenced and validated with youth populations (Nanda, Greenberg, & Morris, 2014; Pae, Greenberg, & Williams, 2012; Tighe & Schatschneider, 2014). This questioning of measures seems a productive research agenda, as the normative study conducted in demonstrating the technical characteristics of the child normed test has the most representative sampling of that test battery in the population. Adults with low literacy have typically been under-represented in norming studies of batteries designed for developing student populations. Consequently, any study of low literate adults with a battery normed with younger groups, is, in a manner of speaking, creating an ability match model of the adult sample. The interpretive question is whether to make the same inferences about the adult's abilities as one would make of a child getting a similar score.

We draw an analogous conclusion here in comparing children to adult-focused models, as did Fowler & Scarborough (1993) to the question: should reading disabled adults be distinguished from other adults seeking literacy instruction? They concluded that there are fewer differences between adults with reading disabilities and adults with reading problems stemming from lack of educational opportunity or other learning factors, and thus the research on reading disabilities may be pertinent to adult learners generally, but that the focus should be on targeting persistent difficulties that can be improved. Deficits that emerged in childhood that interfered with reading development are likely to persist into adulthood unless they were identified and remediated while the child was still in formal school settings. Thus, research on which deficits might occur, how to measure their severity, and what are promising options for addressing instructionally, should continue to be pursued with adults; whereas direct comparisons to children may continue to yield complex, mixed results, often very specific to the criteria used to collect the sample. The extant studies of adult learner models and interventions are consistent with this conclusion, in that measures and approaches adapted from child-focused models demonstrated similarities and differences in comparison to children.

The inspiration and application of child-focused models, however, will remain a practical and necessary reality for the foreseeable future, given that the majority of research interest and funding is directed towards improving the reading ability of children in the K-12 education system before they become adults outside of it. Success improving children's reading would mitigate the need for adult literacy learning services, though we would argue that adults deserve quality research and services while we wait for such success with children to be achieved.

In all of the quality research conducted with adult learners that we have reviewed, we see that researchers attempt to adapt measures, instructional content, and personal interactions to adult sensibilities, respectful of adult's self-awareness of themselves as mature learners. Standardized assessments designed for young children sometimes thwart this adaptation, but even then, the research can respectfully explain why (such as the absence of other measures) to adult participants. Through this adaptation process, the content becomes tailored to an adult population.

Finally, we note that a deficit in childhood that interferes with the acquisition of skill can also have implications for the accumulation of knowledge, experience, and subsequent skills. This lost opportunity in accumulating knowledge through reading of texts impacts learning whenever individuals re-enter learning programs as adults. Skilled reading comprehension proficiency is built upon an interaction of prior knowledge (which includes knowledge of words and language), text content, and the purposes the reader brings to the activity. Significant gaps in knowledge severely handicap the process. For this reason, we reviewed the concept of crystallized intelligence, which is predominantly a measure of the accumulated knowledge and skills acquired from learning and experience. Often, it seems, that research interventions or adult literacy programs have the expectations that remediating specific reading skill deficits in a few hundred hours of contact, can make up for years of missing experience and exposure to language and knowledge in print sources. Lived experience provide some proxy learning, but written text continue to be the largest repository of the world's knowledge. A rigorous, intensive, and comprehensive intervention program, at best, could put adults back on the road of knowledge accumulation that leads to proficiency. Getting to proficiency may require that the adult invest the thousands of hours in reading, exposing them to millions of words, texts, knowledge, and ways of thinking – the quantity of reading that typical readers consume routinely. The good news is that the typical young adult can expect about five times as many years after leaving formal schooling as spent in the current K-12 educational system – more than enough to make up for lost time reading and learning.

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