1246

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Phonological representations of adult poor readers: An investigation of specificity and stability

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ABSTRACT
The phonological representations of adult less skilled readers ($n = 25$) were studied in comparison to those of adult skilled readers ($n = 25$) and adolescent reading-age controls ($n = 25$). Participants were tested on a paired confrontation naming and spelling test, given two times to evaluate consistency of performance, and a pseudoword repetition task. On confrontation naming, less skilled readers were less accurate and less consistent, and they made more phonological errors. Likewise, their spellings were less accurate and consistent than those of the control groups; inaccurate naming influenced their spelling significantly more often than it did the spelling of adult skilled readers. They also had fewer correct responses on the pseudoword repetition task. The results confirm that there are weaknesses in the phonological representations of known and new words for adult less skilled readers, with observable consequences for spelling.

A substantial amount of research points to the importance of the phonological requirements of language and literacy in accounting for individual differences in reading ability. One of the domains studied concerns the underlying phonological processes necessary for language use: the subconscious phonological processing entailed in the encoding, storage, and retrieval of spoken or written speech. Inefficient or inaccurate phonological processing has been hypothesized to contribute to less specified or impoverished phonological representations of words for less skilled readers (Elbro, 1996). To explore this issue, the present study evaluated the quality and stability of phonological representations on two administrations of a confrontation naming task given to three groups of readers: adult skilled readers, adult less skilled readers, and adolescent reading-age controls. We were interested in examining whether the lexical productions of less skilled readers would be less accurate and less consistent than those of the other groups (e.g., producing *stethoscope* as "stefescope" on one occasion and

"sethescope" on another). These kinds of errors would support the theory that less skilled readers are prone to weak phonological representations (cf. Elbro, Nielsen, & Petersen, 1994; Snowling, Hulme, Wells, & Goulandris, 1992). To probe the basis of such difficulties, participants were tested on a pseudoword repetition task. Numerous studies have documented a higher incidence of repetition errors for less skilled readers, finding weaknesses in the formation, temporary storage, and production of novel lexical items (for a review, see Brady, 1997). Such difficulties may contribute to impoverished long-term representations in the lexicon or the need for greater exposure to words to attain fully accurate phonological representations (Aguiar & Brady, 1991). Accordingly, in this study we investigated the association between performance on the pseudoword repetition measure and difficulties on the naming tasks.

Along slightly different lines, a final goal of the study was to assess the spelling of words presented in the repeated naming measures. Spelling errors generally are interpreted in terms of deficiencies in phonemic awareness, attempts to remember what a word looks like, confusion of letter sounds with letter names, or lack of knowledge of orthographic patterns (Treiman, 1993). For individuals acquiring spelling skills, a phase that is common for young children and persists for adult less skilled readers is to produce phonetic versions of words: each phoneme in a spoken word is represented, but the conventional orthographic patterns are not known (Ehri & McCormick, 1998; Moats, 1995). If less skilled readers have impoverished lexical entries, this could further complicate their efforts to master the orthography. By studying the correspondence between pronunciation on the naming task and the spelling of those words, we sought to identify another source of spelling difficulties.

BACKGROUND

Naming

In confrontation naming tasks, pictures of nouns typically are presented in order of decreasing frequency (e.g., *house, canoe, muzzle, sphinx* from the Boston Naming Task) (Kaplan, Goodglass, & Weintraub, 1983); participants are assessed on the accuracy and, sometimes, the speed of their responses. Several characteristics of confrontation naming performance by typically developing subjects have been reported in the literature. For children, naming performance (particularly accuracy) is positively correlated with increasing age and word frequency (Cantwell & Rubin, 1992; Cohen, Town, & Buff, 1988; Fried-Oken, 1982, 1984; Guilford & Nawojczyk, 1988; Kaplan et al., 1983; Kindlon & Garrison, 1984; Kirk, 1992; Leonard, Nippold, Kail, & Hale, 1983; Oldfield & Wingfield, 1966). That is, older children name more words correctly than do younger children, and children generally are able to name more high-frequency words than low-frequency words. A possible exception to this generalization are words acquired at an early age, which may be recalled more easily regardless of their frequency (Morrison, Ellis, & Quinlan, 1992). These patterns hold for adults as well, although improvement in naming seems to plateau and then decline (German, 1990; Wiig & Semel, 1975).

Young children's errors can be categorized into a number of different types. With age, the number of error types decreases: the majority are semantic (e.g., "suit" for *vest*), and a smaller number are phonological (e.g., "cambel" for *camel*) (Cantwell & Rubin, 1992; Fried-Oken, 1982; Kirk, 1992). Yet phonemic cues have been found to be more successful than semantic cues in prompting the target word (Kindlon & Garrison, 1984; Kirk, 1992).

Research conducted with skilled and less skilled readers has found that confrontation naming ability is positively correlated with reading ability (for reviews, see Katz, 1996; Wiig & Becker-Caplan, 1984; Wolf & Obregon, 1992; Wolf & Segal, 1992). As early as 30 months of age, impairment on a confrontation naming task has been documented to be one of the language measures that separates children who are later diagnosed as dyslexic from children who subsequently have typical reading ability (Scarborough, 1990).

To ensure that naming difficulties do not stem from limits in receptive vocabulary, the studies reviewed here controlled for vocabulary knowledge by means of recognition tasks. The results indicate that, although both good and poor readers found recognition easier than naming, skilled readers were able to name more of the words they recognized than were less skilled readers (children: Katz, 1986, 1996; Murphy, Pollatsek, & Well, 1988; Rubin & Liberman, 1983; Swan & Goswami, 1997; Wolf & Goodglass, 1986; Wolf & Obregon, 1992; adults: Cantwell & Rubin, 1992). For example, in a study of first graders, less skilled readers named only 57% of the objects they could recognize, whereas skilled readers were able to name 70% (Rubin, Bernstein, & Katz, 1989).

As observed for skilled children and adults, word frequency and word length influence the accuracy of naming for less skilled readers. Less skilled readers have been reported to be more accurate naming words of high frequency than words of low frequency (Cantwell & Rubin, 1992; Katz, 1986; Swan & Goswami, 1997; but see Wolf, 1982, for different results). The effect of word length on the naming performance of less skilled readers has also been examined, but the results have been mixed. Although one study reported no length effects (Cantwell & Rubin, 1992), two others indicated that less skilled readers do less well at naming pictures that have long names, even when word frequency is held constant (Nation, Marshall, & Snowling, 2001; Swan & Goswami, 1997). The study by Nation et al. (2001) made an important distinction between dyslexic children who have deficits in decoding and children who have average decoding skills but deficits in reading comprehension. The dyslexic children found naming long words to be relatively difficult, whereas children with comprehension difficulties were particularly poor at naming pictures that had low-frequency names. This outcome suggests that the confrontation naming difficulties of less skilled readers who have deficits in phoneme awareness and nonword reading stem from the phonological demands of the task.

A qualitative analysis of errors has indicated that both skilled and less skilled readers make proportionally more semantic errors than phonological errors (Cantwell & Rubin, 1992; Rubin & Liberman, 1983; Snowling, von Wagtendonk, & Stafford, 1988; but see Nation et al., 2001; Swan & Goswami, 1997). In fact, Katz (1986), in a study of third grade poor, average, and good readers, reported no effect of reader group on error type. However, some researchers

have proposed that errors that are classified as semantic actually may occur because of phonological inadequacies (Katz, 1986, 1996; Rubin & Liberman, 1983). According to this view, a phonological deficiency may make it difficult to produce the correct name, and so a word that is better represented or more easily processed may be substituted (Katz, 1986). For example, when attempting to produce *aquarium*, one poor reader responded, "Ack, as, aquarine, fishtank" (Snowling et al., 1988). Additional evidence comes from an analysis of the naming errors of third grade poor readers in a study by Katz (1986). When a semantically related word was submitted for the target word, the frequency of the substituted word was higher than the target word 77% of the time. These observations raise questions about the effects of particular procedures on the incidence of the kinds of errors that are found. For instance, if the experimenter had been targeting the word *aquarium* and had encouraged the participant to try to produce that word (e.g., "What's the other word besides 'fish tank' for that object?"), the trial would have been scored as evidence for phonological errors if the participant had persisted in saying "ack" and "aquarine."

In the majority of the studies discussed here, naming performance of less skilled readers was compared with naming performance of skilled readers of the same age. Four of these studies also included in their comparisons a group of typical readers who were reading at an equivalent reading level as the less skilled group, although the results of these studies are not uniform. In the first study, Snowling et al. (1988) reported that 9- to 11-year-old dyslexics made significantly more errors than chronological age controls but a similar number of errors as reading-level controls. They concluded that the naming development of less skilled readers was proceeding in a similar, albeit slower, way as that of same-age children who were better readers. In contrast, Wolf (1991) compared the naming performance of 17 average to able readers, tested in the second grade, with that of 8 dyslexics, tested in the fourth grade, on the Boston Naming Test (Kaplan et al., 1983). The dyslexic children made significantly more errors than the reading-level controls, leading Wolf to conclude that dyslexic children's development in naming differed from that of average readers of the same reading level. A third study (Swan & Goswami, 1997) also compared the naming performance of children who were less skilled readers (dyslexic and garden-variety poor readers) to age-matched and reading-level controls. The experimental naming task was designed to control for a number of relevant variables (e.g., frequency, length, and age of acquisition). As expected, the results showed that the less skilled readers were less accurate than the age-matched controls. When compared with the reading-level controls, the results supported the Wolf study (1991): the less skilled readers correctly named significantly fewer objects than the reading-level controls. In addition, the dyslexic children were significantly less accurate than the reading-level controls on objects with long names and words of low frequency, showing a higher prevalence of phonological errors. When word frequency was held constant for a sample of short and long words, the dyslexic children were the only group to name significantly more short names than long names. The researchers concluded that "the picture naming deficit of dyslexic children appears to be more severe than either their age or

their reading level would predict" (p. 348). Finally, the Nation et al. (2001) study found that less skilled readers did less well than younger, reading-age controls; they obtained unique effects for less skilled readers, depending on how they were identified: dyslexic children performed less well on long words and made more phonological errors; poor comprehenders did less well on pictures with low-frequency names.

In sum, the research suggests that the naming performance of less skilled readers for words in their lexicon is less accurate than that of both age-matched and reading-level controls. The difficulties that dyslexic children experience in naming long words, as well as the growing evidence for phonological naming errors, point toward phonologically based lexical weaknesses.

Factors underlying differences in naming performance

The task of naming requires the retrieval of object names from long-term memory. Therefore, deficits in phonological processes (e.g., encoding, storage, or retrieval) would be expected to contribute to the specific difficulties in naming performance of less skilled readers.

Deficits in the accurate encoding of speech stimuli may lead to impoverished phonological representations. The ability to encode speech stimuli, when hearing is not a factor, is generally measured using two procedures: categorical perception and pseudoword repetition (see Brady, 1997). In categorical perception tasks, a synthetically created speech continuum is constructed in which the formation of phonemes changes in equal acoustic steps from one phoneme to a phonetically similar phoneme (e.g., /ba/ to /pa/ continuum). Listeners are asked to identify individual stimuli or to discriminate between pairs of stimuli. Subtle reading group differences have been reported (e.g., Godfrey, Syrdal-Lasky, Millay, & Knox, 1981; Werker & Tees, 1987). Less skilled readers have been found to be less accurate (Godfrey et al., 1991) as well as less consistent (Werker & Tees, 1987), even when the task is to identify endpoint stimuli that generally are considered to be the best exemplars of the phonemes in a continuum.

In speech repetition tasks, participants are asked to repeat each item immediately after it is heard. Less skilled readers have more difficulty repeating long words or low-frequency words (e.g., Snowling, Goulandris, Bowlby, & Howell, 1986). Increased phonological similarity of short phrases also differentiates skilled from less skilled readers. For example, less skilled readers are slower and less accurate when repeating tongue-twister phrases such as "blue plaid pants" (Catts, 1986). When the stimuli to be repeated are pseudowords, consistent differences have been found between reading groups, both for children (Aguiar, 1993; Futransky, 1992; Gathercole, 1995; Hansen & Bowey, 1994; Kamhi, Catts, Mauer, Apel, & Gentry, 1988; Snowling et al., 1986; Stone & Brady, 1995) and adults (Apthorp, 1995). Even when compared with children matched for reading age, less skilled readers have been found to be less accurate on pseudoword repetition (Stone & Brady, 1995; Taylor, Lean, & Schwartz, 1989).

Additional evidence of perception deficits for language has been reported by clinicians and in case studies (Blalock, 1982; Campbell & Butterworth, 1985;

Johnson, 1980). In one group of adults with learning disabilities, many could not differentiate correct and incorrect pronunciations of words that sounded similar (e.g., *pacific/specific, wash/watch*) (Blalock, 1982). Likewise, Elbro et al. (1994) found that dyslexic adults had more difficulty selecting words to match a definition when the alternatives sounded alike (e.g., *excavation, excursion, execution*), even when semantic knowledge and years of education were controlled. In many cases, adults reported that they were unaware of their phonological problems. One client, when presented with evidence of her speech discrimination deficits, remarked: "No wonder I can't spell the words. I don't even hear them right!" (Blalock, 1982, p. 606).

The difficulty less skilled readers have in retrieving known names may also be due to deficits in the storage of phonological representations or the retrieval of stored representations. Although the two processes are conceptually distinct, the interdependency of storage and retrieval impedes investigating them separately (Katz, 1986).

Word-finding intervention studies have attempted to contrast the processes of storage and retrieval by providing training in elaboration techniques to improve storage by providing a richer knowledge of target words or by bolstering retrieval through the use of phonemic, locative, and/or category cues. However, a comparison of the outcomes of these studies is difficult due to discrepancies in whether the treatment procedures are defined as targeting elaboration or retrieval. For example, category techniques (e.g., pig belongs to the category of farm animals) are referred to as semantic elaboration techniques in one investigation (Wing, 1990) and retrieval strategies in another (e.g., the participant is given the cue, "This is a picture of a farm animal") (McGregor & Leonard, 1989). The majority of these studies have concluded that a combination of elaboration and retrieval treatments is the most beneficial (for a review, see German, 1992).

In addressing whether naming deficits are due, at least in part, to problems in input, storage, or retrieval, Snowling (1995) offered a parsimonious explanation: naming deficits are related to problems, first, in establishing and, later, in accessing adequate phonological representations. In other words, words that are perceived less clearly or distinctly are less easily remembered and, in turn, less easily recalled (Elbro et al., 1994).

Another process involved in naming is speech production. Naming deficits may stem from a difficulty in articulating the phonological components of the object name. Articulation has been assessed in naming studies through the use of a word repetition task. Following a confrontation naming task, participants are asked to repeat the object names from the naming task as they are produced aloud by the examiner. The results of two separate studies involving children found no differences between skilled readers and less skilled readers in their abilities to repeat the words (Katz, 1996; Swan & Goswami, 1997). Thus, simple articulation deficits do not seem to be a predominant factor in the confrontation naming performance of less skilled readers, as all were able to imitate the phonemic sequences.

It has been hypothesized that deficits may exist at the level of motor planning of articulatory routines. The results of naming studies have indicated that

skilled readers are less accurate when naming long words, which place greater demands on the planning and ordering of phonological segments, or low-frequency words, which have articulatory routines that are less familiar (Cantwell & Rubin, 1992; Katz, 1986; Swan & Goswani, 1997). Interestingly, on a different sort of naming task (i.e., serial rapid naming), Scarborough (1998) reported that reading ability was only associated with rapid naming performance when more complicated motor planning was required (i.e., not for simple yes/no responses).

Support for deficits in motor planning comes from clinical studies as well. Adult less skilled readers have demonstrated continued difficulty with the pronunciation of multisyllabic words (Blalock, 1982; Felton, 1994; Johnson, 1980). Thus, the simple production of phonemic segments has not been shown to differentiate skilled from less skilled readers, but evidence has been found to suggest motor planning deficits in the production of multisyllabic words.

In short, the difficulties of less skilled readers in retrieving object names do not appear to be due solely to factors such as vocabulary deficits or simple articulation deficits. Instead, these problems may be linked to the complex processes involved in establishing, storing, and retrieving the phonological representations of words and in assembling them for production.

Spelling

Because spelling and reading are complementary processes that tap phoneme awareness and decoding skills, it is not surprising that spelling deficits are characteristic of less skilled readers of all ages (e.g., Bruck, 1993; Bruck & Waters, 1990; Ehri, 1989; Pennington et al., 1986; Viise, 1992; Worthy & Viise, 1996; see also Shankweiler & Lundquist, 1992, for a review of the association between learning to read and learning to spell). In fact, continued spelling difficulty is often the most frequent complaint of adult less skilled readers (Johnson, 1980).

In turn, a relationship between naming and spelling is to be expected, given that many of the same complex processes are involved. First, a phonological representation must be retrieved from long-term memory.[1] Next, the phonological components are temporarily stored in short-term or verbal working memory. In naming, articulatory routines are specified prior to speech production, and these may be an intrinsic part of lexical activation, regardless of whether the words are spoken (Liberman, 1999). With spelling, in addition to the accurate retrieval of the phonological representation, an explicit awareness of the word's structure at the phonemic level is required.

In typical spelling development, a child masters the requirements of spelling through a series of predictable phases (Ehri, 1989; Stackhouse, 1990). Although given a variety of names, four phases are generally reported. In the first phase (the preliterate or precommunicative phase), the child is aware of the purpose of written language, but does not yet grasp the alphabetic principle. The second phase (the alphabetic phase) consists of semiphonetic spelling characterized by partial letter–sound correspondence; there is heavy reliance on the auditory and articulatory salience of speech sounds, such that clusters are generally reduced

and voiced/voiceless confusions are prevalent (Moats, 1995). Gradually the child progresses to the later alphabetic phase, known as phonetic spelling. At this point, a one-to-one mapping exists for letters and sounds, making the spelling readable but not necessarily orthographically conventional (e.g., *dayly* for *daily*). In the final phase (the orthographic phase), phonetic spelling is supplemented by morphological knowledge and more sophisticated knowledge of spelling patterns, allowing the child to cope with the morphophonemic spelling of English. Awareness of the morphological structure of words increases with reading exposure (Stackhouse, 1990; Stanovich & West, 1989).

The errors of typical children learning to spell do not occur randomly (Moats, 1995). In English, vowel spellings are more difficult than consonant spellings (Schlagal, 1992). Spellings of some consonants are more difficult than others (e.g., preconsonantal nasals, consonant clusters), and errors are made for phonemes that are phonemically similar (Kibel & Miles, 1994; Treiman, Zukowski, & Richmond-Welty, 1995). Furthermore, position effects have been documented: initial and final positions are easier than medial positions (Stage & Wagner, 1992).

Evidence from studies with older, less skilled readers has confirmed that their spelling development proceeds in a similar manner to that of younger, typically developing readers (Sawyer, Wade, & Kim, 1999), although more slowly and with difficulty at the final stages. When the errors of less skilled readers were compared with reading-level controls, it was generally concluded that both groups made a similar number of errors that could be classified as phonetic (Moats, 1983, 1993; Nelson, 1980; Waters, Bruck, & Malus-Abramowitz, 1988). Others, however, have reported conflicting outcomes (Finucci, Isaacs, Whitehouse, & Childs, 1983; Snowling, Stackhouse, & Rack, 1986; see Bruck, 1993; Moats, 1993, for possible reasons for these discrepancies). Nonetheless, it is generally agreed that less skilled spellers use phonetic information to spell, but they have particular difficulty with more complex phonological patterns (e.g., clusters), phonemes acquired late in speech development (e.g., /r/, /w/), and phonemes that share manner and place of articulation (e.g., /k, g/, /d, t/) (e.g., Kibel & Miles, 1994). In addition, less skilled spellers generally have not mastered the more advanced spelling strategies of their same-age peers.

Another characteristic of less skilled spellers, which has been assessed and reported less often, is the inconsistency of their spelling. When spelling was evaluated using a test/retest paradigm, the errors of less skilled spellers were less consistent (i.e., varying more from time 1 to time 2) than those of skilled spellers (Frith, 1980; Holmes & Carruthers, 1998). In Frith's study, the errors of good readers/good spellers were consistent 41% of the time, whereas only 23% of the errors of the poor readers/poor spellers were identical. Observation of variability in spelling comes from anecdotal evidence as well. Kibel and Miles (1994) commented on a period of instability in the spelling of particular speech sounds in the dyslexic children they studied. In our own experience, variability in spelling has also occurred for the adult less skilled readers we have studied. One student noticed that, in the course of a single lecture, she had misspelled the same word in five different ways.

The importance of consistency in spelling was addressed in a longitudinal

study of third grade children's retention of spelling words (Dreyer, Shankweiler, & Luke, 1992). The children were given their regular end-of-the-week spelling test, and one week later they were given an unannounced test of the same words. It was found that the number of spelling words retained over the span of one week, rather than the number correct on the initial test, predicted spelling achievement in grade seven.

Thus, both skilled and less skilled readers follow a similar path in the development of spelling knowledge. At the point at which both skilled and less skilled readers are spelling phonetically, a phonological analysis of their errors indicates that less skilled readers often experience deficits in the analysis of speech sounds, specifically with speech sounds that have not been well established or are less distinct from one another. As Snowling et al. (1992, p. 21) stated, "If the child is forced to spell from an incompletely specified representation of the spoken word, then there will be variability in output."

Research goals

Deficits in the quality of phonological representations have been proposed as an underlying factor in the reading and language difficulties of less skilled readers. The present study targeted confrontation naming and pseudoword repetition as measures that would be sensitive to the quality of phonological representations and examined the potential role of inaccurate phonological representations in the spelling problems of less skilled readers. Three groups of subjects participated: adult skilled readers, adult less skilled readers, and reading-age controls in the seventh and eighth grades.

The confrontation naming task was designed to include multisyllabic words that were likely to be known by this age group, but were found in pilot work to give rise to a number of mispronunciations. Of particular interest was whether less skilled adults would make more phonological errors and whether the errors they generated would be stable. Would less skilled readers make erroneous but constant lexical entries (e.g., always saying "nucular" for "nuclear") or might the underspecification of words make less skilled readers more likely to permute different versions of words (e.g., "stefoscope," "sethoscope")? To address these questions, the confrontation task was administered two times, approximately one to two weeks apart. We hypothesized that a greater occurrence of inconsistent phonological errors would be observed for the adult less skilled readers, providing evidence that the phonological specifications of their lexical entries were more impoverished. Because it is difficult to obtain adult reading groups that differ on reading but are matched on vocabulary knowledge, reading-age controls were included to distinguish the effects of absolute vocabulary size (i.e., we expected that the vocabularies of adults, including those who were less skilled, would exceed the absolute word knowledge of middle-school children) from the effects of phonological weaknesses. That is, if the adult less skilled readers performed less well than only the adult skilled readers on confrontation naming, then a continuum of vocabulary exposure, from middle school students to less skilled adults to skilled adults, would account for the results. On the other hand, if, as we predicted, the adult less

skilled readers were worse at confrontation naming than the adolescent reading-age controls, despite knowing more vocabulary words, then underlying factors relevant to naming would be implicated. Similarly, performance on pseudoword repetition was expected to be the worst for the adult less skilled readers, and a positive correlation was predicted between the ability to encode and produce novel phonological structures and the ability to name correctly known words.

The spelling component of this study allowed us to analyze spelling accuracy and consistency. After each picture was named in the confrontation naming task, the participants were asked to write down the word. In accord with many studies of less skilled readers, we expected that the adult less skilled readers would demonstrate the weakest performance in spelling accuracy, and that the adolescent reading-age controls would be less accurate at spelling than the adult skilled readers. The particular focus in this portion of the study was on the degree of correspondence between naming errors and spelling errors and whether inconsistency in naming would be paralleled by changes in spelling. We hypothesized that the misspellings of the less skilled readers would be related, at least in part, to their mispronunciations of words.

METHOD

Participants

Participants were selected for three groups: adult skilled readers, adult less skilled readers, and adolescent reading-age controls. The 50 participants for the two adult groups were drawn from the Community College of Rhode Island (CCRI), which enrolls students from a wide range of socioeconomic and educational backgrounds, although the majority of the students attend part time and come from low- to middle-income homes. The reading-age control group comprised 25 typically achieving seventh and eighth graders from two Rhode Island public schools who had word identification scores comparable to the less skilled adult readers.[2]

Assignment to the three reading groups was based on reading ability, as measured by two subtests of the Woodcock–Johnson Tests of Cognitive Achievement: Word Identification and Word Attack (Woodcock & Johnson, 1989). Selection criteria for the adult skilled reader group were scores at or above grade level on both of the reading tests.[3] Placement into the adult less skilled reader group was determined by Word Identification scores that were approximately three to six grades below expected reading levels (i.e., average reading grade equivalent of eighth grade) and Word Attack scores at the same level or lower.[4] This limited range of Word Identification scores for the adult less skilled readers was chosen to reflect clear reading problems for adults and to facilitate locating reading-age controls. Accordingly, junior high and middle school students were screened, and selection was restricted to those students whose Word Identification scores were similar to those of the adult less skilled readers and who had comparable or better Word Attack scores. In addition to having appropriate reading scores, all participants met the following criteria: (a) the age of adult participants was restricted to a range of 18 to 36 years in order to reduce potential

Table 1. *Descriptive statistics for age, gender, reading measures, and cognitive ability*

	Skilled readers ($n = 25$)	Less skilled readers ($n = 25$)	Reading-age controls ($n = 25$)
Age (years)			
Mean (*SD*)	21.53 (4.35)	23.61 (5.89)	13.57 (.84)
Range	18–35.7	18.3–35.7	12.1–14.9
Gender	22f, 3m	21f, 4m	11f, 14m
Word Identification (max. = 57)			
Mean raw score (*SD*)	53.44 (1.26)	48.40 (1.15)	48.48 (1.42)
Range	52–56	46–50	45–50
Mean grade equiv.	14.55 (2.2)	8.45 (.83)	8.62 (.92)
Range	11.9–16.9	6.9–9.7	6.9–9.7
Word Attack (max. = 30)			
Mean raw score (*SD*)	26.20 (1.41)	16.80 (3.97)	24.72 (1.93)
Range	24–29	4–22	22–30
Mean grade equiv. (*SD*)	15.7 (1.79)	4.4 (1.39)	13.0 (3.15)
Range	11.9–16.9	1.6–7.8	7.8–16.9
PPVT-R (max. = 175)			
Mean raw score (*SD*)	149.96 (8.02)	144.24 (6.73)	134.78 (9.46)
Range	132–161	135–161	113–148
Mean SSE[a] (*SD*)	96.20 (8.47)	89.12 (7.83)	105.12 (10.50)
Range	78–111	77–109	80–119
Block Design[b]			
Mean SS[c] (*SD*)	9.76 (2.24)	8.96 (2.03)	11.52 (2.57)
Range	6–14	6–12	8–18

[a]SSE = scaled score equivalents.
[b]Block Design for adults was from the WAIS-R (max. = 51); for children, it was from the WISC-III (max. = 69).
[c]SS = scaled score.

cohort effects; (b) all participants were native English speakers;[5] (c) none of the participants had current articulation, hearing, or neurological disorders;[6] and (d) cognitive functioning was within the normal range:[7] verbal cognitive functioning was measured by the Peabody Picture Vocabulary Test–Revised (PPVT-R) (Dunn & Dunn, 1981), and nonverbal cognitive functioning was measured by the Block Design subtest of the appropriate Wechsler scale (Wechsler Adult Intelligence Scale–Revised, for the adults; Wechsler Intelligence Scale for Children–III, for the adolescents) (Wechsler, 1985, 1991).

A total of 92 individuals met the screening criteria (36 adult skilled readers, 30 adult less skilled readers, 26 adolescent reading-age controls). Aptitude differences between the groups were evident, particularly on the verbal cognitive measure (i.e., PPVT-R). Because strong positive correlations exist between naming performance and receptive vocabulary scores (Badian, Duffy, Als, & McAnulty, 1991; Fried-Oken, 1982), group differences were minimized by dropping individuals with more extreme scores, thus creating three equal-sized groups of 25. See Table 1 for descriptive characteristics for each group.

Measures and procedures

In addition to the selection measures, experimental tasks were administered to test confrontation naming, recognition of words in the naming and spelling tasks (i.e., word knowledge), pseudoword repetition, and spelling.

Confrontation naming. A 47-word naming task, modeled after standardized confrontation naming tests, was designed. Five high-frequency words (i.e., *umbrella, helicopter, computer, astronaut,* and *ambulance*) were interspersed among the stimuli as extra filler items that would assure success on some items. One high-frequency word that was used as a filler item (*ambulance*) elicited naming errors and was thus included in the scoring. One test item (*veterinarian*) was pronounced correctly by only one participant and therefore was eliminated. The Standard Frequency Index (SFI) of the test words ranged from 20.8 to 59.9, with a mean of 37.09 (Zeno, Ivens, Millard, & Duvvuri, 1995).[8] With these adjustments to the word set, a total of 42 words was used for the naming measure. The words averaged 8.9 letters in length and ranged from 3 to 5 syllables. A picture representing each word was selected, and a carrier sentence that provided a semantic cue for each word was constructed (i.e., for *amnesia,* the carrier sentence was "loss of memory usually due to a head injury"). The semantic cue allowed for the inclusion of words that were not easily represented by a picture (e.g., *specific, sympathy*). See Appendix 1 for stimuli list, word frequency values, and carrier sentences.

On each trial, the participants were presented with a picture and given the carrier sentence. Because the purpose of the measure was to obtain a specific oral response, additional semantic cues often were provided (e.g., if the person responded "quotations" for *parentheses,* he or she might be told, "You are in the right category, but there is another name for these marks"). The responses were entered on a score sheet and were also tape-recorded. Errors were coded as to type: phonological, semantic, both semantic and phonological, or other. Errors were classified as phonological if the response was a nonword that was phonologically related to the target word (e.g., "parentases" for *parentheses*) or a real word that was phonologically similar to the target word but had no credible semantic relationship to the target (e.g., "pacific" for *specific*).[9] Semantic errors were responses that were semantically related to the target word (e.g., "merry-go-round" for *carousel*). Errors that combined a semantic and a phonological element were classified as both (e.g., "aardvark" for *armadillo*). Circumlocutions, "don't know," and failure to respond were classified as other. In order to measure consistency, the confrontation naming measure was administered on two separate occasions approximately one to two weeks apart, with stimuli arranged in an alternate order on the second administration. The same procedure was used for scoring on Time 2, with the addition of two new error classifications: different phonological and different semantic. A different phonological error was a phonological error that differed from that produced on the first administration (e.g., for *apostrophe:* Time 1 "postrophe," Time 2 "hypo-postrophe"); a different semantic error was a semantic error that differed from that produced on the first administration (e.g., for *colander:* Time 1 "drainer," Time 2 "strainer").

To determine interrater reliability, 10% of the protocols were scored by both the first author and an assistant using only the tape-recorded responses. Interrater reliability was determined to be .97. Guttman split-half reliability scores for Naming/Time 1 and Naming/Time 2 were .78 and .80, respectively. The standardized item alpha (Cronbach) was .88.

Word knowledge measure. To determine if the words from the confrontation naming measure were within the receptive vocabularies of the participants, a word knowledge measure was constructed. Pictures representing the 42 original target words from the confrontation naming task (*ambulance* was not included) were placed with three semantically related foils for each item in a 2×2 matrix. An occasional phonological foil was also included as one of the three foils. To establish whether the participants were recognizing the word per se and not merely matching pictures they had seen before on the confrontation naming measure, different line drawings for each of the confrontation naming stimuli were used.

Pseudoword repetition. The pseudoword repetition measure consisted of 26 pseudowords that were created by selecting real words and making phonemic substitutions (e.g., *wropriodemnive* from *proprioceptive; adnestaric* from *atmospheric*). A list of appropriate difficulty for this age group was selected, drawing in part on pseudowords used in other studies (Apthorp, 1995). Half of the words were short stimuli (i.e., 3 to 4 syllables), and the other half were long items (i.e., 5 to 7 syllables). See Appendix 2 for a list of the stimuli.

The words were tape-recorded and presented through earphones. The participants were instructed to repeat either the entire word or as much of it as possible. A word was scored as correct only if all the phonetic components were present and in the correct order.

Spelling measure. The spelling task consisted of the 43 target stimuli[10] from the confrontation naming measure. Immediately after the participant orally produced the name of a pictured object from the confrontation naming procedure, he or she was asked to produce a written spelling of the word. No pronunciation of the word was provided; the participant's task was to spell the word represented by the picture. To measure consistency of spelling performance, the spelling measure was administered for each of the two confrontation naming sessions (i.e., Spelling/Time 1, Spelling/Time 2).

Spelling responses on Spelling/Time 1 were scored as correct, incorrect, or other (for giving no response or spelling a word other than the stimulus). The spelling responses on Spelling/Time 2 were scored as correct, incorrect in the same way (as the first misspelling), incorrect in a different way (from the first misspelling), or other (for giving no response or providing an unsolicited word).

Additional scoring of the spelling responses was carried out to analyze spelling errors. Each naming response from Naming/Time 1 was compared with a spelling on Spelling/Time 1 and was scored as follows: conventional spelling (i.e., correct spelling), phonetic rendition of the naming response (e.g., said "porkypine," spelled PORKYPINE; said "rhinosaurus," spelled RHINOSAURUS), or

partially phonetic (some segments of the word were not represented phonetically (e.g., said "aardvark," spelled ARDBARK; said "carousel," spelled CARISOUL). Data from Naming/Time 2 and Spelling/Time 2 were compared and scored in a similar manner.

Testing procedure

Testing for the adults was conducted in two sessions, each approximately 30 minutes in length. In the first session, the order of the tasks was Word Identification, Word Attack, PPVT-R, naming, and spelling. During the second session, which occurred one to two weeks later, the adults were given the Block Design subtest of the WAIS-R, the pseudoword repetition task, and the second administration of the naming and spelling measures. At the end of this session, the word knowledge measure was administered. Individuals were paid for their participation.

For the adolescents, due to the constraints of class schedules, completion of the testing generally required three sessions. In the first, the Word Identification, Word Attack, and PPVT-R tasks were given. The first naming and spelling measures were given at the next scheduled time, which was usually within a one-week period. At the final session, one to two weeks after the naming and spelling tasks had been completed, the Block Design of the WISC-III, the second administration of the naming and spelling tasks, and the word knowledge task were given. Students who completed the study were paid for taking part.

RESULTS

Cognitive measures

After the final selection of participants for each group, analyses were conducted to determine if significant differences were present on verbal or nonverbal cognitive ability. First, the verbal cognitive ability was compared for the three reading groups. When PPVT-R raw scores (i.e., total number of words correct) were entered into the analysis, a significant outcome was obtained, $F(2, 72) = 22.19$, $p < .05$. The results of post-hoc tests (Tukey HSD) indicated that the skilled readers had significantly more words in their receptive vocabularies than the less skilled readers, whose receptive vocabularies were still significantly larger, in absolute terms, than the reading-age controls. When an analysis of variance was conducted on PPVT-R scores, adjusted for age differences (i.e., scaled score equivalents), the overall F statistic remained significant, $F(2, 72) = 19.82$, $p < .05$; however, post-hoc tests revealed a different pattern of results. With receptive word knowledge adjusted for age, the reading-age controls significantly outperformed the adult skilled readers, who, in turn, significantly outperformed the adult less skilled readers (see Table 1).

The outcome for the two adult groups was not unexpected, as skilled readers have been shown to have larger receptive vocabularies than less skilled readers. Similarly, the relative vocabulary advantage of the younger participants was not surprising, given that the majority came from school districts that served a more

Table 2. *Means, standard deviations, and ranges for word knowledge and confrontation naming*

Dependent variables	Skilled readers ($n = 25$)	Less skilled readers ($n = 25$)	Reading-age controls ($n = 25$)
Word knowledge[a] (max. = 42)			
Mean (*SD*)	41.08 (1.08)	40.04 (1.59)	38.24 (1.74)
Range	38–42	35–42	35–41
Total number named correctly at Time 1[b] (max. = 42)			
Mean (*SD*)	34.92 (2.75)	28.12 (4.28)	25.56 (5.10)
Range	28–40	21–37	15–35
Words Known			
Percent named correctly at Time 1[c]			
Mean (*SD*)	85 (.06)	70 (.11)	67 (.12)
Range	73–98	54–89	43–92
Percent named correctly at Time 2[c]			
Mean (*SD*)	89 (.06)	76 (.10)	75 (.12)
Range	76–98	60–100	53–92

[a]SR > LS > RA
[b]SR > LS = RA
[c]SR > LS = RA

middle to upper middle income population than did the community college. Because group vocabulary differences were present, differences in vocabulary were controlled statistically. Scaled score equivalents were used for these analyses.

Another analysis of variance was conducted to determine whether significant group differences existed for nonverbal cognitive ability. Scaled scores were compared because the adult and adolescent participants were tested using two different Wechsler scales. The overall F statistic for scaled scores was significant, $F(2, 72) = 8.17$, $p < .05$. Post-hoc (Tukey HSD) tests revealed no difference between the means of the two adult groups, whereas the mean of the reading-age control group was significantly higher than the mean of either adult group (see Table 1 for group means).[11] For the analyses reported here, Block Design scaled scores were not used as a covariate.

Word knowledge and confrontation naming

To evaluate the participants' knowledge of the particular vocabulary items included in the naming and spelling measures, groups were compared on the number of words recognized in the final word knowledge task. The results of a significant analysis of variance, $F(2, 72) = 23.03$, $p < .05$, and post-hoc tests indicated that the performance of each group differed significantly from that of the others (see Table 2). Because there were differences in familiarity with the

stimuli used in the study, naming scores were adjusted for each participant to reflect the percentage of words known that were named correctly (i.e., the total number of objects named correctly was divided by the total number of words known). The remainder of the analyses was conducted using these adjusted scores.

Using adjusted confrontation naming scores, the results of a 3×2 (Group $\times$ Time) mixed factorial analysis of variance indicated significant effects of time and group and a significant Group $\times$ Time interaction, $F(1, 72) = 84.56$, $p < .05$; $F(2\ 72) = 22.75$, $p < .05$; $F(2, 72) = 3.79$, $p < .05$, respectively. Therefore, although separate analyses indicated that the pattern between the groups remained very similar from Time 1 to Time 2, the data were not combined.

After covarying for group differences in receptive word knowledge (i.e., PPVT-R), results of the adjusted scores yielded the predicted result: the less skilled readers' naming performance was significantly poorer than that of the skilled readers: Time 1, $F(2, 72) = 23.57$, $p < .05$; Time 2, $F(2, 72) = 17.91$, $p < .05$. The performance of the reading-age controls was equivalent to that of the less skilled readers. Thus, although the less skilled readers were familiar with a significantly greater number of the naming stimuli than the reading-age controls were, they were able to name only an equivalent percentage.

Naming scores were then investigated for the possible effect of gender. No significant differences were found for naming performance when scores for males and those for females were statistically compared.

Confrontation naming and error type

Naming errors were classified into four subcategories: phonological, semantic, both (i.e., errors contained both phonologically and semantically related elements), and other. Prior to analysis for group differences, adjusted error scores were computed for each participant: the number of errors in each subcategory was divided by the total number of errors, producing percentage scores.

A repeated measures analysis of variance for all naming errors found a significant effect of group, $F(6, 140) = 8.80$, $p < .05$, and time, $F(3, 70) = 3.53$, $p < .05$, but no significant interaction between group and time. Therefore, for the remaining analyses of naming and error type, the data for Time 1 and 2 were combined.

Results of the follow-up analyses indicated significant group effects only for phonological errors and other errors, $F(2, 72) = 18.08$, $p < .05$; $F(2, 72) = 9.16$, $p < .05$, respectively. Post-hoc tests showed that the less skilled readers made significantly more phonological errors than either the skilled readers or the reading-age controls, whose mean percentages of phonological errors did not differ significantly from one another. For other errors, the less skilled readers made significantly fewer errors than either the skilled readers or the reading-age controls, whose mean scores did not differ significantly from one another (see Figure 1). Despite the comparable total naming scores, phonological deficits appeared to be contributing more to the less skilled readers' inability to name the stimuli correctly, whereas less familiarity with the stimuli was evident for the reading-age controls.

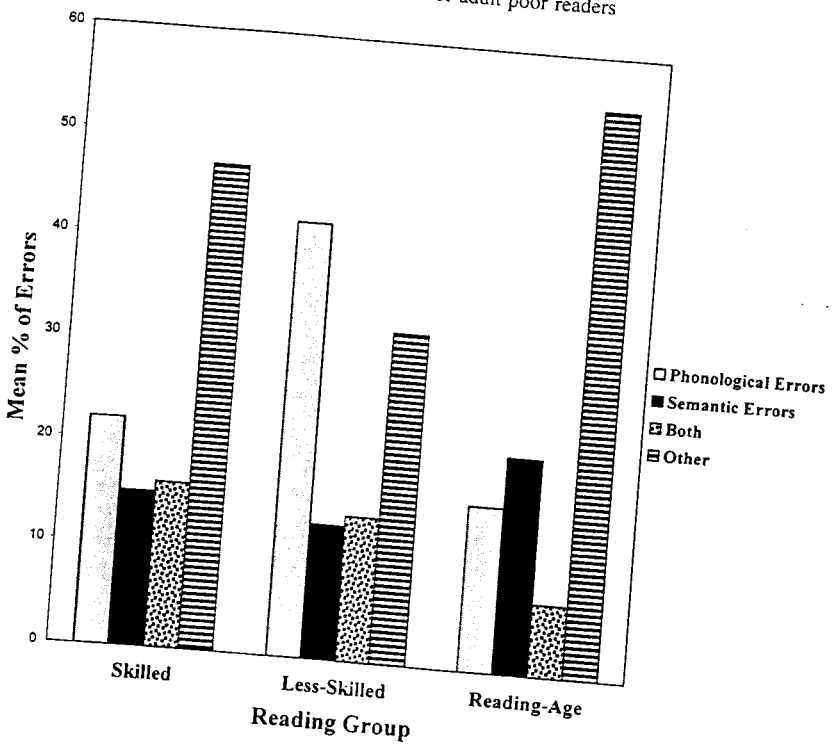

Figure 1. Naming responses by error type.

Confrontation naming and frequency

The study was not designed to investigate word frequency effects across groups; however, a subsequent exploratory analysis of the relationship of frequency and naming ability was conducted. The 42 remaining stimuli (omitting *veterinarian* and including *ambulance*) were divided into a high-frequency group (>38.3) and a low-frequency group (<38.3) by a median split. For each participant, an adjusted score was created that represented the percentage of high- or low-frequency words that each participant knew (i.e., correct on the word knowledge measure). The results of the analyses of variance indicated significant group differences for both high- and low-frequency stimuli: high-frequency, $F(2, 72) = 14.02$, $p < .05$; low-frequency, $F(2, 72) = 24.21$, $p < .05$. For the high-frequency group of stimuli, the results mirrored the overall confrontation naming results. That is, the skilled readers named a significantly greater percentage of high-frequency words that they recognized than either the less skilled readers or the reading-age controls (skilled = 90%, less skilled = 76%, reading-age controls = 78%). For low-frequency stimuli, the skilled readers named a significantly greater percentage than the less skilled readers, who, in turn, significantly outperformed the reading-age controls (skilled = 80%, less skilled = 65%, reading-

Table 3. *Word frequency and chi-square values for Time 1 stimuli with 10 or more phonological errors*

Naming stimuli	Word frequency (SFI)[a]	*df*	Pearson chi-square value	Significance
burglary	41.5	2	13.84	.001
colander	20.8	2	8.54	.014
extinguisher	35.0	2	9.16	.010
specific	59.9	2	13.64	.001
statistic	37.8	2	24.75	.000
stethoscope	43.3	2	12.83	.002
tentacles	43.7	2	7.79	.020

[a]Standard Frequency Index.

age controls = 54%). Lack of familiarity with the stimuli appeared to have a greater influence on the naming performance of the reading-age controls.

Additional exploration was carried out to determine which of the naming stimuli elicited the highest number of phonological errors and which of these words were the most difficult for the less skilled readers to produce. An analysis of each stimulus with 10 or more phonological errors indicated that the three reading groups were significantly different on the following seven words: *burglary, colander, extinguisher, specific, statistic, stethoscope,* and *tentacles*. For six words, the less skilled readers had the highest number of phonological errors. Note that the frequency of three words placed them in the high-frequency group (*burglary, specific, stethoscope*). For *tentacles,* reduction errors (i.e., pronouncing *tentacles* as "tenacles") were more prevalent among the skilled readers. See Table 3 for word frequency and Pearson chi-square values.

Confrontation naming and stability

The confrontation naming measure was administered twice with the goal of examining the stability of performance for each group. Consistency for correct responses was assessed for each individual by counting the number of correct occurrences on both Time 1 and Time 2 for each item. A percentage score, representing the number of words that were correct on Time 1 and also on Time 2 (i.e., number of consistent responses), was computed for each individual by dividing the number of these occurrences by the total naming score for Time 1. The results of the analysis of variance indicated significant group differences, $F(2, 72) = 10.34$, $p < .05$. Follow-up analyses showed that the less skilled readers ($M = 93\%$) had a smaller percentage of consistently correct responses than either the skilled readers ($M = 98\%$) or the reading-age controls ($M = 98\%$), who had equivalent performances.

Inconsistency of responses was analyzed in two ways. First, responses that were correct on Time 1 but incorrect on Time 2 were tallied.[12] Percentage scores were computed for each individual by dividing the number of these occurrences

by the total number of items that were named correctly on Time 1. The result of the analysis of variance was significant, $F(2, 72) = 9.81$, $p < .05$. Follow-up analyses indicated that the less skilled readers ($M = 7\%$) made a greater percentage of these errors than either the skilled readers ($M = 2\%$) or the reading-age controls ($M = 2\%$), whose percentage scores did not significantly differ from one another. The second analysis was conducted by examining the reading groups for the occurrence of variation in phonological errors (i.e., a phonological error on Naming/Time 1 and a different phonological error on Naming/Time 2) and variation in semantic errors. The occurrence of phonologically different errors was modest: the skilled readers made a total of 4; the less skilled readers made 17; and the reading-age controls made 8. Even so, when the percentage scores were computed (i.e., occurrences of phonologically different errors divided by the total number of errors on Naming/Time 1), group differences were found, $F(2, 72) = 9.65$, $p < .05$. Follow-up analyses revealed that the less skilled readers made a significantly larger percentage of these errors than did the skilled readers or the reading-age controls, whose percentages of errors were not significantly different from one another.

Variation from Time 1 to Time 2 in semantic errors occurred only once (in the group of reading-age controls). Therefore, no further analyses were conducted on the consistency of semantic responses.

Pseudoword repetition

In addition to investigating confrontation naming, another goal of the study was to evaluate pseudoword repetition. We wished to examine the association between the basic phonological abilities tapped by this measure (i.e., encoding, brief memory, and output requirements) and confrontation naming.

After covarying for PPVT-R (i.e., receptive vocabulary knowledge), the overall F statistic (Wilks' lambda) was significant for group, $F(4, 140) = 6.09$, $p < .05$. Follow-up analyses indicated significant group differences for the repetition of short, long, and total pseudowords, $F(2, 72) = 16.43$; $F(2, 72) = 9.74$; $F(2, 72) = 15.65$, respectively, all at $p < .05$. Post-hoc tests showed that the skilled readers and the reading-age controls performed significantly better than the less skilled readers on all pseudowords (short, long, and total). The performances of the skilled readers and the reading-age controls did not differ significantly from one another on this measure (see Figure 2).

Spelling

Spelling performance was initially analyzed for accuracy. The participants were asked to give the oral response and then to spell the item. These spellings were scored on the first administration (i.e., Spelling/Time 1) as correct, incorrect, or other (i.e., for either making no response or providing an unsolicited word). Adjusted scores were then computed (i.e., the total number of words spelled correctly divided by the total number of words known).

For results scored as correct spelling, the results of a 3×2 (Group $\times$ Time) mixed factorial analysis of variance indicated a significant effect of group, $F(2,$

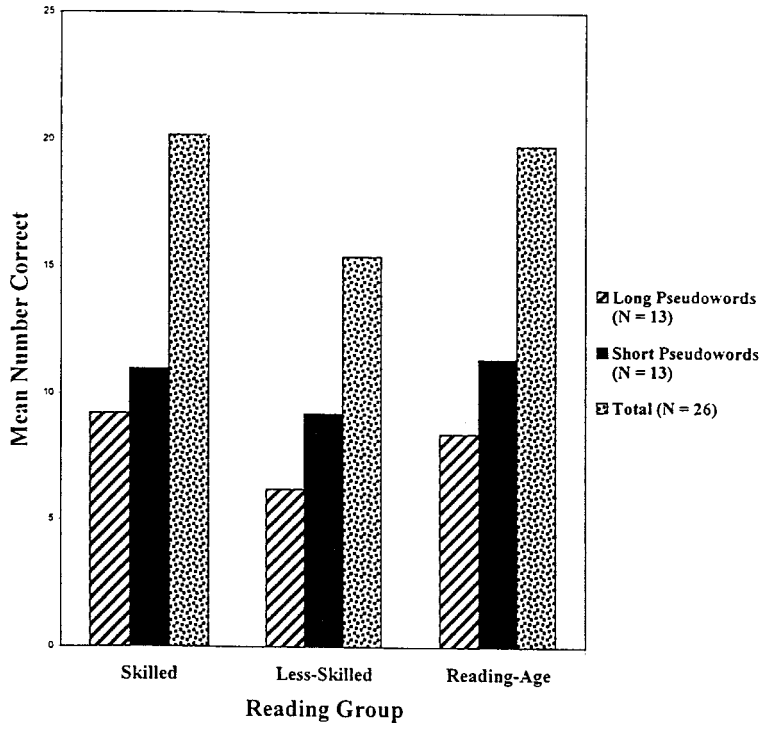

Figure 2. Pseudoword repetition by reading group.

72) = 58.00, $p < .05$, and a significant effect of time, $F(1, 72) = 33.42$, $p < .05$. In view of a nonsignificant Group × Time interaction, the data for Spelling/Time 1 and Spelling/Time 2 were combined.

The result of the multivariate analysis of covariance, with PPVT-R as the covariate, was also significant for group, $F(2, 71) = 59.96$, $p < .05$. On post-hoc tests, the skilled readers ($M = 69\%$) significantly outperformed the reading-age controls ($M = 43\%$), who, in turn, significantly outperformed the less skilled readers ($M = 26\%$).

Based on prior research that found a close link between reading and spelling, the pattern of spelling results was expected. At the same time, the relatively low performance in all groups was probably due to the fact that not all of the confrontation naming stimuli were words with regular spelling patterns (e.g., *tambourine, fluorescent*), making the spelling task more difficult.

Spelling and error type

The participants naming responses on Naming/Time 1 were compared with their spelling responses on Spelling/Time 1, referred to as Name/Spell/Time 1. The same process was repeated for Naming/Time 2 and Spelling/Time 2 (i.e., Name/

Spell/Time 2). The spelling of the naming response, regardless of whether it was the correct response, was scored as conventional (i.e., a correct spelling of the word named), phonetic, or partially phonetic. The creation of this scoring system allowed us to analyze the types of spelling responses each reading group made.

For responses scored as conventional, the results for the naming responses that were spelled correctly paralleled the outcome of the spelling measure. A repeated measures 3×2 (Group $\times$ Time) mixed factorial analysis of variance indicated a significant effect for group, $F(2, 72) = 72.46$, $p < .05$, and time, $F(1, 72) = 31.36$, $p < .05$. Because of a nonsignificant Group $\times$ Time interaction, data for conventional Name/Spell/Times 1 and 2 were averaged. The analysis of variance result was significant, $F(2, 72) = 72.46$, $p < .05$. Post-hoc tests showed the average number of naming responses that were spelled correctly for the skilled readers ($M = 24.7$) was significantly greater than that for the reading-age controls ($M = 13.0$), whose ability to spell the naming responses correctly was significantly greater than that of the less skilled readers ($M = 7.84$).

Prior to the analyses of spelling error types, percentage scores were calculated for each testing time (i.e., each type of spelling error was divided by the total number of spelling errors, not including other errors). A repeated measures mixed factorial analysis of variance was conducted for each of the two error types (phonetic and partial phonetic). For each error type, a significant effect was found for group: phonetic, $F(2, 72) = 25.65$; partial phonetic, $F(2, 72) = 25.65$; both $p < .05$. There was also a significant Group $\times$ Time interaction: phonetic, $F(2, 72) = 10.68$; partial phonetic, $F(2, 72) = 10.68$; both $p < .05$. Therefore, the data for these two variables were not combined.

Post-hoc tests revealed equivalent results for phonetic errors on Name/Spell/Times 1 and 2. For Time 1 and Time 2, the less skilled readers ($M = 50\%$, $M = 44\%$) spelled a significantly smaller percentage of the words phonetically than did the skilled readers ($M = 65\%$, $M = 72\%$) or the reading-age controls ($M = 74\%$, $M = 72\%$), whose percentages of phonetic errors were not significantly different from one another. Conversely, when the groups were compared on partially phonetic spellings, the results were again equivalent for Name/Spell/Times 1 and 2, and an inverse pattern was seen. The less skilled readers ($M = 50\%$, $M = 56\%$) made a significantly greater percentage of these spellings than did either the skilled readers ($M = 35\%$, $M = 27\%$) or the reading-age controls ($M = 26\%$, $M = 28\%$), whose scores did not differ significantly from one another. Thus, the difficulty of spelling for the less skilled readers was evident in the significantly greater percentage of partially phonetic errors that were produced by this group than by either the skilled readers or the reading-age controls.

Spelling and stability

Because the participants produced a written response for each object named on the two administrations of the confrontation naming measure, stability of spelling was also analyzed (i.e., Spelling/Time 1 and Spelling/Time 2). On the second administration (i.e., Spelling/Time 2), responses were scored as correct,

incorrect in the same way (as the first spelling), incorrect in a different way (from the first spelling), or other.

Analyses of consistent and inconsistent performance were conducted in the same manner as the analyses for naming consistency. First, consistency for correct responses was assessed for each individual by counting the number of correct occurrences on Time 1 and on Time 2 for each item. A percentage score was computed by dividing the number of correct occurrences by the total number of correct spellings on Time 1. The result of the analysis of variance was significant, $F(2, 71) = 11.24$, $p < .05$. The skilled readers ($M = 81\%$) and the reading-age controls ($M = 83\%$) had an equivalent percentage of these occurrences, which was significantly greater than that for the less skilled readers ($M = 65\%$).

Two additional analyses were conducted to assess inconsistent performance. Inconsistent performance was defined as (A) correct on Time 1 and incorrect on Time 2 or (B) incorrect on Time 1 and incorrect in a different way on Time 2 (e.g., for *carousel,* producing "carasel" on Time 1 and "carasoul" on Time 2). Percentage scores were computed (i.e., for A, the total number of occurrences was divided by the total correct on Spelling/Time 1: for B, the total number of occurrences was divided by the total number of errors on Time 1). A one-way analysis of variance was conducted for each type of inconsistent response. For each analysis, the F value for group was significant. $F(2, 71) = 9.74$; $F(2, 72) = 41.41$, respectively; both $p < .05$. For both A and B, post-hoc tests revealed the same pattern of group differences. The less skilled readers had a significantly higher percentage of inconsistent responses than either the skilled readers or the reading-age controls, whose percentage scores were equivalent (means: for A, less skilled readers = 61%, reading-age controls = 33%, skilled readers = 18%; for B, less skilled readers = 47%, reading-age controls = 23%, skilled readers = 17%).

Influence of naming on spelling

A comparison of naming scores and spelling scores was undertaken in a second analysis to ascertain whether a phonologically incorrect naming response had led to a corresponding phonetically represented spelling response equally across groups (i.e., the naming response for *armadillo* was "amadillo" and in the spelling response was represented phonetically as "amadillo"). A quantitative analysis of the relationship between the naming response and the spelling response was conducted.

A repeated measures (3×2) mixed factorial analysis of variance was conducted. The results showed significant effects of group, $F(2, 72) = 34.32$, $p < .05$, and time, $F(1, 72) = 8.05$, $p < .05$, and a significant Group × Time interaction, $F(2, 72) = 5.03$, $p < .05$. Thus, separate data were retained for analyses of Times 1 and 2. Significant group differences were found: Time 1, $F(2, 72) = 37.87$; Time 2, $F(2, 72) = 16.36$: both $p < .05$. Although the number of occurrences was small, post-hoc tests demonstrated that the less skilled readers had a significantly greater number of misspellings reflecting mispronunciations than

either the skilled readers or the reading-age controls (means: for Time 1, skilled = 1.08, less skilled = 5.16, reading-age controls = 2.20; for Time 2, skilled = 1.08, less skilled = 3.76, reading-age controls = 1.96).

Because the less skilled readers made a significantly greater number of naming errors that were phonologically incorrect, adjusted scores were computed to represent the percentage of occurrence out of all phonological incorrect naming responses. For this analysis, no significant Group × Time interaction was obtained; thus the data for Time 1 and Time 2 were combined. When an analysis of variance was conducted using the combined data, a significant group difference was found, $F(2, 69) = 10.33$, $p < .05$. Follow-up analyses indicated that the less skilled readers and the reading-age controls phonetically represented all or part of the incorrectly named response a significantly greater percentage of the time than the skilled readers did (less skilled = 93%, reading-age = 86%, skilled = 65%). The skilled readers seemed to have more knowledge of how the word should be spelled, even if they (rarely) mispronounced a word.

Correlational analyses

To examine the correlations between the variables, scores for naming and spelling on Time 1 and Time 2 were combined. Of interest were the associations between reading achievement and cognitive ability (i.e., PPVT-R and Block Design), naming, spelling, and pseudoword repetition. Correlational analyses were conducted for each reading group separately because of differences in cognitive abilities, age, and reading achievement.

For the adult skilled readers, confrontation naming was significantly correlated with vocabulary size ($r = .46$, $p < .05$) and word identification ability ($r = .44$, $p < .05$). Thus, vocabulary knowledge and the skills tapped by the ability to recognize written words were associated with naming ability. With this small sample, no other correlations were significant.

For the adult less skilled readers, a different pattern was found. Confrontation naming was not linked to vocabulary knowledge, but was significantly related to the ability to encode and repeat novel words on the pseudoword task ($r = .40$, $p < .05$). Other significant correlations showed the expected associations for the less skilled readers between word attack and spelling ($r = .60$, $p < .01$) and between word attack and word identification ($r = .44$, $p < .05$).

The reading-age control group was somewhat like both of the other groups. Like the adult skilled readers, confrontation naming and word identification significantly corresponded ($r = .47$, $p < .05$), reflecting shared abilities in retrieving lexical and orthographic entries. However, as with the adult less skilled readers, the ability to perform the pseudoword repetition task was significantly associated with the ability to name ($r = .45$, $p < .05$). Hence, for the younger group of participants, individual differences in the ability to formulate and output new words were related to vocabulary skills, perhaps because they were in an active phase of vocabulary acquisition. In turn, pseudoword repetition was significantly correlated with vocabulary size ($r = .54$, $p < .01$).

DISCUSSION

Deficits in the phonological processes involved in the encoding, storage, and retrieval of the phonological segments of language may contribute to less specified or impoverished lexical representations for less skilled readers (e.g., Elbro et al., 1994). To explore this issue, the present study examined the quality of phonological representations of adult less skilled readers in comparison with adult skilled readers and adolescent reading-age controls using two tasks: confrontation naming and pseudoword repetition. We were also interested in the effect of inaccuracies in naming on spelling performance, particularly for the less skilled readers.

Quality of phonological representations

As hypothesized, the adult skilled readers were significantly more accurate in naming performance than the adult less skilled readers. These results converge with prior research, which found that skilled readers were more precise when recalling words they knew than were less skilled readers. This outcome has been reported for adults as well as children (adults: Cantwell & Rubin, 1992; children: Fowler & Swainson, 1999; Katz, 1986, 1996; Murphy et al., 1988; Rubin & Liberman, 1983; Swan & Goswami, 1997; Wolf & Goodglass, 1986; Wolf & Obregon, 1992).

Although the adult less skilled readers recognized significantly more of the pictured stimuli than did the adolescent reading-age controls, they were able to name only an equivalent number, indicating that differences in knowledge of the stimuli were not directly responsible for the outcome (see Snowling et al., 1988, for similar results). Receptive word knowledge differences, however, did exist for the participants in our study. The less skilled readers had significantly larger vocabularies in absolute terms than the reading-age controls on both the naming measure and the PPVT-R. However, when receptive word knowledge was adjusted for age, the reading-age controls actually had significantly better word knowledge scores (for their age) than did either of the adult groups. A similar occurrence was reported by Bruck (1990) between adults who had been diagnosed as dyslexic in childhood and children in the sixth grade. In part, the disparities may be attributed to differences in socioeconomic backgrounds: in this study, the younger participants were somewhat more advantaged socioeconomically than the adults. Another explanation was provided by Greenberg, Ehri, and Perin (1997), who found adult literacy students had larger vocabularies than reading-age controls in the third and fourth grades but equivalent vocabularies with controls in the fifth grade. They speculated that children's vocabularies may catch up to the vocabularies of adult poor readers because of their greater experience with vocabulary in print.

Although we did investigate the outcome for the groups on high- and low-frequency words, our study was not designed to control for variables that have been noted to confound frequency results (e.g., word length). Yet our results did concur with prior studies reported for frequency. That is, the less skilled

readers named fewer low-frequency words than high-frequency words (Cantwell & Rubin, 1992; Katz, 1986; Swan & Goswami, 1997). However, it should be noted that our less skilled readers had significantly poorer performance on both high- and low-frequency words, suggesting that they had an underlying primary phonological deficit rather than simply had less exposure to words through reading. Furthermore, of the six words that the less skilled readers had noteworthy difficulty in naming, half were of high frequency, and two of these were fairly short but phonologically complex (e.g., *specific* and *statistic*). In a study by Apthorp (1995), adults with learning disabilities were found to have more difficulty with pseudoword stimuli that had similar phonemes across syllable boundaries or a high occurrence of consonants (see also Rapala & Brady, 1990). Further analysis of this issue is needed to illuminate the exact relationship between reading ability and the effects of frequency, length, and phonological complexity of stimuli on naming tasks.

When performance on the naming task was analyzed in terms of error type, the adult less skilled readers made significantly more phonological errors than did the adult skilled readers or the reading-age controls. These results align with those of Nation et al. (2001) and Swan and Goswami (1997), who found evidence for phonological difficulties for poor readers on confrontation tasks, but contrast with those of researchers reporting more frequent semantic errors (e.g., Cantwell & Rubin, 1992; Rubin & Liberman, 1983; Snowling et al., 1988). A critical aspect of the procedure in this study, which may allow the occurrence of phonological errors to be observed, was that the researcher asked the participant to think of another name for the stimulus rather than stopping when a semantic substitution was provided.

A novel feature of this study of confrontation naming was the test/retest design, which allowed us to assess the stability of the naming performance. The hypothesis that the phonological deficits of the less skilled readers would contribute to their less stable performance was supported. The naming responses of the less skilled readers were less consistent for pictured stimuli than were those of either of the control groups: the less skilled readers produced a phonological error on Time 1 and a different phonological error on Time 2 four times as often as the skilled readers and twice as often as the reading-age controls. Even when the less skilled readers could retrieve the correct word, they were less likely to do so on the second occasion. The results from this repeated measure technique conform with the distinctness hypothesis, proposed by Elbro (1996), that the phonological representations of poor readers tend to be less distinct or more impoverished than those of better readers. One can speculate that an indistinct or incomplete representation would be more likely to yield variable patterns when words are produced. Two other findings on the confrontation naming task were compatible with the weak representation view. First, the less skilled readers did not simply have misrepresentations that were incorrect in a constant fashion. Instead, they appeared on occasion to recompute the phonetic elements, producing a new erroneous version. Second, as noted before, half of the words that were most frequently mispronounced (see Table 3), especially by the less skilled readers, were not the low-frequency stimuli but the words with clusters and phonologically demanding phoneme sequences.

The results of the pseudoword repetition task also supported the weak representation view: the less skilled readers did the least well at repeating novel words. In fact, when repeating pseudowords, deficits in phonological processing were even more pronounced than they were with the naming stimuli, where the performance of the less skilled readers was equivalent to that of the reading-age controls. Previous research comparing the performance of less skilled readers with that of reading-age controls on pseudoword repetition also showed this pattern of performance (Stone & Brady, 1995; Taylor et al., 1989; see Brady, 1997, for a discussion).

Difficulties in creating an initial phonological representation or holding the representation accurately seem plausible factors for linking pseudoword repetition with the quality of long-term lexical representations. Aguiar (1993) found that performance on pseudoword repetition was the strongest predictor of the ability to retain newly learned words over time for a group of fourth graders. In the present study, pseudoword repetition was significantly correlated with confrontation naming, both for the less skilled readers and the reading-age controls. Thus, the ability to establish accurate phonological representations may be relevant both to typical vocabulary development and to individual differences in reading.

A cross-sectional study with children in the first and fourth grades also points to correspondences between the quality of phonological representations and both vocabulary development and reading ability. Fowler and Swainson (1999) tested children at these two grade levels on three experimental tasks: naming pictured objects, judging the acceptability of pronunciations (such as "porkuter" for *computer*), and correcting naming errors. In both first and fourth grades, less skilled readers were less accurate than skilled readers on all three tasks. As expected, there also were highly significant differences across grades, with the older children improving in naming skills. The results with the first graders suggest that differences between skilled and less skilled readers in the quality of lexical representations are present even at a point when neither group has had extensive experience with print. Similarly, the sensitivity of confrontation naming at differentiating reading groups has been noted in a small number of prediction studies with young children: children's level of naming accuracy in kindergarten has been found to be one of the strongest predictors of subsequent reading achievement (see Scarborough, 1990, for discussion). Noting the improvements in performance for the older children, Fowler and Swainson proposed that experience with printed words enhances the accuracy and stability of children's phonological representations. Accordingly, for older poor readers, one would expect that ongoing difficulties in forming phonological representations would be compounded by a lack of reading experience (see Anderson, 1999, for figures on differences in words read per year in elementary school according to reading level).

Before leaving the topic of the quality of phonological representations, we want to comment briefly on the components of cognition investigated in the naming and pseudoword repetition portions of this study. These fall in neither the meta-level domain of phoneme awareness measures nor the category of reading and spelling tasks. Instead, they concern the basic phonological pro-

cesses involved in speech perception and production and the derivative phonological processes involved in lexical retrieval and memory. The measures that we used did not stress speed of response, nor was rate of response measured. Indeed, the evidence on deficits in the quality of phonological representations offers a very different explanation for individual differences in reading ability than do current theories that stress naming speed deficits (e.g., Wolf, 1997) or the role of temporal processing (Tallal, Miller, Jenkins, & Merzenich, 1997). To examine whether or how these explanations intersect, future research should include appropriate comparisons of phonological and nonphonological tasks (cf. Mody, Studdert-Kennedy, & Brady, 1997) in order to reconsider the interface of speed and accuracy and to evaluate the multiple demands of tasks (e.g., rapid serial naming is visually presented, but requires naming which, by definition, involves the phonological level of language) (Scarborough, 1998).

The effect on spelling

The spelling task was more difficult for the less skilled readers than for either of the other two reading groups, as predicted by previous research showing a close link between reading and spelling performance (Bruck, 1990; Gallagher, Laxon, Armstrong, & Frith, 1996; Greenberg et al., 1997). Spelling requires not only a distinct phonological representation and good letter–sound knowledge, but also sufficient experience with orthographic spelling patterns. The confrontation naming stimuli were words whose spellings did not follow entirely regular spelling patterns (e.g., *tambourine, fluorescent*), making the spelling task even more difficult. The spelling deficit for the less skilled readers was seen in the earlier stage of spelling development, implicated by the kinds of errors they made: the less skilled readers had a significantly greater percentage of partial phonetic errors compared to phonetic errors than did either the skilled readers or the reading-age controls (Ehri & McCormack, 1998; Moats, 1995). It would be interesting to explore the nature of the spelling errors in a more fine-grained way to investigate whether the incidence of misspellings for the less skilled readers showed evidence of phonological weaknesses. Both Kibel and Miles (1994) and Moats (1995) reported phonological spelling deficits for adolescent poor readers. In a separate set of analyses, we and Louisa Moats are examining the nature of the naming and spelling errors to see if phonological weaknesses (e.g., voicing and place errors, substitution of sonorants, phonological context effects) account for many of the errors of less skilled readers and if these are common to both naming and spelling.

In addition to producing less accurate spelling, the spelling responses of the less skilled readers also were less consistent than those of either control group, as observed in prior studies (Frith, 1980; Holmes & Carruthers, 1998). We propose, as did Snowling et al. (1992), that this pattern reflects, in part, errors and inconsistencies on naming responses. Because the participants did not have a dictated model of the spelling word, spelling may have been based on the naming response that each produced. Anecdotal evidence of this occurring was also reported in Snow and Strucker (2000). When the relationship between naming response and spelling was analyzed, a greater percentage of the less skilled

readers' naming mispronunciations were echoed in their spelling than was the case for the adult skilled readers. In other words, the less skilled readers were attempting to represent phonetically what they said. This finding is important as it suggests that, in addition to the acknowledged causes of poor spelling ability (e.g., weak phoneme awareness, insufficient knowledge of orthographic spelling patterns), another contributing factor may be the impoverished phonological representations of words in the spoken vocabularies of less skilled readers. Nonetheless, in some cases the phonetic spellings of mispronunciations may have been altered by some familiarity with the correct spelling. For example, a student who mispronounced *magician* as "'madician" was overheard saying to himself, "I think it has a 'g' in it somewhere."

Closing comments

The aim of this study was to examine the quality of phonological representations in less skilled readers. The results confirm the value of confrontation naming and pseudoword repetition as techniques for this purpose. The test/retest design for confrontation naming and spelling added a new dimension, allowing further study of the nature of phonological and orthographic representations of less skilled readers. The results support the conclusions that the phonological quality of new and old lexical representations is somewhat impoverished for less skilled readers, and that this weakness probably contributes to their difficulties in learning to spell and read. In addition, poor quality phonological representations no doubt have other consequences in daily circumstances, such as trouble producing a desired word accurately in a conversation or correctly answering fill-in-the-blank items on school exams.

APPENDIX 1

Naming stimuli, frequency, and carrier phrase

Word	Standard Frequency Index	Carrier phrase
accordion	37.4	A musical instrument often used to play polkas. Steve Erkel plays it.
aluminum	53.2	Cans that are recyclable are made of this metal.
ambulance	47.5	Rescue vehicle that takes injured or sick people to the hospital.
amnesia	34.7	Loss of memory usually due to head injury.
apostrophe	40.0	A punctuation mark used to indicate the omission of one or more letters in a word.
armadillo	36.6	A mammal covered with jointed plates of bone and horn.
asparagus	39.3	A vegetable that grows early in the spring.
broccoli	39.1	A dark green vegetable.
burglary	41.5	Breaking into a house with intent to steal.
carousel	29.3	Old-fashioned name for merry-go-round.
cauliflower	36.6	A vegetable with a compact whitish head.
cinnamon	44.3	A spice that comes in sticks, often used to flavor hot cider drinks.
colander	20.8	Utensil used to strain pasta.
dominoes	39.3	A game whose symbol is also the name of a popular pizza restaurant.
equestrian	31.1	A person who rides horses in competition.
escalator	38.8	Moving stairs often found in shopping malls.
exterminator	32.5	A person who sprays chemicals to get rid of bugs.
extinguisher	35.0	Used to put out fires.
fluorescent	22.1	The type of light used in this room, comes in long white tubes.
harmonica	38.8	A musical instrument, sometimes called a mouth organ.
limousine	38.2	A long car driven by a chauffeur.
magician	46.3	A person who pulls rabbits out of hats and makes things disappear.
numerator	27.7	The top number of a fraction.
odometer	33.9	A device for keeping track of the number of miles you drive.
orthodontist	29.3	Dentist who puts on braces, straightens teeth.
parentheses	43.1	A pair of marks that are used to set off words in a sentence.
pediatrician	33.3	A doctor whose patients are all children.
pimento	29.3	A green olive is often stuffed with this.
porcupine	44.5	A mammal that is covered with quills.
quintuplets	22.1	Five babies all born to the same mother on one day.

APPENDIX 1 (*continued*)

Word	Standard Frequency Index	Carrier phrase
rhinoceros	44.6	A large, gray, horned mammal found in Africa.
serrated	31.7	The notched edge of a knife, especially a steak knife.
spatula	38.6	A kitchen utensil used for turning food over.
specific	59.9	Your teacher says, "Don't be so general. Be ____."
statistic	37.8	Researcher is presenting the results with charts, tables and graphs. Together these are referred to as ____. On the back of baseball cards, the information about players, like runs batted in, is called the player's ____.
stethoscope	43.3	Instrument used by doctors to listen to your heart and lungs.
sympathy	49.5	When someone dies, you send their family a ____ card.
synonym	43.6	Two words that have a similar meaning.
tambourine	33.0	A drum-like instrument played by striking with the knuckles and shaking.
tentacles	43.7	The arms or legs on an octopus are called ____.
thermometer	50.5	Instrument used to measure temperature.
xylophone	34.2	A musical instrument played by hitting the wooden bars with small wooden hammers.

APPENDIX 2

Pseudoword Repetition Task

Pseudoword	Word derived from	Syllables	Length
1. nagmivigent	magnificent	4	short
2. mashiplorizated	polychlorinated	6	long
3. voshicle	follicle	3	short
4. aldipioscleronis	arteriosclerosis	7	long
5. tivilinasum	civilization	5	long
6. epleasic	embryonic	4	short
7. terskabacity	perspicacity	5	long
8. broxinal	proximal	3	short
9. pesagummodent	metacomponent	5	long
10. igricalture	agriculture	4	short
11. dobasetensily	somatosensory	6	long
12. fasgujer	vascular	3	short
13. paniminy	calamity	4	short
14. begiashrist	psychiatrist	4	short
15. hymerbetaporvetis	hypermetamorphosis	7	long
16. wropriodemnive	proprioceptive	5	long
17. aglizip	acronym	3	short
18. tigofarnicanisy	psychopharmacology	7	long
19. adnestaric	atmospheric	4	short
20. gonflidation	confligration	4	short
21. phetopedarichy	phenomenology	6	long
22. grishanthenum	chrysanthemum	4	short
23. cheadergym	leadership	3	short
24. bekalapasun	megalopolis	5	long
25. finachronism	anachronism	5	long
26. ivamodranspirakun	evapotranspiration	7	long

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NOTES

1. Spelling here refers to spontaneous spelling, as opposed to spelling from dictation. Because an oral model is available in spelling from dictation, the role of the quality of the lexical entry is reduced.
2. Initially, a public school that serves children from comparable socioeconomic circles as for the adult participants was selected. However, we were only able to obtain 11 students from that school. The remaining 14 students came from a public school serving a middle to upper class community.
3. For skilled readers, the range of Word Identification raw scores was limited to 52–57; Word Attack raw scores were restricted to ≥26.
4. For the less skilled adult readers, the range of raw scores was limited to 41–50; Word Attack raw scores were restricted to ≤22.
5. All participants in the study were Caucasian. During pilot testing, regional dialects were noted, which were taken into account when scoring the naming responses.
6. Participants who were currently on medication for either attention deficit disorder (ADD) or attention deficit disorder with hyperactivity (ADHD) were not disqualified.
7. Due to the difficulty of obtaining a sufficient number of adolescent participants for reading-age controls, scores above normal were accepted.
8. The Standard Frequency Index (SFI) is based on the total corpus. For example, an SFI of 20 represents a frequency per million of .01 (e.g., *colander*), whereas an SFI of 50 represents a word that is found in text 10 times per million words (e.g., *aluminum*).
9. Allowances were made for pronunciations that reflected regional dialect (e.g., for *spatula*, a pronunciation of "spatular" was scored as correct).
10. *Veterinarian* was retained for this spelling comparison because one of the goals of the study was to compare naming responses with spelling responses, and this item was misnamed by nearly everyone.
11. Recall that Block Design scores above average were allowed for the reading-age controls to recruitment difficulty.
12. We were concerned that correct scores on Time 2 that were not correct on Time 1 might have been the result of the participants seeking information regarding the words during the interval between sessions. Improved performance on Time 2 was particularly common for the adolescent reading-age controls, who were in contact with each other more than were the adult groups. Therefore, we elected not to use that pattern of responding (incorrect on Time 1, correct on Time 2) in the analyses as an example of inconsistency in responding.

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