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ABSTRACT

The Study of Adult Reading Acquisition (SARA) is a longitudinal research project designed to measure the development of reading subskills in adults enrolled in instructional programs. The study participants are all students enrolled in a variety of adult education sites and settings, including correctional institutions, community-based programs, adult basic education (ABE) classes, general educational development (GED) classes, public assistance job programs, and tutoring services. The study design serves as a model for using achievement tests in conjunction with cognitive assessments as part of a comprehensive assessment strategy. Included are a vocabulary test, propositional processing tests, a decoding test, a word recognition test, and a silent reading rate test. As in traditional assessment schemes, achievement tests are administered at intervals of instruction appropriate for observing change. In addition, cognitive assessments are given at more closely spaced intervals to monitor stability or change in underlying skills or to decide whether additional diagnostic measures would be helpful. This approach presents a new level of analysis that could help to promote understanding of the enigmatic acquisition processes of adults learning to read. (An appendix provides samples of parts of the assessments.) (Contains 79 references.) (Author/KC)

Cognitive Reading Assessment for Low Literate Adults: An Analytic Review and New Framework

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Table of Contents

Abstract

The Study of Adult Reading Acquisition (SARA) is a longitudinal research project designed to measure the development of reading subskills of adults enrolled in instructional programs. The study participants[1] are all students enrolled in a variety of adult education sites and settings including correctional institutions, community-based programs, adult basic education (ABE) classes, general educational development (GED) classes, public assistance job programs, and tutoring services. The study design serves as a model for using achievement tests in conjunction with cognitive assessments as part of a comprehensive assessment strategy.[2] As in traditional assessment schemes, achievement tests are administered at intervals of instruction appropriate for observing change. In addition, cognitive assessments are given at more closely spaced intervals to monitor stability or change in underlying skills or to decide whether additional diagnostic measures would be helpful.

Overview

The Study of Adult Reading Acquisition (SARA) is a longitudinal research project designed to measure the development of reading subskills of adults enrolled in instructional programs. The study participants[3] are all students enrolled in a variety of adult education sites and settings including correctional institutions, community-based programs, adult basic education (ABE) classes, general educational development (GED) classes, public assistance job programs, and tutoring services. The study design serves as a model for using achievement tests in conjunction with cognitive assessments as part of a comprehensive assessment strategy.[4] As in traditional assessment schemes, achievement tests are administered at intervals of instruction appropriate for observing change. In addition, cognitive assessments are given at more closely spaced intervals to monitor stability or change in underlying skills or to decide whether additional diagnostic measures would be helpful.

Participants were monitored over a six- to seven-month period while they were enrolled in instructional programs. During the course of the study, participants received a variety of tests over a number of sessions. Each participant received an initial battery of baseline tests, then a battery of repeated measures every five to seven weeks. Follow-up achievement and diagnostic tests were also administered. Participants were screened for vision and hearing problems and were interviewed about their reading and leisure habits and educational backgrounds. In this report, we discuss the theoretical rationale, development, and final versions of the SARA Test battery developed by the project team. We also report preliminary reliability coefficients on key SARA subtests.

I. Rationale for the construction of cognitive assessments

In a series of research projects designed to study reading skills in adult learners, we have repeatedly found that existing published achievement tests, although able to rank adults on a single reading ability scale, fail to capture the complexity of adult learners' literacy development and fail to provide instructors with diagnostic information sufficient for making instructional decisions (Sabatini, Venezky, & Bristow, 1995; Venezky, Bristow, & Sabatini, 1994; Venezky, Sabatini, Brooks, & Carino, in press). Although normed on adult populations, most published tests for adult learners are linked to elementary and secondary school developmental scales such as grade level. The practice of uncritically borrowing assessment and instructional techniques from the elementary and secondary systems continues to impede progress in adult assessment and instruction. Critical assumptions underlying their development and use must be reexamined when they are administered in an adult program context.

The assumptions that support the validity of published test series at elementary and secondary levels are not necessarily valid for adult learners as the following example illustrates. An eighth-grade student who has a history of scoring at or close to the normative mean on annual standardized reading tests from the same series can be assumed to have acquired a reasonable mastery of the reading subskills that that level of performance implies. For example, the second- and fourth-grade versions of a standardized basic skills test probably included more items for diagnosing deficiencies in decoding or word recognition ability than does the eighth grade version of that test series. By eighth grade, those items are dropped in favor of items more discriminating for the average eighth-grade student. The types of items chosen for the eighth-grade test represent a reasonable approximation of the skills that a low achieving eighth grader may need to focus learning and practice toward, given that other skill deficiencies would have been diagnosed earlier in the student's career.

The scale score an adult learner receives on a basic skills or functional literacy test of reading, however, is not necessarily based on a reliable, yet broad sampling of items that are developmentally appropriate for that adult. Most critically, one cannot assume that an adult scoring at an eighth-grade level or an analogous midrange scale level, has mastery of decoding, word recognition, logical thinking, or any other specific component of skilled, integrated reading at that level. There is no assessment history to draw inferences about skills, while there are a variety of strategies that the adult could have cobbled together to help him or her achieve this level of performance. This is a serious problem for adult educators who must adapt instruction to a wider range of student ability than elementary or secondary educators usually face, including many individuals with a history of special learning problems. This assessment approach does not allow one to discriminate between a learner with deficiencies in higher level skills versus one who is using a compensatory strategy by applying adequate higher level skills to compensate for deficiencies in basic cognitive processes (Stanovich, 1980). What is required are supplemental measures of cognitive processing skills fundamental to reading acquisition.

A further issue warranting the use of cognitive processing measures concerns the consolidation, maintenance, and retention of skill processes in adult learners. An elementary or secondary student is obliged to confront texts and instructional tasks on a daily basis for 180 days per year for about twelve years. Adult learners, however, have adult responsibilities that translate into far fewer opportunities to immerse themselves in print and instruction, including the necessity to disengage from the learning environment whenever family, economic, or other social responsibilities take priority. The lack of continuous practice and exposure to print may result in adults experiencing more difficulty in attaining or maintaining high subskill levels. Process measures may provide a better opportunity to track whether the fundamentals underlying skilled performance are stable, improving, or declining, in a fashion that the presumed linear growth curve of global achievement skills cannot.

II. Cognitive assessments: Measures of cognitive processing skills

The SARA Tests are referred to as "cognitive" assessments because they attempt to measure cognitive processing skills or components. The use of the terms *cognitive processing skills* or *cognitive processing components* is meant to convey "information processing skills that are usually not directly observable, but that can be verified and tested in the process of experimentation" (Torgesen, 1991, p. 1; see also Nichols, 1995; Snow, 1988; Snow & Lohman, 1989). The description of "cognitively diagnostic assessments" (CDA) provided by Nichols (1995, p. 576) also applies to the SARA Tests:

> The defining characteristic of CDA is that it makes *explicit* the substantive assumptions the test developer is using to construct test materials and assign scores. These substantive assumptions describe the processes and knowledge structures a performer in the test domain would use, how they develop, and how more competent performers differ from less competent performers. Often these substantive assumptions are embodied in psychological theories but may be represented less formally.

In this study, we have identified three basic cognitive processing components that are critical to integrated reading ability: phonological recoding or decoding, word recognition, and propositional processing. We have designed tests to assess the levels of these skills, their interrelationships, and their influence on integrated reading performance. In the following sections, we will attempt to make explicit the substantive assumptions used to construct the materials and assign scores to each test.

A general assumption underlying the development of cognitive assessments is that substantive theory can be used to construct assessments and that assessment results may be used to inform substantive theory as well, that is, their relationship is reciprocal. The CDA approach can be contrasted with the achievement test approach. In the latter, test designers attempt to sample from a universe of skills and knowledge in a domain of interest, but are largely uninterested in the mechanisms test takers use in responding to those items. In SARA Tests, emphasis has been given to understanding test performance in terms of models of the basic cognitive processes learners use to respond to test items.

Although SARA Tests were designed to target basic cognitive processes, that does not mean that each test measures one isolated, elemental cognitive skill, in the way that, for example, an intelligence test attempts to measure "auditory processing." The SARA Tests are pitched at a relatively more coarse level of specificity as befitting the complexity of developmental reading processes. Performance and rate scores for any SARA Test are a function of the participant's ability to coordinate and integrate several levels of elemental processes and strategies related to that component process. Further diagnostic testing may be necessary to assess more elemental processes. The tests are, however, considerably less global and more process oriented than the typical achievement test.

To illustrate, consider a word naming task and the subskills and strategies a participant uses to respond correctly to any particular item. When naming words correctly, the participant may encode the visual characteristics of the letters, use the sequence of letter codes to access directly its lexical code in long-term memory, then retrieve and output its pronunciation. Alternatively, the participant may translate the visual pattern of letters into phonological codes, and use these codes to access the lexical code through a search of the listening lexicon. It is also possible that a participant may use the phonological codes to directly articulate a pronunciation. Of course, the participant may also make guesses based on a few visual features of the word. Other descriptions of skill sequences that include finer grained subprocesses could be provided to fit other theoretical processing mechanisms and models. Correct responses help us determine how efficiently the word recognition component is operating overall, not necessarily the subskill sequence employed on any given item.

Both strategic control and fluent, automatic skill application are necessary to skilled reading (Bentin, 1992; Perfetti, 1985; Stanovich, 1990). All SARA Tests except the standardized test of reading comprehension are presented via computer and have both accuracy and response rate measures. In developing the tests, an attempt was made to construct items that were relatively easy to answer correctly though potentially revealing of individual differences in processing efficiency as measured by response rate. Thus, items that were answered correctly at a high rate in pilot studies by college students and other skilled adult readers were selected for use in the final versions of the tests. However, these items were not always as easy for the study participants. Consequently, both performance and rate scores contribute to the overall profile of an individual's skills. Differences in performance are assumed to indicate the degree or level of subskill ability. For example, a high score on the Decoding Test indicates strong decoding skills; a chance score indicates weak decoding skills and suggests the need for further analyses of the learner's strategic knowledge and control. Differences in response rate help us to understand the efficiency of the subskill. A reader may be able to decode accurately, but is so slow and inefficient that deploying the skill during reading may be a hindrance to increased comprehension until such time as decoding becomes more efficient.

Fluent, automatic cognitive processes only develop in the context of appropriate strategic knowledge and control. Instruction and targeted practice help the learner to develop habits that serve as scaffolds for skill development. However, strategic knowledge must be deployed to be of use to the reader. For example, learning the meaning of a set of common affixes and roots will help middle level readers to infer the meanings of new words in a passage as well as help them to refine their vocabulary knowledge, if they strategically deploy this knowledge during normal reading. The direct benefit of strategic control is not always immediately obvious to the skill it may help develop. For example, strategies that help the reader maintain comprehension even in relatively difficult text may motivate the reader to read more. The increased exposure to text can in turn lead to improved word recognition ability (Stanovich, West, & Cunningham, 1991).

In this study, we use item analysis and think-aloud protocols to explore learner's strategic choices and control. Strategic choices are based on interactions among individual characteristics, task and stimuli features, and levels of subskill ability. For example, a good decoder may rely more heavily on spelling patterns, while a poor decoder may rely more on his knowledge of sight words. For high frequency words, both might respond quickly and accurately (using different underlying subskills). However, these strategic differences may surface in error analysis of low frequency or multi-syllabic words. Words that sound similar to the target may be more representative of a decoding strategy, while words that are visually similar to the target may be more representative of a sight word-strategy. Learners may be aware or unaware of their own strategic choices. Think-aloud protocols help both the learner and the researcher to understand this strategic behavior.

In summary, we have argued for two levels of assessment to monitor adults' reading development. The first requires assessing achievement based on integrated reading performances and verbal ability at regular intervals during development. Traditional assessment approaches such as reading comprehension and vocabulary tests that rank learners against each other and against normative populations are analogs of this type of assessment. This approach has been institutionalized in elementary and secondary schools. However, because most adult students lack comprehensive assessment histories, a second level, consisting of tests of cognitive processing components has been proposed. We have targeted three such processing components: decoding, word recognition, and propositional processing. In addition, skilled reading requires both fluent, automatic skills and strategic control during normal reading and development. As such, we have designed assessments that measure both performance and efficiency of skill processes. In the next section, we describe the implementation of these new measures in the context of the SARA project design.

III. Implementing cognitive assessments in the SARA project design

In an instructional context, an instructor would want to have the flexibility to tailor the assessment strategy to specific student groups and instructional needs. However, in a longitudinal research context, the necessity of maintaining consistent, standardized approaches is paramount. For example, when we found it desirable to include follow-up diagnostic measures targeted toward a subset of students, we administered the new tests to all students for comparative purposes. An instructor would not likely adopt such a standardized strategy. Following is a brief overview of the SARA tests and assessment strategy as implemented in the study design.

Subjects participated in three general categories of tests: (a) baseline and follow-up achievement tests, (b) repeated, cognitive skill tests, and (c) diagnostic follow-up tests. The initial three baseline tests were a standardized test of reading comprehension (1), a vocabulary test of single words (2) , and a listening test of propositional processing (3). Approximately four months into the study (five to seven weeks after the third repeated test session), participants receive a follow-up achievement test battery consisting of (1) and (2) from the initial baseline tests, as well as additional diagnostic tests of phonological processes. Preliminary data analysis of the initial participant pool revealed a wide range from chance to highly proficient performance on the Decoding Test. Consequently, two additional diagnostic tests were designed and administered.

The different baseline and follow-up tests served several purposes. The Reading Comprehension subtest of the Wechsler Individual Achievement Tests (The Psychological Corporation, 1991) is the primary measure used for indicating subjects' comprehension ability relative to a normative population. A baseline indicator of reading ability is useful for making comparisons both within the subject sample as well as against normative populations. The other two measures were computer-based tests developed for this study. Although also baseline indicators, additional reasons for including these tests will be described in the following section. We would not expect to see progress in the short term on a comprehension test or in vocabulary ability. On the other hand, we would expect to observe changes in performance after an appropriate duration of instruction. Thus, these tests were given again, as a post-test, after a four-month interval in this study.

The repeated, cognitive processing tests were developed to measure reading subskills necessary to skilled, integrated reading ability. The component subskills targeted were (a) phonological recoding or decoding, (b) word recognition, and (c) propositional processing. In addition, a silent reading rate measure was also collected during each repeated test session. Though not a component skill, the silent reading results can be used to assess how participants are integrating developing component subskills into real-time reading performance, as well as how they are strategically deploying higher level comprehension processes. Three repeated test sessions (every five to seven weeks) were conducted prior to the follow-up tests, then two more following them. In the following section, we describe the design of each of the SARA Tests.

(Most of these tests are actually small batteries of related subtests as will become clear presently.)

IV. Design of SARA Tests and test paradigms

A. Vocabulary Test

Three test paradigms were used to assess vocabulary levels and knowledge, thus, the Vocabulary Test consisted of three subtests. In the first subtest, learners rated how well they knew the meanings of words on a scale from one to four. The second subtest consisted of a multiple-choice, synonym test based on a subset of the same words. In the third subtest, learners were shown words they identified as well known in the first subtest, but answered incorrectly in the follow-up multiple-choice test. They were asked to pronounce each word, provide a definition, and use the word in a sentence.

Carver (1990) has argued that vocabulary tests are reliable correlates of "reading accuracy level," that is, the most difficult level of material that an individual can accurately comprehend when the material is read at the individual's normal reading rate. This conception is congruent with the correlational models of standardized testing in which reading ability is a composite of a reading comprehension (usually timed) and a vocabulary test score. The relative stability of an individual's vocabulary level over the short term makes it a strong candidate measure for an initial estimate of the learner's verbal ability level. We interpret the learner's baseline score on the synonym test as an integrated, achievement indicator of the operating power (versus processing efficiency) of the individual's reading process. On the other hand, the performance on the scaling and think-aloud tasks are more oriented to issues of processing and strategic control as will be discussed presently.

One could also argue for a vocabulary test that measures word recognition and knowledge in sentence and passage contexts. This is also an interesting and valuable supplemental indicator of reading vocabulary. However, Perfetti (1985) has argued convincingly that *decontextualization* is one of the key obstacles in understanding print versus speech. The "asocial, one-way communication of print" (p. 7) requires of the reader the verbal ability to deal with meanings that are solely "in sentences." The organization and richness of an individual's isolated, decontextualized word meanings is likely to be a critical indicator of his or her efficiency and fluency in overcoming the decontextualization obstacle in text comprehension.

Issues concerning how to define and measure vocabulary size and rate of growth have yet to be resolved. Researchers and educators alike have always agreed that vocabulary knowledge is an important component of reading ability, but a lack of theoretical consensus on key issues such as these complicates an understanding of vocabulary's relationship to the reading process. Beck and McKeown (1991) attribute a resurgence in vocabulary research to the larger role that inference and organization of information are given in information processing models of reading and language comprehension. They see vocabulary acquisition as a complex process that involves establishing relationships between concepts, organization of concepts, and expansion and refinement of knowledge about words. With similar concerns, Anderson and Nagy (1991) review and critique theories of word meanings, semantic and lexical organization, and sentence meanings. They argue for a model in which semantic features serve as lexical organizers of word meanings, rather than word meanings being embodied in those features. They then extend the general model to account for sentence comprehension. Daneman (1988) also argues for a direct overlap between inferencing in comprehension processes and inferring word meanings from context. However, despite the authors success in clarifying some vocabulary-specific issues, more work remains in understanding the relationship of vocabulary to the reading process.

Two goals motivated the development of the SARA Vocabulary Test. The first goal was to develop a self-assessment technique for indicating the size of an individual's reading vocabulary, relatively independent of the quality of his or her word meaning knowledge. The second goal was to begin to explore the quality of an individual's word meaning knowledge. The rationale for a self-assessment technique was to provide learners with an indicator of their working word knowledge relative to some external standard such as frequency of words in print or academic vocabulary terms such as might be used on a standardized test. Key to the validity and reliability of such a technique is that learners can accurately and honestly judge how well they know a word that they see presented. Since other researchers have had mixed results using such self-assessment techniques (Read & Nation, 1986), the multiple-choice, synonym test, in addition to its use as a baseline indicator, was included as a cross-check both for us to establish validity and for learners to calibrate their judgments.

However, correctly answering a synonym test item may be a more stringent test of vocabulary knowledge than recognizing the meaning of a word in a reading context. As a partial hedge against the possibility that a learner did know the meaning of a word as indicated by his or her scaling judgment, but found the multiple-choice item too difficult, we gave the learner the opportunity to see the word again, to pronounce it, to tell us what it means, and to use it in a sentence. This task also helped us accomplish our second goal of probing the quality of learners' word meaning knowledge. In early piloting of the task with adult learners, we found a variety of response types. A student might respond that he or she knew a word well because he or she could accurately pronounce the word. The student might mis-identify one word as another. The student might recognize a word's roots and prefixes from other words, but not know the meaning of the word presented. The student might express confidence in a totally inaccurate meaning and so forth.[5] Consequently, we consider this task to be a potentially rich source of insights into learners' metacognitive and strategic thinking.

In summary, the multiple-choice, synonym subtest can serve as a baseline indicator, while the other subtests provide information for learner reflection and more in-depth diagnostic uses by the instructor. Because vocabulary growth is gradual, it would not be productive to repeat the synonym subtest too frequently. The self-scaling subtest, on the other hand, is designed for repeated use by a learner, with changing items suited to the learner's instructional program. However, in this study design, the three-part SARA Test was administered only as a baseline and follow-up measure.

B. Propositional Processing Tests

Propositional processing was measured using a sentence verification or picture-sentence comparison paradigm. The Propositional Processing Test was developed to measure targeted sentence-level processes. The task is designed to elicit propositional and sentence encoding strategies, which are considered basic underlying processes of reading comprehension in general. In the typical sentence verification task, the subject is shown a picture such as

=>

+

and then reads a sentence like "The plus is over the arrow," or "The plus is not over the arrow." The sentence can either be affirmatively or negatively worded and agree (true) or disagree (false) with the picture.

The typical verification study has participants respond to a small set of stimuli (e.g., plus, arrow, star, dollar sign) and a small set of conditions repeated many times. The measure of interest is the accumulation of reaction time differences over the repeated presentations. The repetition allows the participant to settle into a particular strategy. Since we were more interested in learners' general encoding strategies for natural language, we developed items that varied both the subjects of the sentences (e.g., triangle, square, rooster, house) as well as the relationships between pairs of these items (over, under, in, out , bigger, smaller).

The sentence-picture comparison paradigm has been used to study propositional encoding, syntactic analysis, verification and negation processes, and logical reasoning (Carpenter & Just, 1975; Clark & Chase, 1972; Cohen & Faulkner, 1983; Kim, 1985; MacLeod, Hunt, & Matthew, 1978). Efficient encoding of propositions from verbal or pictorial sources, processing of syntactic complexity, manipulation and integration of propositions in working memory, the ability to make logical comparisons such as verification and negation, and the executive control of operations are all information-processing building blocks that are in the repertoire of skilled readers. This task requires the use of these skills in reading and listening contexts.

Carpenter and Just (1975) see the purpose of explanatory models of the sentence verification task as related to the understanding of language comprehension within an information processing framework.

> The model deals with the internal representation of a sentence in short-term memory and the operations applied to that representation in order to verify it. The verification process will be examined in terms of elementary mental operations such as the comparison of two elements... and control processes that govern the sequence in which operations are performed.... (p. 45)

Similarly, Clark and Chase (1972) cite the integral part that the process of "sentence-picture comparison" has in many common psychological tasks and its fundamental relation to many psycholinguistic studies. Clark and Chase's model is representative of a class of information processing models used to explain verification tasks (Carpenter & Just, 1975; Clark & Chase, 1972; Cohen & Faulkner, 1983; Glushko & Cooper, 1978; Hunt, 1980; Kim, 1985; McLeod, Hunt, & Matthew, 1978). Clark and Chase propose an explanatory model in which pictures and sentences must be represented in the same mental format that encodes meaningful interpretations of sentences and pictures rather than perceptual properties. It is assumed further that the interpretations are coded as elementary propositions.

Clark and Chase's processing model for a verification task in which the picture precedes the sentence is as follows. At stage one the picture is encoded as a single proposition in a single form. For the example illustrated above, the form would always be "arrow is above plus." (They cite linguistic considerations for why "above" is easier to encode than "below.") At stage two, the sentence is encoded. Positive sentences are encoded as one proposition, while negative sentences are encoded as two propositions (see Table below).

Sentence	First proposition	Second proposition
The arrow is above the plus.	(arrow is above plus)	--
The plus is below the arrow.	(plus is below arrow)	--
The arrow is not above the plus.	(arrow is above plus)	(it is false)
The plus is not below the arrow.	(plus is below arrow)	(it is false)

At stage three, several comparisons of the propositions and transformations must be performed before a final verification decision is made. First, the subjects of the picture (arrow or plus) and sentence propositions are compared. If they do not match (A="arrow is above plus" versus B="plus is above arrow"), then the proposition is transformed (B becomes "arrow is below plus"). If the prepositional relationships do not match (A="arrow is above plus" versus B="arrow is below plus"), then change the truth index (B becomes "plus is above arrow" and "it is false"). Finally, the truth values of the matching embedded sentences are compared. The processing time for each of these stages is assumed to be additive.

The response latencies their model predicts were supported in their research; however, others have found support for alternative processing models. In general, Carpenter and Just (1975) summarize the two main empirical results persistently found in most sentence verification studies of this type as follows:

> First, there was an interaction between the kind of sentence (affirmative or negative) and the type of response. True affirmatives were verified faster than false affirmatives, but false negatives were verified faster than true negatives. The second main result was that negative sentences took longer to verify. Both of these results are common to many other studies.... (p. 46)

The sentence verification paradigm has also been used to study other aspects of propositional processing especially processing resource demands on working memory. "Although people find it exceedingly easy to compare information from linguistic and pictorial sources, e.g., to decide whether a sentence is true or false of a picture, little is known about how they do it" (Clark & Chase, 1972, p. 472). This opening statement of Clark and Chase's 1972 paper was based on the relative ease with which college students perform verification paradigm tasks. However, many researchers have found that negation judgments take considerably more processing time to make correctly, even for the college students. Kim (1985) found evidence for consistent patterns of development of the concept of negation for Korean- and English-speaking children.

Hunt (1980) theorized that flexibility of strategy choice may interact with structural differences in basic cognitive processes (such as working memory) and attentional allocation to determine individual differences in performance and response latencies in verification tasks. Cohen and Faulkner (1983) found some evidence to support this claim. They found that old (M=67) and young (M=23) subjects were similar in their choice of strategies; however, they were different in their execution. Both older and younger subjects who chose the more efficient rule-based strategies did not differ significantly in their response latencies. However, when older subjects chose the less efficient strategies that make heavy demands on processing resources, they were less efficient than their younger counterparts who employed the same demanding strategy.

The Propositional Processing Tests in this study include both a listening and reading version. The listening version is administered as a baseline measure, the reading version is used as a repeated test. In interpreting the results of the reading version of this task, we were concerned that some low level readers might have problems with the initial encoding of the visually presented sentence, while others would have problems with the complex set of propositional transformations necessary to reach a decision. By introducing a listening version, we could compare the different strategic possibilities that result from different presentation modalities. In the listening condition, the student must store in working memory the sentence spoken and execute appropriate propositional transformations. In the sentence condition, students have the opportunity to review the sentence as many times as they wish until they reach a decision.

In summary, the Propositional Processing Tests provide a number of opportunities for examining the efficiency of individual's propositional processing as a function of strategic preferences and resource allocation. For example, by analyzing the ratios of performance and response rate for each of the four item types (i.e., affirmative-true, negative-false, etc.), we may be able to infer strategic choices and the efficiency of their application.

C. Decoding Test

Decoding was measured using a forced-choice, pseudoword comparison test paradigm. In the Decoding Test, the learner must decide which of two made up words sounds like a real English word. One word of each item pair is a pseudohomophone (e.g., chese), while the alternative is a pseudoword (e.g., blaff). The task requires a minimum of two steps. First, the student must recode the spelling patterns into a phonological or speech code. This may include vocalizing or subvocalizing a pronunciation. Next, the student must compare the phonological representation to entries for English words in the listening lexicon. If a match is found, then the search is over. If no match is found, then the student may try legal, alternative recodings based on his or her knowledge of English spelling patterns. The task eliminates the use of sentence or passage context, meaning, or morphology as word recognition strategies, hence, the use of a phonological recoding or decoding strategy is the only viable alternative available.

Phonological processes of language include all cognitive operations that perceive, encode, recode, transform, and output phonological codes, that is, speech-based codes. The listening lexicon, for example, is presumed to be constructed from phonological codes that index the semantic and syntactic meanings of words. Decoding, phonological decoding, and phonological recoding are among the various terms used to describe the process of applying letter-sound relations to transform printed words into phonological codes or pronunciations. Some authors use these terms interchangeably, others use them to imply different underlying processes and assumptions (Share, 1995). Ehri (1991), for example, defines phonological decoding as the transformation of the "spelling of words into pronunciations via the application of grapheme-phoneme rules and then searching the lexicon of spoken words to find a meaningful word that matches the pronunciation just generated" (p. 385). This definition comes very close to describing the operations performed by a student taking the SARA Decoding Test.

A substantive proportion of research supports the view that phonological decoding is a skill necessary for the development of word recognition (Vellutino & Scanlon, 1991; see also edited volumes by Brady & Shankweiler, 1991 and Templeton & Bear, 1992). According to Bentin (1992), "the ability to decipher phonology from writing is a prerequisite for reading and understanding written words at the first encounter, and needs to be mastered before efficient reading can occur" (p. 204). Nonetheless, phonological decoding is only one of the possible ways to read words. Other ways of reading words are by analogizing to known words, by memorizing the orthographic structure of a word, and by contextual guessing. Ehri (1991, 1995) reasons that phonological decoding provides the reader with the most reliable means for verifying that unfamiliar written words are accurately recognized. It also enables readers to read sight words more efficiently.

The evidence for the importance of phonological processes to reading, however, is even more widespread than the functional value to decoding suggests. For example, evidence from cognitive studies suggests that phonological codes of visually presented stimuli that can be named (e.g., pictures of objects, colors, numbers) are used for short-term memory tasks after the age of about five even by deaf students (Conrad, 1972; Hanson, 1991). Studies of reading disabilities repeatedly show deficits in phonological processes (Lundberg, 1989; Olson, Wise, Conners, & Rack, 1989; Torgesen, 1991), though a smaller proportion may experience visual, orthographic, or combined processing problems (Willows, Kruk, & Corcos, 1993). Phonological processing problems can affect reading in at least two ways. Inefficiency of encoding and retrieval processes may reduce verbal working memory, which in turn constrain both listening and reading comprehension levels (Mattingly, 1991; Pennington, Van Orden, Kirson, & Haith, 1991). Or, individual differences in phonological abilities can impede the development of fluent decoding abilities, which in turn diminish the efficiency of word recognition processes. The former is partially assessed by the SARA Propositional Processing Tests. The latter is more directly assessed in the Decoding Test.

Phonological decoding is preceded developmentally by phonological awareness.[6] Phonological awareness is the metalinguistic ability to manipulate phonological elements and has been repeatedly found to be a predictor of future reading ability in pre-school and elementary age children (Abouzeid, 1992; Bentin, 1992; Ehri, Wilce, & Taylor, 1988; Liberman, 1989; Lundberg, 1989; Maclean, Bryant, & Bradley, 1988; Vellutino & Scanlon, 1988). Studies have shown that infants have the ability to distinguish between words on the basis of single phonemes (Eimas, 1975; Eimas, Miller, & Jusczyk, 1987). Yet, many other studies have also shown that even at the age of four children are unable to isolate the first phoneme of a word or to say how a word ends. According to Bentin (1992), children have phonological awareness, but until they learn to read the written alphabet, this "early phonological awareness" only helps them to manipulate the rimes and onsets of the syllables of spoken words. It is with the "alphabetic principle" that the "phonemic awareness" develops and so does the ability to phonologically decode. Vellutino and Scanlon (1988) suggest that "a child's ability in phonemic segmentation and phonetic decoding may set upper limits on the child's ability to learn to identify printed words" (p. 113).

Because many of the students in the SARA study performed at chance levels on the forced-choice paradigm of the original decoding task, it was deemed necessary to design measures that were more revealing of processing strategies for individual words. This led to the development of two follow-up diagnostic tests, administered in the final test session. The first test was a think-aloud version of the Decoding Test consisting of a subset of 20 item pairs from the Decoding Test. Participants were asked to pronounce aloud each pair of words, then talk out loud as they decided which one sounded more like a real English word. The second test used a lexical decision paradigm. It consisted of 40 single word items, repeated in three blocks. The words were also derived from the same list used in the Decoding Test. Students were asked to make a yes or no decision as to whether each word sounded like a real English word.

In summary, the empirical evidence supporting the centrality of phonological processes to reading acquisition is beyond question. The precise nature of the relationship of phonological processes to word learning, recognition, and other reading processes is, however, still to be explored. Research is also ongoing to determine what roles decoding plays in normal adult skilled reading, especially in relationship to conceptions of working memory and other language processes (Carello, Turvey, & Lukatela, 1992; Gough & Walsh, 1991; Paap, Noel, & Johansen, 1992). However, the overwhelming majority of studies suggest a role for decoding skill both in normal and disabled development. The SARA Decoding Test provides an opportunity to assess the performance and efficiency of students' decoding skills in a paired-word context paradigm, with an emphasis on common, single-syllable orthographic spelling patterns. The follow-up diagnostic measures provided additional information regarding individual word decoding strategies.

D. Word Recognition

Visual word recognition levels were measured using a word naming test paradigm. The Naming Test consisted of a sequence of three naming subtests: words, numbers, and pictures. Word recognition ability is inferred from a measure of word naming speed and accuracy. The word lists consist of equal numbers of one, two, and three syllable words (non-proper nouns, verbs, and adjectives only) randomly selected from five frequency bands of Kucera and Francis

(1967) word counts. The main function of the number naming task is to establish a baseline naming rate of an overlearned, non-orthographic, visual symbol system. Thus, differences in lexical access and articulation independent of visual word recognition can be considered in analyses. Picture naming rates are a more complex measure of lexical access efficiency than number naming, since naming a picture presumes accessing its semantic category prior to accessing its phonological representation in the verbal lexicon and pronouncing it. It is an empirical fact that skilled readers can name high frequency words faster than naming objects depicted in pictures.

Rapid word recognition is essential to skilled reading. The ability to read words rapidly is important to text comprehension because actively applying cognitive effort to recognizing a word wastes resources under the assumptions of a limited capacity processing model. These resources are then no longer available for the execution of higher level strategic processes (Perfetti, 1985). Word recognition and comprehension are widely considered the two fundamental processing components of reading, with the acquisition of skilled word recognition ability considered as the primary priority of beginning readers (Gough & Walsh, 1991; Hoover & Tunmer, 1993; McCormick, 1994; Perfetti, 1985; Siegal, 1993). Not only is word recognition ability correlated with reading ability in adults, but it is also an independent predictor (Stanovich, 1991). Perfetti (1986) and Stanovich (1990, 1991) have suggested that word recognition ability deserves the status of an acquired cognitive module (Fodor, 1983), that is, a data-driven, impenetrable, and automatic cognitive processing component. Visual word recognition has also been one of the most studied domains of cognitive psychologists in recent years (Besner & Humphreys, 1991; Wolf, 1991). Despite this activity, debate continues regarding the structure and sequence of cognitive processes of word recognition. Current theories are unable to explain the complex, contradictory experimental results, though a variety of pre- and post-lexical access routes built from serial, parallel, and network information processing models have been proposed (see Frost & Katz, 1992 for review of theories).

Rapid and accurate word recognition is, nevertheless, a well known accomplishment of skilled reading. Cattell (1906) is credited for first observing the counterintuitive fact that readers could recognize whole words as quickly as they can recognize a single letter and can name some whole words faster than letters (cited in Ehri, 1991). Eye movement research has confirmed the rapidity of word recognition rates, as well as settling another historically contentious issue by confirming that nearly every word is fixated during normal reading (Just & Carpenter, 1987; Rayner & Duffy, 1988). Skilled readers neither perceive larger chunks of words nor skip over several words per fixation. The acquisition and developmental models and processes that culminate in these cognitive achievements are as vigorously discussed and debated as the models of skilled word recognition performance.

Ehri (1991) describes five ways to read words: decoding, analogizing to known words, detecting and pronouncing orthographic patterns, guessing from context, and by sight or direct lexical access. The first three are methods for reading unfamiliar words or nonwords; they do not necessitate lexical access, at least not directly. The Decoding Test is a measure of the development and fluency of these decoding aspects of word recognition ability. Guessing from context cannot account for the rapid, automatized word recognition performance of skilled readers and will not be discussed further.

Direct lexical access via sight word recognition, as conceived here, suggests prior exposure to the word in print resulting in a strengthening of the lexical access route, whatever the nature of that route, between the visual representation and the lexical entry of the word. Ehri (1991) describes behaviors that indicate sight-word reading:

- when words are read as whole units without pauses between phonemes and syllables;
- when words are read more rapidly than nonwords with similar spellings;
- when correct spellings can be distinguished from homophonous spellings; and
- when irregularly spelled words are pronounced correctly rather than phonetically.

The first of these behaviors is measured in the word naming task in this study.

One consistent empirical result is the correlation between the frequency of words in print as measured by counts such as Kucera and Francis (1967) and sight word recognition in developing readers. That is, familiar words are recognized more rapidly and accurately than unfamiliar words and the frequency of words in print is a good approximation of familiarity for most skilled readers. As readers become more experienced, the size of their sight word vocabulary increases. For example, in a sight word reading test of 50 words graduated in frequency from high to low, Adams and Huggens (1985) found three phases of responses reflecting a shift from reading familiar sight words to unfamiliar words: fast and accurate reading, hesitant but accurate reading, and incorrect identifications. Consequently, we expect to see a relationship between the speed and accuracy of readers in the study when plotted against the frequency of the words in the test list, as well as individual differences between readers in their average recognition rate. Because voice onset time triggers the computer to erase the presented stimuli, a hesitant, but accurate recoding strategy could only be used if the entire pronunciation were produced prior to an attempt at articulation. Consequently, online attempts to sound out words produce errors, while successful silent rehearsal will produce long reaction times. Error analyses can be used, in part, to infer these strategic choices.

In summary, whether or not skilled, fluent, automatic word recognition ability necessitates high levels of decoding ability, the behavior associated with high levels of word recognition is the rapid naming of words gradated by their frequency of occurrence in print. The Naming Test measures word naming rate in relation to the related, but distinct processes required for naming pictures and numbers. Although rapid, fluent decoding (under the assumption that no lexical entry exists) could be used as a strategy, the emphasis in the word naming task is on rapid access to the stored lexical entries of the most frequent 10,000 words in print, regardless of access route.

E. Silent Reading Rate

The paradigms used to measure silent reading rates were online presentation of texts in a paragraph-by-paragraph and sentence-by-sentence mode. A primary goal of the silent reading test was to maintain as natural a reading context as possible for the subjects while still collecting as fine-grained rate data as possible. Although other researchers have argued for the naturalness of various presentation techniques including word-by-word presentation (see Kieras & Just, 1984), we were concerned that adult low level readers might not be comparable to the populations that are most often represented in the research literature. For this reason, we presented short passages (150 to 300 words) paragraph-by-paragraph, then in subsequent sessions sentence-by-sentence. This methodology has proven to be relatively natural for our adult readers, given that for many of our participants, reading of continuous text is never a wholly natural act.

Reading rate has been of interest since the beginning of the century (e.g., Huey, 1908). It had been included as a measure on the National Assessment of Educational Progress (NAEP, 1972) before being dropped in the mid-1970s. Throughout, however, reading rate has been a difficult measure to interpret, partly because of large individual differences in reading rate found even among skilled, college level readers. Furthermore, individual rates are highly sensitive to task and text variables. Finally, correlations with reading comprehension are only moderate, reflecting, in part, a speed versus accuracy trade off that interacts with individual differences in ability and reading purpose.

In spite of the measurement difficulties, reading rate is often considered along with comprehension accuracy in measuring reading ability. Several researchers have suggested defining effective reading as the product of comprehension and rate (Carver, 1990; Jackson & McClelland, 1975; Perfetti, 1985). However, it is more difficult to quantify this relationship than this simple equation suggests. One compromise has been to measure one dimension accurately, at the same time setting a minimum threshold for the other. In most standardized tests, this is accomplished by setting a time limit. Thus, comprehension ability is the number of items answered correctly given an upper bound of time available. The efficiency of individuals who finish more quickly is not measured. Alternatively, one can measure rate accurately and hold individuals to some minimal comprehension requirement such as recalling the gist of a passage.

Reading rate can be measured for oral or silent reading. Silent reading rates are generally more rapid than oral rates for the same individual. Although more revealing of word and phrasal miscues, oral reading is a practice usually confined to classroom settings and recitals. Most skilled readers read silently, at a rate that is typical, natural, or normal for themselves. Carver (1990) labels this process "rauding" to signify that the reader's purpose is primarily to comprehend the text, not scanning it for information (a more rapid rate) nor attempting to memorize its content (a slower rate). For example, college level readers read silently at a rate of about 250 to 300 words per minute (wpm) with materials that are at or below their reading level, though Perfetti (1985) reports that individual differences ranging from 150 to 400 wpm are not uncommon.

In general, text, task, and individual variables affect reading rate. Texts that are difficult relative to the reader's general reading level result in a decrease in rate. Many readers and especially those learning to read, subvocalize or read aloud when a text is relatively difficult. With especially difficult texts, even skilled readers have been found to subvocalize. However, when the text is easy relative to the reader's reading level, then differences in text difficulty do not influence the rauding rate. That is, skilled readers are likely to read a fourth, sixth or eighth grade text at about their typical rauding rate. Task variables, on the other hand, almost always influence rate. Tasks such as skimming or scanning for information can increase rate, while tasks such as learning or memorizing to answer questions can decrease rate. Background knowledge and reader interest also affect rate. More background knowledge about a topic tends to facilitate more rapid reading, while greater reader interest often results in a slower, more deliberate rate. When one also considers how metacognitive activities such as comprehension monitoring and self-correction or executive control of strategies including figuring out novel words from context or previewing upcoming text might influence rate, one understands why Carver (1990) thinks reading rate is treated as a "nuisance" that many other researchers simply avoid.

For some researchers, however, this fine-grained interaction between text, task, and reader is an opportunity to learn about the reading process. Techniques for studying reading rate include eye-fixations (e.g., Just & Carpenter, 1980, 1984, 1987; Rayner & Carroll, 1984); presenting text on a screen at a fixed rate (see Potter, 1984); or having the subject control the rate of presentation of each word (Aaronson & Ferres, 1984; Mitchell, 1984), or sentence (Graesser & Riha, 1984; Haberlandt, 1984). The value of these techniques derives from the presumption that variations in reading rate at the word and sentence level reveal cognitive subprocesses. By manipulating text and task variables at the word, sentence, and passage level, researchers can make inferences about the underlying processes. By looking at individual differences, researchers can make inferences about different developmental and strategic responses to text and task variables.

Eye fixation research has revealed that the average, skilled reader fixates nearly every word in a text with an average fixation of about 250 msec, but with large variations across words. Word-by-word variations in fixation duration are believed to indicate differences in amount of cognitive processing by the individual. Rayner and Carroll (1984) distinguish two kinds of processing models based originally on eye-fixation research: the cognitive lag hypothesis versus process monitoring hypothesis. "The cognitive lag hypothesis refers to the position that higher level processing cannot keep up with the visual intake of information...the processing monitoring hypothesis, suggests that fixation duration directly reflects at least some higher level processing on the word being fixated" (p. 132). The cognitive lag hypothesis implies memory buffers containing information taken in but not fully processed.

Rayner and Carroll (1984) describe Just and Carpenter's (1980, 1984, 1987) eye-mind assumption and immediacy assumption as an extreme version of the process monitoring hypothesis. In Just and Carpenter's model, during each fixation the average reader performs many relatively distinct levels of processing including word recognition, syntactic and semantic analysis, propositional encoding, and integration into a text representation. Thus, during each fixation the average reader immediately encodes the word, accesses its meaning, determines its syntactic and semantic roles, and encodes it into a proposition before the next fixation. If the fixation falls on the last word in a proposition, the reader immediately integrates the proposition into a more general text representation before proceeding to the next word. Other integrative operations are performed at the end of sentences and paragraphs. Levels of processing are only postponed when more information is necessary. Thus, eye fixations are a direct window on the cognitive operations of the mind, hence, the eye-mind assumption. Rayner and Carroll (1984) favor a position between the two hypotheses, suggesting that fixation duration accurately reflects lexical access of a particular word, but certain higher order processes lag behind fixation.

Researchers using sentence level reading times (Graesser & Riha, 1984; Graesser, Haberlandt, & Koizumi, 1987; Haberlandt, 1984; Yekovich & Walker, 1987) also assume that total reading time reflects underlying cognitive processes. They analyze intra-sentence variables (e.g., word length and frequency, total words, propositional density) across sentence variables (e.g., anaphoric references), passage level variables (e.g., sentence sequence, story grammar, passage coherence), task (retell the gist, remember as much as you can, or answer comprehension questions), and background knowledge (e.g., schemata/scripts). Their results support the value of using silent reading techniques for exploring both lower and higher level processes that occur during natural reading.

In summary, we have used the online presentation of texts of moderate difficulty to monitor participants reading rate. The reading rate research highlights a general problem in the development of silent reading tests, namely., how to equate reading passages across subjects and across repeated sessions. No fully satisfactory solution has yet been developed for doing this. However, the techniques for analyzing differences in processing rates across sentences can be used to make comparisons across a group of developing readers, as well as inferences regarding the influence of fundamental cognitive processes on integrated reading ability.

V. Conclusions and future directions

The cognitive assessments and test paradigms described in this report are derived from a rich literature of developmental and psychological research and theory. Nonetheless, the precise interrelations and interactions of the processes in skilled reading and across a developmental trajectory are still largely unspecified. Also, the relationship of psychological research to instructional models is a complex one. Furthermore, the application of the empirical conclusions drawn from these literatures to a population of adult learners is a relatively new venture. Following are some issues that the current research approach either currently or in the future hopes to address.

One issue that the current research begins to address is what is a reasonable interval for observing change in a component process skill due to instruction or guided practice. Is the six-week interval arbitrarily chosen in this study too short or too long a time? A second issue is at what levels do improvements in component skills begin to show an influence on reading achievement. Several corollary hypotheses are tenable. Perhaps component skills are only necessary, but not sufficient, to improvement in higher level skills. Perhaps component skills decline in the absence of continued practice and improvement in higher level skills. Perhaps component skills can be deployed through various strategic choices to support or thwart skilled reading. One final issue is the influence of aging on the acquisition and fluency of component skills and reading development in general. Perhaps reading acquisition after certain ages becomes a race against time, pitting the construction of new knowledge and fluent skill processes against the slow decline in cognitive processing efficiency across adulthood. Many more studies of adult learners are necessary to make even tentative guesses about these issues.

In conclusion, adult educators and researchers have been chagrined by the persistent finding that adult learners show insignificant progress on achievement measures (e.g., Venezky, Bristow, & Sabatini, 1994), a result often belied by the anecdotal observations of their instructors, families, and the learners themselves. The current approach presents a new level of analysis that could help to understand the enigmatic acquisition processes of adults learning to read.

Endnotes

[1] The terms "participant," "student," and "learner" are used interchangeably The term "test" is used to refer to a collection of tasks, subtasks, or subtests. The latter terms are used interchangeably. When capitalized, "Test" stands for a particular test name, such as the SARA Vocabulary Test, which consists of three subtests, subtasks, or tasks.

[2] Assessments can be used either to provide the student or instructor with information for decision-making or for program evaluation or monitoring. The integration of SARA assessments for classroom or program decision-making awaits future research opportunities. Also, a comprehensive strategy would include a third component—instruction-based assessments. Instruction-based assessments help coordinate the day-to-day instructional activities to student goals; see Venezky & Sabatini, 1995.

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[5] It has been pointed out by a reviewer that if the learner read the self-scaled words aloud before scaling them we would know whether they recognized them beforehand. Then, words mis-identified could be read aloud and only then rated by the learner. This seems like a helpful suggestion, especially for an interactive process between instructor and learner. In fact, a feature of the original computer program allows students to ask for a word to be pronounced aloud, but it was disabled for the study. We hope to incorporate such improvements to the research in the future.

[6] In retrospect, it would have been interesting to include a measure of phoneme awareness or phonemic segmentation skill in the study. Preliminary analysis has led us to develop a number of additional diagnostic measures related to phonological and orthographic processing. However,

given the suggestive findings of Byrne & Ledez (1983) in low literate adults, a phoneme segmentation measure would have been useful, if only to confirm the validity of the other phonological tasks. A question remains whether the various existing tests are valid or reliable for adult learners. Again, thanks to a reviewer for pointing this out.

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Appendix

Table A-1

List of words used in self-evaluation survey

principal	civilization
invite	supposition
confederation	tranquillity
vibrating	transparent
unanimous	rush
heinous	trip
longevity	immerse
extension	predatory
method	customary
rancid	exterior
normal	humorous
fraudulent	placid
started	dialogue
tall	various
abundant	foolish
eliminate	bright
succinct	touch
engrossed	abolish
violent	subtlety
hypothesis	schism
symmetrically	sound
smooth	factory
terminate	oppose
acquire	everyone
avenue	desire

Table A-2

Lists of sentences from Propositional Processing Test.

Demonstration and Practice Trials in Fixed Random Order

Sentence	True/False
The arrow is above the plus.	t
The plus is above the arrow.	f
The arrow is not above the plus.	t
The plus is not above the arrow.	f
The arrow is not above the plus.	f
The plus is below the arrow.	t
The plus is above the arrow.	f
The arrow is not below the plus.	f
The arrow is below the plus.	t
The arrow is above the plus.	f
The plus is not above the arrow.	t
The plus is not below the arrow.	f
The arrow is below the plus.	f
The plus is not below the arrow.	t
The arrow is not below the plus.	t
The plus is above the arrow.	t
The plus is below the arrow.	f

Test Trials Sentence Pairs

1 The square is in the triangle.
2 The square is not in the triangle.

3 A dollar sign is under a star.
4 A dollar sign is not under a star.

5 The star is between the two circles.
6 The star is not between the two circles.

7 The square is taller than the circle.
8 The square is not taller than the circle.

9 Both keys are inside a circle.
10 Both keys are not inside a circle.

11 A house is under a car.
12 No house is under a car.

13 The letter A is as big as the letter B.
14 The letter A is not as big as the letter B.

15 The rooster is standing on the square.
16 The rooster is not standing on the square.

17 The star is touching the fish
18 The star is not touching the fish.

Table A-3

Word list for phonology-orthography test:

Form A1			Form A2		
1	sluck	**shure**	1	fep	**jene**
2	**clew**	nutch	2	**skoop**	chake
3	thort	**dout**	3	roaf	**skool**
4	cump	**brane**	4	**syne**	clie
5	**trane**	cheem	5	**thawt**	treen
6	fike	**bloe**	6	**toun**	bliff
7	**syne**	clie	7	stive	**dert**
8	**skoop**	chake	8	**trane**	cheem
9	deke	**ruff**	9	**mait**	nour
10	fise	**leeve**	10	druff	**fite**
11	**mait**	nour	11	fise	**leeve**
12	fep	**jene**	12	noush	**leep**
13	goap	**lerne**	13	**laff**	mide
14	druff	**fite**	14	sluck	**shure**
15	**laff**	mide	15	deke	**ruff**
16	raup	**wirk**	16	**powt**	herf
17	stune	**groe**	17	stune	**groe**
18	**jirm**	doan	18	**wyfe**	cleb
19	**theef**	luff	19	celm	**shoan**
20	roaf	**skool**	20	troe	**breth**
21	**klip**	gorm	21	cump	**brane**
22	**thawt**	treen	22	**klip**	gorm
23	**troo**	laup	23	**jirm**	doan
24	celm	**shoan**	24	**clew**	nutch
25	**powt**	herf	25	goap	**lern**
26	**toun**	bliff	26	fike	**bloe**
27	**wyfe**	cleb	27	raup	**wirk**
28	troe	**breth**	28	**theef**	luff
29	noush	**leep**	29	**troo**	laup
30	stive	**dert**	30	thort	**dout**

Note: Pseudohomophones are in bold type.

Form B1			Form B2		
31	trode	**brawt**	31	chage	**fense**
32	drow	**bigh**	32	phuns	**sweap**
33	slipe	**snoe**	33	swean	**slyde**
34	**cheak**	proght	34	**stait**	cheme
35	mawf	**rool**	35	**bight**	treem
36	blaff	**nooze**	36	swite	**cawf**
37	**stait**	cheme	37	**cort**	wauf
38	phums	**sweap**	38	mawf	**rool**
39	menge	**kwote**	39	dight	**shaim**
40	**wirm**	skoog	40	**furst**	fooze
41	dight	**shaim**	41	**wirm**	skoog
42	chage	**fense**	42	trobe	**nirse**
43	pife	**cense**	43	menge	**kwote**
44	**furst**	fooze	44	**krum**	hape
45	**krum**	hape	45	trode	**brawt**
46	saip	**shaik**	46	**fownd**	sleth
47	**fownd**	sleth	47	blait	**creem**
48	chack	**soop**	48	**wurse**	gurst
49	drave	**hoap**	49	**chefe**	dawt
50	swean	**slyde**	50	**chese**	durse
51	**nife**	kwane	51	blaff	**nooze**
52	**bight**	treem	52	drow	**bigh**
53	**tawt**	wirp	53	pife	**cense**
54	blait	**creem**	54	**cheak**	ploght
55	**chefe**	dawt	55	**nife**	kwane
56	swite	**cawf**	56	saip	**shalk**
57	**wurse**	gurst	57	chack	**soop**
58	**chese**	durse	58	drave	**hoap**
59	trobe	**nirse**	59	**tawt**	wirp
60	**cort**	wauf	60	slipe	**snoe**

Note: Pseudohomophones are in bold type.

Table A-4

Lists of items in picture and word naming tasks.

List of simple line drawings:

balloon, carrot, butterfly, camel, chair, desk, elephant, pencil, scissors, truck, key

List of 10 practice words:

adopted, blue, cell, childhood, claim, decided, items, pocket, prevailing, smell

Lists of test trials:

Frequency log band	Number of syllables	List 1	List 2	List 3	List 4
1	1	act	state	speak	bed
1	1	thing	head	run	hope
1	2	alone	little	trying	nation
1	2	trouble	story	answer	despite
1	3	agreement	evidence	easily	possible
1	3	already	according	national	family
2	1	tall	ship	hill	send
2	1	wild	fund	won	drove
2	2	judgment	carry	dinner	contract
2	2	exist	cover	index	talking
2	3	essential	primary	substantial	wonderful
2	3	universe	location	musical	expression
3	1	ranch	bone	vein	star
3	1	match	lunch	drill	curt
3	2	rapid	lovely	weekend	angry
3	2	prepare	massive	witness	error
3	3	improvement	survival	retirement	ethical
3	3	terrible	gallery	expensive	forgotten
4	1	fee	tent	rail	lift
4	1	bunch	trap	pill	tore
4	2	combine	noble	desert	porter
4	2	flavor	parent	tumor	alike

4	3	employer	confident	prospective	referring
4	3	embassy	unlikely	biblical	mentally
5	1	frieze	curse	owe	flock
5	1	flung	grim	cab	cake
5	2	spokesmen	viewing	unwed	comprise
5	2	lengthy	puzzle	safely	convert
5	3	viola	strenuous	antigen	honeymoon
5	3	disappear	gasoline	marital	undertake

Table A-5

Description of word list frequency band characteristics (based on Kucera & Francis, 1967)

Freq.log band	1st/last word	Rank	Freq	Log	% per million	Words per band	Cum. words
1	through	92	969	3	47%	936	1027
	unless	1028	101	2.01	70%		
2	actual	1029	100	2	70%	1113	2140
	waves	2141	51	1.71	77%		
3	advertising	2142	50	1.71	77%	1185	4025
	yours	4027	25	1.4	84%		
4	absorbed	4028	24	1.38	84%	2023	6048
	writings	6051	15	1.18	88%		
5	customary	6052	14	1.15	88%	2070	8118
	zinc	8125	10	1	91%		

Table A-6

Sample passages from silent reading test.

Medium passages

The case of the raised dots

A French boy named Louis lost his sight when he was three years old. Six years later he entered a Paris school for orphans. There Louis learned the alphabet by feeling twigs formed into the shape of letters.

Louis studied hard. Despite his blindness, he did well in science and music. By the time he was nineteen, he had become a well-known organist. But his ambition was to teach others who were blind like himself.

Louis knew that a French army captain had worked out a system of using raised points to stand for the letters of the alphabet. But the point symbols were too large to be useful. Louis improved on the captain's idea of point writing. He worked out simple point symbols that could be felt with the fingertips. Blind people could use this system to read and write.

Since the new symbol system had no name, a word had to be invented for it. "Why not call it Braille?" asked one of Louis's students. That seemed a good way to honor Louis Braille. And that system is now called braille all over the world.

****

The Animal World

Human beings are members of the animal kingdom. And so are whales, lizards, lions, and hawks. Animals are classified into groups called classes. We belong to the class called mammals, the same class as dolphins, cats, elephants, gorillas, and many others. (Mammals are animals that nurse their young on milk.)

The smallest animal on earth is so tiny it can live inside a blood cell. The largest animal is one third the size of a football field. The variety of animals, large and small, is almost endless. The one thing we share in common is that we're all connected. What people do to the environment affects animals and, in turn, we depend on animals for own survival.

Creatures invisible without a microscope are so small that it's hard to tell whether they are animals or plants. With larger animals, you can see the difference in two ways. First, a living thing that moves independently is likely to be an animal. Second, if it eats—takes in and digests food—it is probably an animal.

On the planet we all inhabit, different types of animals live in different ways and in different places. Some animals burrow into the ground; some fly through the skies. Some like it cold;

some like it hot. Different animals do things differently. Some eat tree bark, while others feast on each other. But all animals try to survive and to reproduce.

****

Bicycles of today and yesterday

In the late 1800s, bicycling became a popular sport. Many people rode a type of bicycle called the High-wheeler. If you were to put a High-wheeler next to a bicycle of today, you would see many differences.

The front wheel of the old bicycle was about five feet high. This means that the bicycle was as tall as some riders! The seat was on top of the high front wheel. To get up to the seat, the rider had to put a foot on a footrest and jump up on the high wheel. The back wheel was much smaller.

Today's bicycle, in contrast, has two wheels of equal size. A rider can get on the bike by standing next to it and putting one leg over the frame.

The bicycle of yesterday had some safety problems. Riders sat so high that they could tip over easily. The tires were made of thin, hard rubber. A small bump in the road could jar a rider or make a rider fall.

Today's bicycles, on the other hand, are safer to ride. The wheels are easier to keep on the road. Tires filled with air make the ride softer and smoother.

The old High-wheeler may have been exciting. But most people would probably prefer to ride today's safer, faster bikes.

****

Difficult passages

X-ray photographs

Today, more than 200 million X-ray photographs are taken every year to help identify and correct health problems. They are especially valuable for diagnosing lung cancer because the differences in the densities of the tissues in the chest show up clearly on an X ray. X rays are now routinely used, not only by physicians, but also by chiropractors for detecting spinal misalignments and by dentists for locating small cavities. Industry uses X rays to inspect welds and to detect flaws and weak spots in pipes, insulation, high-pressure boilers, and other equipment. Even the art world, which uses X rays to help identify old paintings, has profited from Roentgen's discovery.

As with most discoveries, X rays haven't proven to be all good. Due to the early lack of information about this radiation, many scientists and patients at one time suffered illness as a prolonged exposure to the rays. The penetrating X ray, it was found, can damage cells and produce cancer. But one such precaution as limiting exposure times and using lead as a protective shield were begun, X rays could be used more safely.

Although X rays have not been able to turn metal into gold, nor beam knowledge into the brains of students, their many uses have made the selection of Wilhelm Roentgen as the first Nobel Prize winner for physics an acclaimed decision.

****

The dangers of cigarettes

The fact that puffing on a cigarette is an unhealthy act is no longer seriously disputed, even by the tobacco industry. Much of the current medical debate has shifted to two related questions: Is nicotine addictive? And how dangerous is environmental tobacco smoke?

Tobacco companies insist that nicotine, which is contained in varying amounts in all cigarettes, does not create a habit so powerful that it impairs a person's ability to quit. But the overwhelming consensus in the scientific community is that nicotine is an addictive substance. A Surgeon General's report has concluded it is as addictive as heroin or cocaine.

There is evidence that some cigarette-company researchers have long known that it is the nicotine that appeals to smokers. A 1972 internal memo by a Philip Morris scientist contended that "no one has ever become a cigarette smoker by smoking cigarettes without nicotine." That was proved again a few years ago, when the company introduced the nearly nicotine-free Next. The public wasn't interested. The industry claims smokers turn away from such cigarettes because they lack "taste" or "flavor." But researchers maintain that these cigarettes taste no different; they lack the kick nicotine provides. A 1992 study found that people who puffed Next cigarettes didn't show the brain-wave changes that smokers ordinarily exhibit.

Tobacco companies have heavier artillery when it comes to challenging the EPA's 1993 report that labeled environmental tobacco smoke, or ETS, a carcinogen. They charge that the report-a review of 30 epidemiological, animal and laboratory studies conducted during the past two decades-is fundamentally flawed. The Congressional Research Service and some independent scientists have also criticized the report.

The EPA found that fumes rising from the tips of lighted cigarettes (as opposed to the smoke that users exhale) is the most hazardous, with high concentrations of 17 carcinogens. The agency also concluded that the environmental smoke produces serious respiratory illness in young children.

Table A-7

Summary statistics and correllation coefficients of key SARA subtests.

Test	Total items	Total subjects	Mean	SD	alpha coef.
PP - Lis	32	128	25.34	5.59	0.89
PP - Rdg	32	102	24.38	6.15	0.90
DEC - A1	30	48	21.63	7.32	0.92
DEC - B1	30	51	21.96	5.70	0.86
DEC - A2	30	24	24.58	6.01	0.90
DEC - B2	30	29	21.83	6.60	0.89
DEC - AB12	60	52	43.88	11.54	0.95
WREC - A	30	25	21.60	6.40	0.94
WREC - B	30	25	25.00	5.52	0.92
WREC - C	30	25	24.12	4.91	0.90
WREC - D	30	24	24.71	5.71	0.93

Note: Alpha coefficients computed based on Kuder-Richardson Formula 20 (Allen & Yen, 1979). PP-Lis=Propositional Processing Test, Listening version; PP-Rdg=Propositional Processing Test, Reading version; DEC-A1=Decoding Test, version A, session one subjects; DEC-B1=Decoding Test, version B, session one subjects; DEC-AB12, Decoding Test, version A & B items combined, subjects in session one and two combined; WREC-A through D=Word naming task, version A through D

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