Reading Research at Haskins: A Personnel History

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My talk will be partly an intellectual history but mostly a tour of the personalities whose science and spirit have shaped reading research at the Lab. Everyone who has passed through the Lab has left a mark. There was no one I was not happy to know and work with. I am still thrilled to be surrounded by some of the most capable and creative speech and language scientists on the planet. There is a mix of bright people from different disciplines and this has a consequence. As everyone here knows, one of the qualities of the Lab is its juxtaposing of different but related areas of study (like research on speech gestures and research on reading). One of our special qualities is that Haskins has always fostered interaction among its different specialties. The open floor plan here and in the old Lab on Crown St are examples of that intention. Over the years, I frequently got involved in a research project because the people discussing it near me were rather loud. And whenever I considered working in a research area that was, for me, an intellectual stretch, I was able to feel comfortable because, although working at the limits of my own expertise, other Lab members who were experts where I was not kept me from making mistakes—at least much of the time if not always. Because of this "corporate climate" Haskins is a great place for postdocs: They know that they can talk freely with anyone and that they have access to excellent technical resources.

I'll begin with some general history of psychology to give the younger people a feeling for what the prevailing theoretical climate was like when I started grad school in the 1950's. Research on the cognitive processing of reading was largely nonexistent in experimental psychology before the 1960's because the prevailing metatheory of learning was antithetical to cognitive theories. The major theories at that time focused only on variables that could be directly observed. In graduate school, I was criticized by my professors for offering explanations that, for example, required the idea of a short term memory. Such an idea was brushed off as "too cognitive." I was told to stick to what I could see and measure: input variables, output variables; anything else was not scientific. Concepts like short term memory were called "intervening variables", something that "intervened" between observed input and observed output and, because an intervening variable was not itself observable, it should not be allowed to do any heavy theoretical work. Even 10 years later, not everyone was convinced that a science of reading should abandon stimulus-response theory. To counter this older way of thinking, Eleanor Gibson wrote in 1971, "…I will state boldly and baldly an assumption that I take for granted. Reading is a cognitive process. No S-R theory is going to help us."[1]

The limitation of S-R theory was, of course, very constraining and, consequently, not productive. Everyone probably knows the story of Noam Chomsky's famous review in 1959 of B. F. Skinner's book on language, "*Verbal Behavior".* Skinner's approach was to consider language acquisition in terms of the *functions* that language afforded. A child learns to say, "May I have a glass of water" in order to satisfy its thirst. This was considered different from learning to label something as "water"; that would require a different functional explanation. You were not allowed to propose the existence of a mental lexical entry with the phonologics and semantics for "water", concepts that seem both central and mundane today. Of course, the idea of a biological disposition for language was discouraged; the organism was a blank slate that was filled in by experience. Against this prevailing mindset, Chomsky showed that Skinner's stimulus-response explanation of language was insufficient to account for what language is actually capable of, like infinite variety, center embedding, etc. You all know this story, I think.

While I was still enrolled in grad school at UMass/Amherst, and for two years on postdoc afterward, I worked at Stanford University's Institute for Mathematical Studies in the Social Sciences. There, everyone was cognitive…and mathematical. We studied learning and memory. Short term memory was hot. Stanford was not the only institution that was throwing over the old unfruitful S-R psychology but it was the premier center for mathematical model work at that time. Among the young people and faculty, there was an expansive sense that we were going to revolutionize the field of experimental psychology. The faculty had a brilliant roster of men (there were almost no women in the field then): Bill Estes, Gordon Bower, Pat Suppes, Dick Atkinson, and frequent visitors like Bill McGill and Duncan Luce. Even the grad students and postdocs were brilliant; they included Dave Rumelhart, Jim Townsend, Bill Batchelder, Joe Young, Donald Norman, and later Richard Shiffrin. The neural network people here probably know their debt to David Rumelhart. They may not know that he was influenced at Stanford by his teacher William Estes and that it was Estes who lent his considerable prestige to the budding discipline of neural network modeling by hosting a meeting on the topic at a Psychonomics Society conference in the mid-1980's. Shortly after that, Phil Rubin and I offered a six-week seminar on neural network models based on Rumelhart & McClelland's book, *Parallel Distributed Processing.*

Alvin Liberman

Al Liberman was not president of Haskins in the 60's when I was at Stanford; he became president in 1975. But he was head of the Psychology Dept at UConn. He came to Stanford (to the Center for Advanced Study in the Behavioral Sciences) for the academic year 1964-1965. I had a friend at Stanford who had recommended me for a job at the University of CT Psych Dept. The then acting-head at UConn must have asked Professor Liberman to have a look at me because I was invited up to the Center for a visit. Professor Liberman and I had tea, chatted, and as I was departing he handed me a slim volume called Syntactic Structures by someone I had never heard of. Professor Liberman casually asked me to read it and come back and tell him what I think. Next week, I returned the book and I allowed how this Noam Chomsky fellow had one or two good ideas. I must have passed the test because a week later UConn wrote asking me to come east for an interview.

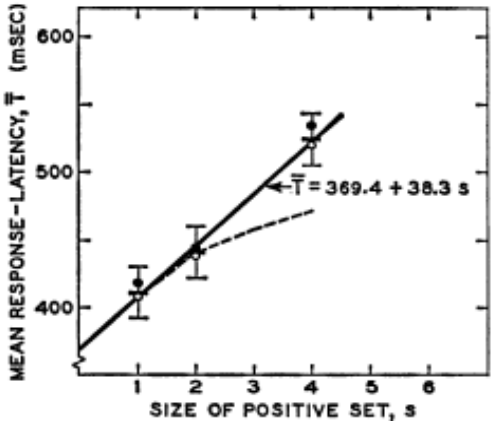
That interview, by the way, consisted of meeting for two hours with four senior professors. No job talk. They hired me. I later learned that my chief attraction was that they thought I wouldn't scare the clinical psychology students when I taught them statistics.

I didn't join Haskins immediately. In fact, I didn't get involved until seven or eight years after arriving at UConn. By the time I did join the Lab, I had already been applying the new concepts of cognitive psychology and their experimental techniques to research on reading, There were a few other young reading researchers at other universities (Chuck Perfetti, Jon Baron, Frank Vellutino and others) and we all knew each other. None of us was over the age of 35.

A lot of researchers in the 1960's were concerned with memory and, particularly, short term memory. At UConn, that included Michael Turvey. He and I worked separately for the most part although we talked to each other a lot. Mike also had a different line of research from memory; he was developing the work on visual perception that won him an APA young researcher award. However, his research from the direct-realism, ecological perspective was still a few years away. As many of you know, once it was developed, Mike's version of the realist approach had a deep effect on how Haskins people think about speech perception.

In this same period of time, Chomsky was giving support to theories that proposed modular structures like memory capacity. To give you a sense of how theoretical thinking was changing from the old to the new, I'll describe a simple but central paper, a landmark discovery by Saul Sternberg.[2] Sternberg, working at Bell Labs, published a short article in the journal Science in 1966. The fact that it was published in the premier American science journal should cue you that this was a breakthrough experiment because in those days hardly anything psychological was ever printed in the journal Science. In Sternberg's task, the job of the participant was simple: listen to a short random series of spoken digits (1-5 numbers), for example, the sequence 3, 7, 1, 5. At the end of the sequence there was a short beep followed by a probe digit, say, the number 7. The subject had to respond quickly with a key press: yes, if the probe digit had been in the series and no, if the digit had not been. The subject was nearly always correct; what was of interest was how long it took to respond. The RT graph looked like this.

Sternberg Probe Digit Experiment



Sternberg, S. High speed scanning in human memory [1966] Science, *153*, 652-654.

The result is a linear function in which it takes 38 ms to mentally compare the probe to each memorized digit before coming up with the answer, yes or no. The result was very easy to

replicate; I, and many others, did so readily. Now, understand that the time it took to mentally scan a number, 38 ms, was much, much faster than people can perform consciously. If you tried to use conscious inner speech to run through the memorized numbers—if you tried to talk to yourself—the inner speech rate would be three or four times slower than 38 ms. So, the cognitive process is below the level of awareness; subjects cannot tell you how they come up with the correct yes-or-no decision; they have no insight.

This simple experiment indicated that an unconscious mental process could be studied quantitatively, chronometrically; it promised that the components of mental processing might be isolated and measured by the amount of time they took to execute. This could be done in spite of the fact that the mental process under study could not be observed directly. Of course, this was not the first timing study of mental processes—that history goes back to the nineteenth century—but Sternberg's paradigm spawned an explosion of research ideas involving hypotheses about mental functioning and it hastened the end of S-R dominance. The present day work at Haskins on printed word processing uses experimental techniques that are descendants of the paradigms introduced in the 1960's. I'm thinking of Haskins researchers like Laurie Feldman, Jay Rueckl, Jim Magnuson, Julie Van Dyke, Dave Braze, and others. There were others besides Sternberg who introduced new concepts and techniques. Paul Kolers who studied various visual transformations of print, George Sperling who studied iconic memory, Michael Posner who demonstrated processing modularity in various cognitive and perceptual systems. Lloyd Peterson who influenced studies of memory, and many others.

For me, adapting these new approaches to the study of individual differences in reading was easy. And fun. And profitable: I published a few papers showing that poor readers did not differ from good readers in their visual perceptual abilities or mental processing speed. The only thing that did differentiate them from good readers was their speed of encoding words. So, for example, poor readers had mental scan speeds that equaled those of good readers and they had simple reaction times that were also the equal of good readers. Once a poor reader had read a word, they could "think" with it just as quickly as a good reader. What poor readers could not do was actually read a word as quickly as a good reader. So I spent a couple of years proving that the problem with poor readers was that they couldn't read very well. Very amusing. But the research did focus reader ability differences at the word level and it added to the growing literature that refuted the claims that the causes of poor reading were problems in visual perceptual processing or visual short-term memory. Now, the new focus was on how the printed word makes contact with its linguistic counterpart in the mental lexicon. Posing the question in that framework was exactly the right approach.

Nevertheless, the idea that poor readers have some deficit in basic perceptual processing—visual or auditory—is still with us. This putative deficit is often said to be general and not specific to the language system itself. For example, there is the hypothesis that a problem in processing rapidly changing auditory signals will compromise the ability to hear fine distinctions in phonemes. If I can put my bias up front, I don't think that we'll find the explanation of poor reading in this direction. Of course, there are some poor readers who have perceptual deficits that impact their ability to read well. But most poor reading, I think, is not of this origin but, rather, is tied to problems within the language system.

One form that the perceptual deficit hypothesis took in the 60's and 70's was that dyslexics saw words backwards. This seems ridiculous now but it was taken seriously then. Proponents of this

approach meant backwards letter order; that's why a child might read the word *was* as the word *saw*. Nowadays, we might explain behavior of this sort—it occasionally happens to normal beginning readers—as a letter translation phenomenon. But back then, it was seen as evidence of a visual perceptual deficit and lots of people spent lots of research time on it. And I can say "ditto" for theories involving auditory perceptual deficits.

Don Shankweiler

In the early 60's, Donald Shankweiler was at Haskins in New York. He had been a postdoc in Cambridge, England and, more recently, a researcher at the Montreal Neurological Institute. He was, and is, a neuroscientist who was interested in speech and language. He though then that the cause of dyslexia might be a failure of hemisphere dominance. This was a hypothesis proposed in the 1920's by Samuel Orton. To Orton, the difficulty for dyslexics could be described as a difficulty associating the printed word to its spoken form. Hemispheric imbalance came into the picture because that imbalance was hypothesized to disrupt the connection between the visual stimulus (the printed word) and the auditory stimulus (the word's pronunciation). Don worked with cerebral dominance ideas in the 1960's and early 70's. Independently, I also published research on laterality and reading disability in collaboration with colleagues in England.[3] All of us who did research in this field found greater hemispheric asymmetry for good readers and this was ascribed to the language function of the left hemisphere; language was said to be more strongly dominant for good readers. Don was working with this idea and was using dichotic listening as a tool. (Dichotic listening puts different audio stimuli into each ear, requiring the listener to resolve them.) At the same time, at Haskins, he was spending most of his time on standard speech research, not dyslexia. He is one of the authors of a landmark speech paper many of you know, *Perception of the Speech Code* by Liberman, Cooper, Shankweiler and Studdert-Kennedy.[4]

Like my own research program, Don's was involved in testing and rejecting some of the many theories of reading failure that were around at that time such as visual or auditory perceptual problems, problems of the cerebellum and balance, motor skills, eye control, etc. For one research group, even unusual sensitivity to certain wavelengths of light was claimed to be the poor reader's problem. Based on this, a commercial company sold the New Zealand government thousands of tinted glasses of different hues so that each child could work at his or her optimal visual wavelength when learning how to read.

Isabelle Y. Liberman

While still at Haskins in New York, Don met Isabelle Liberman. Isabelle was the wife of Alvin Liberman. She had received a PhD in clinical Psychology from Yale and was now working part time at the Children's Hospital in Newington, CT, which treated children with developmental and neurological problems. Isabelle found herself working with learning-disabled children and she became increasingly uncomfortable with the absence of research-based solutions to the children's problems. Eventually, she got a faculty position in the UConn School of Education where she developed a masters program to train remedial teachers and later, a PhD program to train researchers. Around this time (the mid 1970's), I joined the Haskins reading group.

A side-note…I don't know if Isabelle ever desired to be in UConn's Psychology Department instead of the School of Ed (her degree was, after all, in psychology). But she would not have been allowed to be in the same department as her husband. The rules at the time were very restrictive; spouses could not be members of the same department. Of course, this usually meant that it was the man who got the faculty job and his wife took a position as a research associate instead---or stayed at home.

But here was Isabelle Liberman in the School of Ed. She and Don began investigating the theories of reading failure that were popular at the time. Perhaps the first research of theirs that set them on the right track was research on the kinds of errors that children made when reading aloud. They found that errors were much more likely to be linguistic in nature rather than visual. For example, errors were more common if the letter was a vowel than if it was a consonant. Whether a letter was or was not reversible visually, like the letters *d* and *b*, was not very important. In research by others on short term memory in normal adults, it was discovered that phonemic similarity accounted for the bulk of errors that were found. For example, if a set of random letters was memorized, recall was more readily confused if they had overlapping phonetic features than if they had very distinctive pronunciations. Visual similarity was much less salient than phonetic similarity. In the prevailing terminology of the day, the memory errors were called acoustic confusions by everyone except, of course, the researchers at Haskins. The errors were not acoustic, they were phonetic. In those days, Haskins researchers seemed to be the only people who knew the difference.

In retrospect, it would seem that Don's research on speech and Isabelle's interest in the speech work at Haskins would *have* to color their theoretical thinking about dyslexia sooner or later. The breakthrough came when it was acknowledged that in order for a child to understand the relationship between spelling and the meaningless phonemes that make up spoken words, a certain skill was required. It was a skill that was a prerequisite to learning to read. Don put it this way: "It seemed that children would need to know that [spoken] words contain segments like consonants and vowels". If children could not take apart a spoken word and chop it into its phonemic components, they would not be able to match these phonemes to their corresponding letters on the page. Or the reverse—when they needed to spell, they couldn't choose the letter that corresponded to a particular phoneme. Isabelle first stated this idea in 1971, in an article in the Bulletin of the Orton Society[5].

This idea developed into the idea of phonemic awareness: being able to consciously analyze a spoken word into its phonemes. If a child knows that that the spoken word *cat* has three "sounds", they can match the phonemes with the letters that stand for these sounds. If the child is unable to consciously analyze the phonemic structure of *cat*, it will be impossible for them to see the relationship between letter and sound. Some children, who have good intelligence, a supportive family, and a good preschool environment, still fail to find this task easy. It then falls to a sympathetic and well-trained teacher to correct it. All too often, the teacher is not aware of the child's problem, and, even if she is, does not know the appropriate methods to ameliorate it. And if the child is not among the brighter kids or is not well prepared for the school experience, the lack of phonemic awareness can be devastating, leading to a domino effect of school failures.

Here is an example of typical data from that period[6].

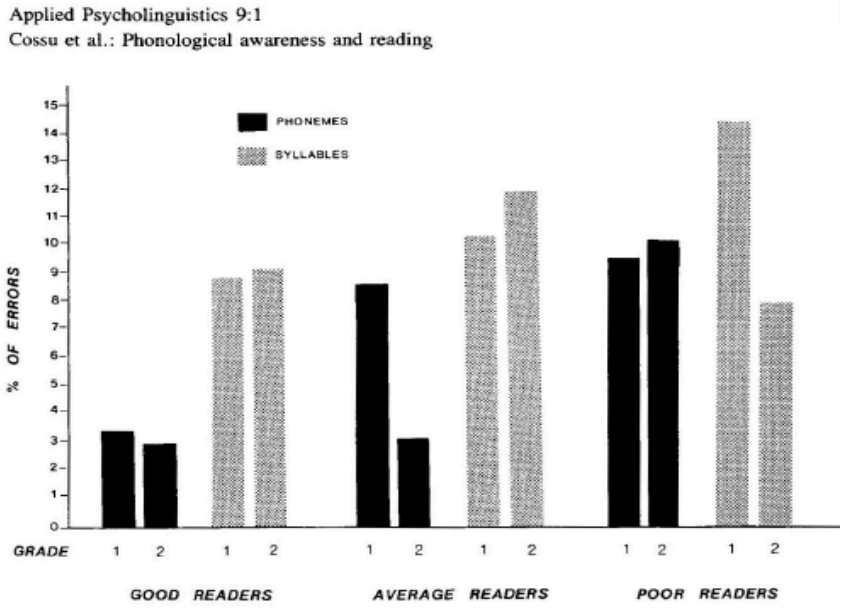


Figure 2. Percent errors in segmentation on the phoneme test and the syllable test in first- and second-grade children grouped by reading ability.

IGNATIUS MATTINGLY

The reading researchers greatly benefited from the speech researchers at Haskins who educated us about phonetics. These included Arthur Abramson, Leigh Lisker, and Kathy Harris. In addition, there was a linguist at Haskins who had multiple talents that proved useful to us. Ignatius Mattingly was involved in writing computer programs that performed speech synthesis; he made computers talk. He did this not as an engineering trick but in order to study how humans speak. But he also took an interest in our reading research What he did for the reading group was to organize our half-formed thoughts into more sophisticated formalisms. For example, he extended the idea of phonemic awareness to the ideas of phonological awareness and, more broadly, linguistic awareness. Here are some examples of awareness. If someone is asked to generate words that rhyme with *pick* most people would consciously understand how to do that particular phonological task. But they may—or may not—be able to generate words that contain the morpheme *magic* (e.g., *magician, magical*). That's a task that requires morphemic awareness. And awareness affects the ability to be analytic about language. We all believed Al Liberman who said, repeatedly and at regular intervals, "Reading is parasitic on speech".

At the time, the conventional view was that reading and speech were similar and differed only because one of them came to us by ear and the other by eye. Children who were poor readers were sometimes said to be better "auditory learners" than "visual learners" as if their nervous systems favored the ear or the eye. Ignatius didn't believe that reading and listening were parallel processes. He stressed the differences: speech is acquired naturally, reading is not; writing is a cultural artifact that was invented. It is based on speech; writing transcribes speech. Therefore, the reader has to translate writing into speech. Print never translates into meaning without first going through language.

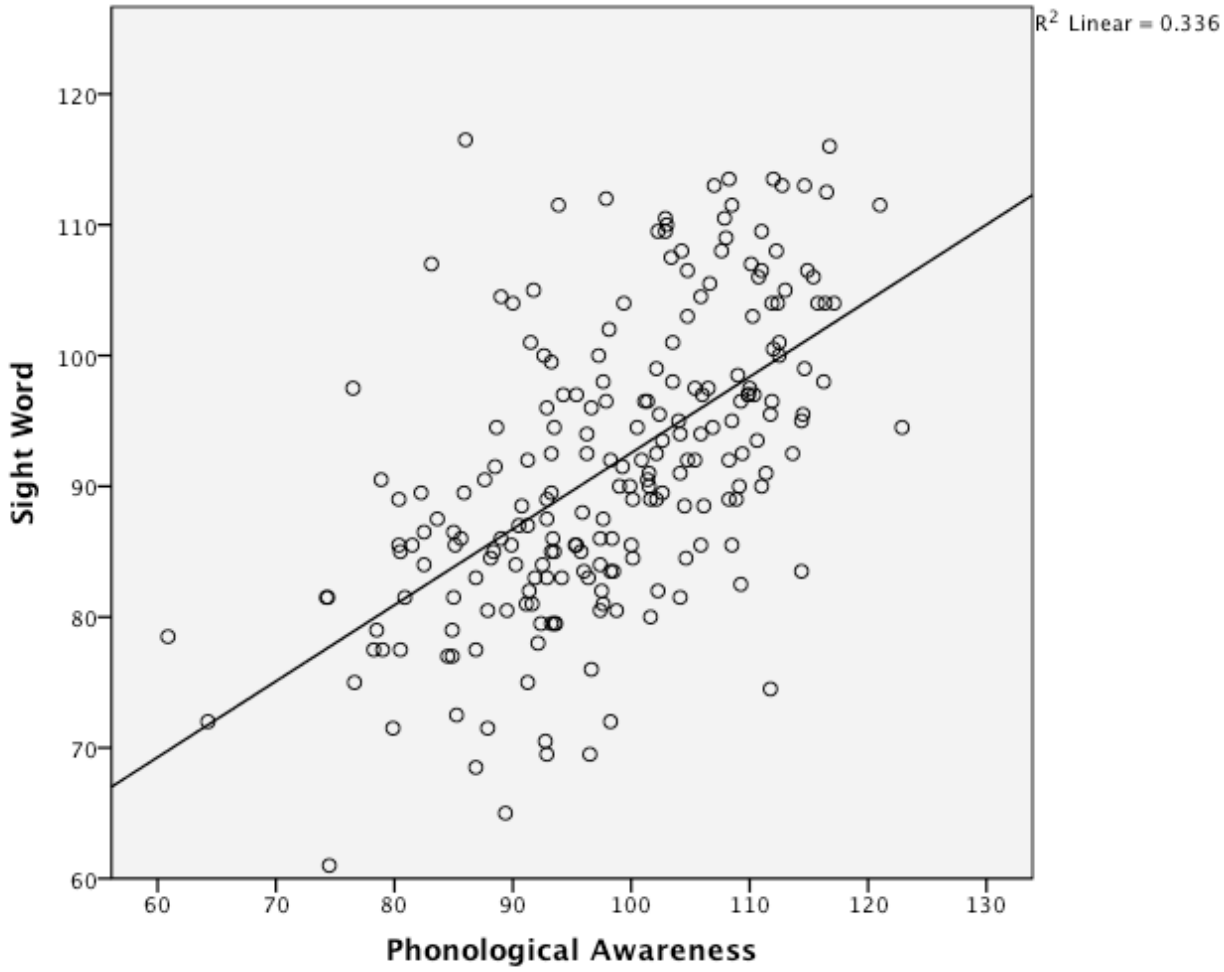
An example of this was seen in a paper by Donna Erickson, Ignatius, and Mike Turvey in 1977[7]. Kanji is a Japanese orthography (writing system) that has no phonologic components. A reader has to memorize which Japanese spoken word the character represents. People hypothesized that when Kanji was read, no speech was involved; readers looked at the character on the page and

the meaning of that character was stimulated, but not its sound. But when Japanese participants silently read Kanji, they were slower when the words sounded similar than when they did not. If readers had gone directly from print to meaning, bypassing the words' phonetics, they would not have been tripped up by the homophony. Many other experiments showed similar results; reading invoked inner speech.

Now I want to introduce the bad guy in my story. Ken Goodman is a man who everyone says is kind and gentle. However, he has a theory of reading[8], since the 1970's, that the Haskins group thought was wrong, even dangerously wrong. Goodman was the major proponent of the view that the way to teach children to read was to get them to guess at what the printed word was on the basis of one or two or three letters in the word taken together with the context of that word. Was the story about a zoo? Then if you see a word that starts with the letter *E*, it's likely that the word is *elephant*. He called reading a psycholinguistic guessing game. More commonly, this approach was called Look-Say or Whole Language. Children were expected to develop sight word vocabularies without being taught, explicitly, to decode. By the 1970's most school systems used some form of the Look-Say approach. Now, Look-Say will work with most children because they will intuitively discover many of the rules for decoding. That is, they will pick up on the consistencies and semi-consistencies in spelling and teach themselves what phonemes the letters represent. If a child has phonemic awareness (and most do), they can analyze their speech into phonemes and make the correspondences with letters or letter clusters. But for a certain portion of children, Look-Say does not work and they fail at reading. Some poor readers with poor phonemic awareness reach college. I currently study these students under the Haskins' A40 grant. The students are bright—they are in college, after all—and they use their intelligence to help them figure out what the word on the page is if it isn't already in their sight-reading vocabulary. But these students cannot decode well; they have difficulty in reading words they have never been exposed to before. Of course, there are many more people who lack phonemic awareness and never learn to read at an acceptable level at all. They may never graduate from high school, much less make it to college.

Here is a scattergram of my data with college students. It shows the relationship between phonological awareness and word-reading ability.

Word reading and phonological awareness in college students R=.604[1]



Isabelle held weekly meetings in her office in the School of Education. Don and I attended, as did Isabelle's grad students and the occasional Psychology Department grad student. These meetings were where we discussed the influence of speech on reading and criticized each other's experimental work. These meetings were very important in establishing the UConn/Haskins reading research program. Several of Isabelle's students went on to have important research careers of their own, including Margie Gillis, who studied with Isabelle and remained in contact with her for years after.

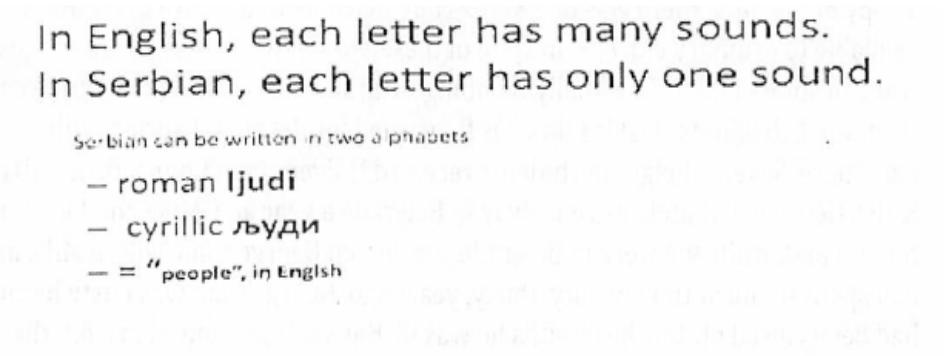
[1] This plot is not the same as the one Len used in his talk. (Accordingly the R in Len's title and the R^2 in the figure are not quite compatible, although they are close.) We could not find a readable copy of Len's original figure. However, these data are from the same population and are of the same type as in his original figure for this talk.

It is difficult to overestimate the effect that Haskins' work on the phonological deficit hypothesis has had on the theory and practice of reading. In the last forty years, reading instruction has changed across America in response to the original work which, of course, has been elaborated and extended not only by Haskins scientists but by many other researchers across the world. Among the Haskins people involved in this translational work in the 1970's and 1980's were Susan Brady, Carol Fowler, Vicky Hanson, Virginia Mann, and Paul Macaruso. I know that most of you here today are familiar with the present day manifestations of this tradition and I don't need to detail it. An excellent source of material on this legacy is the recently published volume dedicated to Don Shankweiler, "Explaining Individual Differences in Reading: Theory and Evidence," edited by Sue Brady, Dave Braze and Carol Fowler.[9] However, we need to recognize that, in spite of the successes achieved in teaching reading by focusing on phonology, many schools now utilize systems that are unwholesome mixtures of phonics and whole language. The mixture is dangerous because, in the hands of unreflective teachers, it can emphasize the worst parts of each approach.

I'll come back to the teaching of reading a little later. But next I want to talk about adults who are skilled readers and Haskins research on the cognitive processes responsible for printed word recognition. Here, the issues revolved around the unconscious mental mechanisms responsible for skilled reading.

GEORGIJE LUKATELA

In the 1960's, Georgije Lukatela spent a sabbatical year at Haskins. George (as we anglicized him) was a professor of communications engineering from the University of Belgrade in what was then the country of Yugoslavia. Once, in a casual conversation with Mike Turvey, George happened to mention that people in his country were taught to read their language, Serbo-Croatian in two different alphabets, both of which represented the exact same spoken language. One alphabet was Cyrillic (similar to the Russian alphabet) and the other was Roman, similar to the alphabet we use for English and many European languages.



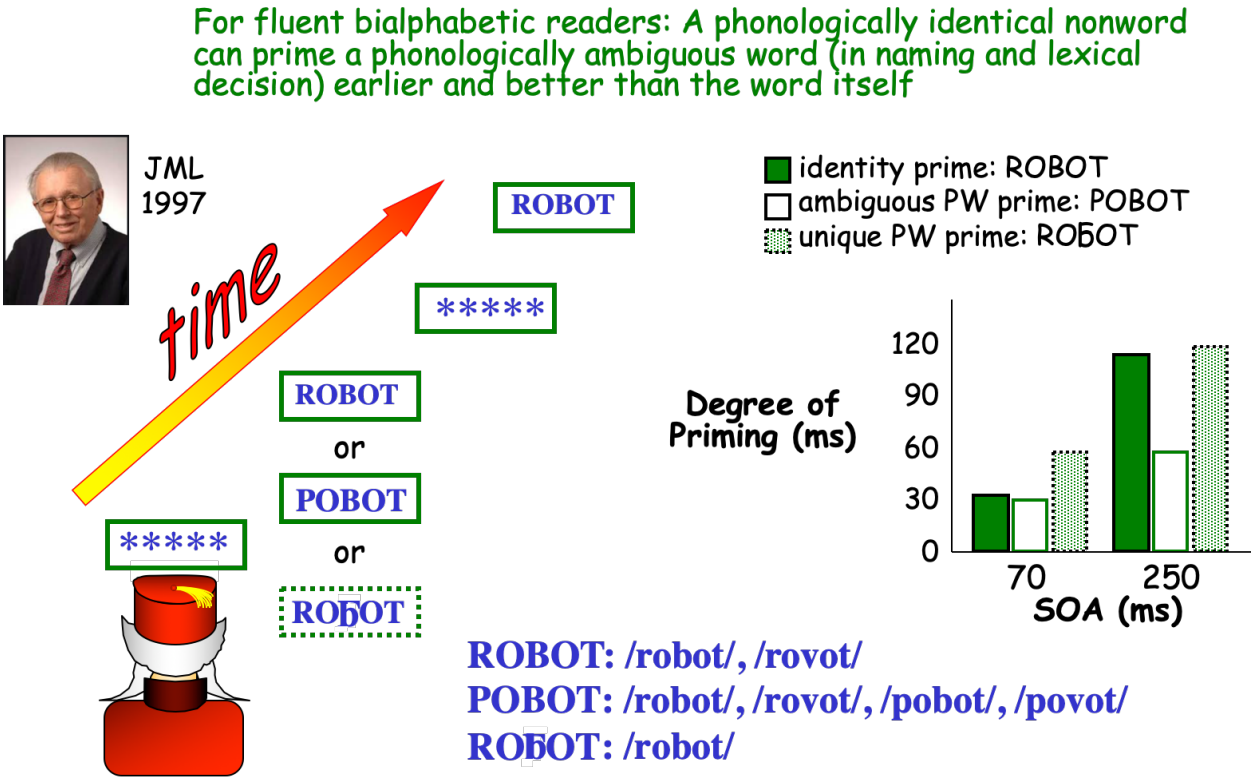
Some letters are common to both alphabets. Some of these common ones have the same pronunciation in both alphabets and some have different pronunciations. This strange bi-alphabetic situation came about for historical and political reasons. Mike immediately saw the potential for experimental psychologists to make mischief. Specifically, the experimenter could now separate the visual (printed) aspects of the stimulus from its phonological manifestation. For example, in a lexical decision task, one could briefly present a printed word in one alphabet followed by a target in the other alphabet. Or, one could even present stimuli that mixed letters from the two alphabets. The variations are many.

This presented an opportunity for those of us at Haskins who were attempting to answer an important question about the cognitive mechanisms involved in reading a word. Simply put, the issue was whether or not printed word recognition required transformation of the printed word to its phonological form. This, of course, seems related to the question studied in the Erickson et al study I just mentioned. But the focus here is on how a word in the lexicon is initially activated, not the aftermath of lexical activation. Was the phonological form required for semantic activation of the word in the reader's mental lexicon? In ordinary reading, do you have to determine what the printed word sounds like, consciously or unconsciously, before you know what it means?

By that time, we already suspected that phonology was required for *learning* to read. But was phonology important for the skilled reader also? George and Mike pursued this question using Serbian as a tool at first (later they utilized English as well). Mike and Claudia Carello opened up Belgrade for a unique research opportunity. From the late 1970's through 1990 (when the Balkan war started) Mike, Claudia, Laurie Feldman and I visited Belgrade regularly to run experiments. The logistic problems were many; for example, we had to smuggle Macintosh computers into the country to run our experiments because of a United States ban on bringing even desktop computers to a communist country, Experimental data were often recorded with pencil and paper trial by trial, and, if you wanted to make a copy of the data, there was one Xerox copy machine in the entire city that was available to ordinary citizens. In spite of these difficulties, in spite of embargos, wars, in spite of the USA actually bombing Belgrade during the Bill Clinton years, the Belgrade Lab and its Haskins link has flourished for decades. Laurie is still collecting data there. Several Belgrade students received University of Connecticut PhDs. Sadly, Georgije Lukatela passed away in Belgrade a year ago. Mike and I went to his funeral and, while we were in Belgrade, we visited George's lab, where Mike and I had spent so much time twenty, thirty, years ago. George's lab was dusty because it had been closed off for the months he was ill. But sunlight poured in from the large windows onto a bookcase with Haskins Status Reports, dating

back to the 1960's. I pulled one out at random and showed it to Mike. It was Ignatius Mattingly's PhD dissertation on speech synthesis.

Although the work on Serbo-Croatian continues to the present, the country of Yugoslavia has split up, and we now call the language Serbian. Mike and George have published a remarkably large and cohesive set of papers over the years demonstrating that phonological effects, including phonetic effects, can be found in the early stages of printed word recognition. They have shown this for English as well as Serbian. Incidentally, these papers also represent some of the cleverest experimental designs in our field And I have to mention that George's productivity was so well known to everyone that whenever he gave a presentation to UConn's Language and Psychology group, we always advertised the title of his talk as "Lukatela's Experments du Jour".



Lukatela, Savic, Urosevic, & Turvey (1997)[10]

Here is an example of one of those experimental designs in Serbian using the two alphabets. Participants had to decide if the target string of letters on the computer screen was a real word or not. Sometimes it was a real word (e.g., the word *robot*) and sometimes it was just a pronounceable letter string (e.g., the string *tibar*). The target was preceded by another letter string that was so brief that participants were not able to consciously identify it, a subliminal

letter string. Although it could not be seen consciously, it is capable of facilitating the response to the target.

In the figure, the target is the word *robot*, which is a real word in Serbian, just as it is in English. There were three possible preceding letter strings: (1) *robot*, identical to the target (which, as you would expect, should make a response to the target easy and fast), (2) a letter string that has different pronunciations depending on whether it is read in Cyrillic or Roman (*rovot* and *pobot*, respectively)—neither one is identical to the target, and (3) a letter string made up of letters that mixes letters from the two alphabets so that it can't be read in one or the other but can only be blended from the two (it is pronounced *robot*, the same as the target). The graph shows that the target was facilitated just as much by the unique string as the string that was identical to the target. That is, a brief prime that does not look identical to the target but sounds identical was as strong a priming effect as when the target primed itself. The entire experiment contained about 120 targets, 40 of each type. This is strong proof that when participants read the target they were aided by the phonology of the prime, not how it looked.

A lot of my own work made comparisons between Serbian and other languages. The general idea was that readers of a given language should adapt their cognitive reading mechanism to fit their language's orthography (spelling system). With regard to phonology, this idea says that a reader can use decoding for lexical access or, instead, rely on visual recognition of the word's letters to initiate the process of lexical activation. Which of the pathways to the lexicon is used will depend on whether the spelling system makes decoding easy or not. Serbian is an example of extremely easy decoding. There is a one-on-one relation between each letter and its sound, i.e., between a letter and its phonemic value. It is simple in the other direction also; each sound in the language has only one letter which represents it. This is far different from English where letters often have more than one phonemic realization and each phoneme can often be spelled in more than one way. So, Serbian and English lie on different ends of a continuum called *orthographic depth.* Serbian has a shallow orthography (a one-to-one relation between letter and sound) and English's orthography is deep (many-to-one). Languages with orthographies that lie in between on the continuum include Finnish and Spanish at the shallow end and French and German at the deeper end.

I had been working with Shlomo Bentin, a researcher at Hebrew University in Jerusalem, when he suggested that I work with one of his students, Ram Frost. This was in the mid-1980's. Ram came to Haskins and we planned an ambitious study in which we were to compare three languages on the orthographic depth continuum. The three languages were Serbian, an example of an extremely transparent (or shallow) orthography, English, which is opaque (or deep), and Hebrew, which in the form that adults read, is extremely opaque because it is written without most of its vowels.

The experiment required Ram to travel to three countries in order to collect data. The experimental design was challenging, to say the least. The basic tool was a comparison between lexical decision and naming in each language. We suspected then, and know for sure now[11], that when subjects are required to name a printed word, i.e., say it out loud, they depend on decoding phonology much more than when they make a lexical decision, i.e., judge silently whether the printed string is a real word or not.

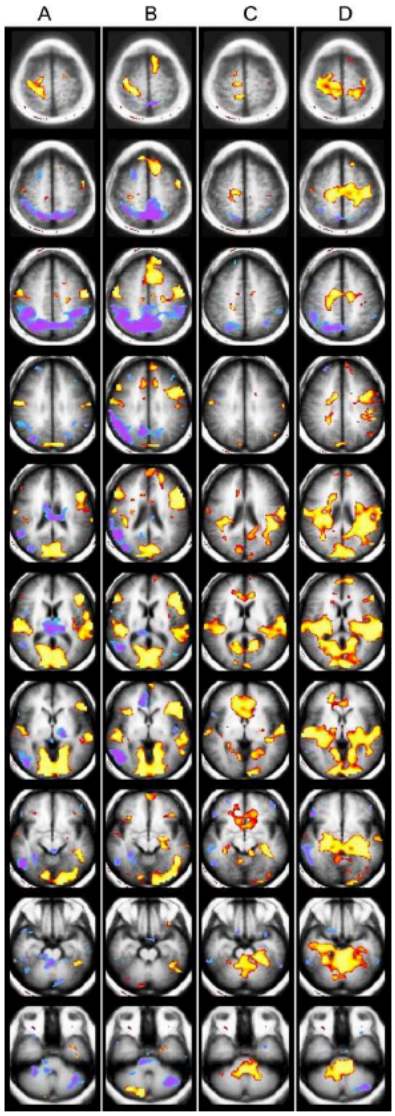


Fig. 3. From left to right: (A) lexical decision repeated minus baseline; (B) lexical decision new minus baseline; (C) naming repeated minus baseline; (D) naming new minus baseline. Increases in activity are colored red/yellow; decreases are colored purple/blue.

Behaviorally, responses in Naming (compared to LD) show bigger decoding effects. The same is seen in the neurobiology where regions of the brain involved in phonology (e.g., IFG) are more active in naming than LD.

Katz,, L., Lee, C., Tabor, W., Frost, S., Mencl, W. E., Sandak, R., Rueckl, J., & Pugh, K. [2005]

For a shallow orthography, like Serbian, readers should use decoding for naming more than readers of other orthographies because decoding is an efficient way to get to the lexicon. For a very deep orthography like Hebrew, they don't have a choice; decoding won't work efficiently for printed words that have no vowels, so naming should be like lexical decision.[12] Here is the result:

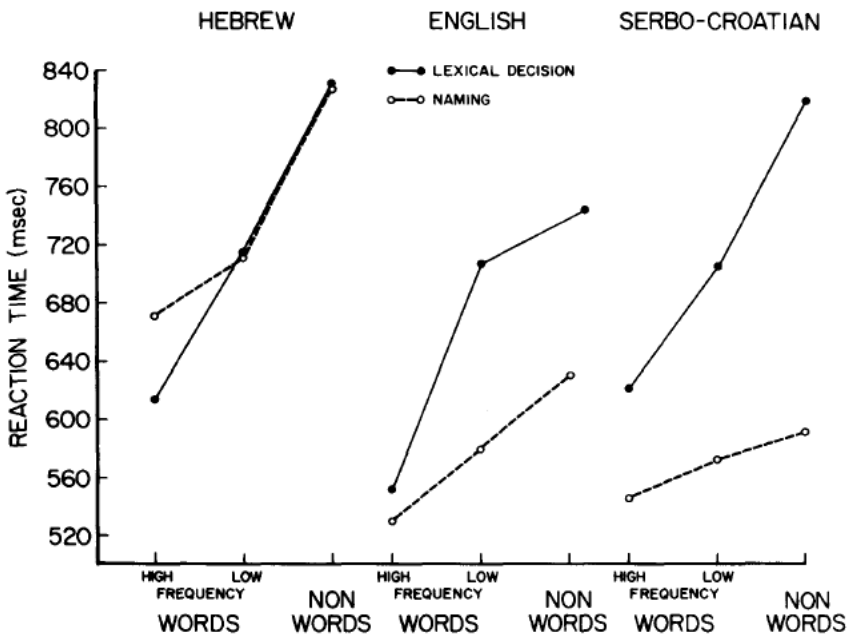


Figure 1. Average response time to high-frequency words, low-frequency words and nonwords in the naming task (dashed line) and in the lexical decision task (solid line) in Hebrew, English, and Serbo-Croatian.

Frost, R., Katz, L., & Bentin, S. (1987).

As predicted, Serbian shows a large difference between lexical decision and naming. Hebrew shows almost no difference, and English whose orthography is deeper than Serbian but not as deep as Hebrew is in between. This is consistent with what came to be called the Orthographic Depth Hypothesis. The relative activity between the two routes to the lexicon depends on the writing system.

I spent several weeks in Istanbul in the early 1990's, lecturing and collecting data on children's reading. When I spoke about orthographic depth to a group of Turkish researchers, they politely pointed out that the word *shallow* also has a pejorative meaning ("John has a shallow personality") and wouldn't it be better to refer to Turkish as a *transparent* orthography instead of a shallow one? I agreed, although that now makes English an opaque orthography, which also can be understood as pejorative.

Laurie Feldman did her dissertation work on Serbian. She had also worked on Japanese and, since then, has gradually expanded the languages she studies. Laurie's focus has been on the role that morphology plays in word recognition, in both its inflectional and derivational forms. An example of the kind of question she has asked is this: when you read the word *baker* do you unconsciously parse the word into *bake* and *-er*? The latter is English's way of indicating an agent: in this case, a person who bakes. What about the word *corner*? Do we parse this word and come up with a mistake? *Corner* does not mean "a person who corns". It turns out that the semantic aspect of morphology counts when we unconsciously access the lexicon. How it counts is a beautiful story that Laurie has told us in her own legacy talk. I should add that the Belgrade program has been fruitful in more than just the science. In 1982, Laurie met her future husband,

Petar, a Serb, when they had both been booked into the same hotel in Paris. Petar's home was in a city just north of Belgrade. It turned out that when he had been an undergraduate at the University of Belgrade, he had been a test subject for Lukatela on a few occasions. The products of *that* collaboration are two young adult sons, now in college.

Ken Pugh arrived a year or two after Ram. In my mind, the two of them are twinned. There was a friendly rivalry between them: two bright, talented young men. That rivalry once spilled over into a one-on-one basketball game, the outcome of which it is better not to speak about. Basketball aside, Ken did some very nice work with me on word recognition over the next few years. We studied how the neighborhood of a word affects the speed of reading a word. A word's neighborhood consists of the words that look or sound similar to the target word in various ways. For example, the word *milk* has a neighborhood that includes the words *silk, mile, mink*, etc. It's simple to sum up that research: neighborhoods count. The recognition of a printed word activates lexical representations of similar words. Whether that activation is facilitative or inhibitory is a more complicated story.

Around 1990, Don Shankweiler and I began to work with Ben and Sally Shaywitz who are pediatric neurologists at the Yale Medical School. The Shaywitzes were convinced that phonological awareness was the key to understanding dyslexia and they greatly admired Isabelle and Al Liberman. On the Haskins side, Al encouraged us to move into brain research because he said, "Psychology must be based on biology". In those days, functional MRI had not yet been invented. We did structural MRI studies of good and poor readers, looking at the relative size of various brain regions, like the planum temporale.

At one point the Shaywitzes wanted us to commit ourselves to devote more time to their project. Don and I demurred, having full plates. But we, with Al's encouragement, sent young Ken Pugh to the Shaywitzes. By the way, Ken likes to describe Al, Don, and me as his mentors. But I, for one, don't remember giving Ken much advice in those days.

Soon functional MRI became available and Ken took to the technique quickly and showed himself to be talented at designing studies. We published prolifically, including a Nature paper that provided the cover picture for the journal that week. Ken brought in Einar Mencl in 1996; Einar was a recent Dartmouth PhD. After a few years of working with the Shaywitzes. Ken reached a point where he was able to bring the work directly into Haskins. Steve Frost, a PhD student of mine from UConn, joined the team. Rebecca Sandak came in 2001 and Nicole Landi in 2005; both were Chuck Perfetti PhDs at Pittsburgh. Julie Van Dyke, also from the University of Pittsburgh, joined us. Rebecca tragically died in an auto accident in 2006. In the few years she was with us, she deepened the neurobiological reading research on phonology and semantics and invented experimental paradigms that are still in use.

Anne Fowler Susan Brady

Anne Fowler and Susan Brady beban studying ways to develop effective techniques for teaching reading to children, based on their association with Isabelle Liberman and the research Haskins had generated over the previous 20 years. Their approach was to focus on the teachers: to educate the teachers about the basic principles of phonological awareness and other types of linguistic awareness. They developed detailed instructional programs. The idea was that if the teachers really understood what their pupils needed to know in order to read, they could adapt themselves appropriately to individual students who had different abilities and skill levels. They avoided a mindless prescriptive approach that is used all too often in directing elementary school teachers.

By 1999, I felt that Anne, Susan, and their colleagues had made great headway and that Haskins should present its message to the wider education world. I thought the way to do this was to have a three-day seminar, which would feature the Haskins researchers and our messages both scientific and educational. Al Liberman liked the idea and gave me much support. In order to pay for it, we charged attendees $600 each. It was held at UConn's then new South College. Steve Katz came on board Haskins at that time as a research associate and it fell to him to take care of the details like assigning dorm rooms, cafeteria chits, college credits for continuing education, printing documents, fielding inquiriies, parking permissions, etc., while I

[….SOME TEXT MISSING]

Also Ken Pugh talked about the brain and individual differences in reading. Brian Byrne talked about the alphabetic principle, and Marilyn Adams talked about why phoneme awareness is important.

Most of the attendees were reading specialists in elemenary or middle schools. I also invited a few politicians who were interested in education. The seminar was a big success and we even made a profit. Anne and Susan worked with state officials to obtain grants that, in the year 2000, would set up the first Early Reading Success (ERS) project in several schools in the region. I remember many, many meetings over the next two years that took place in and around the State House in Hartford. Anne and Susan would drag Don and me to these meetings. It became clear that Don and I were not meant to actually speak at any of these meetings with legistlators or the head of the Department of Education or the Commissioner for Children; we were merely window dressing. So we would sit quietly and look professorial while Anne and Susan spun their eloquent webs. Margie Gillis was brought on board to help administer the program. ERS worked in classrooms in kindergarten and grades one and two. They worked with over 200 teachers in 20 schools in CT and RI. Based on their experience in bringing research to practice, ERS people developed professional development models and tools for teacher training, and establshed three CT model schools to serve as demonstration sites. Joan Baron and I were the principal internal evaluators of these projects, providing statistical analyses and descriptive documentation that was the public face of ERS.

By 2003, it was becoming increasingly clear that Anne's illness was very serious and she and Susan began to groom Margie to take on a leadership role. Anne passed away in 2004, a loss that is still felt by those of us who knew her.

The ERS program went from strength to strength. Schools across the state of Connecticut signed onto the program. The program's model was to provide a Haskins mentor for every school. The mentor taught teachers the various aspects of phonological and linguistic awareness and then monitored their progress and the progress of their pupils. Since then, Susan Brady has continued to refine the methods in studies in Connecticut and Rhode Island. She has trained second generation researchers and educators who are now high level educational administrators, people who carry into practice the Haskins research legacy. A recent chapter by Sue in the volume dedicated to Don Shankweiler that I mentioned gives state-of-the-art description of what the phonics approach has done for reading outcomes in the real world.[9]

By 2010 it was clear that the ERS program was constrained by Haskins' basic research focus and the Lab's nonprofit legal structure. It would make more sense to have the appled unit work as an independent entity. So, Margie Gillis set up a company called Literacy How, which Haskins regards as a sister organization. We share contacts and information with Literacy How and we have proposed mutual projects.

Around the year 2000, Elena Grigorenko and I began studying reading in Russian schoolchildren. The Russian orthography is transparent. An added interest was the study of the genetics of reading disability. Elena, who has appointments inYale's Psychology Department and the Child Studies Center, brought her expertise in genetics to the Lab. She remains as our key researcher on the genetic influences in reading. Elena has contributed to Haskins fMRI studies as well as behavioral studies.

Recently, I have published a few papers with Elena and a former student of hers, Adam Naples. With Adam leading the way on an analysis of Russian data, we studied the genetic aspects of the relationships between phonological awareness and rapid naming. Both relate to reading ability but in independent ways. In a second paper, we examined genetic models for the relationship between lexical decision and comprehension. In the draft of a third paper, Adam mentions a minor result that poor readers have simple reaction times equal to good readers; poor readers don't have perceptual-motor systems that respond more slowly than good readers. I informed Adam that I had published that same result (in a study of American children) 40 years ago in 1971, some years before Adam was born. I am still undecided whether to be pleased or displeased by this.

Since the 1980's, Don Shankweiler, along with many collaborators, has been examining the mechanisms involved in the cognitive processing of syntax. In. recent years, Dave Braze and Julie Van Dyke have worked closely with Don. I'll give you a sample of their research of the reading process that goes beyond processing of the single word. A recent study (with Whit Tabor, Rob Fulbright, Einar Mencl, and Ken Pugh) searched for the regions of the brain that are active for both reading sentences and listening to speech. Reading, goes the hypothesis, must co-opt some preexisting circuitry that is specalized for speech, but which circuits? Now, the brain regions that are important to reading words and sentences were known prior to this study. Several research groups, Haskins prominent among them, have studied reading words and reading sentences using fMRI and electrophysiological techniques. This particular study[13] asked about the overlap between reading sentences and listening to them, that is, where do reading and listening converge in the brain? The results showed that the main locus of convergence was the inferior frontal region, a region well-known to be a very important region for processing speech, per se. A second question asked was whether or not the dependence of reading on speech was a function of the reader's skill level. Was there a difference between good and poor readers in convergence of brain function? The graph shows that such a relatinship does exist. The solid line is the linear fit, the dotted line, the quadratic. The linear correlation is .55, the quadratic, .73. Clearly better readers show greater convergence between reading and listening.

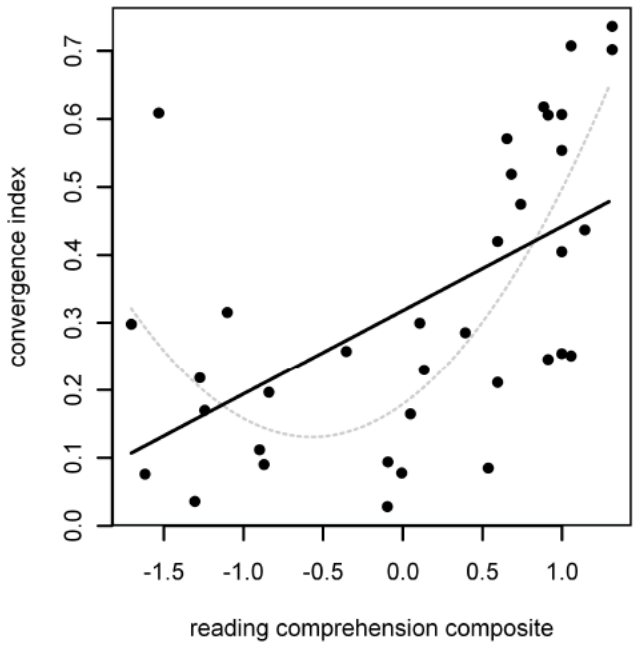
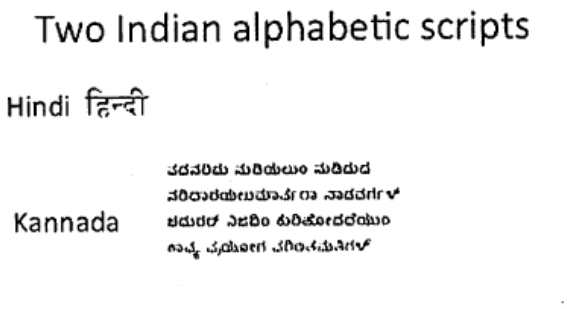


FIGURE 3 Reading Comprehension Composite scores plotted against the Convergence Index in dorsal IFG, with linear and curvilinear fits.

Shankweiler, Mencl, Tabor, Braze, Puvh, & Fulbright (2008).

Steve Frost and colleagues published related fMRI research that explored the relationship between phonological awareness and brain activation patterns during processing of print and speech as well.[14] While the Shankweiler study looked at young adults, the Frost study tested young readers from six to ten years of age. Behavioral measures of phonological awareness (PA) were positively correlated with activation levels for print relative to speech tokens in superior temporal and occipito-temporal regions. Differences between print-elicited activation levels in superior temporal and inferior frontal sites were also correlated with PA measures with the direction of the correlation depending on stimulus type: positive for pronounceable pseudowords and negative for consonant strings. These results supported and extended the many indications in the behavioral and neurocognitive literature that PA is a major component of skill in beginning readers and point to a developmental trajectory by which written language engages areas originally shaped by speech for learners on the path toward successful literacy acquisition. So, when learning to read, areas of the brain originally specialized for speech are co-opted.

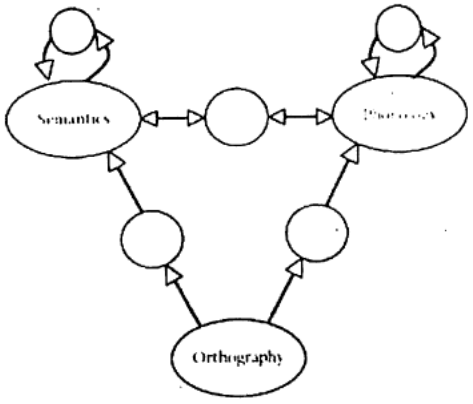


Haskins researchers continue to look at printed word recognition in various languages. At the moment, I am working on Korean and on two languages of India, Hindi and Kannada. The Korean work, with Professor Yang Lee, is designed to demonstrate phonological effects in Korean printed word recognition, similar to the Serbian research. The Indian work is in collaboration with Ken Pugh, a Haskins grad student, Anurag Rimzhim, and a professor at Mysore University, Prakash Padakannay who Ken invited for an extended stay at Haskins. Ken has been very active in establishing liaisons between Haskins and labs within the USA and around the world, more than I could describe in a brief paper. Particularly fruitful among these have been connections with labs in Taiwan and Finland.

It is good to have a curmudgeon around. Every lab should have one: someone who forces you down to earth when it would be easier to work only with people who agree with you. Mike Turvey has been Haskins' resident curmudgeon. With regard to brain studies, Mike will sometimes dismiss all brain research as mere 19th century phrenology. Proving him wrong is vary salutary. The approach of Ken, Einar, Steve Frost, Nicole and the rest of the Haskins neurocognitive gang is a systems theoretic approach where it is the *interplay* of brain systems that accounts for reading. Reading doesn't "live", so to speak, in any one region. The brain has various modules each of which has evolved to do certain kinds of tasks that are required for human survival. Reading co-opts these modules, bringing them together as an ad hoc system to accomplish this very high form of cultural adaptation.

I should mention, even if only briefly, that the neurocognitive group has recently been exploring the importance of reading ability and individual differences in metabolite concentrations with regard to neuronal function. The questions of interest here are whether reading skill is related to the prominence (or dearth) of certain compounds that are known to affect neural transmission. Rob Fulbright has been prominent in that effort.

One manifestation of the systems approach to brain function that I mentioned above is offered by Jay Rueckl. In a recent chapter[15] titled, "Computational Modeling and the Neural Bases of Reading and Reading Disorders," Jay and Mark Seidenberg discuss how to model interacting brain regions within the general theoretical framework of the triangle model which is, itself, an example of the more general modeling approach called connectionist modeling or parallel distributed processing.



The triangle model adapted from Harm and Seidenberg (2004).

Here, the general idea is that there are two information pathways that take print (say, the spelling *cat*) and convert it to activate the mental lexicon (e.g., the word *cat* in lexical memory). One pathway to memory involves partially decoding the print and transforming it into phonology, then using the phonology to address our speech lexicon and, finally, contacting the meaning of the word. This is the path from orthography-to-phonology-to-semantics. The other is a direct route from orthography-to-semantics, with phonology activated secondarily. In practice, both pathways may be activated in overlapping and interactive fashion during the 200 milliseconds it takes to recognize the word. Partial information may be transferred back and forth before the stimulus word in the lexicon reaches sufficient strength. It is possible for one of the two pathways to dominate the final result.

Identifying these ideas with real brain circuits and using the model to account for all the details of printed word recognition behavior requires a lot of expertise. There are many facts about word recognition that are well-known and a successful model must be able to account for them. These phenomena include: effects of word frequency, spelling inconsistency, imageability, how reading skill and experience interact with morphology, implicit memory effects, and many others.

Most recently, Jay has been studying the implications for word processing theories of the letter translation effect. This is a phenomenon in which slightly scrambled leters are often perceived as a normally spelled word. For example, the misspelling *jugde* may be perceived as the word *judge*, the reader filing to notice the shifted letters. Jay uses neural networks as his primary modeling tool for the translation effect.

There are many Haskins researchers who frequently contribute to the reading research program although their main interest is in more general language issues rather than reading, per se. These include Jim Magnuson, Whit Tabor, John Preston, and others. Daragh Sibley has been a most appreciated postdoc. A new A40 proposal on speech and reading is being prepared now in which the leadership roles are held by Nicole Landi, Jay Rueckl, Jim Magnuson, and Ken Pugh.

So, the tradition of reading research that began at Haskins over 40 years ago, continues. Its premise that reading was a linguistic process (“Reading is parasitic on speech”) hasn’t changed and still provides the motivation for new research directions. Early work on phonemic awareness

and hemispheric lateralization finds continuity with recent research on individual differences in spoken language and neurocognitive processing ("Psychology must be based on biology"). Work continues on understanding how skilled readers accomplish word recognition, syntax and comprehension. Research has begun on pre-reading children (birth-to-five) partly because of the hope that by detecting problems related to poor reading early we will avert them.

Footnotes

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Also: for up-to-date information on phonics research, see:
Brady, S. (2011). Efficacy of phonics teaching for reading outcomes: Indications from post-NRP research. In Brady, S., Braze, D. & Fowler, C. (Eds). *Explaining individual differences in reading: Theory and evidence*. (pp. 69-96). New York: Psychology Press.

Acknowledgements: Thanks to Claudia Carello and Mike Turvey for the graph of the Lukatela, *et al.*, experiment. Thanks to Steve Katz for assistance in all phases of preparation of this document.