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The Essence of the Science of Reading
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At the NIH, Lyon was responsible for the direction, development, and management of research programs in reading development, cognitive neuroscience, developmental psychology, behavioral pediatrics, language and attention disorders, and human learning disorders. He was responsible for translating NIH scientific discoveries relevant to the health and education of children to the White House, the United States Congress, and other governmental agencies. Prior to becoming chief of the CDBB in 1991, he had work in the NIH as a research scientist since the early part of the 80s. On July 1, 2005 Dr. Lyon resigned from his position at NICHD and accepted a position with Best Associates as a senior vice president for research and evaluation. He is currently a Distinguished Professor of Education Leadership and Policy at Southern Methodist University in Dallas Texas and a Distinguished Scientist at the Center for Brain Health in the School of Brain and Behavior Sciences at the University of Texas in Dallas.

After being established in 1963 with funding, a large amount of the research over the time from the 1960s to the end of the century had been made possible through the direction and funding of the National Institute of Health (NIH). The number of studies published expanded exponentially each decade. As director of the department that administered this work, Lyons was in a unique position of knowing what the research studies were, what they were about and what they produced. During this time, the essence of “The Science of Reading” took shape. This knowledge was established during the latter part of the twentieth century. It was spoken and written about by Lyons, chief architect of the work. Any work beyond this time has mainly been about further applications, added details and written reviews of this core development.

Lyon presented several reports to committees in Congress that translated important findings up to that time. His speeches serve as an accurate and concise report of what had been learned and what became known as the Science of Reading. The two selections posted are a good place to begin in gaining an understanding of the Science of Reading. As stated earlier, this science is long on theory and short on practical application, which means teaching. It’s more about the what and why than about the how to teach.

The Science of Reading: What’s been learned, G. Reid Lyon, 1998, An unpublished speech to U.S. Congressional Committee on Labor and Human Resources.

Reading: A Research-Based Approach, Jack M. Fletcher and G. Reid Lyon, 1998 published chapter.

G. Reid Lyon’s Speech to Congress, 1998.

After noting the seriousness of the problem of children failing to learn to read, Lyons tells about NIHCD studies on:

1. How children learn to read;
2. Why some children have difficulties learning; and
3. How we can help.

The first two questions are theoretical in that they seek background explanations. The third question is an attempt to apply the theories. In comparison to the first two questions, the third question is where the Science of Reading is weak. Teachers are left with generalities and principles, which sets the focus and direction, but provides little clear applications. Lyons acknowledges this fact.

The Science of Reading consistently finds that the most important part of learning to read is at the beginning – how it gets started. Lyons explains that learning to read, especially at the start, is difficult. But, why so difficult? For one thing, it doesn't come naturally. "The vast majority of children must learn how to **connect sounds in words to the letters that represent them**, known as the alphabetic principle". This means learning the "connections between the 40 or so sounds of spoken English (the phonemes), and the 26 letters of the alphabet." In so doing, the "would-be reader must understand that our speech can be segmented or broken into small sounds (phonemic awareness) and that the segmented units of speech can be represented by printed forms (phonics)". Thus, the importance and function of an alphabet is explained. It took years to verify.

Lyon asserted that without this kind of learning the high level of failure being observed will continue. He identified the source of difficulty. It "lies primarily with learning the relationship between speech and reading. It's about understanding the differences between the structure of sounds in speech and letters in print. ... Abstract letters must be linked to abstract speech sounds, called phonemes, in order to obtain meaning from print texts." To make this link a child "must understand that our speech can be segmented or broken into small sounds and that the segmented units of speech can be represented by printed forms." This is "absolutely necessary for the development of accurate and rapid word reading skills."

The ability to distinctly hear speech sounds is where the difficulty begins in learning to read. "The sounds in our speech are not spoken discretely and separately." They are thus hard for the ear to hear. "We now know that the brain performs this function in speech for us." So, "There is no need to become more aware of the sounds (in speech) **except for when they are needed for reading an alphabetic language.**"

A new reader must learn to "hear" the sounds more clearly and distinctly to match them with letters in words. Most importantly, new readers must also become capable of pronouncing and forming words from the print. Early researchers, (see posting Language by Ear and by Eye 1971) found this critical glitch, **really a block in getting started** learning how to "sound out" spellings to form the word. **At first, the learner has no idea how letters in words can produce a word that has one sound that is evident to the new learner.** There are more than one letter in words. They must be translated to a word that sounds like one sound. This is where the block exists for many children. Learning this skill with the ear, translated to the voice, is more difficult for some than others. This does not mean that there is brain dysfunction or damage, just less efficiency at the neurologic level. This variation in efficiency is part of nature's

“unbroken continuum of ability”. The good news is, the efficiency can be improved with teaching and practice. (But no particular ways to accomplish this are identified. It only describes what the child must learn to do.)

Lyon explains that “the ability to read is not a result of a biological process that emerged naturally in human history. It must be taught.” Once speech sounds start to become learned, the primary task is to learn how to decipher the printed alphabetic code into speech. “Phonological codes involve a structure of oral language that is not naturally obvious to the non-reading child. Knowledge of this structure must be learned by beginning readers to appreciate how the alphabetic print represents speech. Phonological codes are activated early in word recognition in both beginning and in skilled readers.” They are learned through an early phase of “sounding out” sounds that letters make, **provided they can get beyond the aforementioned “block” in learning.** Otherwise learning is at a stand still. If successful, “This then moves into a more skilled phase of automatic word recognition. Thus, the relationship between speech and reading can be learned and learning to read can get started and can progress.”

Children must learn to apply these skills so well that they can read a large assortment of words at a high rate of accuracy and at a fast, fluent pace. Acquiring these skills takes experience, practice, and instruction. **Amazingly, even with the variation among individuals, this can be accomplished by most children within the first few grades.**

Research has identified at least “four factors that hinder reading development... irrespective of their socioeconomic level and ethnicity.” The first factor concerns phonemic awareness. It is primary. Lyons states, “.. difficulties in decoding and word recognition are at the core of most reading difficulties.” Why? “Poor readers have substantial difficulty developing the alphabetic principle”. Why? “The culprit appears to be a deficit in phonemic awareness - the understanding that words are made up of sound segments called phonemes. ... Children who lack phoneme awareness have difficulties linking speech sounds to letters (phonics) – their decoding skills are labored and weak, resulting in extremely slow reading.”

Lyon claims that “the importance of the role of instruction has been underestimated in the science thus far.” He does not specify where and what the underestimation was, especially in the application of phonemic awareness to decoding. (getting beyond the “block”.) At this point, the Science of Reading is still heavy on theory, that is, what must be learned and why, and is light on the details of instruction. (how-to methods) Details of early lesson-by-lesson instruction have yet to be covered or decided by research, even up to the present time.

Lyon describes, in the speech, six ways that “phonemic awareness plays in the development of phonics skills and fluent and automatic word reading.” He then identifies six kinds of deficits that contribute to reading comprehension. He claims that the sad situation on this whole story is that many teachers are underprepared to teach reading. “More alarming is the fact that both university and state department of education requirements for teaching of reading may not

reflect, in any way, the type and depth of knowledge that teachers must have to ensure literacy for all.”

Lyon concludes his speech with eight general recommendations for: parent involvement, pre-schooling, importance of reading out-loud, early identification and intervention, kindergarten, adequate instruction time, the importance of explicit, systematic instruction (without know-how specifications), colleges of education, and the importance of research-based teaching.

This account presents the essence of what has become known as the Science of Reading. It took four decades to develop. It continues to serve to the present day as its core substance. The volume of published research since the 1960s and 70’s (observed in lists of references) attest to the level of research produced. A National Reading Panel declared, in 2000, that phonemic awareness and phonics were two essential components of teaching reading to children along with vocabulary, comprehension and fluency.

Lyon’s recounting of the volume of completed research is as follows: .

“... the NICHD research program produced a body of highly replicable findings that have been reported in over 2,000 journal articles since 1965.... During the past 33 years, NICHD scientists have studied the reading development of 34,501 children and adults. A research network consisting of 41 research sites in North America, Europe, and Asia has been developed. The early (and continuing) work of investigators at the Haskins Laboratories—the cornerstone of the research supported by NICHD on reading failure—has had international influence leading to a large accumulation of data supporting the identification of key components of reading and reading failure.” (see complete listings at the end of the next posting, “A Research-Based Approach”.)

Reading: A Research-Based Approach, book chapter, Jack M. Fletcher and G. Reid Lyon, 1998

This writing follows the same outline as Lyon’s speech of the same year but with more detail. For instance, right from the start, in pointing out the relationship of reading and speech, the authors inserted a quote from Alvin Liberman, “a noted speech scientist” from the Haskins Laboratories regarding the argument that **reading is dependent on language but is not a natural outgrowth of language.**

“A proper theory of speech is essential to an understanding of how people read—the most relevant consideration arises out of the deep biological gulf that separates the two processes. Speech, on the one side, is a product of biological evolution, standing as the most obvious, and arguably the most important, of our species-typical behaviors. Reading/writing, on the other, did not evolve biologically, but rather developed (in some cultures) as a secondary response to that which evolution had already produced. A consequence is that we are biologically destined to speak, not to read or write. Accordingly, we are all good at speech, but disabled as readers and writers; the difference among us in reading/writing is simply that some are fairly easy to cure and some are not.” A. Liberman (1997)

(The work of Alvin Liberman will be referred to, in more detail, in later accounts of the Haskins Laboratory postings.)

One of the chief concerns of the Science of Reading has been to uncover the mystery of reading at the word level that had existed for centuries. In the Lyon/Fletcher writing, the focus is on the primary importance of learning at this level. “Word recognition skills are intrinsic to reading, reflecting the need to decipher print, whereas language comprehension pervades all areas of literacy.” These two kinds of skills are combined within the framework of the “simple view of reading”, proposed by Gough in the 1970s. (A selection of Gough’s writings, on this subject, are posted on this website.)

The differences between how beginning readers and skilled readers read are noted: “the task for the beginning reader is to move from the early phases of ‘sounding out’ words to the more skilled phase in which word recognition occurs instantaneously. ... When children learn how print represents the internal structure of words, they become accurate at word recognition; when they learn to recognize words quickly and automatically, they become fluent.” The task is to first change the print to speech, i.e., know the word’s pronunciation, and, from this, recognize the word from the reader’s spoken vocabulary in memory.

In discussing causes of poor reading, the report gives additional information. Reading disability is not “qualitatively” different than normal beginning reading. “Reading failure reflects the lower end of reading proficiency; no qualitative characteristics distinguish the poor reader from the good reader.” At the lower end, problems involve “cognitive deficiencies” with single word recognition due to neurological, familial, cultural and linguistic diversity, as well as instruction.

The research at five sites is described. From this, it is concluded that “Although more research is needed, (and is continuing,) the work at these sites provide hope for children who read poorly. Much more is needed, however.”

Here, the authors indicate how practical applications are still undecided. “For instance: no NICHD data support a single approach to phonics, much less a specific sequence, number, or set of rules that must be learned, or an essential role for decontextualized drills” to get beyond the “block”. Adequate research on these items simply have not been conducted.

Although the specifics for applications are ambiguous, general principles drawn from theoretical studies are available, Lyon quotes Keith Stanovich, “That direct instruction in alphabetic coding facilitates early reading instruction is one of the most well established conclusions in all of behavioral science.... Conversely, the idea that learning to read is just like learning to speak is accepted by no responsible linguist, psychologist, or cognitive scientist in the research community.” (1994, pp. 285-86) Promising studies on instruction are cited. “Current evidence shows that effective classroom instruction can prevent reading failure in many children (Blachman 1996, 1997; Foorman et al. 1998).” (The number of failures remain. Even though there has been excellent demonstrations of the effectiveness of some applications, there is still a need for comparative studies on various teaching applications of the general principles to successfully teach children in getting beyond the “block” of learning how to translate printed words to speech, vocally form letters into words, at its simplest level.)

The assumption has been made, by education practitioners, that once the theory and why questions are understood, the practical applications will follow. Lyon/Fletcher concur that this assumption has been made but has not proven true. It is a false assumption. They acknowledge

that more research is needed to help develop cost-effective models for early identification, prevention, and intervention. (See interview of Lyons below on this question.)

(The sad irony is that we have known about reading development and reading difficulties well before the turn of the century and little progress in effectiveness is observed. This report, like most of the studies in The Science of Reading, stresses what must be learned and why, but not enough verified details on how to teach.)

ADDITIONAL QUOTES FROM AN INTERVIEW WITH THE CHILDREN OF THE CODE .

Dr. G. Reid Lyon - Converging Evidence - Reading Research on What It Takes To Read | Children of the Code.pdf

In this interview Lyons gives more detail on what was reported in the two postings.

Lyon: WHAT DO WE KNOW? Number one, we know that reading is complex and most people give it short shrift as I did when I was a third grade teacher. I just took it for granted. It's one of the most complex, unnatural cognitive interactions that brain and environment have to coalesce together to produce. ... in an alphabetic language... **the job of the beginning reader is to lay sound on top of these print characters** because it's literally impossible to memorize all this stuff.

So, ... when we say, what does it take to be able to learn to read, we know that it initially takes a clear understanding that the language we hear is composed of smaller sounds. These are called phonemes, the smallest units of sound.

[We don't hear three sounds in the word] "cat because nature has given us an oral language that allows us to communicate rapidly so that when I say cat, I don't say /c/ /a/ /t/. What I say is cat and the minute I start to say cat that /a/ and the/t/ sound co-articulate or bundle together **and come by the ear as one pulse of sound**. Phoneme awareness is much more difficult because you don't hear the sounds. **The brain has to pull from that one burble or acoustic bundle, the three sounds because the ear won't. The ear never hears the individual sounds unless we spell them out.**

Interviewer: So, in that sense, the whole phonemic awareness piece of this is an artifact of learning to read, **not something we would naturally have to develop to process the distinctions in oral language.**

Lyon: You do not need phonemic awareness to listen and speak. Because I'm not spelling the words out.

Interviewer: Yet much of our research seems to suggest that the lack of this is some deficit in children.

Lyon: It's only a deficit if they don't get it to learn how to read. A deficit is only a deficit if it impacts negatively on something critical that has to be developed.

[Is it a deficit in the ability to learn or hear the hidden phonemes and match them to letters? -a deficit in the ability to learn about phonemes and how to use them?]

Interviewer: It's a deficit with respect to the conditioning necessary to **take in** this artificial process.

Lyon: Yeah, it is an artificial process.... But you know, phonemic awareness is **absolutely critical**, non-negotiable to understanding how to read, **to knowing how to bring sound to print because we have an alphabetic language, but it is in no way sufficient.**

Interviewer: a kind of 'placeholder' or 'formatting' that's necessary for... later processing.

Lyon: we can't find good readers who don't have it. **IT TAKES PHONICS.. phonics is nothing more than a relationship between sound structure and print structure.** [between letters and sounds]

Interviewer: Can we say at this point that the processing efficiency...

- That's happening faster than thought,
- That's underneath thought,
- That's taking in the eyes' scan of the letters,
- That's converting these letters into sounds,
- That's generating this virtually heard or actually spoken stream of thought
- That gets popped out like an assembly, construction,

(is related to) the formation of the reflexes that are underneath volitional awareness – that are generating all of this.

If they form (all of this) inefficiently, they consume too much brain bandwidth and drag down comprehension?

Lyon: Yes, the capacity that goes into this print level work is far too great to give room for comprehension for relating new to known. ... The majority of our kids who have a tough time – they are slow, they are labored in their reading, **they are hitting the wall on a lot of these print skills.**

[**teachers** must understand all of this (theoretical explanation) and be ready to make adjustments [in instruction] so that all learn to read. They must be able to do this. And they're able to do this because of **"having a much deeper understanding of what it takes to pull print off a page, relate it to what they know, what the kids know and are able to apply, generalize, summarize, predict and so forth."**

Yet, there is no "best" program known for those children at the lower end.

[**Yet there still is a need for and value in**] knowing the sequences that are most efficient to move kids to mastery. **If you look at the instructional programs that are most beneficial for kids at risk, that really do get swallowed up by this ambiguity, those instructional programs carry a sequence of presentation designed to move kids systematically... Being very systematic takes an enormously talented teacher to do that who knows the answers to those four questions.** That's when they become responsive. ... what we will do is vary all of these teeny components, we'll study units of analysis, we'll study the load – the cognitive linguistic load, we'll study the type of feedback the teacher gives, we'll study the examples from different programs. **(and conclude) no one program is going to be equally effective and why a program is not effective for certain kids.**

Interviewer: One of the things that we've done is try to map out the ambiguity. **A letter doesn't have a definitive sound value as you know, it is almost like a wave or a particle....**

Lyon: Well, It co-articulates.

Interviewer: It co-implicates in the contextual field in that sometimes there are many words down the road that determine what the sound of a letter is. That's how far ahead and how much time buffering we've got to be doing in order to make this thing work.

WHOLE LANGUAGE

Lyon: what happened in the 60s and 70s were great intellectual leaps in terms of oral language, that indeed oral language is natural. Listening and speaking is species universal. That's why kids in Tokyo and in Toledo know the same sounds initially.

Interviewer: Somewhere between a million and a hundred thousand years.

Lyon: But what's amazing is kids all over the world can handle the same consonants and vowels. So, it's species universal, it is proto-plasmically driven. Reading isn't. unnatural, arbitrary.

The leap was: reading is language, therefore reading is natural, and therefore you do not teach the specific skills of the features

[The interview was abruptly ended due to a power shortage.]