

## Dyslexia : Auditory or Phonologic Deficit ?

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I would like to start by thanking the organizers of this conference for this privilege of presenting my work at this important gathering. I am happy to be back in Paris as it brings back wonderful memories of my sabbatical leave that I spent here, the friends I made and my discovery of the wealth of research going on in Europe. As for my presentation, I do hope that the facts will speak for themselves on this controversial issue of the auditory versus phonological bases of reading disability.

It is a well-known fact that poor readers are typically inferior to their normal reading peers on a variety of linguistic tasks. These include phoneme awareness, which requires the manipulation of phones within words like adding, deleting or reversing the order of phones in a word; phoneme discrimination, involving minimal pair consonant-vowel nonsense syllables like /ba/-/da/, /pa/-/ta/ and /sa/-/La/; speed and accuracy in lexical retrieval; verbal short-term memory; syntactic awareness and semantic processing on tasks of listening and/or reading comprehension. The question is whether there is some kind of link between these : Is there a primary deficit that gives rise to all other problems ?

In 1973, Isabelle Liberman proposed that the primary obstacle in learning to read stemmed from a lack of awareness that words can be analyzed into sequences of phonemes. Since then, it has been repeatedly shown that phonological deficits are present in *every* poor reader and that phonemic awareness is the single best predictor of reading success. But why is phoneme awareness difficult to achieve for poor readers ? A growing body in evidence points to a deficit in speech perception, its ramifications being manifested at various levels of phonological processing.

There appear, however, to be conflicting views regarding the *nature* of those deficit in speech perception. According to the speech-specific hypothesis, poor readers difficulties stem from their weak phonological coding abilities. That is, their auditory capacities are normal, but they have difficulty deriving phonological segments from the acoustic stream of speech. Proponents of the auditory temporal processing deficit hypothesis, however, claim that children with language-learning difficulties have trouble in processing sounds fast enough to distinguish rapid acoustic changes in speech. This claim is based on three assumptions : (A) « rapid auditory temporal processing » is essential to speech perception; (b) the left hemisphere's specialization for speech perception and so for phonology, is grounded in a prior specialization for « rapid auditory temporal processing »; (c) Phonological deficits in some disphasic children, some aphasic adults and some reading-impaired children, or dyslexics stem from deficits in « rapid auditory temporal processing ».

What then, is the evidence in support of each of these views ? For the speech-specific hypothesis, it is the consistently low performance of poor readers, on speech but not on non-speech, under demanding conditions; their poor short-term memory for words but not non-verbal sounds or pictures; and, the similarity of their error patterns on verbal recall tasks, whether the stimulus words are presented auditorily or visually, suggesting a deficit in phonological representation that is common to both modes of input rather than independent deficits in both vision and audition.

In support of the general auditory hypothesis is the finding that poor readers tend to be impaired in certain nonspeech auditory tasks like (a) temporal order judgment (TOJ) for rapidly presented complex tones differing in fundamental frequency; (b) sensitivity to rate and depth of acoustic frequency modulation; (c) choice reactiontime to pure tones differing in fundamental frequency; (d) auditory localization. Furthermore, performance on linguistic tasks relevant to reading. However, there appears to be a major flaw in this line of reasoning: None of these deficits are known to be related to *speech* perception per se. So, for example, there is non phonetic contrast that is specified by a difference in fundamental frequency of a pair of complex tones. Additionally correlational findings do *not* serve as evidence for *causality*. A causal role for a particular auditory deficit in defective speech perception can be acoustically-matched nonspeech control. And, finally, performance on temporal order judgment and other perceptual tasks may vary with general cognitive capacity, including attention, intelligence and rate of development. Unless these factors are taken into account, it would be difficult to interpret the results obtained on such tasks. Let's then take a closer look at the auditory temporal processing point of view.

The auditory hypothesis claims that poor readers have significantly greater difficulty than normal readers in (i) temporal order judgment (TOJ), at short interstimulus intervals (ISI), and (b) processing brief and rapidly changing acoustic information, such as the spectral changes typical of formant transitions signaling place of articulation at the onset of stop consonant-vowel syllables such as /ba/ and /da/.

In our investigation of these claims, Mody, Studdert-Kennedy and Brady (1997) hypothesized that if poor reader's problems with /ba/-/da/ are due to a failure of temporal analysis (i.e. TOJ) the task should be equally difficult when these stimuli are paired with fricatives rather than with one another. If however, these problems arise from the close acoustic-phonetic similarity of /ba/ and /da/ such that they are difficult to discriminate at rapid rates of presentation, then increasing the contrast should improve poor readers' discrimination and identification. A group of 20 poor readers, preselected for their difficulty with /ba/-/da/ TOJ were tested against a matched group of good readers on discrimination of /ba/-/da/, /ba/-/sa/ and /da/-La/. A comparison of the two groups' performances on TOJ and discrimination of /ba/-de/ yielded no effect of ISI on the good readers, who also made no errors, but a significant increase in errors with a decrease in ISI for the poor readers. The difference between TOJ and discrimination was not significant by post-hoc test, which was in keeping with Tallal's finding in 1980 with reading-disabled children. Interestingly, however, when we repeated these tasks with /ba/-/sa/ and /da/-La/, poor readers' difficulties at the short ISIs disappeared. Both good and poor readers had close to errorless performances on TOJ and discrimination of /ba/-/sa/ and /da/-La/;

Thus, poor readers' problems are not in TOJ itself, but in discriminating similar syllables presented at rapid rates. But then is the similarity that poses the problem auditory or phonetic in nature ?

To this end, we next tested the two groups on their ability to discriminate sinewave syllables modelled after the F2 and F3 trajectories of /ba/ and /da/. We hypothesized that if poor readers suffer from a general deficit in the processing of brief and rapid spectral changes such as those found in the second and third formants at the onsets of /ba/ and /da/ and which serve to differentiate these syllables, they should do significantly worse than the good readers on discriminating these acoustically matched sinewave analogs of the same.

However, as we can see, poor readers did not differ from the good readers on the interaction between the two due to sharp increase in errors by the good readers at the shortest ISI. This

though was found not significant by a post-hoc test of the difference. In short, ISI had no significant effect on nonspeech for the good or poor readers. Thus, poor readers did not differ from good readers in their ability to process brief and rapidly changing spectral information, despite the predictions of the general auditory hypothesis.

It is the comparison of the speech and nonspeech performances of the two groups that yield some interesting insights : (1) a strong effect of condition in the good readers but only a weak one in the poor readers. That is, changing from speech to nonspeech appeared to penalize the performance of the good readers but had no effect on the poor readers. (2) A strong effect of ISI for speech but not for nonspeech in the poor readers (3) no effect of ISI for speech or nonspeech in good readers.

This was further confirmed by a two way ANOVA of speech vs nonspeech in the poor readers only which yielded no effect for condition, a significant effect for ISI as also a significant condition by ISI interaction, attributable entirely to the effect of ISI on speech.

The key finding then in all these results was that whatever difficulties were induced in the poor readers by increasing the rate of presentation of the syllable pairs were not similarly induced by the nonspeech control patterns. Taken together, these results demonstrate that poor readers difficulties with /ba-/da/ discrimination were specific to the speech stimuli and cannot be attributed to a general auditory deficit in perception of brief and rapidly changing acoustic cues.

And, in yet another experiment aimed at testing the relative sensitivities of good and poor readers to brief and rapid spectral changes. Mody et al. employed a /seI-stel/ continuum in a categorical perception paradigm. Here, we manipulated the extent of the brief 40 ms F1 transition, the perception of which was integral to changing one's perception from /seI/ to /stel/. Once again, poor readers did not differ from good readers, the crossover points being very similar for the two groups.

That isn't to deny the improvements that have been observed with Fast ForWord, a clinical intervention program developed by Tallal and colleagues. However, to what extent are the claims and assumptions of the auditory hypothesis, on which Fast ForWord is based, justified when : (1) The claims have not been confirmed by several independent and carefully controlled studies. (2) The reasons for the improvement are unclear due to the lack of proper experimental controls. More specifically, is it the consistent and manageable rate, rather than the training of temporal processing skills with acoustically-modified speech that underlies the improvement ? Besides, which of the various manipulated components is responsible for the improvements we see: the extended duration of the speech signal, the amplification of the transitional elements or the adaptive training in temporal processing ?

According to Tallal et al (1996), the results of these manipulations is « appreciably slower speech with a staccato quality ». But slower speech may be easier to perceive than normal speech *not* because the auditory system does not have to contend with rapid transitions, but because the reduced rate allows more time for a disabled language system to form adequate phonetic representations.

But, what then is the relation between deficits in tone TOJ and in speech ? How do we explain the co-occurrence of these deficits ? As Nicholson and Fawcett (1994) clearly showed, dyslexics were slower than chronological age-matched controls on a selective choice reaction time task with tones. However, when compared to reading age -and chronological age-matched controls, the dyslexics were slower on words but not on nonwords. Thus, while dyslexics may show some form of slow down, the explanation of a general temporal processing deficit proposed by Tallal and colleagues cannot account for this difference in

reaction time to words vs nonwords. Nicholson and Fawcett conclude by suggesting two separate but coexisting deficits: « a phonological deficit in lexical access with a non-phonological deficit in stimulus classification speed ».

A final piece of evidence against the importance of auditory temporal processing in speech perception comes from work done by Tallal herself, with Stark in 1981. These authors found that language-impaired children who had difficulty with /ba/-/da/ also had significantly greater difficulty with /sa/-La/ than normal controls. This was contrary to their expectations as they claimed that the frication noise « would be of sufficient duration to allow these children to discriminate normally between these syllables ». Tallal and Stark concluded that their language impaired children may have had intermittent high frequency hearing loss, as is sometimes the case with such subjects. However, the speech-specific proponents contend that /sa/- La/ like /ba/-/da/, are phonetically similar, differing only on a single phonetic feature of place of articulation, and hence posed a problem for these children. In fact, in a separate experiment Mody and colleagues also made a similar finding where good and poor readers did not differ in their phoneme boundaries on a /su-Lu/ continuum but poor readers were significantly less consistent in their labeling of the tokens.

Taken together, these findings support a speech-specific account of reading disability. The withdrawal, by Tallal and colleagues, of the tone TOJ task called the STAR as a screening measure for use with Fast ForWord and the inability of this measure to accurately predict which language impaired children would qualify as likely candidates for the intervention, raises further questions as to the scientific basis of the auditory temporal processing deficit claim.

I would like to end with a quote from the Journal of Speech, Language and Hearing Research (April, 1998) which states that « ... dyslexia has a documented and compelling *linguistic* basis (Shaywitz, Yale School of Medicine). Evidence that dyslexia represents an *auditory-specific perceptual deficit is weak and not supported by available empirical research.* (Musiek, Dartmouth School of Medicine). »

In conclusion, I would like to say that we need to better understand the facts before we try implementing them in the form of remediation for language-impaired children who are vulnerable and ultimately depend on us to design what is best for their *long-term* interest. We owe it to them and to our professional code of ethics. For it is only when we have the science right can we be expected to design the best possible intervention. Thank you.