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Learning to read; attaching your ear to your tongue

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Those of a certain age will recall their first magnetic audio recorder. What a thrill! Press **RECORD** and speak into the microphone. Then press **REWIND** and **PLAY**, and listen to your own voice. But that's not your voice! Oh my, is this a defect in the recorder? Of course not – you have just discovered that what you hear when you speak is not what listeners hear. The complex acoustic signature transmitted by your bones and other tissue, along with the airborne signal to your own eighth nerve and auditory cortex are not what your listeners hear. Consider now what this may mean for the growth and development of speech, and its impact on reading and other cognitive tasks.

The learning that occurs in early childhood (kindergarten through third grade) forms the foundation that will significantly influence a child's later success in school, and ultimately in life and society [1, 2]. Speech skill, quantized by measures of accuracy, rate, and prosody, [3] has been shown to be an accurate predictor of reading comprehension [4] and reading proficiency [5]. Observational records or analyses of one-on-one interactions are currently the major components of speech fluency assessment. Whereas these techniques can provide valuable information for teachers when they are administered properly, they are time-consuming and can be subject to a teacher's expectations. In addition, the results of these tests commonly boil down to only a norm-referenced datum, i.e., a percentile score, which provides teachers with little information to help guide instruction and is often extremely difficult to interpret. Moreover, the lack of an easy-to-administer and objective assessment of speech fluency for children in Pre-Kindergarten (age 4) to Grade 2 (age 7) has led to a "wait to fail" model in our schools. All a teacher can do is react to deficits discovered in the third grade "high-stakes tests" [6]. Furthermore, traditional tests of speech fluency often tell a teacher what a child cannot do; they do not offer principled reasons regarding why a child is having difficulty with a particular concept. Consequently, teachers adopt various strategies of their own invention; some successful, some not. Most significantly, these traditional methods of assessment do not provide teachers with "next steps" or recommendations for remediation.

Without early intervention, children who are struggling with reading in early childhood almost invariably become weak readers in middle and high school [6]. While there is now a greater push for individualized instruction and targeted intervention, traditional assessments that are in current use are not designed to meet the unique needs of individual children [7, 8, 9].

The key to the development of an effective intervention program is to identify what works best for an individual student to help that child overcome a particular difficulty [10]. Whereas reading and writing may be regarded as secondary facets of an innate language learning capacity that students bring with them to school [11], the earliest indication of language failure, and thus the opportunity for intervention, is not necessarily dependent upon the several years of training required to convert language to and from written words [12]. The focus on phonemic awareness and reading fluency is one of the founding principles of the No Child Left Behind (NCLB), and the Reading First federal initiatives for improving early education in the United States.

The research data discussed here will guide us as we develop speech analysis software that builds on the successes of Children's Progress, Inc. (CPI) to assess and diagnose children's academic performance. Our company has developed a new kind of assessment tool, the Children's Progress Academic Assessment (CPAA), a dynamic assessment in language arts and mathematics that adapts to a child's series of responses, examines several factors and integrates these results to gain a deeper understanding of the child's learning successes and failures. This technology is described more fully in United States Patent No. 6,511,326 B1, awarded on January 28, 2003 and titled "Adaptive Evaluation Method and Adaptive Evaluation Apparatus." The research team that has been working on the CPAA for the past few years has made tremendous progress in turning a novel and unique psychological invention into a valuable commercial product. To date, over 90,000 children in 39 states have used the CPAA.

The proposed development of what we call "voice mirroring" instructional technology builds on an existing prototype of an apparatus initially proposed in the *Quadrate Mind* [12], and further clarified in a pending US Patent titled *Apparatus, System, and Methods for Researching Speech Development* developed by Professor Eugene Galanter. It is suggested that many of the speech problems that children exhibit may be attributed to the fact that they simply cannot hear their own voice well, just as we are surprised by the playback of recordings of our own adult speech [12].

To examine this hypothesis, a prototype voice mirroring apparatus was constructed. This apparatus consisted of a microphone, amplified and connected to a headphone to present an 88 dB audio side-tone to a child's air-borne acoustic speech. This device allowed a child to hear his/her own voice at a sound level greater than what is normally heard, as a reflection of the sound field heard by others. The primary conjecture driving the present experiment was that a child who is given the chance to hear speech as others hear it will be able to make appropriate vocal adjustments necessary to acoustically define the way printed words on the page must sound. It should be noted that for the purposes of this study, the voice mirroring apparatus used was a reengineered commercially available toy not connected to a computer.

A preliminary investigation was conducted by the author with 22 children, ages 7 and 8, at an elementary school in New York City. Each of these students was asked to tell a teacher-technician a short fairy tale, and their performance was video-recorded. Students were then asked over the next semester to read stories aloud twice a week over a six-week period during sessions with their teacher in their regular reading classes. Eleven students, chosen randomly, were asked to read the stories while utilizing the voice mirroring apparatus; the remaining 11 students read the stories while wearing the apparatus, but with the amplifier turned off. After six weeks, all 22 students were asked to read another short passage and their reading was again video-recorded. Four judges (teachers) unaware of the experimental manipulations were then asked to view the recordings and rate each child's reading fluency before and after the six-week period. The judges were asked to classify whether or not each child's reading had improved. The results (presented in Table 1) show that children who received the "voice mirroring intervention" were judged to display improved reading fluency compared to children who did not receive the intervention. Overall, children in the intervention group were almost three times as likely to be judged as having improved, whereas children in the control group were roughly equally likely to be judged as having improved as not improved. The children's before and after storytelling videos were also examined by a speech specialist. The specialist's judgments favored the children who had used voice mirroring. Admittedly, this preliminary study has a small sample size and the effects of the intervention cannot be reliably stated to have had a significant effect; however, the results provide ample reason for excitement about the potential of such an intervention.

Table 1. Judges' ratings on the improvement of reading fluency of children who received the voice mirroring intervention compared to control children.

	Judge	Intervention		Control	
Improved	A	7	**32**	6	**23**
	B	9		7	
	C	9		4	
	D	7		6	
Not Improved	A	4	**12**	5	**21**
	B	2		4	
	C	2		7	
	D	4		5	

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