# Improved Language Skills by Children with Low Reading Performance who used Fast ForWord Language[1]

## MAPS for Learning: Product Report 3(1)1:13


## ABSTRACT

452 children in classrooms at 9 U.S. elementary school districts were identified by their teachers as being "at-risk" for failure in reading and language arts. Standardized testing revealed that these children scored well below age-expected levels of performance and lower in language comprehension and phonological awareness than in word reading ability. An intensive, adaptive, computer-based training program designed to improve the accurate aural reception of the spectrotemporal structure of speech was administered to 288 of them; 164 children served as controls. Children worked at training exercises for 100 minutes/day for an average of about 30 school days. Complex acoustic signal (speech) reception training resulted in gains in: a) speech reception and comprehension, b) phonological awareness important for successful reading initiation, and c) in other language and behavioral measures. More than 70% of the group receiving speech reception training showed a significant improvement in language comprehension, with an average 1.8 years in language-age advancement over their pre-training performance. These studies indicate that early, intensive computer-based skills training in speech recognition and language comprehension can significantly reduce measures of risk for later academic failure in reading and language arts for the majority of young, less skilled school-age children including children learning English as a second language.


**Keywords: Nationwide, experimental design, randomized control trial, random assignment, public elementary schools, Fast ForWord Language, Test of Auditory Comprehension of Language, Revised Edition (TACL-R), Phonological Awareness Test (PAT), Woodcock-Johnson Psycho-Education Battery-Revised (WJR).**

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The majority of children who perform poorly in American schools first experience difficulty in learning to read, write and spell. These "language arts", as they are referred to in public education, represent the most prevalent area for learning problems in the United States (Shaywitz et al., 1997; Shaywitz, 1998). For most children, the struggle to achieve success in the language arts begins in the early years of school. Children with limited academic achievement ultimately receive special educational services, but usually after reading failure and/or general academic failure have been well established (Riley, 1994). At the same time, elementary school teachers can readily identify children in their classrooms that are academically "at-risk" within the first weeks of school. This identification occurs primarily on the basis of a student's limited language and communication capabilities, limitations that a large body of research has shown to be strongly correlated with reading and general academic failure (Snow et al., 1998).

The importance of explicit language instruction in learning to read is well documented, for review see Snow et al., 1998 and Moats & Lyon, 1996. Briefly, they review the large body of evidence showing the critical role that oral language comprehension skills play in the development of early reading success. These include but are not limited to the impact that phonological awareness, syntax and semantic skills have on children's ability to benefiting from an orally presented language arts curriculum. In low achieving populations the relationship between language and reading performance has also been documented. Similar prevalence estimates of approximately 7.5 percent for specific language impairments in kindergarten (Tomblin, et al, 1997) and specific reading impairments in second grade (Shaywitz, et al., 1990)

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[1] **Adapted from:** Miller,S.L., Merzenich, M.M., Tallal, P., DeVivo, K., Linn, N., Pycha, A., Peterson, B.E., Jenkins, W.M., (1999). Fast ForWord Training in Children with Low Reading Performance. Nederlandse Vereniging voor Lopopedie en Foniatrie: 1999 Jaarcongres Auditieve Vaardigheden en Spraak-taal. (Proceedings of the 1999 Netherlands Annual Speech-Language Association Meeting).

along with the common co-morbidity of these disorders strongly suggests a shared etiology between language and reading problems (Stark et al. 1984; Bishop & Adams, 1990; Scarborough, 1990; Catts, 1993; Torgesen, et al., 1994; Bird, Bishop, & Freeman, 1995; Hynd, et al., 1995).

In earlier reports, we described an effective computer-based adaptive training method for ameliorating the fundamental speech reception and language comprehension problems of children with language and learning impairments (Merzenich et al., 1996; Tallal et al., 1996). This novel approach was based on integrative and behavioral neuroscience studies demonstrating that the representations of rapidly successive or rapidly changing stimuli (speech) in the cerebral cortex are subject to powerful, age-independent brain plasticity-based learning effects (Recanzone, Merzenich, & Schreiner, 1992; Wang et al., 1995; Kilgard & Merzenich, 1998; for reviews see Merzenich & deCharms, 1996; and Merzenich & Jenkins, 1995). Major improvements in accurately distinguishing and identifying rapidly successive and rapidly changing sensory inputs in high fidelity can be achieved by a limited period of adaptive training in even adult subjects (Karni, 1993; Merzenich et al., 1996). A substantial proportion of children with specific language and related reading impairments do not resolve the spectrotemporal fine-structure of speech with normal accuracy (Liberman et al., 1974; Tallal & Piercy, 1973; 1974; Leonard et al., 1992; Stark & Heinz, 1996; for review see Leonard, 1996). Abnormally strong backward detection and recognition masking interferences between rapidly successive acoustic inputs in children with language impairments could degrade their neurological representations of rapidly successive and rapidly changing acoustic inputs including speech (Tallal & Piercy, 1973; Protopapas et al., 1997; Wright et al, 1997; Stein & McNally, 1995; deWeirdt, 1998; Stark & Heinz, 1996; and Cornelissen et al., 1996; for review see Farmer & Klein, 1995). Developmentally, this problem in complex acoustic signal (speech) reception can be demonstrated in infants supporting an etiology that is initiated in prenatal or early postnatal development (Benasich & Tallal, 1996).

While neurological (Galaburda, 1993, Hagman et al., 1992; Shaywitz et al., 1998) and genetic (Cardon, et al., 1994; 1995;. Grigorenko, et al. 1997) factors have been shown to play an important role in the genesis of language and reading skills and their disorders, it is also known that early language experience contributes powerfully to the development of normal speech reception abilities. Extensive research has demonstrated that early experience with a specific language alters an infant's phonetic perceptions within the first months of life (Kuhl, et al., 1992; Eimas, et al., 1987) and that an impairment of the capacities of an infant to resolve the spectrotemporal details of incoming complex acoustic inputs can delay and degrade speech and language development (Gravel & Wallace, 1995, Roberts, et al., 1997). We reasoned that biologically-based language learning problems could very plausibly require or become exacerbated by an alternate language learning progression in a brain with otherwise-normal learning capacity.

On the basis of cortical plasticity studies of skill learning conducted principally in animal models, we hypothesized that sharp improvements in the receptive language abilities of these children might be achieved by an acceptably limited period of highly targeted intensive speech reception and language training. Further, it could be predicted from cortical-plasticity research that clarifying the neurological representations of acoustic speech signals would lead to representations of speech in more salient and distributed neurological forms and subsequently produce substantial impacts on the perceptual and cognitive operations related to language. The critical importance of early oral language experience for acquiring age-appropriate language development and subsequent academic success in reading supports the understanding that aspects of disordered language and reading are learned. These experiential or learned influences are subject to powerful learning effects following intensive training. We have hypothesized that providing an intensive and comprehensive speech and language training program to non-disordered children will have a preventive effect on the number of students experiencing academic failure (Merzenich, et al., 1997; Merzenich & Jenkins, 1995).

Many of these predictions have been demonstrated to be correct, as evidenced by data collected in both the laboratory and the clinic (Merzenich et al., in press). The majority of more than 17,000 children with language and learning problems now trained to receive speech in higher fidelity by this new method have attained normal or above-normal abilities of acoustic speech reception after training. Statistically significant gains in language usage and in attentional-, memory- and other cognitive-based skills have also been recorded in parallel. We have recorded improvements following intensive adaptive speech and language training on standardized measures of digit span, confrontation naming, sequencing and delayed memory tasks. Questionnaire data has shown significant improvements for evaluations of self-esteem, problem solving and pragmatics. As these results were initiated first through anecdotal reports and post-hoc data analyses, we are currently addressing these issues through a priori planned experiments in laboratory and field experiments.

To date, most of the children who have progressed through this training program qualified for, and were receiving special education services in their respective schools due to language and/or reading impairments. The present study was initiated to evaluate the possible impacts that intensive speech reception and language training in this general form could have for the far larger population of American school age children who are not categorized as language or learning impaired, but who are nonetheless recognized as less skilled and/or "at risk" for failure in reading and general academic failure.

## METHODS

*Participants*

Five hundred and eighty-five elementary school children were invited to participate in a research study to examine the role of computer-base language training on academic performance. One hundred and fifty-one children were excluded from the present study due to a failure to complete the pre- or post-evaluations (n=59); or failure to complete four weeks of Fast ForWord training (n=28), or were students currently receiving special education services (n=64). Four hundred and thirty-four children were identified as "academically at-risk" by their classroom teachers and were assigned to either receive daily computer-based acoustically modified speech and language training (training group, n=288), or assigned to remain in their classroom's standard curriculum program (control group, n=164). Children were identified as "academically at-risk" by classroom teachers based on the child's performance in their language arts curriculum. For the purposes of the present study children currently receiving special education services are excluded.

Specifically, classroom teachers were asked to identify children performing in the lowest quartile within the language arts curriculum of their classroom, including children with a bilingual background. Each school district was asked to identify a group of 60 elementary school children primarily within kindergarten to third grade, although a small number of 4th and 5th grade children also participated. Twenty-two percent of the subjects had English as their second language. Due to the requirements of this computer-based training, informed consent was obtained from each child's parent or legal guardian, and all children received a battery of standardized reading and language measures. In addition, parents and teachers were asked to complete a questionnaire about the child's learning style and behavioral characteristics. Evaluations of reading were collected as part of a longitudinal evaluation of the impact of language training on reading development; they will be reported separately. A stratified randomization procedure assigned children to either receive acoustically modified speech and language training (training group), or to remain within the regular education curriculum (control group). Sampling was randomized within each grade and gender to restrict the influences of age and gender differences due to sampling error. Assignment to the training group and control group occurred with a fixed 1.74:1 ratio.

An additional experimental "comparison" group (n=64), children with documented problems in language arts curriculum and receiving special education services for these difficulties, were also included in the study. Results from this "special education" population shall be reported separately. The modified speech group worked under the supervision of a speech-language or educational professional on computer-guided adaptive training speech and language exercises administered for 1 hr 40 minutes daily, five days a week for 25-40 days. All subjects received standardized tests of language comprehension and phonological awareness administered by school personnel immediately prior to and following completion of the training program.

*Materials and Procedure*

**Fast ForWord Training Program:** Fast ForWord is an adaptive computer training program, based on the acoustically-modified speech and language training described above and described in detail previously (Merzenich et al., 1996, Nagarajan et al., 1998). The child wears headphones to hear the instructions or stimuli and uses the computer mouse to respond. The training program consists of seven exercises presented in the form of computer games which are organized such that the child first trains on basic acoustic reception abilities and progresses to exercises that are designed to improve the child’s syntactic and semantic skills. Each training exercise (game) began with training on that exercise and at a level at which most children can perform. The difficulty level continuously adapted so that the child got the majority (about 80%) of answers correct. Initially, brief, rapidly changing acoustic elements of speech (Block Commander, Language Comprehension Builder, Phonic Match, and Phonic Word) or acoustic signals (Circus Sequence, Old McDonald's Flying Farm, and Phoneme Identification) were stretched in time or amplified. The acoustic elements and signals adaptively approached normal speech speeds as the child progressed. The ending level for all of the training exercises was normal unmodifed speech or acoustic signals. During the exercises the child received trial-by-trial feedback. After an incorrect response was given, the correct response was shown before the next trial was presented. Correct responses were rewarded by sounds, lights, progress indicators, on-screen animations, and points. The points were converted to tokens for exchange in the child's local token economy.


Circus Sequence Builds rate of processing and temporal sequencing skills.


Phoneme Identification Helps children to distinguish phonemic sound changes.


Old Macdonald's Flying Farm Teaches children to identify specific phonemes.

***Figure 1*** *Lower Level FM Sweep and Phoneme Training: Three exercises that provide adaptive individualized training on the acoustic rate processing (within and between) non-verbal and phonemes sounds.*

*Circus Sequence (CS)* built the rate processing abilities both within and between nonverbal sounds. The child was trained to discriminate between a sequence of two brief successive acoustic sweeps which are separated by a specified inter-stimulus-interval (ISI). The sweeps are frequency-modulated (FM) glides that sweep upward from a base frequency or sweep down to the same base frequency, thus there were four possible combination of glides: down-down, down-up, up-down, and up-up. There were three base frequencies, 0.5, 1, or 2 kHz, six stimulus durations, stepping from 80 to 25 ms., and 45 inter-stimulus-intervals stepping from 500 to 0 ms. The child begins with the longest sweep durations and ISIs, cycles through the base frequencies, and progresses to shorter sweep durations and ISIs following progressively more accurate performance.

*Old McDonald's Flying Farm (OMDFF)* taught children to distinguish sound changes at the level of individual phonemes. In this exercise the child captured a flying farm animal which started a phoneme stream. The phoneme stream consisting of a random number of foil phonemes plus a target phoneme from one of the following sets of consonant-vowel (CV) pairs: /gi/ vs. /ki/, /chu/ vs. /shu/, /si/ vs. /sti/, /ge/ vs. /ke/, or /do/ vs. /to/. The child was required to release the animal within 125 ms of the presentation of the target CV. Voice onset time (VOT) and fricative-vowel gaps were extended and then systematically shortened to natural speech rates. There were also five levels of ISI decreasing from 500 to 300 ms.

*Phoneme Identification (PI)* taught children to identify specific phonemes. The consonant-vowel (CV) and vowel-consonant-vowel (VCV) stimulus pairs that were used are /ba/ vs. /da/, /be/ vs. /de/, /bi/ vs. /di/, /va/ vs. /fa/, and /aba/ vs. /ada/. The child heard a target stimulus which is one of the stimulus pairs, then one of a pair of animated characters vocalizes either the target or foil syllable. The child's task was to identify which animated character vocalized the target syllable. There are three presentation orders: target stimulus alone, target followed by foil, and foil followed by target; and 26 levels differentiating where the ISI, speech length, and amplification of frequency transitions was varied.

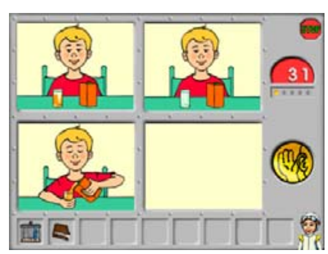
*Phonic Match (PM)* reinforced memory and reasoning skills within simple word structures that differ from each other by a single phoneme. The task was to match CVs by pressing the correct two tiles in succession in a 2x2 grid game board (3x3, 4x4, or 5x5 grid at higher levels). Pressing a tile evoked an aural CV, so the child had to accurately hear each CV and remember its location on the game board. The stimuli were 96 CVCs and CVs. The degree of confusability of the CVs and CVCs was included in constructing a task difficulty continuum. Speech length could be stretched 1.5, 1.25, or 1.0 times normal speech and the brief acoustic elements were amplified by +20, +10, or +0 dB. The maximum number of responses for each grid size was set below a level determined by a Monte Carlo sampling procedure to achieve the correct answers by random play. Completing a game board with fewer presses resulted in extra game points. Fewer presses indicated that the child reliably heard and remembered the CV and CVC speech.

*Phonic Words (PW)* **c**hallenged the child to distinguish between words that differed only by an initial or final consonant. The child heard the word and then chose the picture that best depicts the word from a choice of two pictures. Speech length could be stretched 1.5, 1.25, or 1.0 times normal speech and the brief acoustic elements were amplified by +20, +10, or +0 dB.


Phonic Match-Reinforces Memory and Reasoning Skills Within Using Simple Word Structures That Differ by a Single Phoneme


Phonic Words-Teaches Phoneme and Word Recognition Skills for Complex Words Which Differ by a Single Phoneme


Block Commander-Teaches Listening Comprehension and Syntax Through the Use of Simple Sentence Structures




Language Comprehension Builder-Introduces Increasingly Complex Sentences Requiring Higher-Level Language Skills, Including Morphology, Syntax, & Grammar

***Figure 2*** *Higher Level Language Training: Four exercises that focus on the auditory discrimination, recognition and comprehension of individual words and sentences.*

*Block Commander (BC)* taught listening comprehension and syntax, and trained short term memory through the use of increasingly complex sentence structures. In this exercise, the child touched or moved objects on the computer screen in response to increasingly more complex verbal instructions similar to the Token Test for Children (DeSimoni, 1978). Objects vary in size (large, small), color (red, blue, white, yellow, green), and shape (circle, square). The exercise begins with acoustically modified speech (1.5x normal duration; fast elements amplified by +20dB) and changes adaptively through 5 processing levels. The processing algorithm prolongs speech in time by 1.5, 1.25, or 1.0 times normal, and amplifies brief acoustic elements by +20, +10, or +0 dB (Nagarajan et al, 1998).

*Language Comprehension Builder (LCB)* introduced increasingly complex sentences to develop higher-level language skills, including phonology, morphology, syntax, and grammar. The LCB exercise was adapted from the Curtiss-Yamada Clinical Language Evaluation (Curtiss and Yamada, unpublished). After hearing a sentence, the child points to the target picture out of 2-4 pictures. The sentences vary in grammatical structure and complexity and systematically present more than 40 syntactic and grammatical structures. Sentences were initially presented with the speech length prolonged 1.5 times and with fast elements differently amplified by +20 dB, +10 dB or +0 dB, then systematically progressed in 4 steps to natural speech.

*Training Protocol*

Each child trained for 1 hour 40 minutes/ day, 5 days/week over an average of 39 training days (SD = 15.5, range 15-116 days). Training duration varied considerably and is based on several factors including the child's motivation, the absence of progress on the training exercises or an issue in public facilities might be access to the computer facilities. For example, most children stopped playing when the child reached a 90% performance level on 5 of the 7 games, or when the therapist judged that the child had received enough training. Some children continued to play after achieving 90% on 5 of the 7 games. The percent complete for each game for each day of game play, pre and posttest scores on the CELF receptive and expressive quotients, and age were obtained for the 288 children. A game history graph showed the percent complete by day visually for each of the seven games for each child.

*Evaluation Measures*

**Test of Auditory Comprehension of Language, Revised Edition** (TACL-R) (E. Carrow-Woolfolk, Pro-Ed, Inc., Austin, TX, 1985). The TACL-R examines comprehension for spoken language and consists of the following 3 subtests: Word Classes and Relations, Grammatical Morphemes, and Elaborated Sentences.

**Phonological Awareness Test (PAT)** (C. Robertson & W. Salter, LinguiSystems, Inc., East Moline, IL, 1997). The PAT test is designed to assess phonological processing abilities. It consists of eight subtests, two of which were administered to children in the study. The Isolation subtest (PAT-I) measures a child's ability to identify the initial, medial or final sound in a spoken word; the (PAT-D) Deletion subtest measures a child's ability to delete specific sound parts (syllables or phonemes) of words (e.g., "Say chair. Now say it again, but don't say /ch/").

**Single Word Reading (WJRWD)** (Letter-Word Identification Subtest,Woodcock-Johnson Psycho-Education Battery-Revised, R.W. Woodcock & M.B. Johnson, Houghton Mifflin Company, 1990). The Letter-Word Identification measures the subjects reading *identification* skills for isolated letters and words. The subject is shown words or letters and asked to identify them. The subtest begins with pictures to teach the task and then moves to increasingly more complex words.

## RESULTS

The pre-training language abilities of all subjects identified as "academically at risk" were determined prior to group assignment. Group assignment was completed using a stratified randomization procedure with a ratio of experimental to control children of 1.74:1.0. Prior to training, average performance on measures of receptive language, phonological awareness, and single word reading measures was equivalent to a z-score of –1.04 which approximates the 14$^{th}$ percentile of performance for this test within the general population, a finding that supports the 'at-risk" status for these children as assigned by the classroom teachers (Brown, et al., 1990; Finucci, et al., 1984; Vellutino, et al., 1996. For both groups prior to training, measures of language comprehension and the isolation and deletion of phonemes were significantly lower than measures of single word decoding (Fig 3). Pairwise comparison of pre-training performance means were analyzed using z-scores due to differences among the tests and their underlying normative distributions (e.g., mean=100, SD=15 vs. mean=50, SD=10). Comparisons of the tests revealed significantly lower performance for each language measure as compared to the measure of single word reading: TACL-R vs. WJWRD, t= 28.7; p<.001; PAT-I vs. WJWRD, t=19.2, p<.005; PAT-D vs WJWRD, t=22.0, p<.001. Pairwise comparisons of the other measures failed to reach statistical significance.

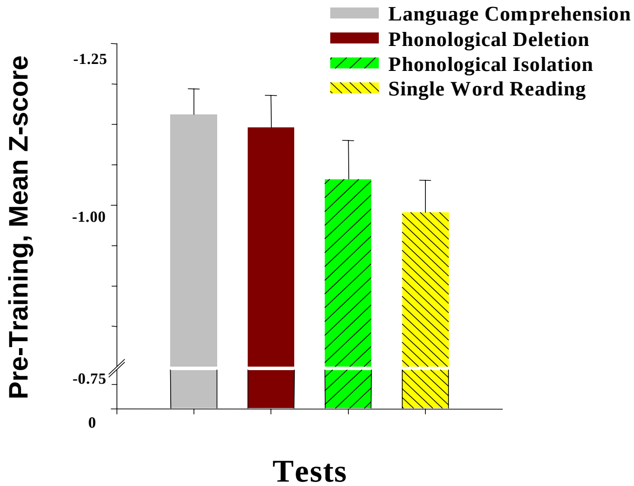



***Figure 3.*** *Pre-training Z-scores indicate the mean and standard error for individual measures of language comprehension, phonological processing and single word reading.*

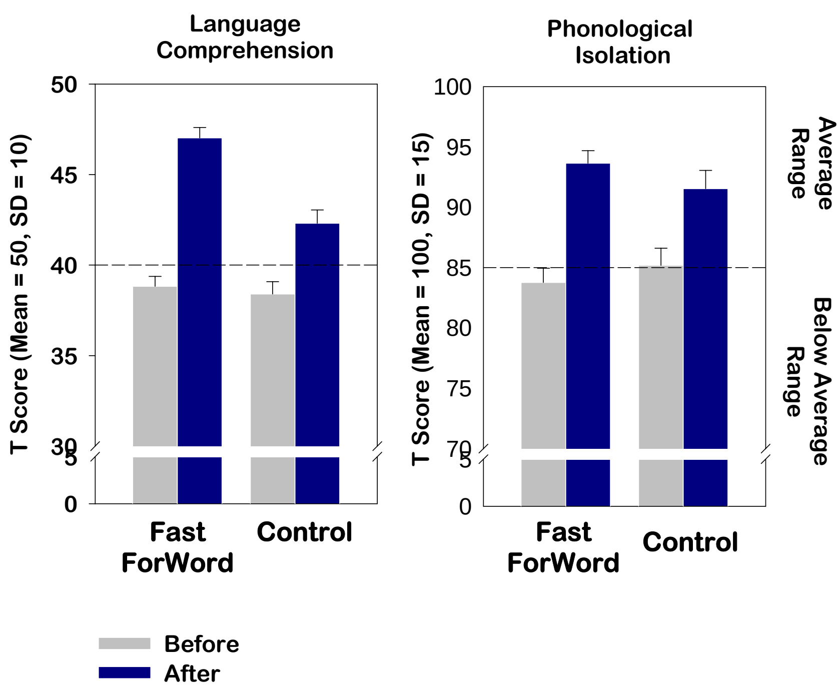



***Figure 4****. Pre- and Post-training means and standard errors in language comprehension (TACL-R) and phonological isolation (PAT-Isolation) are presented for children receiving Fast ForWord training and those in the control group who did not receive Fast ForWord training.*

Performance in phonological isolation for both groups varied as a function of phoneme position, with significantly better performance for the identification of initial position phonemes, compared to medial- or final-position phoneme isolation. It could therefore be reasoned that during the first years of school measures of receptive language and phonological awareness (isolation and deletion) provide a better reflection of a child's "academic risk" for failure in reading and language arts than a direct measure of single word reading performance. A conclusion which is inconsistent with many educational approaches that fail to recognize the importance of language instruction for literacy development this approach is consistent with previous work demonstrating the under-identification of school-age children with language problems and a direct link between language problems and reading impairments.

Comparison of pre- and post-training performance indicates that a program of intensive speech and language training can significantly improve the benefits of a standard educational curriculum for children "at-risk" for academic failure. Children receiving the intensive computer and Internet language-based training made significant improvements in both language comprehension and phonological awareness abilities. Comparison of the groups in phonological awareness showed statistically significant improvements from pre to post-training for both groups in language comprehension performance ($F(1,386) = 207.0$, $p<.0001$; Figure 4) and on both measures of phonological isolation ($F(1,383)=95.7$; $p<.0001$, Figure 4) and deletion ($F(1,383)=93.6$; $p<.0001$). Larger gains were recorded for the group receiving speech and language training, with those differences reaching statistical significance on both the language comprehension ($F(1,386)=26.3$, $p<.0001$) and phoneme isolation tasks ($F(1,383)=4.9$; $p<.026$), see Figure 4. Comparisons of the groups on the phoneme deletion task failed to reach statistical significance. Note, an alpha levels of 0.05 was used for all Comparison analyses.

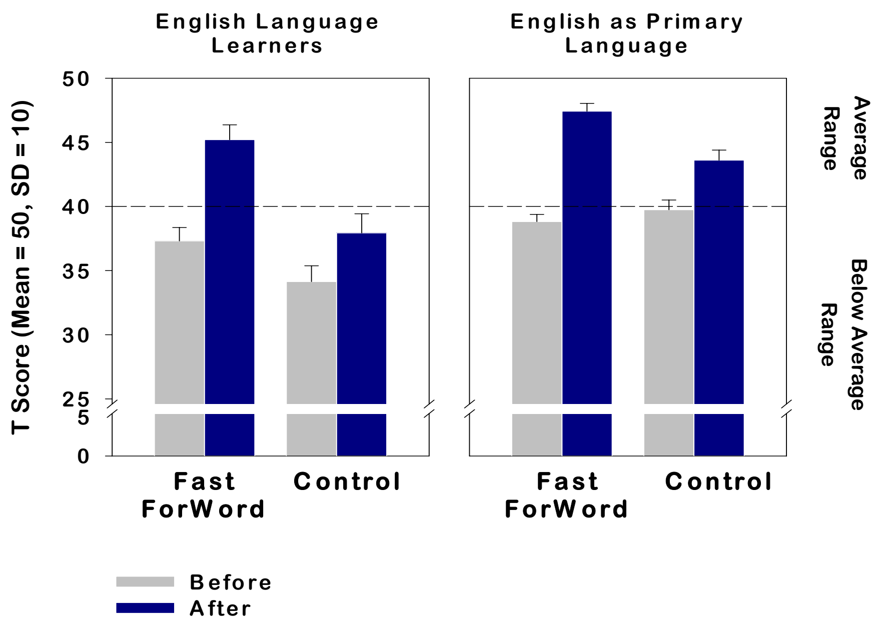



*Figure 5*. *Pre- and Post-training means and standard errors in language processing (TACL-R) are presented separately for children receiving Fast ForWord training and controls based on whether they are learning English as a Second Language or English as a Primary Language.*

**English as a Second Language**

The presence of a second language presents significant difficulties in diagnostic and treatment planning for children with poor language learning. Children learning English as a second language (ESL) and language-impaired children may receive similar scores on tests of English Language achievement but with different learning histories and learning profiles. There is evidence that second-language learners make perceptual reference to the phonetic categories of their native language (Leather and James, 1996), impairing their ability to perceive these categories in the target language. Such problems may surface in reading difficulties. Studies analyzing the cognitive reading processes of ESL learners in the United States have found that, while these processes are substantively similar to those used by native English readers, they tend to occur more slowly for ESL learners (Fitzgerald, 1995).

In the present study, both the training and control groups contained students who were identified as ESL learners (experimental n = 53; control n = 32). Of these, 76% spoke Spanish as a first language. All students were administered a battery of language and reading tests at the beginning of the six week period, and again at the end. The battery included measures of auditory comprehension of language, phonemic isolation and deletion, and single-word reading and decoding. Testing was conducted in English by school staff members.

Results suggest three primary findings, see Figure 5. First, the auditory comprehension performance of the ESL subjects who underwent training demonstrated greater gains over a six-week period than did those of the control subjects ($F(1, 79) = 4.63$, $p = .034$). The experimental subjects demonstrated an overall gain of 7.90 points on the auditory comprehension measure, and the control subjects demonstrated a gain of 3.79 points. Second, the changes in auditory comprehension performance demonstrated by the ESL learners in the study did not differ significantly from those of the native English speakers (NESL). Third, there were differences between trained ESL and NESL subjects. An analysis of the experimental group revealed a significant difference between ESL and NESL speakers on measures of phoneme deletion ($F(1, 233) = 5.20$, $p =.023$)). The ESL subjects (10.68 point gain) demonstrated significantly more improvement than NESL subjects (5.79 point gain). Results of the study suggest that acoustically-modified speech and language training may be successfully applied with ESL students in school settings.

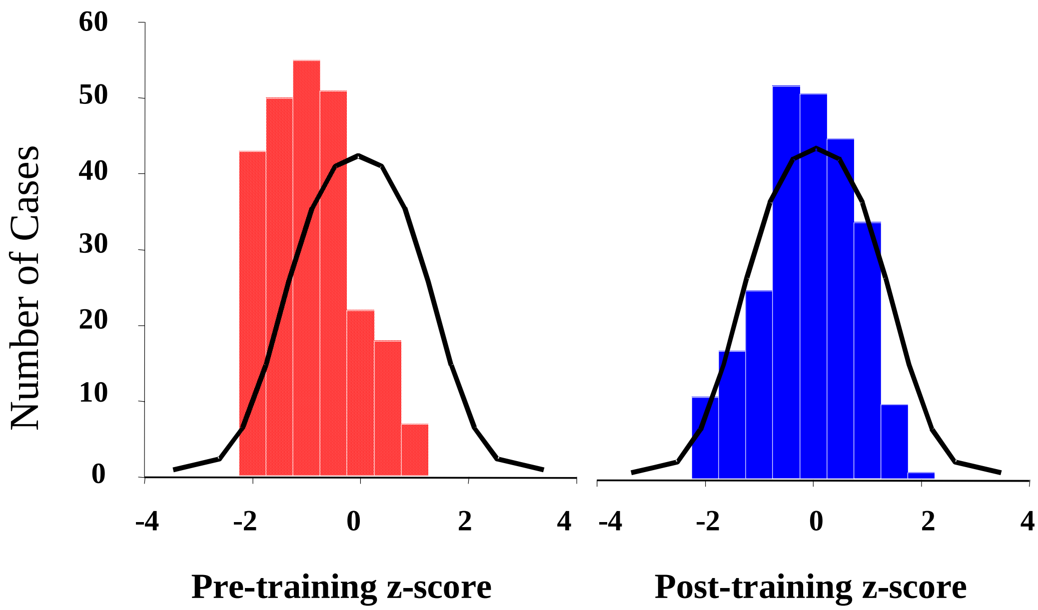



***Figure 6.*** *Pre- and Post-training frequency histograms using Z-scores of language comprehension performance (TACL-R) for the speech and language training group. The bold lines superimpose a bell curve on the histogram to represent the standard normal distribution of scores on this test.*

**<u>Risk Status</u>**

The group effects illustrated in Figure 4 fail to adequately address the extent to which the speech and language training has changed the academic risk of these children. Pre- and Post-training frequency histograms using z-scores of language comprehension performance, allowing direct comparison to the table of normal "bell" curve, indicate a large positive shift in the performance distribution for children following the 4-8 weeks of intensive speech and language training. Prior to training the language comprehension performance for both groups was well-below average, approximately at the 12.5 percentile for the normal distribution (–1.14 z-scores), a finding consistent with the “at-risk” status assigned by their classroom teachers. At post-testing, control group performance had improved (21st percentile or -0.8 z-scores) but was still well-below age-expected performance levels and lower than the performance of the training group (38th percentile or -0.3 z-scores). The number of subjects performing at or above the median in age-corrected language comprehension performance improved for the trained subjects from 11.4% to 39.0% as compared to 12.0% to 16.2% for the control group ($\chi^2$=22.06,p<.0001) for post-testing difference between experimental and control subjects.

Individual outcomes were considered significantly changed (positively or negatively) if the actual post-training score was different enough to exceed some estimate of an expected post-training score based on error. We used a calculation of the expected post-training score, termed a standard error of prediction (SEP), of sufficient value that it cannot be reasonably attributed to measurement error and regression effects. The standard error of prediction was calculated as 1.96 SEP where $SEP = SD_x (1-r_{xx})^{.5}$ where $SD_x$ is the pretest standard deviation of the sample and $r_{xx}$ is the test-retest reliability of the measure. For discussion of the derivation of this formulae see L.M. Hsu, 1995; Lord & Novick, 1968; Gulliksen, 1987. Significant gains in language comprehension performance, as compared to changes in performance that might be attributed to measurement error and regression effects, were identified for 67.1% of individual subjects that received the speech and language training with an average improvement of 1.8 years. The percentage of children who significantly benefited was significantly larger than would be expected by chance ($\chi^2$=47.9, p<.001) or was observed in control group (49%, $\chi^2$=46.2, p<.001) (Experimental versus Control subjects $\chi^2$=15.85, p<.0001).

The participating children, not currently receiving special education services but expected by their teachers to fall further and further behind in the classroom, showed highly significant benefits from intensive, adaptive speech and language listening training in this trial. These results are notable not only because of the substantial magnitude of language improvements demonstrated for the majority of trained children, but also because of the rate of language learning that was recorded. Further, 75% of children were effectively removed from the "at-risk" category, with performance scores at the post-training evaluation within 0.5 sds of their age-expected median performance. Positive behavioral changes in attention, cognitive flexibility and distractibility paralleled these language advances.

## DISCUSSION

A child with low reading performance is commonly impaired in their ability to separate and reliably identify and manipulate the smallest units of words or phonemes – that is, they lack ‘phonemic awareness’. In addition, difficulties with the syntax and semantics of a language are found to differ among fluent and less skilled readers, including dyslexics. The present results support these findings demonstrating significantly lower performance in language comprehension and phonological processing abilities in children identified as struggling in the reading curriculum in their classroom. As a result of training, children improved these abilities that in turn should enable them to better initiate reading. It should be remembered, however, that learning to read itself still involves intensive training after a language training program such as *Fast ForWord* training has been completed.

The highly successful application of the neuroscience-based *Fast ForWord* training program in these children, selected by their classroom teachers as poor readers, further demonstrates the impact that language instruction can have on children without clinically identified speech and language impairments. Similar improvements for children learning English as a second language strongly supports an expanded role for direct and intensive language instruction to improve language and phonological processing in these children within six weeks of program initiation.

These results further support that there is nothing fundamentally wrong with the learning machinery in the brains of children with low reading performance. Despite their functional limitations, these children retain a powerful capacity for learning as it applies to the fundamental listening skills that are critical for normal language operations. It shall be very interesting to record whether or not these training program-induced gains are sustained, as earlier research indicates is the case for children with language impairments (Bedi et al., unpublished manuscript). In addition, it will be important to document whether this training results in substantial wider cognitive impacts on memory- and attention-based skills, as has been recorded in children with language problems (Beitchman et al., 1986; Cantwell et al., 1984; Tallal et al., 1989). Studies are now underway to determine whether additional phonological awareness and sound-orthographic training can further augment these effects, which can be anticipated given the strong established correlations between accurate speech reception and these cognitive. Given the fundamental role of oral language in curriculum instruction and the critical importance of phonological awareness and other fundamental acoustic reception skills for successful reading initiation, substantial downstream gains in achievement in these children can be anticipated.

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