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Changes in backward masking thresholds, reading, phoneme awareness, and language skills following an auditory training program

Daniel Thomas Valentine

To the Graduate Council:

I am submitting herewith a dissertation written by Daniel Thomas Valentine entitled "Changes in backward masking thresholds, reading, phoneme awareness, and language skills following an auditory training program." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Speech and Hearing Science.

Mark Hedrick, Lori Swanson, Major Professor

We have read this dissertation and recommend its acceptance:

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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We have read this dissertation

and recommend its acceptance:

Mary L. S.

Colleen P. Gilrane

Accepted for the Council:

Vice Provost and Dean of Graduate Studies

Changes in Backward Masking Thresholds, Reading, Phoneme Awareness, and Language Skills Following an Auditory Training Program

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Abstract

Deficits in auditory temporal processing, or the ability to process the rapid sequence of auditory stimuli within speech, have been linked to reading and language disorders. It has been suggested that a temporal processing deficit interferes with the development of phonological awareness, a prerequisite to early reading skills. This investigation examined the effects of an intense auditory training program, Fast ForWord (FFW; Scientific Learning Corporation, 1998) designed to increase auditory temporal processing on a group of children with poor reading skills. Two primary research questions were posed. Will children increase temporal processing abilities, as measured through backward masking, immediately following FFW and will temporal processing abilities be sustained six months following FFW? Secondly, will children increase reading, phoneme awareness, and language skills immediately following FFW, and will increases continue six months after FFW?

Twenty-six children participated in experimental testing and the FFW program. Thresholds for simultaneous masking and three conditions of backward masking were obtained pre and post FFW, and six months following FFW. Behavioral testing included reading (word attack, word identification, and passage comprehension), phoneme awareness, and expressive and receptive language. A group of children who did not receive FFW training were administered the same tests immediately after FFW and six

months after FFW in order to determine if children with FFW training demonstrated greater developments in reading and language skills.

Thirteen children in the experimental group had more than a year delay on the word attack and word identification subtests and 13 children had reading measures that ranged within six months of age-equivalency The two subgroups in the experimental group differed significantly on all tests of reading, phoneme awareness and language measures with the exception of the Nonword Repetition Task. Backward masking thresholds were not significantly different between the two groups. Immediately following FFW, backward masking thresholds for all conditions improved. Even though masking thresholds improved, there were no increases in reading and only a modest increase on phoneme awareness as measured by the Nonword Repetition Task (p= .05). Both groups demonstrated increases in expressive language skills. Further assessment six months after FFW did not reveal a significant increase in 0-ms gap backing masking thresholds. In addition a control group that did not have the auditory training had significantly similar backward masking thresholds. Previous increases in language skills were not sustained at the end of the school year and there were no significant increases in reading skills. All three groups increased in phoneme awareness based on the NWT, however, only the children in the low average reading group significantly improved scores on the Lindamood Auditory Conceptualization test.

This study calls into question the efficacy of an intensive auditory training program to improve reading skills. Although, phonological awareness abilities improved over the course of the school year, there were no improvements in reading abilities. The FFW program is designed to target an increase in auditory temporal processing skills, however, this investigation revealed that immediate improvements in backward masking thresholds do not necessarily precipitate increases in reading abilities.

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Chapter I

Introduction

Recent research in early reading acquisition has moved from a top-down process to a bottom-up process. Goodman portrayed reading as a top-down process or what he referred to as a psycholinguistic guessing game in which the child uses minimal syntactic, semantic, and graphic cues to make sense of the text (Goodman, 1967). In the last twenty years, however, the emphasis has been more bottom-up and researchers have investigated the importance of phonological awareness to establish early literacy (Bradley & Bryant, 1983; Goswami, 2000; Wagner, Torgesen, & Rashotte, 1994). The work of Tallal and colleagues studied language and reading delays in young children and they speculated that an underlying mechanism, such as a deficit in temporal processing, impedes the perception, storage, and recall of phonemes that facilitates early word decoding (Tallal, 1980, Tallal, 1984; Tallal, Miller, & Fitch, 1993). With the use of sophisticated technology, such as fMRI, scientists are beginning to speculate that dyslexia is a result of atypical neural patterns in regions of the brain that are associated with phonological processing, attention, and memory (Habib, 2000; Shaywitz et. al., 1996, Shaywitz et al., 1998). Such research in the neurobiological development of reading acquisition has led to an intervention program that provides intensive auditory training to improve the perception of the acoustic cues in speech to strengthen connections in the areas of the brain responsible for word decoding (Merzenich, Jenkins, Johnson, Schreiner, Miller, & Tallal, 1996). This introduction reviews this research and describes how a temporal processing deficit influences reading acquisition.

Reading Acquisition

By the end of the third grade, if a child is expected to read successfully he will need to encounter over 25,000 distinct words (Adams, 1990) and yet during the primary grades, only a few thousand words are given direct instruction (Juel & Minden-Cupp, 2000). To accomplish the task of learning how to read, it has generally been accepted that children go through stages of reading development, each building on the other (Byrne, 1992; Ehri, 1991; Frith, 1985). Frith (1985) proposed three primary stages. The first stage of reading acquisition is called the logographic. In this phase, the child uses graphic cues to help identify the word and assign meaning. For example, with frequent exposure to advertisement signs such as *Crest* toothpaste or *McDonalds,* the child learns to associate the whole image of the word to its spoken form. During this stage also, children may attach non-phonetic strategies to recognized letters in words. For example, "mom" might be, "hump-hump-circle-hump-hump" (Gough, Juel, & Griffith, 1992). In the second stage, alphabetic, the child discovers the alphabetic principle or the grapheme-sound relationship. At this time the child is able to attach sound to each letter and blend them to arrive at the spoken form. In the third stage, the orthographic, he learns how to chunk letters, sometimes morphemic units (e.g., un, -ed) or non-morpheme letter strings (e.g., str, nk, or ook). During this stage, retrieval time of the stored units is faster and the lexicon is accessed directly without phonological mediation (Coltheart, 1978).

Phonological Awareness

A large body of literature exists correlating the emergence of a child's phonological awareness and his ability to decode words (Bradley & Bryant,1983; Bradley, Mclean, & Crossland, 1989; Gough & Tunmer, 1986; Morais, Cary, L, Alegria, & Bertelson, 1987; Vellutino & Scanlon, 1987; Wagner, Torgesen, & Rashotte, 1994). Phonological awareness is the sensitivity to syllable and intrasyllable units (rimes), and the segmentation and blending of phonemes in a word structure (Swank & Catts, 1994; Treiman & Zukowski, 1996). Researchers have argued that phonological awareness is a heterogenous skill with different properties that develop at different stages (Goswami, 2000; Treiman & Zukowski, 1996). Reciprocally, however, a child's explicit awareness of syllable and word structure increases as exposure to literacy or print increases (Bentin & Leshem, 1993; Ehri & Wilce, 1980). Studies have shown that improving phonological awareness increases decoding skills (Alexander, Anderson, Heilman, Voeler, & Torgesen, 1991; McGuinness, McGuinness, & Donohue, 1995). If a child has deficits in phonological awareness, or in the mechanisms that underlie phonological awareness, this could cause delays in establishing grapheme-sound relationships.

Dual-Route Theory of Reading Acquisition

The dual-route cascaded theory (DRC) of reading (Coltheart, Curtis, Atkins, & Haller, 1993) provides a model to understand how the printed word (the orthography) is translated to speech (the phonology). It differs from other connectionists theories of reading (Ans, Carbonnel, & Valdois, 1998; Seidenberg & McClelland, 1989) which proposes reading any string of letters is based on a system of weighted connections that are strengthened by a single procedure based on word knowledge and mediated by orthographic and phonological units. The fundamental characteristic of the DRC is that it provides two different processing routes for converting print to speech (Coltheart, 1978; Coltheart, et al., 1993). A reader who has learned a new word stores its representation in an internal lexicon or mental dictionary. This representation can be retrieved from the internal lexicon along with its pronunciation. This is what is known as the lexical route for reading aloud. Only words that have been previously learned may be accessed through this route. If a word is a nonsense word, or a word that does not have a stored representation, the reader must employ the nonlexical route. This second route allows for the decoding of pronounceable letter strings. This requires the mapping of a set of general rules that specify the accurate correspondence between the orthography and the phonology (the grapheme-phoneme correspondence system, or GPC).

The nonlexical route will use the GPC system to map rules or infer rules in order to translate letter strings of phonemes. In English there may be a single phoneme to grapheme correspondence, or there could be a single phoneme to a number of graphemes (or letters), but no more than four letters. Therefore, rules are generated when words are presented with their pronunciations. The GPC algorithm will infer all rules that are related to the word's spelling and pronunciation and will update the database. A simple one-to-one correspondence of phoneme- grapheme, such as in "rent" where r - /r/, e - /E/, n - /n/, t - /t/, is stored in the database. The rule for mapping similar words is inferred on further exposures (cent, bent, etc.). Consequently, the rule system is learned and reinforced through exposure to text, spellings and pronunciations.

Coltheart et al. (1993) explained that GPC rules may be context sensitive, for example, rules for the pronunciation of initial letter "c" as in either cat or city. Also, some rules may be position specific, as in the case of "y" in gym or sky. In addition, rules are learned for letter strings that match only one phoneme, for example "igh" - /aI/, as in the word blight. The algorithm will match a correspondence of the pronunciation of /blaIt/ to the letters "blit" but it fails to match the one-to-one correspondence to the "igh." It is at this time the rule is discovered for the spelling-sound correspondence of "igh" as /aI/. When the one-to-one correspondence rule fails, the algorithm maps the single phoneme to the letter string and stores this in the database. Frequency of exposure with words that infer their rules strengthens them and learning novel words becomes easier because conflicting rules are disregarded.

The second route of the dual theory of reading, the lexical route, relies heavily on research of the visual word recognition system (McClelland & Rumelhart, 1981; Rumehart & McClelland, 1982) and employs initially three components for word recognition: visual feature detectors, letter detectors, and visual word detectors. Coltheart et al. (1993) describe the lexical route of word recognition as "cascaded processing" (Figure 1). When a word is encountered, it activates letter detection features that then activate word detection features. Each entry in the lexicon is connected to its spoken word production, so the word detection features in turn activate the phoneme system. The more common the word is, the sooner it will activate the phoneme system. Irregular or exception words may take longer for complete activation, or to generate a final output. The reason for this latency is that exception words may generate different outputs at the phoneme level and therefore these competing outputs must be resolved by what the researchers call an inhibition process. The more frequent or common the exception word is, the faster it will activate the phoneme system and the more likely the phoneme system will be activated via the lexical route. However, the less common the exception word is, the more likely there will be competition between the lexical and nonlexical route.

A criticism of the DRC is that it does not allow for recoding, or a system that always accesses the phonological module (Ehri, 1992; Share, 1998; Share & Jorm, 1987). Based on evidence that young developing readers require only a partial knowledge of the grapheme-phoneme rule system in order to successfully read words, Ehri maintains that the phonological module is always accessed initially in reading words and is superior to

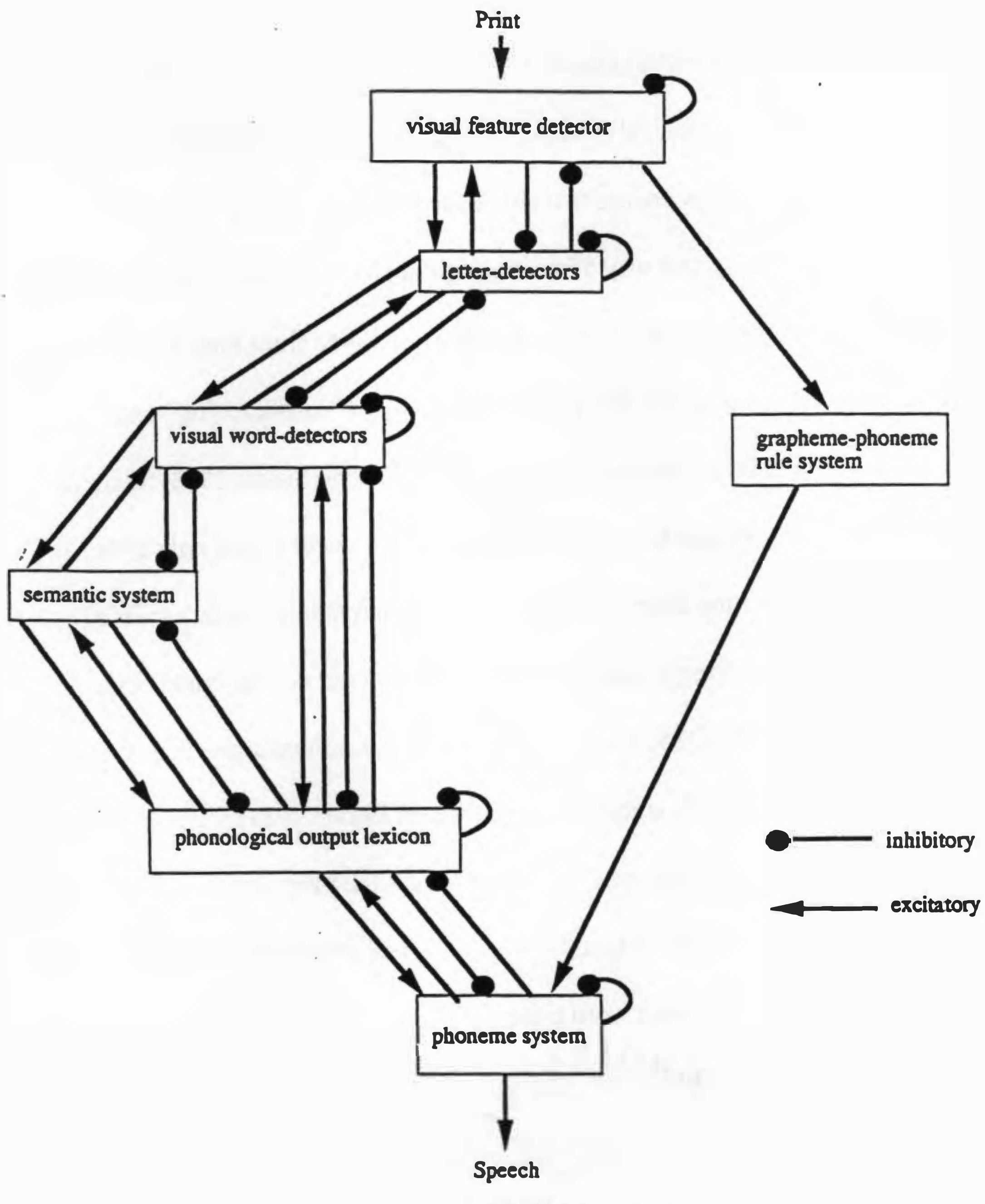

Figure 1. The dual-route cascaded model of word reading: after Coltheart et al, (1993).

arbitrary visual letter associations (Ehri & Wilce, 1985). Additionally, through always directly accessing the phonological module, young readers will strengthen grapheme-phoneme associations by a procedure that she describes as "recoding." Ehri (1992) describes the term recoding as a way of translating "letters into sounds by application of letter-sound rules and then recognizing the identities of words from their pronunciations" (p. 107). Later research suggested that recoding is a way of "self-teaching" and strengthening the connections between the sounds and letters (Share, 1998; Share & Jorm, 1987). There is evidence that children begin to read novel words only after they have made the transition from the logographic stage (reading words as visual images) to the alphabetic stage (reading words by sound-letter correspondences), (Ehri & Wilce, 1985; Frith, 1985; Share, 1998). These researchers argue that it is impossible to read through only sight word recognition. Ehri (1992) proposed that a visual-phonological route is better able to quickly access the phonological system. She suggested that this route consists of many connections and that the phonological system is always activated when retrieving word meaning (this includes both in alphabetic and orthographic stage reading). Unlike the DRC that she says only accesses the one connection to the lexicon, her theory allows for many sound-letter connections that provide faster access to the lexical memory while ignoring other word choices. In addition, because the phonological module of the system is always accessed in her visual-phonological route theory, this phonological recoding continues to strengthen connections and is a mechanism to facilitate self-learning.

Later versions of the DRC have attempted to answer this criticism (Coltheart et al., 1993) by suggesting that the visual feature detectors do not directly access only the lexicon, but activate the phonological system where the sound letter rules are stored. The authors described the activation that operates in the lexical route as one of cascading:

> Because the whole system works in cascade, the partial activations of various word units in the visual word recognition must cascade forward to these units' analogues in the spoken word lexicon, and activation must then cascade onto the phoneme units in the phoneme system corresponding to the pronunciations these activated entries in the spoken lexicon. (p. 605)

Ehri (1992) questioned the lexical route of the DRC because it does not require phonological recoding. However, the later version of the DRC makes clear that the nonlexical route establishes the grapheme-phoneme correspondence and maps rules for these relationships to the phoneme system. Rules are strengthened though frequency of exposure and stored in the phoneme system so that when a word which has been previously learned is encountered, the lexical route can access the meaning directly along with its phonological output.

Temporal Processing Deficit Hypothesis

The processing of speech begins with the acoustic signal being received by the auditory system. This information is analyzed by the peripheral auditory system and passed as a neural signal to higher levels in the auditory system (Moore, 1997). In the peripheral and the higher central auditory system, a wide range of analyzers extract information from the original acoustic signal, such as 1) perception of loudness, 2) frequency selectivity, 3) temporal processing characteristics, 4) pitch perception, and 5) the presence or direction of the signal (Moore, 1997). Understanding speech involves analyzing the acoustical properties that are presented to the auditory system in a rapid sequence (Merzenich et al., 1996; Tallal, 1990) and associating meaning to the auditory stimuli. Research has demonstrated that this in fact begins at an early stage in language development as infants begin to show preference to native language sounds (Best, 1994; Eimas, Miller, & Jusczyk, 1987; Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993). If there is a deficit in the auditory system which impedes the analysis of the acoustic information or corrupts the signal, than this could affect the weighting scheme that codes and stores the information (in this case, phonemic information) to make meaningful distinctions in the language (Juscyk, 1993; Stark, Tallal, McCauley, 1988; Tallal, 1990; Tallal, 1993).

Merzenich and colleagues (Merzenich & Jenkins, 1995; Merzenich, Schreiner, Jenkins, & Wang, 1993) suggested various reasons for a temporal processing deficit: 1) extended otitis media that interferes with the clarity of speech, 2) an inherited faulty auditory processing system, 3) inefficient strategies that extract only partial information from the acoustic signals, and 4) an immature auditory system, including neural centers responsible for interpretation and storage of the signals. Any one of these causes could lead to deficits in temporal processing ability that segments and integrates the information coming into the auditory system. According to their hypothesis, this could result in neurological changes that negatively affect the mapping and storage of phonemic representations and could lead to language and reading deficits (Merzenich et al., 1993; Merzenich, Tallal, Peterson, Miller, & Jenkins, 1999; Miller, Linn, Tallal, Merzenich, & Jenkins, 1999; Tallal et al., 1993).

Atypical Neurological Organization and Reading Disorders

One of the first researches who suggested that reading disorders may occur due to atypical neurological organization was Samula Orton (1925). Later in the 20th century research investigated Orton's hypothesis on postmortem studies that found greater left hemispheric asymmetries of various cortical areas for individuals that had normal reading when compared to dyslexics (Galaburda & Kemper, 1979; Galaburda, Sherman, Rosen, Aboitiz, & Geschwind, 1985). Specific locations of these asymmetries that involved language functioning include the left perisylvian and inferior prefrontal cortices. Later studies in the 1990s used magnetic resonance imaging (MRI) and functional magnetic resonance imaging (fMRI) which is noninvasive and has the ability to measure blood flow in response to a stimulus or task. Using this technology, researchers have observed decreased activation patterns in regions of the brain when comparing individuals with and without reading disorders (Shaywitz et al.,1996, Shaywitz et al., 2000) as well as asymmetries in surface size of different regions of the brain between individuals with and without reading disorders (Gauger, Lambardino, & Leonard, 1997; Larsen, Hoien, Lundberg, & Odegaard, 1990). Primary regions of interest included: 1) the striate cortex, the prestriate area to the temporal-occipital region, and the left occipital region for visual word processing, 2) left temporoparietal cortex and the anterior superior temporal cortex for phonological processing, 3) the inferior anterior cingulate cortex for attention, and 4) the left inferior frontal-precentral sulci and inferior and mid frontal gyri for semantic processing (Kent, 1998; Shaywitz et al., 2000).

If a temporal processing deficit may negatively influence the development in regions of the brain, resulting in asymmetries or faulty processing of stimuli, research has proposed that intensive training could change cortical structure. In one study, researchers trained adult monkeys to discriminate the differences between series of sounds or touches (Recanzone, Schreiner, & Merzenich, 1993). The monkeys were rewarded for correct responses, but punished for incorrect responses. Neural response time of brain electrical activity was recorded following each session. The researchers found that as the monkeys improved their ability to discriminate accurately between the rapid series of touches and sounds that electrical brain activity measuring the timing of neural responses in the cortex increased and became more synchronous.

The researchers concluded that the training to improve the rapid discrimination of sounds and touches increased and strengthened the neural connections. Merzenich and colleagues attributed the brain's ability to reorganize and strengthen connections through activities that excited many hundreds of thousands or millions of neurons to cortical plasticity (Merzenich & Jenkins, 1995; Merzenich et al., 1993; Recanzone, Schreiner, & Merzenich, 1993). The notion of cortical plasticity is based on the Hebbian Principle that significant inputs that excite neurons simultaneously are mutually strengthened (Hebb, 1949). Later research in the brain's ability to change based on increasing neural networks demonstrated that although ideally this is accomplished more successfully at an early age, the brain also has the capacity to form new connections at any age (Kotulak, 1996).

Using research that has studied cortical plasticity and theories that suggest a temporal processing deficit contributed to language and reading deficits, Merzenich, Tallal and colleagues proposed that a computer-based program that modified synthetic speech stimuli could strengthen neural connections in the language centers of the brain to increase the accurate discrimination of speech sounds presented in a rapid sequence (Merzenich et al., 1996; Tallal et al., 1996). In a recent investigation, this hypothesis was examined (Temple et al., 2003). Twenty children with poor reading performance on the Word Attack, Word Identification, and Passage Comprehension subtests of the

Woodcock Reading Mastery Tests completed the FFW program. A series of reading, language, and phoneme awareness tests were administered before and after the training program. In addition to this, functional neuroimaging scans were completed on each participant while they performed a phonological identification task and a visual identification task. It was hypothesized that following the auditory training, children would demonstrate greater activity in 1) the left temporal-parietal cortex during phonological processing, 2) the anterior cingulate gyrus and hippocampus, responsible for attention and memory, respectfully, and 3) greater right hemisphere activity in regions homologous to the language centers located in the left as a result of compensatory effects. Following FFW, the children in the experimental group displayed similar neural activity when caompared to a group of children (n-12) with normal reading skills who did not receive FFW. Children in the experimental groups improved reading and language scores following FFW. The increase was not only significant, but in the areas of reading, their scores improved into the normal range (>85).

Increased activity was observed in the regions of interest which included the left temporo-parietal cortex, bilateral cingulate gyrus, the left hippocampal gyrus, as well as a number of right hemisphere regions. Correlations between increases in activity in the regions of interest and the behavioral testing were found between the left temporo-parietal area and phonological awareness (word blending) and oral language. The authors concluded that a direct effect of the training program was improved phonological awareness skills, while a secondary consequence was reading improvement. This research investigation provided evidence that a group of children with reading delays who completed the FFW program were able to increase brain activity in the left temporo-parietal regions at activity levels which resembled children without reading delays.

Placing the Temporal Processing Deficit Model Within a Reading Model

Habib's model (2000) of the temporal processing deficit theory largely accommodates the neurophysiological data that suggest dyslexics have atypical neurological organization. Habib theorizes that deficits in the ability to process any rapid presentation of speech, nonspeech, visual, or ideational stimuli is a universal characteristic of people with dyslexia. He hypothesized that this temporal deficit is a result of abnormal maturation of the neurons and their connectivity, especially in the language processing areas of the brain. As a result, this deficiency interferes with the processing of any kind of function that requires synchronizing, integrating, or interpreting rapid sequences of stimuli. Deficits in temporal processing, consequently, might not only adversely affect the phonological processing unit but the visual processing unit as well.

Hypothetically, a temporal processing deficit might negatively affect a child's ability to decode words quickly and accurately in order to store phonemic representations and the rules for allowable combinations. Within the DRC model such a disorder would cause delays in mapping these rules and arguably require more exposures to a word before it is stored in the phoneme system for retrieval via the lexical route. Likewise, a temporal processing deficit would also negatively affect the rapid assigning of phoneme to grapheme or the recall of the phoneme to grapheme in Ehri's direct phonological access model.

Early investigations by Tallal and associates revealed deficits in the processing of rapidly presented auditory stimuli for language impaired children (Tallal & Piercy, 1974) and for children with reading delays (Tallal, 1980). This research measured the ability to identify two different stimuli (tones and speech syllables) that were separated by a variable inter-stimulus-interval (ISI). In other research, participants with specific language impairment demonstrated poor ability to discriminate stop consonants with rapid formant transitions (Tallal & Piercy, 1975). However, when the formant transitions were prolonged, there were no differences in responses of children with language delays and children with normal developing language.

Recent research has expanded to investigate the role of auditory processing in reading development. Various studies have investigated perceptual differences between children with and without reading deficits by varying voice onset in a speech syllable continuum (Manis et al., 1997); varying F2-F3 transitions in a speech syllable continuum (Nittrouer, 1999; Rosen & Manganari, 2001; Serniclaes, Sprenger-Charolles, Carre, & Demonet, 2001); modifying time and frequency of synthetic speech syllables (McAnally, Hansen, Cornelissen, & Stein, 1997); comparing thresholds of auditory temporal order judgements (Heath, Hogben, & Clark, 1999); and comparing thresholds of backward, simultaneous, and forward masking conditions (Bishop, Carlyon, Deeks, & Bishop, 1999; McArthur & Hogben, 2001). Studies using backward, forward and simultaneous masking have found differences between both reading-impaired children and language-impaired children when compared to children with normal language and reading abilities (McArthur & Hogben, 2001; Wright, Lombardino, King, Puranik, Leonard, & Merzenich, 1997). These studies have suggested a causal link between temporal processing deficits (as measured by backward masking) and reading and language impairments.

Tallal and colleagues (Tallal et al., 1996) found that children with language delays showed age-equivalent significant improvement on standardized language assessments following a four-week auditory training program to improve temporal processing abilities. From this work, Tallal and her associates developed Fast ForWord (FFW; Scientific Language Corporation, 1998) which is available commercially and is often recommended for children with reading and language delays. There has been only a handful of published studies (Gillam, Loeb, D.F., & Friel-Patti, S., 2001; Hook, Marcaruso, & Jones, 2001; Marler et at., 2001; Thibodeau, L., Friel-Patti, S., & Britt, L., 2001) that have attempted to replicate the conclusions made by Tallal et al. (1996). Recent studies have failed to find differences between FFW and more direct reading/language intervention approaches (Beattie, 2000; Hook et al., 2001). Two other current studies have investigated changes in auditory processing by measuring backward and simultaneous masking thresholds as well as language assessments prior to and following the FFW program (Marler et al., 2001; Thibodeau et al., 2001). However, these studies did not specifically examine children with reading delays and the number of participants in each of these studies was very small.

Purpose of the Present Investigation

The purpose of this study was to investigate changes in temporal processing as measured by backward masking thresholds before and after FFW, an intensive auditory training program. Additionally, it examined changes in reading, phoneme awareness, and language skills to test the hypothesis that improves in temporal processing would precipitate improved reading and language abilities. Masking thresholds and behavioral testing results were also compared to a control group that did not participate in FFW in order to evaluate the efficacy of the program. Finally, testing six months following FFW was conducted to explore whether possible long-term increases were sustained.

If improvements in auditory processing skills (as measured by backward masking) were found to increase along with reading and phoneme awareness ability, it would give support to the theory that the reading mechanism is not a dual-route process (Coltheart, et al., 1993) but a single route mediate by the phonological system (Ehri, 1992). However, if phoneme awareness is improved following an intensive auditory program, but word reading does not demonstrate an equal improvement, this might provide evidence that young readers are using both a lexical and nonlexical route for word reading.

Chapter II

Review of the Literature

Reading Delays and Temporal Auditory Processing

The link between auditory temporal processing deficits and reading delays was initially advanced by Tallal's early studies (1980, 1984) and later research has replicated these findings (Cestnick & Jerger, 2000; Reed, 1989). According to her hypothesis, children with reading delays have auditory perceptual deficits that interfere with the learning of sounds and their symbols that develop phonological awareness and other pre-reading skills (Tallal, 1980). Tallal first tested this hypothesis using 20 children (age range 8-12 years) with a reading composite delay of one year or more. Results were compared to a control group of children (mean age 9;7) from a previous study (Tallal, 1976). She measured their ability to discriminate nonverbal stimuli in two different tasks; one that required identification of temporal order and another that did not. The first was similar to the Rapid Perception Test (RPT) used in Tallal and Piercy (1974) which required the children to discriminate between a high and low tone in all possible pairs (e.g., high/high, high/low, low/low, and low/high). The children responded by pressing panels on a response box to indicate the order of the tones that were presented. The ISI was consistent for the testing phase (428 ms), but after the children reached testing criteria, the ISI was decreased on a continuum that included 8, 15, 30, 60, 150, and 305-

ms intervals. The second procedure did not require the children to indicate the order of the two tones, but simply respond whether they were the same or different. Again, for this procedure, a practice phase was completed using a consistent ISI of 428-ms before introducing the same ISI continuum used in the RPT. Results were compared to a group of children with normal language development from a previous study (Tallal, 1976). There were no differences between the groups for either procedure when the ISI was 428 ms. However, when the ISI was decreased, the percentage of error responses of children in the reading-delayed group was significantly higher than children in the control group. These results did not correlate with age, verbal IQ, or performance IQ; however, there was a strong correlation with deficits in reading nonreal words.

Tallal (1974) admitted that there was a great deal of variability among the 20 participants. In fact, 12 of the 20 children performed within normal limits on the auditory perceptual tasks. She speculated that subgroups may have confounded the results and that children with a reading delay and a language delay may demonstrate temporal processing abilities inferior to those with normal developing language and a reading delay.

Over the past decade, Tallal's conclusion concerning the causal link between temporal processing deficits and reading and phonological processing difficulties has been challenged. Mody, Studdert-Kennedy, and Brady (1997) argued that there was a confusion concerning the distinction of temporal properties of events versus identifying or discriminating brief events. In other words, they believed that the deficits in temporal processing could not be identified by procedures when the stimuli were simply presented rapidly by manipulating the ISI. Secondly, they argued that Tallal's basic paradigm for temporal order judgement (TOJ) did not consistently reveal errors of TOJ. Error responses for same-different judgements might represent errors in identification rather than temporal judgement. They considered errors of reversal to be true temporal judgement errors.

Mody et al. (1997) tested their hypothesis that children with poor reading abilities have deficits in discriminating phonemic contrasts rather than a temporal processing deficit. In a procedure similar to Tallal (1980) they presented two synthetic speech stimuli, one that was acoustically similar (/ba/-/da/) and another pair that was acoustically dissimilar (/ba/-/sa/ to one half of the group and /da/ - /ʃa/ to the other half). Similar to Tallal (1980) they tested the pairs using the temporal order judgement and simple same/different discrimination that varied the ISI (10, 50, 100 ms). The investigators found that poor readers performed inferiorly to the control group for the perception of /ba/-/da/ for both the TOJ and discrimination tasks. In addition, errors for the poor reading group increased as the ISI decreased, whereas the control group was unaffected by the change in ISI. Differences between the groups were not demonstrated for the pairs of syllables that were phonemically dissimilar even when the ISI was decreased. They concluded that even poor readers can judge temporal order, if they can discriminate the stimuli. Consequently, rather than a temporal processing deficit, the problem may be one of poor phonological representation.

In the same study, they tested the hypothesis that poor readers who have deficits in auditory processing of speech sounds also would have difficulty processing nonspeech auditory signals. The researchers generated two sine waves of 250 ms that mirrored the frequency trajectories of F2 and F3 of /ba/ and /da/ from their previous experiment. The listeners were first asked to perform an identification task. Results showed no differences between the poor-reading group and the control group. The authors concluded that the differences found in the previous experiment of the identification of /ba/-/da/ were related specifically to speech discrimination and not to an auditory processing deficit. When the ISI was decreased in a discrimination task using the stimuli, those children in the poor-reading group slightly outperformed children in the control group. They suggested that the results demonstrated that errors of the children in the poor-reading group in a speech discrimination task could not be attributed to an auditory processing deficit in the perception of rapidly changing acoustic information.

In the third experiment, the researchers tested whether poor readers differed from a control group in their perception of synthetic speech syllables that varied in F1 onset. They created two synthetic speech syllables, /seI/ and /steI/, that varied the F1 onset from 211 - 611 Hz in 50-Hz intervals. The children responded by pressing a panel with a picture of a girl when they thought they heard /seI/ or a picture of a dog when they thought they heard /steI/. Unlike Tallal and Stark (1981), the children with reading impairments did not demonstrate any less sensitivity to the variation of F1 transition when compared to the control group. In conclusion, the authors stated that there was no support to claim that deficits in reading were related to either temporal processing deficits or difficulties processing rapid changes of formant transitions. Rather, they suggested that poor readers have deficits in discrimination or difficulties with phonological categorization.

Nittrouer (1999) further tested the theory that deficits in temporal processing produce difficulties in phonological processing in children. Children between the ages of 8 and 10 were divided into two groups based on a reading subtest of an achievement test. Phonological abilities of the participants in each group were assessed by three phonological awareness tasks that included phoneme identification in words, phoneme deletion in words, and phoneme manipulation within words. Using the same paradigm in Tallal (1980), Nittrouer attempted to replicate Tallal's results on a larger group of children with and without reading and phonological deficits. She changed the tone sequence task by adding sequences of three and four tones to create a temporal order judgement condition. Results did not show any group differences and the poor-reading group did not display any greater difficulty perceiving temporal order judgement than the normal-reading group.

There were three different speech perception tasks in Nittrouer's (1999) experiment that all measured discrimination of the stimuli on a continuum that varied specific acoustical properties. The first varied the onset of voicing in /da-ta/ from 0 ms to 40 ms in 5-ms steps. The second, /seI- steI/ varied the gap following the initial consonant and voicing from 0 ms to 50 ms in 5-ms steps. The children were asked to respond to which was most /seI/-like or /steI/-like. The stimuli in the third task contained vowels that were naturally produced but the fricative noises were synthetic (/sa/- /ʃa, and /su/- /ʃu/). The center frequency of the noises varied from 2.2k Hz to 3.8 kHz in 200-Hz steps. The third task determined whether children were relying on fricative-noise spectra cues to discriminate between the pairs. Nittrouer hypothesized that children with poor temporal processing deficits would rely more on spectral noise cues rather than formant transitions to discriminate sounds.

There were no significant differences between the two groups for either task involving /da-ta/, or for /seI-steI/. The author concluded that the children in the poor-reading group were in fact taking advantage of formant transition cues and brief bursts of voicing onset to make these discriminations. Differences between the two groups, however, were identified in the task that varied the fricative-noise spectra when discriminating /sa/-/ʃa/ and /su/-/ʃu/. Contrary to the temporal processing hypothesis, the children in the poor-reading group appeared to be relying on formant transition cues more than other acoustic properties in the speech stimuli.

Tallal has maintained that poor readers (as well as children with specific language impairment) have deficits in perceiving brief acoustic cues that are required to make discriminations between speech sounds (Tallal, 1980; Tallal & Stark, 1981). Later studies have challenged this notion (Mody et al., 1997; Nittrouer, 1999). McAnally et al. (1999) tested the following hypothesis: if children have difficulties in perceiving differences in speech sounds that vary the formant transitions, then their perception should improve by increasing the durations between formant transitions. They tested two groups of adolescent males (n=15) with and without reading delays. CVC syllables that contained all possible combinations of stop syllables with the vowel /a/ were synthesized. In the first set, syllables were either stretched in time or compressed in time without altering the fundamental or the formant frequencies (time manipulation), but the rate of change was manipulated. A second set of stimuli was created in which the frequencies of formant transitions were stretched or compressed, changing the trajectory of the formant transitions without altering the duration of the vowel (frequency manipulation). The children indicated their response to the auditory stimuli by matching it with the written form of the CVC syllable on a computer screen. The authors did not find significant main effects between the two groups of children and demonstrated that both time and frequency manipulation affected identification. Even when their analysis investigated the performance of individuals that improved their discrimination of the CVC syllables with time and frequency changes, examples were found from both groups of children. This study directly questions the effectiveness of an auditory training program which manipulates frequency and timing aspects of the speech syllable to increase temporal processing abilities (Merzenich.et al., 1996; Tallal et al.,1996).

Tallal (1980) suggested that there may be subgroups of children with reading delays, those with and without oral language deficits, and that those children with concomitant oral language deficits may exhibit greater deficits in temporal processing. Heath et al. (1999) attempted to replicate the findings in Tallal and Piercy (1974) and Tallal (1980). They assessed a total of 47 children between the ages of 7 and 10 and were able to create subgroups that included language delay and reading delay (LDRD), specifically reading delay (SRD), and normal readers without language delays. The auditory procedures in this study included a discrimination task similar to the RPT as described in Tallal (1980). The second task was similar to the previous one; however, it included an adaptive procedure to measure threshold detection of the pattern of the stimulus. Results did not identify any group differences for the first procedure and participants in each group performed worse when the ISI was decreased. Differences in temporal order judgement thresholds (RPT) were found only between the normal-reading group and the LDRD group. Although Heath et al. (1999) did not replicate Tallal's findings for all the children in the reading-delay group, they did show that only children with oral language and reading delays demonstrated higher thresholds in a temporal order judgement task. This is consistent with Tallal's notion that only children with both language and reading delays may demonstrate inferior performance on auditory tasks, such as the RPT, when compared to children with only a reading delay or only a language delay.

In yet another study that attempted to replicate Tallal (1980), Marshall, Snowling, and Bailey (2001) studied the performance of children on auditory judgement tasks in comparison to performance on tests of phonological and reading abilities. The procedures that measured auditory processing ability were similar to Tallal (1980) and tested both temporal order judgement and same/different discrimination. The phonological processing tasks measured explicit phonological abilities (phoneme deletion and rhyme oddity) and implicit phonological abilities using the Nonword Repetition task (NRT, Dollaghan & Campbell, 1998). Performance on the auditory tasks correlated directly to performance on the phonological tasks that were administered. Regression analyses showed that phoneme deletion, rhyme oddity and age were the best predictors of reading performance. The auditory repetition tasks were not a predictor for either basic reading tests or phonological processing tasks.

In the second part of this study, the authors compared results from the same tasks in experiment 1 for three groups of children: a dyslexic group, a reading-age matched control group (RA) with reading skills within 6 months of chronological age, and a chronological-age matched control group (CA) with normal reading abilities. Based on Tallal's hypothesis (1980), they predicted that dyslexics should demonstrate greater phonological processing deficits and auditory processing deficits when compared to children in the CA and RA groups. Children in the dyslexic group performed significantly lower on the NRT and the phoneme deletion task when compared to the children in the two other groups. Differences on the auditory processing tasks were seen between the dyslexic group and the CA, but not the RA control group. According to Tallal's hypothesis, it would be expected to see differences on the auditory repetition tasks between the RA and the dyslexic group because the dyslexic group demonstrated greater deficits in phonological processing. Contrary to predictions, the shorter ISI did not significantly affect the dyslexic group any more than the RA group. This study identified a subgroup of four children that scored significantly worse on the auditory tasks than other children in the group. However, these four children, who performed very poorly on the auditory repetition tasks, did not necessarily exhibit poorer phonological abilities. In fact, 10 out of 16 children in the dyslexic group exhibited phonological processing difficulties equal or lower than the four children in the subgroup. In summary, the authors argued against a causal link between auditory processing skills and phonological processing skills.

Research over the past five years has questioned Tallal's assumption that there is a causal link between an auditory processing deficit of perceiving the rapid acoustic changes in speech and reading deficits. Based on her research, she argued that deficits in auditory processing adversely affect the acquisition and storage of phonological representations. This leads to poor phonological awareness skills which adversely affects reading development. Using Tallal's identification and discrimination test paradigm with speech and nonspeech stimuli, researchers have been unable to replicate her findings and they have questioned the causal link between temporal processing abilities and reading/phonological skills (Marshall et al., 2001; Mody et al., 1997; Nittrouer, 1999).

Research With Masking Procedures and Language Impairments

Several studies over the last few years have investigated the relationship between auditory masking and reading/language impairments. The masking paradigm includes three different conditions: backward masking, where a brief tone is presented prior to the masker; forward masking, where a brief tone is presented following the masker; and simultaneous masking, where the tone is presented concurrently with the masking noise. Using an adaptive procedure, thresholds are obtained for the detection of the tone in the presence of the masker.

Wright and her colleagues (1997) reported data from backward, forward, and simultaneous masking using both broadband noise and notched noise. They tested two groups of eight children with and without specific language impairment. For each masking condition, thresholds were established using an adaptive two-interval two-alternative forced-choice procedure (2I2AFC) for the detection of a 1000 Hz tone. The noises, or maskers, were a 600-1400 Hz bandpass noise and a 400-800 Hz and 1200-1600 Hz notched noise. The reason for the different maskers was to investigate whether children have difficulties in temporal or spectral sound conditions. Results showed a significant group difference for the backward masking condition only and the language-impaired group thresholds were almost 40 dB higher than the normal language group. The difference in thresholds was seen for both bandpass and notched noise. Based on these findings, they declared that children with specific language impairments, as well as reading delays, could benefit from auditory training programs that focus on auditory temporal processing similar to findings of Merzenich et al. (1996) and Tallal et al. (1996).

Buss, Hall, Grose, and Madhu (1999) raised the issue that attentional factors may have compromised the results of Wright et al. (1997) regarding backward masking. They reported variability exists with young children around 8 years old, but there was a trend of more adult-like thresholds for backward masking after 8 years of age. These researchers compared performances of 14 children between the ages of 5 and 11 years and 11 adults for backward, forward and simultaneous masking. They used an adaptive three-alternative forced-choice paradigm (3AFC) to measure thresholds in each of the masking conditions for both a 100 Hz-wide masker and a 1200 Hz-wide masker. Both maskers were centered at 1000 Hz, which also was the signal frequency. Children under the age of 7 responded by clicking on an animated panel on a computer screen (and the responses were entered in by the examiner on a response box); and those older than 7 used a response box with lights that indicated the presentations of the sound intervals.

Results showed great variability in backward masking performance and significant effects for age for thresholds in quiet and in the 1200 Hz bandwidth noise for forward masking. Increasing the bandwidth of the backward masker to 1200 Hz improved thresholds for adults, but not for younger children. However, those children who performed better with the 100 Hz bandwidth and tended to do more adult-like on the backward masking condition, also showed a trend to improve with the 1200 Hz bandwidth masker. These results may have been due to the listeners using across-frequency cues for tone detection. A significant learning effect, however, may have been present since the 1200 Hz bandwidth masker always preceded the 100 Hz bandwidth masker. Because there was not evidence for the interaction of age and backward masking, they concluded that the cue to detect a tone in a backward masking condition was as difficult to use for adults as it was for children. Consequently, attentional factors or learning factors cannot be discounted when interpreting thresholds for backward masking data.

Hartley, Wright, Hogan, and Moore (2000) further investigated differences in backward and simultaneous masking of four groups of participants across age groups: a six-year-old group (mean: 6;5 yrs, n=16), an eight-year-old group (mean: 8;2 yrs, n=10), a ten-year-old group (mean: 10;1; n=10), and adult listeners (mean: 26;1: n=10). They measured the detection of a 1000-Hz tone in the presence of four masking conditions: one backward and three simultaneous masking conditions. In the backward masking condition, the 20-ms tone was presented just prior to a 300-ms bandpass noise (the masker). The simultaneous masking conditions were: 1) 20-ms tone 200 ms after the onset of the bandpass noise, 2) 20-ms tone temporally centered in the masker, 3) 20-ms tone 200 ms after the onset of a spectrally notched masker. The backward masking condition and the first simultaneous masking condition were presented to measure temporal resolution. The next two simultaneous masking conditions presented the tone in a notched noise masker and temporally centered in a bandpass masker to assess frequency resolution. The intent of the investigation was to examine whether there would be an interaction between age and temporal and frequency resolution. Research in the past has been inconclusive as to when children reach adult-like performance on these two conditions. Results identified that backward masking thresholds decreased dramatically until the age of 11 years. After the age of 11, the thresholds begin to plateau. The second major finding of this study revealed that performance on the simultaneous masking conditions measuring frequency resolution appeared to develop by the age of six. In contrast, backward masking involves the integration of mature cortical functioning and therefore, may not be developed until the age of twelve. Evidence from this study demonstrated a strong correlation between IQ and performance for both improved frequency and temporal resolution, suggesting that these abilities are related to central processing skills rather than the auditory processing system, per se.

In order to address the concerns of a learning effect and other influences of backward masking, Bishop et al. (1999) compared thresholds of backward masking in three test session over a 12-month period. The investigation obtained backward masking thresholds in different presentation procedures (2I2AFC and 3IFC), variations in the tone-masker gap (0 ms vs. 100 ms prior to the masker), and a dual masking condition (tone before and after the masker). Participants included three groups: language-impaired children, normal-language children, and adults. Across three sessions of backward masking, the data showed that there were significant learning effects after the first session, but no improvement of thresholds between sessions two and three. Although not significant, there was a trend for the performance of children in the language-impaired group to deteriorate over time. There was a significant effect for the procedure used and each group performed better using the 3IFC method. Performance for backward masking improved on the second trial when the procedure was switched to the 3IFC method, especially for those participants who did poorly with the 2I2AFC procedure. They suspected that the 2I2AFC places greater encoding demands on the listener as opposed to the 3IFC. The former required the listener to assign attributes to each and hold in memory before making a decision. With the latter, the listener only indicated when a difference in the signal was present and then chose the appropriate panel. Comparisons between backward masking at 0 ms and 100 ms revealed differences only between the adult groups who had lower thresholds for the 100-ms gap before the masker. Children in both the language-impaired group and normal-language group did not demonstrate any differences on the two conditions.

Results from the backward masking task did not show a difference between the language-impaired group and the normal-language group. The investigators reported large individual variations between threshold estimates, but no standard deviations were reported or analyzed. Also, the study did not discuss the method for averaging each trial or repeating a trial if thresholds widely varied. Such information could be helpful in determining the reason for the large individual variation in each group. In addition to the backward masking task, two other auditory tasks in this study failed to show a difference between the two groups of children. These were frequency modulation thresholds (obtained by discriminating a frequency modulated tone from an unmodulated tone) and fundamental frequency discrimination without spectral cues. This raised a question whether performance on these auditory tests identified a temporal processing problem and whether this was related to a language impairment. Correlation analyses were completed between behavioral tests and the masking tasks that were administered. The behavioral tests included language, phonological awareness, reading tests and IQ assessments. Results did not show any link between language impairment and the children who did or did not present evidence of a temporal processing deficit based on the auditory tests that were administered. The results of their experiments led the authors to suspect the causal link between auditory processing deficits and language impairments.

Rosen and Manganari (2001) posed a similar question as Bishop et al. (1999) in order to investigate the relationship between auditory processing and dyslexia. They compared temporal order judgements of /ba-da/ to backward masking performance and temporal order judgement of /ab-ad/ to forward masking performance with a group of children with and without reading deficits. The tasks were used to investigate whether poor ability to discriminate rapidly presented syllables is related to the deficits in perceiving formant transitions (Tallal, 1980) or whether it arises from phonological deficits (Mody et al., 1997). The temporal order judgement test was similar to previous paradigms (Mody et al., 1997; Tallal, 1980) which presented each possible pair combination at each ISI (0, 10, 50, 100, 400 ms) in random order. The paradigm for the masking tasks was a 2I2AFC adaptive procedure that also presented a bandpass noise and a notched noise for each backward, forward, and simultaneous masking conditions. The participants were eight children with dyslexia and eight age-matched controls. The participants ranged from 11 - 14 years, and those in the dyslexic group showed a reading delay of at least 18 months. Phonological testing included a nonword reading task and spoonerism.

Children in the normal reading group had lower (better) thresholds than children in the poor reading group, but only for the backward masking with the bandpass noise. Differences for forward and simultaneous masking were not identified. Results from the temporal order judgement tasks were not significant between the groups, leading to speculation that abilities involved in backward masking are distinct from formant transition discrimination.

McArthur and Hogben (2001) presented a different masking paradigm and found that, like Tallal (1980) and Heath et al. (1999), there are often subgroups that are relevant to the understanding temporal processing deficits. The study recruited four groups of children: language impaired-poor readers; language impaired-average readers, poor readers with average spoken skills, and a group of children with normal language. The auditory procedures included backward masking and an intensity discrimination task that established an intensity level where the listener could identify an adjusted less intense test tone compared to a standard tone (63 dB SPL) at least 75% of the time. The backward masking procedure then presented the same standard tone and test tone. In addition, the ISI values between the test tone and the masker varied from 50,125, 250, and 500 ms. Several subjects were removed from the study because of suspected validity of the results, although standard deviations or conditions of variability of thresholds were not reported. The authors speculated that varying the ISI caused unusual confusion for some of the participants. Results of backward masking identified threshold and ISI value differences only between the language impaired-poor readers and the other three groups. Although this evidence is not consistent with research that demonstrated elevated thresholds of backward masking with children with impaired language, it does lend support to those who have suggested that backward masking tasks may be unusually more difficult for children with both an oral language and a reading delay.

Research over the past 10 years has shown that children with language impairments and reading deficits have higher thresholds in backward masking when compared to children with normal language and reading skills (Rosen & Manganari, 2001; Wright et al., 1997). However, this has not gone unchallenged. Bishop et al. (1999) failed to find differences in backward masking thresholds between language-impaired children and children with normal language abilities. In addition, there was no correlation between thresholds in backward masking and performances on reading, language, and phonological awareness tests. Other research suggests, however, that there may be only a subgroup with both oral language delays and reading delays, that might find the task of backward masking unusually difficult (McArthur & Hogben, 2001).

Research and the Fast ForWord Program

Research reviewed here has challenged early evidence from Tallal and her associates that there is a causal link between temporal processing deficits and reading difficulties. However, there has been little investigation of the effectiveness of the recommended treatment program, FFW, for children with temporal processing deficits. The developers of the FFW program have published evidence of dramatic increases in language development following a four-week auditory training program that was later trademarked as the Fast ForWord Program (Merzenich et al., 1996; Miller et al., 1999 Tallal et al., 1996). FFW is a computerized software program based on Tallal's research that specifically targets the listener's ability to acoustically discriminate modified speech (phonemes, words and sentences) in order to improve phonological awareness, language, and reading abilities. The program consists of seven exercises that present speech stimuli which are acoustically modified. The formant transitions in the consonants are stretched or compressed (modifying changes in duration) and the intensity of that segment is amplified. Also, in speech exercises that involve discrimination of pairs, the ISI is gradually decreased. When the child demonstrates discrimination accuracy, the formant transitions and the intensity are gradually changed to normal speech. In the one non-speech exercise, the child must identify the order of a high and low tone while the ISI between the tones is gradually decreased. The program claims to "train the brain" to increase awareness of the rapid acoustic cues in speech by listening to synthetic speech syllables and words that are modified gradually to normal speech targets as the child progresses successfully through the program. Table 1 presents the seven exercises in the FFW program.

Since the program has been commercially introduced to the public, there has been very little research that has replicated the original 1996 studies. The Scientific Learning Company has vast amounts of field data collected over the past five years from thousands of children who have completed the program, but only a few studies have been published on the world-wide web (Scientific Learning Corporation, 2002). Independent research

Table 1

Brief Description of the FFW Exercises

Name of Game	Skills targeted
1. Circus Sequence	High/low tone temporal order task (.5, 1, 2 kHz of six stimulus durations) with adaptive interstimulus interval (ISI, 500 to 0 ms)
2. MacDonald's Flying Farm	Discrimination of phonemic changes. Voice-onset time (VOT) and fricative-gaps were lengthened and gradually shortened.
3. Phoneme Identification	Identification of modified phoneme (VOT, fricative-gaps, and amplification of frequency transitions) within field of two with adaptive ISI.
4. Phonic Match	Increasing complex matching exercise to target memory skills, and nonsense syllables differed by a single phoneme (speech extended and acoustic elements amplified).
5. Phonic Word	Discrimination of modified words that differ by one phoneme (extended and amplified).
6. Block Commander	Comprehension of simple directions (speech extended and amplified).
7. Language Comprehension Builder	Presents increasingly complex sentences to reinforce syntactical and morphological language structures (speech extended and amplified).

into this program is difficult due to the cost of the software license and the intensiveness of the intervention. In addition, due to the lack of access to the stimuli used in the program, it is not possible to modify the stimuli for research purposes. Consequently, few studies have been published, and those that have been published have used only a handful of participants (Gillam et al., 2001; Marler et al., 2001; Thibodeau et al., 2001).

Longitudinal studies with larger subject sizes in order to research the efficacy of FFW are beginning to emerge. Hook et al. (2001) explored changes in reading, language and phonemic awareness skills immediately following FFW and over a period of two years. Children who ranged in ages from 7 to 12 were recruited to participate in the FFW program (FFW, n=11). Children were included in this group if they scored below the 16th percentile on either the Word Attack (WA) or the Word Identification (WI) subtests of the Woodcock Reading Mastery Tests (WRMT), or if their verbal IQ scores were at least 1 standard deviation above the WA or WI subtests. A second experimental group of children who received an Orton-Gillingham approach (OG, n=9) were closely matched the FFW group in age and reading ability. This program provided Orton-Gillingham (OG) intervention to children one-on-one, one hour a day, five days a week. Children in this group were administered the LAC and the subtests of the WRMT before and immediately after FFW. A third group, Language Control (LC, n=11), was comprised of children that were similar in age and reading/language ability to the FFW group. The children in the LC group had a comparable education program as children in the two other groups, but they did not receive any specialized reading instruction. Children in this group were administered the same tests the FFW group had received. They did not participate in the pre-FFW testing, but they were part of the follow-up testing.

The intervention programs for the FFW and OG groups took place over a 5-week period during the summer vacation. Testing for the FFW group and the OG group occured before and immediately following FFW. Follow-up testing was administered to the FFW group and the LC group at the end of the academic year and the end of a second academic year.

Following the FFW and OG treatment programs, children were re-administered tests of reading and language. Immediate gains were made only in the area of phonemic awareness (LAC) for both experimental groups. The FFW group made no significant gains on the WI, WA, or the Passage Comprehension (PC) subtests from the WRMT. Only the OG group only demonstrated a significant increase in word attack skills. Long-term effects were compared to children in the LC group. There were significant increases over time, but no group effects. Increases in LAC were only shown from scores immediately post FFW and the final testing period after two years. Increases in WA, WI, and PC for children in the FFW and LC groups occurred between the period immediately following FFW and the end of the first academic year. The authors concluded that the gains could not be completely attributed to maturation, but the increases were a result of the structured multi-sensory reading program both groups received. However, the FFW program alone did not result in greater reading development or faster increases of reading abilities.

This study identified that language skills for the FFW group increased immediately following the training program. The children in the OG group were not administered a language assessment so there were no other pre-post group comparisons. However, there were no long-term gains following testing after the first and second academic year and there were no significant differences between the FFW and the LC group. The authors believe that the immediate gains in language scores were either a result of the intense auditory training program that might have increased attention to task, or due to familiarity of items on the language test that was re-administered in such a short period of time.

Ten of 11 children in the FFW group had difficulties completing the Circus Sequence activity which involves the identification of high and low tones presented rapidly. Analysis did not find a correlation between performance on this activity and the LAC, or phoneme awareness. The fact that children in the FFW group demonstrated immediate improvement in phoneme awareness, but demonstrated poor gains in the auditory discrimination activity may run counter to Tallal's hypothesis that children with deficits in perceiving rapidly presented auditory stimuli have difficulties perceiving speech which affects their phoneme awareness and reading abilities.

In another study Beattie (2000) compared the effectiveness of FFW with another computer program (Success Maker; SM) designed to improve reading and study skills. Sixty-four children between the ages of 11 to 16 met the criteria for the study. The children were initially referred by their classroom teachers and qualified for the study by performing in the bottom quartile on one or more of standardized test in receptive language, reading, spelling, and phoneme awareness. Fifty-five of the 64 children demonstrated deficits in both reading and receptive language skills. The participants were randomly assigned to five groups and completed two phases of intervention that lasted between 32 and 42 hours each. Group 1 receive FFW-1 and FFW-2 training, Group 2 received SM during both phases, Group 3 received FFW-1 and SM, Group 4 received SM and FFW-1, and the control group received no intervention. The same tests administered prior to the training activities were presented again following the second training phase. Analysis of the post-training data did not reveal significant increases in the receptive language or reading abilities for any of the five groups.

Beattie investigated differences between the groups in terms of practical significant difference scores for each of the dependent variables. This analysis calculated the difference between each possible pair of the group means for each of the dependent variables. Although no group was identified as having greater mean increases on a cluster of assessments, some interesting differences were identified. Group 1, which received FFW1 and FFW2 had the least gain in phoneme awareness. This was unexpected since the FFW program provides intense instruction on phoneme identification. Equally unexpected, however, was that Group 1 had the greatest improvement of mean scores on the GORT. This could possibly mean that the FFW2 program provided greater instruction in the reading content area than SM or the traditional curriculum.

Although this study failed to demonstrate that participants completing FFW or a combination of FFW and SM have significantly higher gains in receptive language and reading assessments following training, the investigator admitted that lack of recommended training intensity may have been a factor. Scheduling conflicts and computer malfunctions often prevented students from completing the recommended daily training of 100 minutes for FFW. Although the participants in groups 1, 3, and 4 completed the total number of training hours for FFW, the average daily number of minutes was far fewer than100 minutes.

Marler et al. (2001) completed a study that compared behavioral and psychophysical testing pre- and post FFW and a Laureate Learning System (LLS) software program designed to increase language development. Participants were seven boys ranging in age from 6;10 to 9;3 years. Of the four children who were identified with language impairment, two completed FFW and two completed the exercises in LLS. Three children with normal language skills served as a control group. Behavioral testing included language testing and intelligence, although no criteria for selection of subjects were presented. The two children in the LLS group had similar language abilities, but IQ scores varied (83 vs. 102). No test scores were reported for the three normal language participants.

Backward and simultaneous masking procedures were performed prior to the FFW program and measured each week during the program until completion four weeks later. Psychophysical testing took place weekly in order to investigate the learning effects of backward masking. The researchers chose a three-interval three-alternative forced-choice paradigm (3I3AFC) rather than a 2I2AFC paradigm to present the stimuli in order to reduce demands on memory, and yet be more demanding than the 3I2AFC paradigm used by Bishop et al. (1999). No statistical analysis of the data was reported because of the small subject pool. Children in the normal-language group had higher thresholds for simultaneous masking than backward masking, and the difference between the two conditions was much greater than the four children in the language-impaired group. There was a trend for backward masking thresholds for the normal-language group to decrease over time. There was no obvious pattern for the four children in the language-impaired group and therefore, results were examined individually. One participant in the FFW group had essentially the same thresholds as the normal listeners. The other FFW participant displayed thresholds similar to language-impaired children reported in Wright et al. (1997). The children in the language-impaired group showed little difference between simultaneous and backward masking initially, but the differences between the two conditions increased over time (lower backward masking thresholds).

Marler et al.'s study could not provide evidence that the FFW program or the LLS system provided significant benefit over a short period of time in temporal processing. The authors believed that the use of the 3I3AFC paradigm increased memory load and cognitive demands (independent of auditory processing) which may have resulted in the lack of a difference in backward and simultaneous masking thresholds for the language impaired children. Correct responses for each interval during the masking procedures were analyzed and results showed that the children in the impaired language group were less accurate than the children in the normal language group. They concluded that the increased demand of the masking procedure, along with decreased accuracy of responses from the children in the language-impaired group might support the argument that increased cognitive and memory demands significantly influence thresholds in backward and simultaneous masking, independent of auditory processing abilities. It is important, however, to point out that previous studies have shown a correlation between IQ and decreased thresholds in backward, forward, and simultaneous masking tasks. IQ scores for the children in the normal language group were not reported, but two of the four children in the impaired language group had reported IQ scores that were below 85. This might have affected the performance of these children for the masking tasks, especially if the authors wanted to increase memory demands by using a 3I3AFC paradigm.

Thibodeau et al. (2001) evaluated the temporal processing abilities of five children who completed the FFW program. The psychophysical testing battery included backward and simultaneous masking, as well as frequency sweep discrimination.

Backward masking thresholds and frequency sweep discrimination thresholds were recorded each of the five weeks the children participated in the FFW training activities. Simultaneous masking thresholds were obtained in the first, third and fifth sessions. In addition to the five language-impaired children, five normal-language children were included to serve as a control group. As in previous research, simultaneous masking thresholds were similar across the two groups and were higher than backward masking thresholds. Standard deviations for the two masking procedures were reported and there were not differences between the two groups. Surprisingly, thresholds for backward masking were not significantly different between the two groups, and changes in the thresholds for either simultaneous masking or backward masking during each of the five recorded session coinciding with the FFW program were not significant within or between the two groups. Also, frequency sweep thresholds did not reveal any differences between the two groups. The authors found that the greatest improvements in backward masking thresholds were obtained between the first "practice" session and the second testing period; they did not find any further evidence of decreased backward masking thresholds on subsequent trials. These results are contrary to previous research (Bishop et al., 1999) that suggested a learning effect with backward masking.

Conclusion

Over the past decade, there have been numerous research studies that have challenged the notion that a temporal processing deficit results in poor phonological processing leading to poor reading and language skills. Mody et al. (1997) challenged Tallal's (1980) conclusion that faulty perception of phonemes was caused by poor discrimination of rapidly presented events. Further research by Nittrouer (1999), McAnally et al. (1999) and Marshall et al. (2001) evaluated the temporal processing abilities of reading and language-impaired children and were unable to replicate Tallal's findings, suggesting that the link between temporal processing deficits and reading delays is suspect. Additional research using forward, backward and simultaneous masking procedures following Wright et al. (1997) also has been inconclusive and has not supported the notion that temporal processing deficits are related to reading delays (Bishop et al., 1999; McArthur & Hogben, 2001; Rosen & Manganari, 2001).

Studies that specifically measured changes in reading and phoneme awareness have not shown conclusively that the auditory training component of FFW provides immediate or long-term benefits when compared to more traditional intervention approaches (Beattie, 2000; Hook et al., 2001). Investigations with language-impaired children completing FFW have failed to show increases of temporal processing as measured by backward masking thresholds (Thibodeau et al., 2001). However, initial data from this proposed study found that children with poor and low average reading delays decreased backward masking thresholds following FFW.

Purpose of the Present Investigation

The purpose of the present study was to investigate the effectiveness of FFW, which is a computerized auditory training program designed to increase the temporal processing abilities of children in order to facilitate language and reading development. Presently, there have been only two studies that have analyzed psychophysical and behavioral measurements pre- and post-training on the FFW program (Marler et al., 2001; Thibodeau et al., 2001), and these two studies have obtained the measurements only immediately following FFW. Also, these studies have had small subject sizes and have had a range of language and IQ abilities within the groups.

This study was designed to measure the temporal processing and reading, phoneme awareness, and language abilities of children with reading delays before and after FFW training in order to investigate any changes as a result of intense auditory training. In addition, the study investigated abilities six months after FFW to discover if lower backward masking thresholds could be sustained after an intensive computer program, and whether increases in temporal processing facilitated long-term improvements in reading, phoneme awareness, and language skills. In addition, it compared testing results to a group of children who did not participate in FFW in order to discover whether FFW training actually precipitated lower backward masking thresholds and whether reading and language improvements were greater for children completing FFW.

Research Questions

The present research study proposes to investigate the following questions:

1. Do masking thresholds decrease (improve) for the experimental group immediately following FFW and if any changes are found, will they be sustained six months following FFW?
2. Are there differences in masking thresholds between children who completed FFW and a control group who did not?
3. Do standard deviations of masking thresholds for children in the experimental groups improve immediately following FFW and six months after FFW for all masking conditions?
4. Are standard deviations of masking thresholds higher for a group of children who did not receive FFW training immediately following FFW and six months following FFW?
5. Do reading, phoneme awareness and language abilities increase for children in the experimental group immediately following FFW and six months after FFW?
6. Are changes in reading, phoneme awareness and language skills different for children in the experimental group than those in the control group who did not complete FFW training?

7. Are there any correlations between masking thresholds and reading, phoneme awareness, and language testing results?

8. Are there any specific FFW activities that correlate with changes in reading, phoneme awareness, language results and masking thresholds?

Chapter III

Method

Participants

Experimental Group

Research participants were all students at Walnut Hill Elementary School in Harriman, Tennessee. The Harriman city school system was awarded a grant to offer the FFW program to students in their schools who had delays in reading and language development. Forty-two children were recommended by their classroom teachers, the reading specialist, and in some cases, their parents to participate in the FFW program. These children demonstrated low reading performance in classroom activities and placed in the lower quartile on the reading portion of the Terra Nova Tennessee Comprehensive Assessment Program. This standardized test is given to all elementary children in the state of Tennessee each year to measure progress in content areas. The school obtained permission from each child's parent before beginning FFW. From this group, only children between 7 and 10 years old were identified as possible participants. Prior to testing, each child submitted a signed informed consent form from his/her caregiver, and he or she also signed an assent form.

Walnut Hill provides a traditional reading program that encourages active reading skills with an emphasis on comprehension. Students who received special reading resource classes were instructed using the Wilson Reading System approach were provided with approximately two hours of instruction a week.

All of the children were tested to assure normal pure tone audiometric thresholds (ANSI, 1996) at 25 dB HL or better at 500, 1000, 2000, and 4000 Hz. The caregivers of each participant completed a speech-language questionnaire to rule out history of head injury, seizures, and ADHD (Appendix A). All children demonstrated average or better nonverbal intelligence (standard score of 85 or better) based on the Test of Nonverbal Intelligence-3 (TONI-3) (Brown, Sherbenou, & Johnson, 1997).

Control Group

In order to obtain a control group, teachers from the third and fourth grade classes at Walnut Hill Elementary were asked to recommend children to participate in experimental testing. None of these children were originally recommended for FFW. Informed consent from parents and informed assent from the children were obtained before testing. Children in the control group demonstrated normal hearing acuity (25 dB HL or better at 500, 1000, 2000, and 4000 Hz, ANSI, 1996) and had nonverbal IQ quotient score of 85 or above on the TONI-3. A language and medical history questionnaire was completed by the caregiver to rule out ADHD, seizures, or brain injury.

The study targeted long-term improvements in reading and language abilities, therefore, it was important to test children who had the same reading and language arts curriculum as the treatment group. The children were evenly distributed across the same third and fourth grade classrooms in which children completing FFW were enrolled. Chronological ages were within the same age range (8 to 10 years old). It was impossible to match the children in the control group for reading and language levels. Because all children from the third and fourth grades who had reading deficits were originally recommended to complete FFW training, this left only children who had normal or above reading abilities. Testing for the control group took place in a quiet room on the school campus during a four- week period following the post testing of the children in the experimental group. Children with scores of more than one and half standard deviations above the mean in reading and total language were not included in the control group. 17 children were tested and 13 met criteria. Participants in the control group were administered the hearing screening, the TONI-3, the reading, phoneme awareness, and the language tests.

Assessments Pre and Post FFW and 6 Months Post FFW

Participants completing FFW training were administered a battery of tests prior to commencing the program. Following FFW training, participants in the experimental group were assessed using alternative forms of the tests (if available) to measure improvements of reading, phoneme awareness, language skills, and backward masking thresholds. During this time, participants in the control group were administered this same battery of tests. Approximately 6 months following the completion of the FFW training, all participants were again administered the same tests given prior to FFW training with the exception of the TONI-3.

Reading Assessments

Two subtests from the Woodcock Reading Mastery Tests (WMRT), Woodcock, 1987) were used to measure reading single words aloud. The Word Attack subtest, which assesses decoding abilities, and the Word Identification subtest, which assesses sight-word abilities were both administered by the principal investigator.

To measure reading comprehension proficiency, the Gray Silent Reading Tests, (GSRT), (Wiederholt & Blalock, 2000), Form B, was administered. This was presented to the participants as a group and monitored by the teacher supervising the FFW program, or by the participant's classroom teacher.

In order to characterize the reading delay of the children who were recommended to the training program, age equivalent scores were used to identify children with a reading delay, rather than grade equivalent ranges, because a number of the participants had been retained one or more times. Age equivalent scores were used instead of standard scores because all of the children were recommended to participate in the FFW training based on intervention status. Classroom teachers, parents of the children, and the reading specialist made recommendations because the children displayed difficulties with classroom work and homework because of low reading skills. Consequently, it was assumed that there would be many children with a profile of poor performance, but still not present a score on a reading evaluation of more than 1 standard deviation below the mean. Secondly, Walnut Hill Elementary is a small school with approximately 100 children in the third and fourth grades. The likelihood of obtaining a large group of children going through FFW with a standardized reading score below 85 was remote. Finally, one of the purposes of this research was to investigate the effectiveness of FFW in a school-based program. The use of FFW in public schools has grown tremendously over the past three years. At this time, there is little published data that can help school administrators and teachers decide who will benefit most from FFW. Most school districts that are presently using FFW in the East Tennessee area use the child's scores from yearly statewide examinations, as well as teacher and parent recommendations. In addition, because of interest in the program, some parents have insisted that their child have the opportunity to complete FFW, even when their child was performing average or above on language and reading activities. Age equivalent scores helped identify a larger group of children with a reading delay, and provided a representative group of children who are participating in FFW in a school-based program.

Language and Phoneme Awareness Assessments

Language abilities were assessed using the Clinical Evaluation of Language Fundamentals - Third Edition (CELF-3) (Semel, Wiig, & Secord, 1995). This test provided standard scores for receptive and expressive language abilities. Phonological processing abilities were evaluated using the Lindamood Auditory Conceptualization (LAC) test (Lindamood & Lindamood, 1997) and a nonword repetition task (Dollaghan & Campbell, 1998). The LAC provided a total converted score and minimum score for a grade equivalent. Form A of the LAC was administered prior to the FFW training. The nonword repetition task consisted of four items each of one syllable, two syllables, three syllables, and four syllables. Research has shown that this process-dependent task has differentiated children with language impairments from children without language impairments (Dollaghan & Campbell, 1998; Weismer, Tomblin, Zhang, Buckwalter, Chynoweth, & Jones, 2000). A cassette tape of the 16 nonwords from the Dollaghan and Campbell (1998) study was provided from these researchers for this investigation. The audio from the cassette was transferred to a compact disk. The participants listened to the instructions and the nonwords, arranged in a random order, that were presented via a portable CD player and headphones. The children's repetitions of the nonwords were recorded using a Radio Shack Omnidirectional Impedance lapel microphone and a Sony cassette tape recorder (TCM-919). Responses were transferred onto a score sheet and consonant errors, vowel errors, and total errors were recorded. Additions of vowels or consonants were noted, but like the original study (Dollaghan & Campbell, 1998) they were not included in the total number of errors.

Test Administration

Testing took place in the child's school in a quiet room. Psychophysical testing was completed in a portable classroom outside the main building. Ambient noise levels were obtained using a Larson-Davis 800B sound level meter before testing. Levels were recorded two times and the average was 41 dBA.

Testing was completed over three different sessions in order to minimize the amount of time the child was taken out of class during the day. The principal researcher administered the WA and WI subtests of the WRMT, followed by the LAC. The LAC was administered during the same session because the presentation time was relatively short. The second testing session included the administration of the CELF-3. The CELF-3 was administered by the principal researcher, certified speech-language pathologists who work in the Roane County school district and trained second year graduate students studying speech-language pathology at the University of Tennessee. Individuals who assisted in the language testing were blind to the child's group assignment. During the third session, backward and simultaneous masking thresholds were measured. The Nonword Repetition task was conducted in the same room following psychophysical testing. These two tasks were administered by the principal researcher. The GSRT was administered as a group during their computer lab day and monitored by the computer lab instructor. The principal researcher scored all tests administered to the participants. Table 2 summarizes the testing before and following FFW.

Psychophysical Measures: Simultaneous and Backward Masking Protocol

Stimuli

The masker was a bandlimited sample of Gaussian noise that extended from 700 Hz to 1400 Hz. The masker was presented for 300 ms, at 41 dB/Hz pressure spectrum level. The signal was a 1000-Hz tone having a duration of 20 ms. Masker and signal had 10-ms cos2 ramps. All stimuli were generated digitally at a rate of 50 kHz (AP2, TDT) and were played out of a digital-to-analog converter (DD1, TDT). The stimulus was passed through a digital attenuator (PA4,TDT), routed to a headphone buffer, and presented monaurally in the right ear over Sony
headphones.

Signal detection thresholds were measured using a 2-down-1-up tracking procedure. A 71% correct point was used for the psychometric function (Levitt, 1971). Trials were presented within a two-interval two-alternative forced-choice procedure (2I1AFC). The beginning step size was 4 dB and reduced to 2 dB after the first two reversals. Testing continued until eight reversals were obtained. Threshold estimates were computed as the average of levels at the last six track reversals. Similar to the

Table 2

Summary of Pre and Post Fast ForWord Testing

Pre Fast ForWord	Post Fast ForWord
1. Pure Tone Hearing Test	1. Pure Tone Hearing Test
2. Word Attack and Word Identification, Woodcock Reading Mastery Tests, Form G	2. Word Attack and Word Identification, Woodcock Reading Mastery Tests Form H
3. Lindamood Auditory Conceptualization Test, Form A	3. Lindamood Auditory Conceptualization Test, Form B
4. Nonword Repetition Task	4. Nonword Repetition Task
5. Clinical Evaluation of Language Fundamentals-Third Edition	5. Clinical Evaluation of Language Fundamentals-Third Edition
6. Gray Silent Reading Tests, Form B	6. Gray Silent Reading Tests, Form A
7. Masking Conditions	7. Masking Conditions
8. Test of Nonverbal Intelligence-Third Edition	

methodology in Buss et al. (1999), at least two threshold estimates were obtained for each condition, however, if thresholds differed more than 5 dB, then a third was completed. Following this, if a third threshold differed by more than 8 dB from either of the first two, a fourth run was completed or until two thresholds were within 10 dB. Mean averaging occurred across all runs with standard deviations of five or less. This was done to decrease variability in threshold estimate (Hedrick, Schulte, & Jesteadt, 1995).

Thresholds were first measured in quiet, and this was used for training the task. The four masking conditions were then presented in random order, and acceptable thresholds were obtained before moving onto the next condition. The children responded to the auditory stimuli by using a mouse and clicking on one of two panels with an animated picture. Feedback was provided for correct responses (a "thumbs up") and incorrect responses (a stop sign).

The children sat at a desk and wore headphones (Sony 2500). Tone detection measurements of thresholds were made for the following four conditions: 1) a 20-ms tone presented in the temporal center of a 300-ms bandpass (600-1400 Hz) noise (simultaneous masking); 2) a 20-ms tone presented 20 ms before the 300-ms bandpass noise (0-ms backward masking); 3) a 20-ms tone presented 40 ms before the 300 ms bandpass noise (20-ms backward masking); and 4) a 20-ms tone presented 60 ms before the 300-ms bandpass noise (40-ms backward masking).

The Fast ForWord Training Program

Participants were removed from their regular classroom activities each school day for approximately one hour in the morning and one hour in the afternoon. Children who qualified for special reading resource did not receive any reading intervention during FFW training. All of the students that were receiving reading resource were part of the Poor Reading Group. All students, however, continued to participate in reading activities in their third or fourth grade classrooms. The FFW program was loaded on individual computers in the school's computer lab which had approximately 30 computer stations. Each child sat in front of a desktop computer with a 14-inch color monitor screen and the auditory stimuli were presented through headphones. The child completed four exercises in the morning and three in the afternoon. The presentation order of the exercises was randomized daily by the FFW software. Progress through the various levels of each activity depended on the child's percentage of accurate responses. A trained monitor supervised the children during their training and assisted with any technical difficulties with the computers.

Most participants completed the FFW program after six weeks of training, or between 30-34 sessions. Post FFW testing began for all participants at this time. This training time was similar to Merzenich et al. (1996).

Parent and Teacher Questionnaire

An open-ended questionnaire was distributed to the parents and teachers of the students who completed the FFW program. The form was distributed two weeks after the conclusion of FFW and one month following the winter break. This allowed parents and teachers time to observe any academic or social behavior changes in the children who completed FFW. The questionnaire (Appendix B and C) was developed from a brief interview following FFW by Loeb, Stoke, and Fey (2001).

Analysis

Results were considered in terms of both group and individual effects. A repeated measures ANOVA was used to investigate group trends of the psychophysical data pre and post-FFW intervention and 6 months following the completion of FFW. Results from the behavioral testing were analyzed to measure results in reading, language, and phonological awareness skills following the Fast ForWord program. Finally, a correlation analysis among all pairs of variables for group was conducted to investigate trends following the FFW program.

Reliability of Test Administration and Scoring

The WA and WI subtests of the WRMT and the NRT were recorded on an audiotape (Sony TCM, 919). A certified speech-language pathologist from the UT

Hearing and Speech Center listened to and scored three samples from each group chosen at random. Interjudge agreement of standard scores was 98% and 97%, respectively, on the WI and WA subtests. Interjudge agreement from the NRT task was 91%. To measure reliability of scoring the CELF-3, three test forms from each group were chosen at random and rescored and agreement was 96%. Upon review of the scoring of the subtest, Word Classes, it was noted that on two forms the total raw score was inaccurate. Consequently, all forms were reviewed and checked for accuracy and changes in standard scores were adjusted on two test forms. The design of the form for this subtest might have caused the confusion because in column 1 there is a subtotal, but in column 2 only a raw score. An error was detected by adding only the total correct in column 2 and placing this in the raw score box at the bottom.

Chapter IV

Results

Participants

Experimental Group

Forty-two children who attended an elementary school in East Tennessee were recommended by their teachers, the reading specialist, and their parents, to complete FFW training. Seven children were not administered initial testing because they were taking medication for attention deficit hyperactive disorder. Of the remaining 35 children were tested, nine were excluded from experimental testing procedures. Five of these nine children scored more than one and half years above age equivalency on both the WA and WI subtests, and two scored below 85 on the TONI-3. The remaining two children discontinued FFW training after initial testing. One child moved out of the area and another child stopped FFW training on the parent's request. A total of 26 who completed FFW participated in the experimental testing over a 9-month period.

Following the initial testing of children going through the FFW program, it was discovered that there were subgroups. Thirteen children had Word Attack or Word Identification scores that were more than a year below age-equivalency and 13 had scores within six months or better of age-equivalency (two of the children did not complete the experimental testing). The two groups differed significantly on both WA and WI results prior to FFW (WA, F (1,24) = 21.12, p = <.01; WI, F (1,24) = 32.92, p = <.01). In order to compare results, the experimental group was divided into two groups, a Poor Reading group (PR) and a Low Average Reading group (LAR). None of the standard scores on the WA subtest for the PR group fell within the range of the range of standard scores for children in the LAR group. Only one of the participant's standard scores in the PR group was within the range of those in the LAR group on the Word Identification subtest. The LAR had significantly higher mean scores for the GSRT (F (1,24) = 10.11, p =<.01), LAC (F (1,24) 5.31, p = .03), and CELF-3, (F (1,24) 6.08, p =.02). Group differences on the NRT did not reached significance (F (1,24) 2.2, p =.15). A basic description of participants is located in Table 3. Individual results for all participants of both behavioral and psychophysical measures are located in Appendix G.

Control Group

Classroom teachers recommended 20 children who were not initially recommended to participate in FFW at the beginning of the school year. Seventeen children were administered the same battery of tests the children in the experimental groups were given following FFW (Consent forms were not returned for two of the children recommended for the control group and one child moved from the area before

Table 3

Mean Scores with Standard Deviations for Poor Reading Group and Low Average Reading Group

	Poor Readers		Low Average Readers	
	M	SD	M	SD
Age	113 mos.	9	107 mos.	8
TONI-3	94	8	96	12
WA	90	5	100	6
WI	88	6	99	3
GSRT	77	10	86	14
LAC	64	14	75	7
NRT	83	11	88	7
CELF-3	88	12	97	7

Note. TONI-3 = Test of Nonverbal Intelligence- Third Edition, WA = Word Attack, WI = Word Identification (from the Woodcock Reading Mastery Tests), GSRT = Gray Silent Reading Tests, LAC = Lindamood Conceptualization Test, NRT = Nonword Repetition Task, CELF-3 = Clinical Evaluation of Language Fundamentals-Third Edition final testing at the end of the school year). Children with scores of more than one and half standard deviations above the mean reading and total language scores of children in the LAR group at the time of FFW post-testing were not included in the control group. Thirteen children met criteria. Table 4 reports mean scores for testing results with standard deviations. A one-way ANOVA compared mean scores for all results of children in the three groups. All test results for the CG were significantly different from the PR group at the $p=.01$ level with the exception of the NRT ($p=.19$), which there were no significant differences. The control group did not significantly differ from the LAR group on the WA ($F(1,23) = 1.9$, $p= .18$), GSRT ($F(1,23) = 4.1$, $p= .05$), LAC ($F(1,23) = 1.2$, $p= .28$), NRT ($F(1,23) = .02$, $p= .9$), CELF-3 ($F(1,23) = .19$, $p= .67$). Differences were found only on the WI subtest ($F(1,23) = 5.5$, $p= .03$).

Pre and Post FFW Psychophysical Measures

Masking Thresholds

Each child completed the masking tasks and small prizes and snacks were provided for motivation. The procedure which consisted of pure tone thresholds (a training task), three backward masking conditions and a simultaneous masking condition lasted an average of 75 minutes. Because care was taken to obtain accurate thresholds, some children required more time than others to achieve this.

Table 4

Brief Descriptive Information for Control Group

	M	SD
Age	109 mos.	9
TONI-3	94	7
WA	105	9
WI	107	7
GSRT	98	12
LAC	83	13
NRT	91	5
CELF-3	103	11

Note. TONI-3 = Test of Nonverbal Intelligence- Third Edition, WA = Word Attack, WI = Word Identification (subtests from the Woodcock Reading Mastery Tests), GSRT = Gray Silent Reading Tests, LAC = Lindamood Conceptualization Test, NRT = Nonword Repetition Task, CELF-3 = Clinical Evaluation of Language Fundamentals- Third Edition

A repeated-measures analysis of variance was performed on the threshold data. The between-subjects factor was group (2: PR and LAR). The within-subjects factors were FFW (2: pre and post FFW) and masking conditions (4: simultaneous and backward masking at 0-ms, 20-ms, and 40-ms gap). The alpha level was set at .05. Mean masking thresholds and standard deviations, pre and post FFW, for the two groups that participated in FFW training are shown in Table 5. Analysis of the masking data did not reveal group differences (F (1,24) = .13, p= .72) and there were no group differences for any of the masking conditions. A pairwise comparison using Sidak adjustment for multiple comparisons indicated that simultaneous masking thresholds were significantly higher (poorer) than thresholds for 0-ms gap condition, which were higher than thresholds in the 20-ms and 40-ms gap conditions (Simultaneous> 0 ms > 20 ms > 40 ms). Main group effects and their interactions are presented in Table 6.

One of the primary research questions was whether children participating in FFW training would show a decrease masking thresholds after FFW. Both groups had significantly lower thresholds (better) on each condition following FFW training (F (1,24) = 7.04, p=.01). The interaction of FFW and masker was nonsignificant (F (3, 72) =.59, p=.62).

Table 5

Means and Standard Deviations of Masking Thresholds (dB SPL) for Children in the Poor Reading and Low Average Reading Groups: Pre FFW and Post FFW

Pre Fast ForWord	Poor Readers		Low Average Readers	
Condition	M	SD	M	SD
Simultaneous	71.55	6.19	70.76	5.72
Backward				
0-ms gap	67.99	12.90	64.33	10.41
20-ms gap	52.18	13.26	57.32	12.26
40-ms gap	48.15	12.92	49.72	12.38

Post FFW	Poor Readers		Low Average Readers	
Condition	M	SD	M	SD
Simultaneous	68.46	4.55	68.30	3.59
Backward				
0-ms gap	60.73	12.6	60.20	12.16
20-ms gap	49.75	12.24	54.02	13.57
40-ms gap	44.24	11.17	47.60	10.54

Table 6

ANOVA Table for Masking Thresholds and Interactions for Poor Reading and Low Average Reading Groups: Pre FFW and Post FFW

Variable	df	Error	F	Significance
FFW	1	24	7.04	.01
FFW x Group	1	24	.20	.66
Masker	3	72	71.68	<.01
Masker x Group	3	72	1.76	.16
FFW x Masker	3	72	.59	.62
FFW x Masker x Group	3	72	.23	.87
Group	1	24	.13	.72

Standard Deviations

Another question of interest was not only whether masking thresholds improved, but also whether standard deviations of thresholds improved. Lower standard deviations may indicate a learning effect or greater ease of identifying the tone in the presence of the masker, as well as evidence of attention to the task. Computed standard deviations for each acceptable threshold were averaged for each of the four masking conditions (see Table 7). Similar to masking thresholds, there were no differences between the groups (F (1,22) = .08, p=.77). Table 8 reports interactions between FFW, group, and standard deviation masking condition. Unlike the masking thresholds, however, there was not a significant difference following the FFW program (F (1,24)= <.01, p= .96). Standard deviations varied according to conditions, similar to thresholds (F (1,72)= 12, p = <.01). A pairwise comparison using Sidak adjustment for multiple comparisons found that simultaneous masking had significantly lower standard deviations than all other conditions and the 0-ms gap had lower standard deviations than the 40-ms gap condition.

Pre and Post FFW Reading and Language Results

Reading Assessments

Table 9 itemizes results of the three reading assessments for both groups pre and post FFW. Table 10 summarizes the statistical analyses of FFW and group for the three

Table 7

Means and Standard Deviations of Standard Deviations (dB SPL) for Children in the Poor Reading and Low Average Reading Groups: Pre FFW and Post FFW

Treatment Period	Condition	Poor Readers M	Poor Readers SD	Low Average Readers M	Low Average Readers SD
Pre Fast ForWord	Simultaneous	2.46	2.40	3.31	4.02
	Backward				
	0-ms gap	4.42	4.14	4.63	3.45
	20-ms gap	5.48	5.28	4.98	4.99
	40-ms gap	9.28	6.88	7.38	7.76
Post Fast ForWord	Simultaneous	1.48	.72	1.29	.96
	Backward				
	0-ms gap	5.17	6.00	5.94	3.48
	20-ms gap	7.52	6.66	5.00	6.72
	40-ms gap	7.13	4.59	8.14	6.00

Table 8

ANOVA Table for Standard Deviations of Masking Thresholds and Interactions for Poor Reading and Low Average Reading Groups: Pre FFW and Post FFW

Variable	df	Error	F	Significance
FFW	1	24	<.01	.96
FFW X Group	1	24	<.01	.94
Masker	3	72	12.02	<.01
Masker X Group	6	72	.43	.72
FFW X Masker	3	72	.99	.38
Time X Masker X Group	2	57	.71	.51
Group	1	24	.08	.77

Table 9

Mean Scores and Standard Deviations for the Word Attack, Word Identification, and the Gray Silent Reading Tests for Children in the Poor Reading Group and Low Average Reading Group: Pre FFW and Post FFW.

Pre FFW	Poor Readers		Low Average Readers	
Test	M	SD	M	SD
WA	90	5	100	6
WI	88	6	99	3
GSRT	77	10	86	14

Post FFW	Poor Readers		Low Average Readers	
Test	M	SD	M	SD
WA	91	6	102	8
WI	88	6	101	4
GSRT	75	13	89	9

Note. WA = Word Attack, WI = Word Identification, GSRT = Gray Silent Reading Tests

Table 10

ANOVA Table for Reading Mean Scores and Interactions for Poor Reading and Low Average Reading Groups: Pre FFW and Post FFW

Test	Variable	df	Error	F	Significance
WA	FFW	1	24	1.26	.27
	FFW X Group	2	24	.1	.75
	Group	2	24	27.50	<.01
WI	FFW	1	24	2.72	.11
	FFW X Group	2	24	1.14	.30
	Group	2	24	40.27	<.01
GSRT	FFW	1	24	.01	.91
	FFW X Group	2	24	.99	.33
	Group	2	24	10.11	<.01

Note. WA = Word Attack; WI = Word Identification; GSRT = Gray Silent Reading Tests reading assessments, WA, WI, and the GSRT. The LAR group had significantly higher scores than the PR group for all three reading assessments prior to FFW and following FFW. This investigation asked whether mean scores on the reading assessments would increase following FFW. Analysis of the data did not reveal a significant increase of standard scores for any of the three reading assessments following FFW (WA: F (1,24) =1.26, p=.27; WI: F (1,24) = 2.72, p=.11; GSRT: F (1,24) =.01, p=.91).

Phoneme Awareness

The NRT and the LAC were administered to measure phonemic awareness and results are reported in Table 11. Table 11 reports the percentage correct on the NRT, and the weighted total score from the LAC, along with standard deviations. A research question that was asked was whether children in both groups increased phonemic awareness skills following the FFW training. Pre-FFW, the LAR group had significantly higher scores on the LAC (F (1,24) = 6.91, p =.015), but there were no differences between the groups for the NRT (F (1,24) = 2.62, p= .119). Increases on the LAC following training did not reach significance, F (1,24) =1.07, p=.31). Post FFW scores for the NRT barely reached significance, F (1,24) = 4.37, p=.05. Table 12 presents the statistical findings for phonemic awareness.

Table 11

Means and Standard Deviations of Phoneme Awareness Results for Children in the Poor Reading Group and Low Average Reading Group: Pre FFW and Post FFW

Pre FFW	Poor Readers		Low Average Readers	
Test	M	SD	M	SD
LAC	64	14	75	11
NRT	83	11	88	7
Post FFW	**Poor Readers**		**Low Average Readers**	
Test	M	SD	M	SD
LAC	66	12	77	11
NRT	87	9	91	5

Note. LAC = Lindamood Auditory Conceptualization; NRT = Nonword Repetition Task

Table 12

ANOVA Table for Phoneme Awareness and Interactions for Poor Reading and Low Average Reading Groups: Pre FFW and Post FFW

Test	Variable	df	Error	F	Significance
LAC	FFW	1	24	1.07	.31
	FFW X Group	2	24	.01	.94
	Group	2	24	6.91	.02
NRT	FFW	1	24	4.37	.05
	FFW X Group	2	24	.18	.68
	Group	2	24	2.61	.12

Note. LAC = Lindamood Auditory Conceptualization Test; NRT = Nonword Repetition Task.

Expressive and Receptive Language

The CELF-3 was administered to each child, before and after FFW, and the total language score, expressive language score and receptive language score for the two groups are reported in Table 13. Analysis of the interactions for all language scores are shown in Table 14. A research question concerning behavioral testing was whether language scores would improve after FFW training. Children in the LAR group had higher total language scores (F (1,24) =6.77, p =.02) and higher receptive language scores (F (1,24) = 8.9, p =.01); however, the expressive language subtest did not reach significance between the two groups (F (1,24) = 2.8, p =.11). The analysis found that both groups had a significant increase following FFW for the total language score (F (1,24) = 13.85, p =.001) and the expressive language portion (F (1,24) =13.60, p =.001). Improvement in receptive language skills barely reached significance (F (1,24) = 4.37, p = .047).

The CELF-3 has three subtests for the expressive language score and three subtests for the receptive language score. Children between the ages of 6-8 have a different set of subtests than children between the ages of 9 and above. However, there are 4 subtests that are common to each age group. Two subtests are part of the receptive language portion, Concepts and Directions and Word Classes, and two are part of the expressive portion, Formulated Sentences, and Recalling Sentence. Means and standard

Table 13

Means and Standard Deviation of the CELF-3 Summary, Expressive and Receptive Portions for Children in the Poor Reading Group and Low Average Reading Group: Pre FFW and Post FFW

Pre FFW	Poor Readers		Low Average Readers	
Test	M	SD	M	SD
CELF-3	88	12	97	7
Expressive	88	14	95	8
Receptive	89	11	100	12

Post FFW	Poor Readers		Low Average Readers	
Test	M	SD	M	SD
CELF-3	93	12	102	8
Expressive	94	13	101	10
Receptive	94	12	104	8

Note. CELF-3 = Clinical Evaluation of Language Fundamentals-Third Edition

Table 14

ANOVA Table for Language Abilities and Interactions for Poor Reading and Low Average Reading Groups: Pre FFW and Post FFW

Test	Variable	df	Error	F	Significance
CELF-3	FFW	1	24	13.85	.001
	FFW X Group	2	24	.05	.82
	Group	2	24	6.77	.02
Expressive	FFW	1	24	13.60	.001
	FFW X Group	2	24	.02	.88
	Group	2	24	2.83	.11
Receptive	FFW	1	24	4.37	.047
	FFW X Group	2	24	.07	.79
	Group	2	24	8.89	.01

deviations for the four subtests are found in Table 15. There were no significant group differences across the four subtests (see Table 16). Only the Recalling Sentences subtest was shown to have significantly increased following FFW (F (1,24) = 5.83, p =.024) and this was evident for both groups.

Correlation Between Psychophysical and Behavioral Testing

A Pearson Correlation analysis was performed on the data before FFW training and following FFW training in order to investigate whether the psychophysical results correlated with the behavioral testing data. Variable pairs were selected at the p<.01 level or beyond. All possible pairs and correlations are found in Appendix D. There were no significant correlations between the psychophysical data and the behavioral testing prior FFW, and similarly, there were no significant correlations between the psychophysical data and the behavioral test results.

Analysis of Performance on the FFW Exercises

Participants in the FFW group were dismissed from the program when they achieved 90% completion on five of seven exercises (dismissal criterion recommended by Scientific Learning Corporation). Percentage completion score represents the percentage of the exercise the participants had mastered. Eight of 13 participants in the PR group meet the 90% criterion on at least 5 out 7 of the FFW exercises. Only 2 of 13

Table 15

Mean Scores and Standard Deviations (in parentheses) for the Four Common Subtests of the CELF-3. Results are Pre and Post FastForWord for the Poor Reading Group and the Low Average Reading Group

Subtest	Poor Readers		Low Average Readers	
	Pre FFW	Post FFW	Pre FFW	Post FFW
Recalling Sentences	7.77 (3)	9.46 (3)	9.92 (2)	10.15 (2)
Word Class	7.20 (2)	8.85 (4)	9.53 (2)	9.70 (2)
Formulated Sentences	8.54 (2)	8.38 (2)	8.92 (2)	10.08 (2)
Concepts and Directions	8.92 (3)	9.38 (2)	10.15 (2)	10.62 (2)

Table 16

ANOVA Table for Subtests of CELF-3 and Interactions for Poor Reading and Low Average Reading Groups: Pre FFW and Post FFW

Subtest	Variable	df	Error	F	Significance
Recalling Sentences	FFW	1	24	5.82	.02
	FFW X Group	1	24	3.63	.08
	Group	1	24	2.27	.15
Word Class	FFW	1	24	3.37	.08
	FFW X Group	1	24	2.30	.14
	Group	1	24	2.77	.11
Concepts and Directions	FFW	1	24	.85	.37
	FFW X Group	1	24	<.01	1
	Group	1	24	3.80	.06
Fonnulating Sentences	FFW	1	24	1.04	.32
	FFW X Group	1	24	1.79	.19
	Group	1	24	2.11	.16

participants in the LAR group met this same criterion. Despite the higher number of participants in the PR group meeting criterion by the end of the six-week training period, there were no significant differences between the groups on each of the exercises. Figure 2 displays group means for each exercise and Table 17 presents a one-way ANOVA for significant differences between groups.

All participants in each group met criterion on the Phonic Words and Language Comprehension Builder. The most challenging activity was the Circus Sequence where only three participants in the PR group and only one participant in the LAR met the 90% criterion. Individual performance on each activity of FFW is examined in Table 18. As a group PR met criterion for only three of seven exercises, and LAR met criterion for only two of seven of the FFW exercises. A Pearson Correlation analysis did not find any significant correlations between the FFW activities and the behavioral testing (see Appendix E). Variable pairs were selected at the $p<.01$ level or beyond. Only three activities correlated significantly with the psychophysical testing which met significance. The first was the Circus Sequence and simultaneous masking ($r = .53$, $p = .005$), and 20-ms gap backward masking ($r = .57$, $p = .002$). The second was Phonic Identification and 20-ms gap backward masking ($r = .57$, $p = .002$) and finally Phonic Match and simultaneous masking ($r = .53$, $p = .006$).

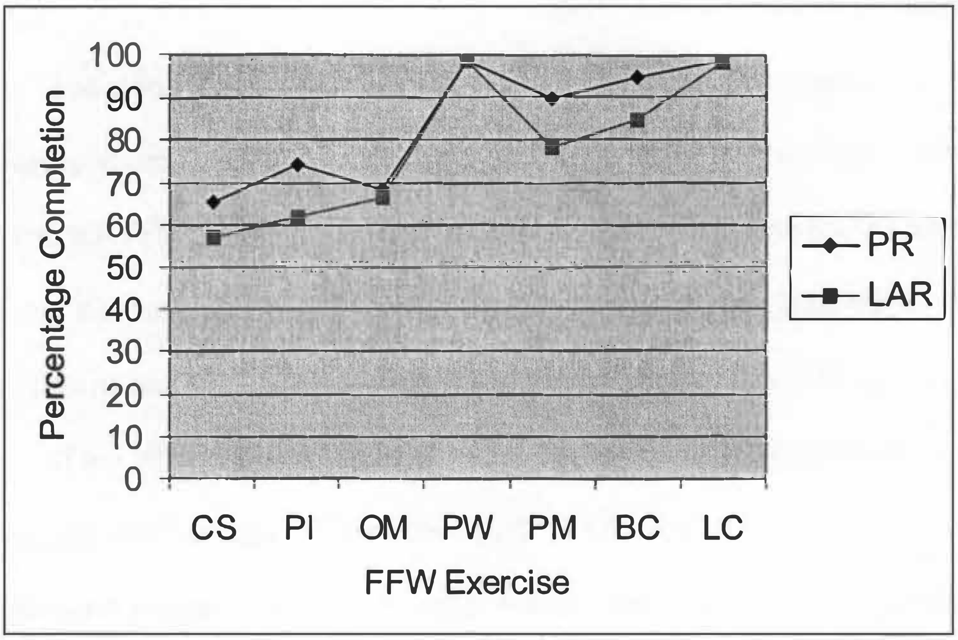

Figure 2. Comparison of group means for percentage completion on each FFW exercise.

Table 17

One-Way ANOVA to Compare Group Means for Each of the FFW Exercises

	Poor Readers		Low Average Readers			
Exercise	%	SD	%	SD	F	Significance
CS	65	31	57	26	.43	.52
PI	75	26	61	24	1.73	.20
OM	68	30	66	28	.04	.84
PW	98	1	98	1	.09	.76
PM	89	3	78	7	2.00	.17
BC	94	2	85	6	2.78	.11
LC	98	1	98	1	1.69	.21

Note. CS = Circus Sequence, PI = Phoneme Identification, OM = Old MacDonald's Flying Farm, PW = Phonic Words, PM = Phonic Match, BC = Block Commander, LC = Language Comprehension Builder. % = percentage of the activity completed.

Table 18

Percent Completion of FFW Activities, Days in Program, and Total Number of Activities Successfully Completed

	Activities								
Participant	CS	PI	OM	PW	PM	BC	LC	DIP	TAC
Poor Readers									
1	4	39	22	98	94	98	97	36	4
2	99	99	96	99	91	99	99	26	7
3	94	62	44	98	92	97	99	36	5
4	71	100	96	98	91	95	99	26	6
5	82	53	95	99	90	95	99	34	5
6	34	28	73	99	92	92	98	30	4
7	99	79	97	99	94	96	99	20	6
8	18	46	55	98	51	98	99	34	3
9	85	92	22	98	93	76	97	34	4
10	86	95	35	97	94	96	98	27	5
11	71	97	97	98	93	96	98	24	6
12	54	100	91	99	93	97	99	26	6
13	42	79	67	99	94	96	98	27	5

Table 18. Continued.

Participant	CS	PI	OM	PW	PM	BC	LC	DIP	TAC
	Activities								
Low Average Readers									
1	85	100	77	99	95	98	99	23	5
2	52	55	92	98	93	97	99	26	5
3	28	46	95	98	91	74	97	34	4
4	87	82	23	98	69	97	98	30	3
5	83	65	81	98	94	98	99	30	4
6	71	51	58	99	50	33	97	24	2
7	29	14	9	98	90	71	95	34	2
8	43	51	98	99	53	93	98	29	4
9	30	54	71	98	94	97	98	34	4
10	29	63	51	98	91	96	98	26	4
11	99	100	95	99	93	97	99	20	7
12	36	46	65	97	92	54	96	27	3
13	70	76	45	99	92	96	99	30	4

Note. CS = Circus Sequence, PI = Phoneme Identification, OM = Old MacDonald's Flying Farm, PW = Phonic Words, PM = Phonic Match, BC = Block Commander, LC = Language Comprehension Builder, DIP = Days in Program, TAC = Total Activities Completed. Scores for the seven activities represent percentage of the activity completed.

Parent and Teacher Questionnaire

A one-page questionnaire consisting of 12 items that was developed after Loeb et al. (2001) was used as an exit interview instrument for parents. Also, another one-page questionnaire consisting of 12 items was developed for the teachers who taught the children who participated in FFW. Questions were designed to be open-ended in order to elicit comments and opinions about the FFW program and the progress of the child. These included comments about perceived efficacy of the program, participant satisfaction, and advantages and disadvantages of the program. Qualitative methods were used to identify patterns in the responses. Eighteen of 26 caregivers returned the questionnaire, and all five teachers completed the survey. Each of the five teachers, however, combined their comments concerning FFW for the students in their class when possible (Appendix B contains responses to each item for the parent questionnaire and Appendix C contains responses for the teacher questionnaire).

Parent perception of the FFW training was generally favorable. Thirteen out 18 responded that they thought their children benefitted from FFW and only five indicated the opposite. Fourteen of 18 indicated that they believed their children enjoyed the program because the learning activities were presented as a computer game and only 4 of 18 felt that their children did not enjoy the FFW computer activities. Interestingly, 18 of 18 responded that their children played computer games on either a Play Station or Nintendo game equipment at home. Only 4 of 18 specifically responded that they felt the program helped to improve reading or other related school work. Although responses were favorable, a number of parents (6) were concerned their children were missing class time or other activities in order to complete FFW training. When asked how parents would compare or rate the FFW to other intervention programs, 10 of 18 were unsure and 8 of 18 were generally positive. Overwhelmingly, most parents agreed that the advantages of the school providing the FFW program were because it was offered at no charge and it was convenient for their children to attend the sessions. Fourteen of18 parents said they would recommend FFW.

Teacher responses, on the other hand, were quite different from parent responses. Only one of the teachers indicated that she saw progress in one student's class work. All the teachers complained that the FFW schedule disrupted their classroom activities and put the students who participated in FFW behind in their school work. At the same time, teachers indicated that the students did enjoy FFW because of the computer game format. However, all of the teachers said that students complained that the training was too long. All five teachers rated traditional reading instruction over the FFW program. Four teachers said the primary advantage of offering FFW in the schools was the convenience for the students. One teacher said that the program offered an alternative style of learning. All the teachers listed that the primary disadvantage was the time the students missed from their classes. Most teachers (3) were unsure whether to recommend FFW, one teacher said she would recommend the program as a supplemental activity in the summer, and one teacher said she would definitely not recommend FFW to other students.

Post FFW and 6 Months Post Testing Results

Masking Thresholds

Following FFW training, masking thresholds were obtained from a control group of children who did not participate in FFW and for the two groups who did participate. Table 19 compares the masking threshold of the three groups immediately following FFW and 6 months later. There were no differences among the two groups that participated in FFW training and the control group who did not receive FFW training (F (2,35) = .25, p = .78).

In order to determine whether improved backward masking thresholds would be sustained, testing was conducted 6 months following the completion of the FFW program. Similar to the results of post FFW training (F (1,22) = 7.04, p=.02), masking thresholds improved six months after training (F (1,35) = 10.61, p = .003). However, the interaction of time and condition revealed that only backward masking thresholds for the 20-ms gap (F (1,35) = 6.68, p = .01) and 40-ms gap (F (1,35) = 11.9, p =.001) conditions were significantly lower. 0-ms gap backward masking did not reach significance (p =.10) The masking thresholds and interactions are reported in Table 20. A pairwise analysis using Sidak adjustment for multiple comparisons showed significant differences between masking conditions each of the three times measurements were obtained (Simultaneous

Table 19

Means and Standard Deviations of Masking Thresholds (dB SPL) for Children in the Poor Reading Group, Low Average Reading Group and Control Group: Post FFW and 6- Months Post FFW

Post FFW	Poor Readers		Low Average Readers		Control	
Condition	M	SD	M	SD	M	SD
Simultaneous	68.46	4.55	68.30	3.59	69.80	3.85
Backward						
0-ms gap	60.73	12.6	60.20	12.16	58.42	10.30
20-ms gap	49.75	12.24	54.02	13.57	51.55	14.24
40-ms gap	44.24	11.17	47.60	10.54	44.11	10.75
6-Months Post	Poor Readers		Low Average Readers		Control	
Condition	M	SD	M	SD	M	SD
Simultaneous	66.00	2.55	68.15	3.67	69.83	3.66
Backward						
0-ms gap	55.84	13.72	55.77	11.44	60.25	10.48
20-ms gap	44.84	10.00	43.84	10.43	49.33	14.16
40-ms gap	39.54	10.39	38.38	8.38	42.33	7.58

Table 20

ANOVA Table for Masking Thresholds and Interactions for Children in the Poor Reading Group, Low Average Reading Group and the Control Group: Post FFW and 6-Months Post FFW

Variable	df	Error	F	Significance
Time	1	35	10.26	.003
Time X Group	2	35	2.02	.15
Masker	3	105	13.12	<.01
Masker X Group	6	105	.12	.99
Time X Masker	3	96.76	3.15	.03
Time X Masker X Group	5	96.76	.16	.92
Group	2	35	.25	.78

>0-ms gap>20-ms gap>40-ms gap). Figures 3, 4, 5, and 6 compare masking thresholds pre, post and 6 months post FFW.

Standard Deviations

Immediately following FFW, analysis revealed that standard deviations for both groups were not significant (F (1,24) = .08, p=.77) and they did not significantly decrease (F (1,24) =<.01, p= .96). Computed standard deviations for each acceptable threshold were averaged for each of the four masking conditions (see Table 21). Similar to masking thresholds, there were no differences between the groups (F (2,35) = .13, p=.88). Table 22 reports interactions between time, group, and standard deviation masking condition.

Similar to findings immediately post FFW, there was no change in standard deviations for masking thresholds (F (1,35) = .45, p=.51). A pairwise analysis using Sidak adjustment for multiple comparisons found that standard deviations for simultaneous masking was significantly lower than the three other conditions; however, there were no significant differences between the three backward masking conditions. Lower standard deviations may indicate a learning effect or greater ease of identifying the tone in the presence of the masker, as well as evidence of attention to the task.

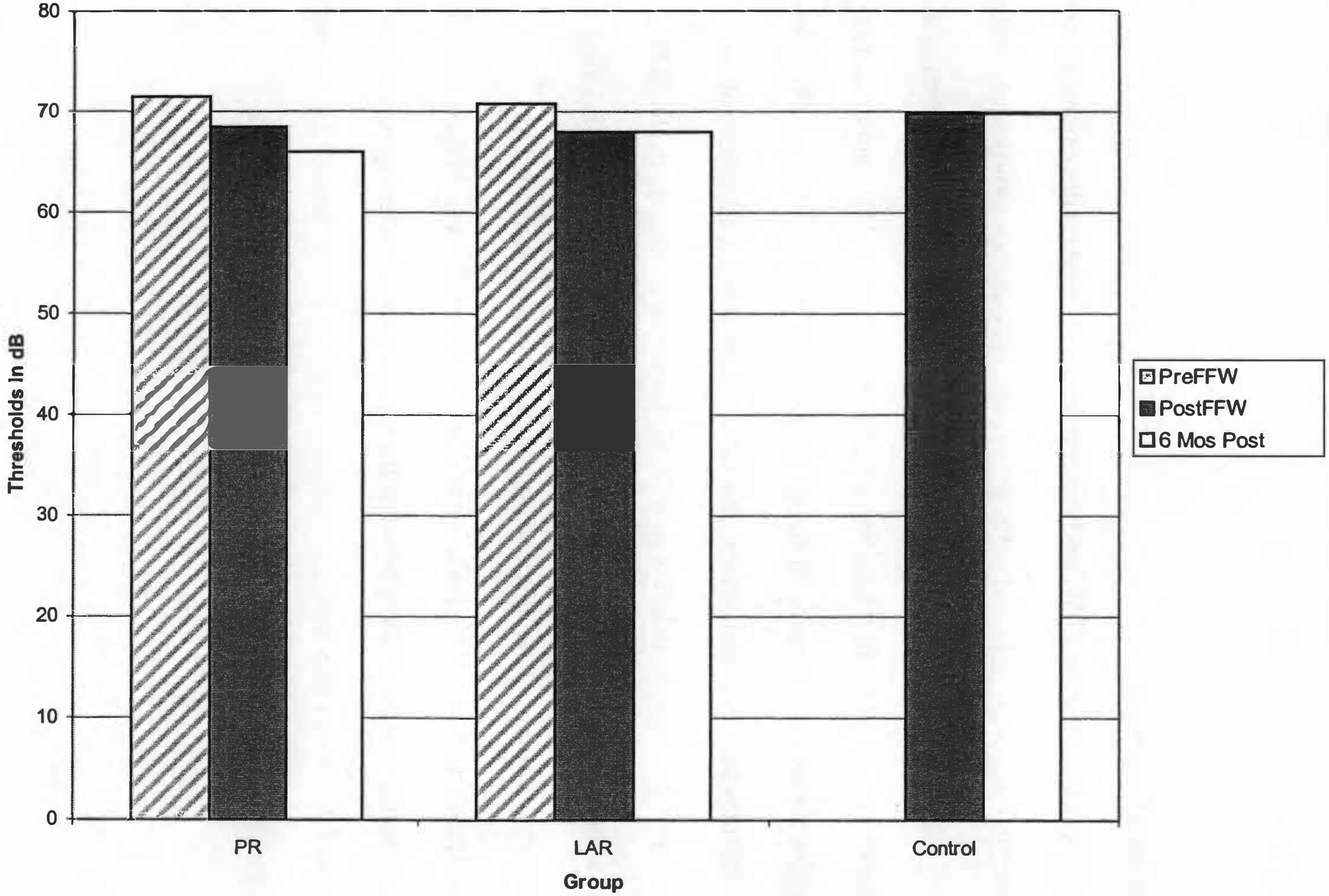

Figure 3. Simultaneous masking thresholds for three groups.

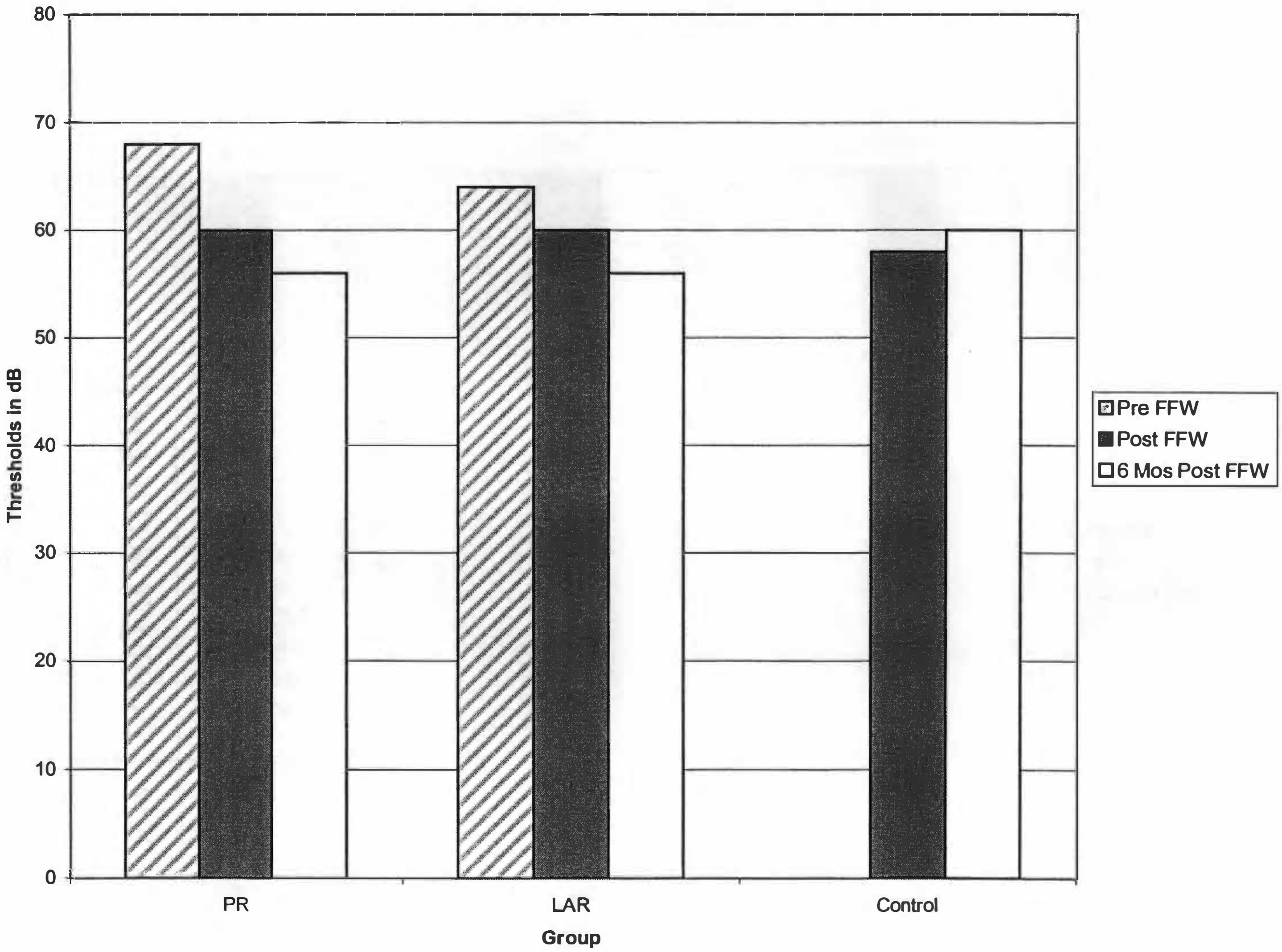

Figure 4. 0-ms gap thresholds for three groups.

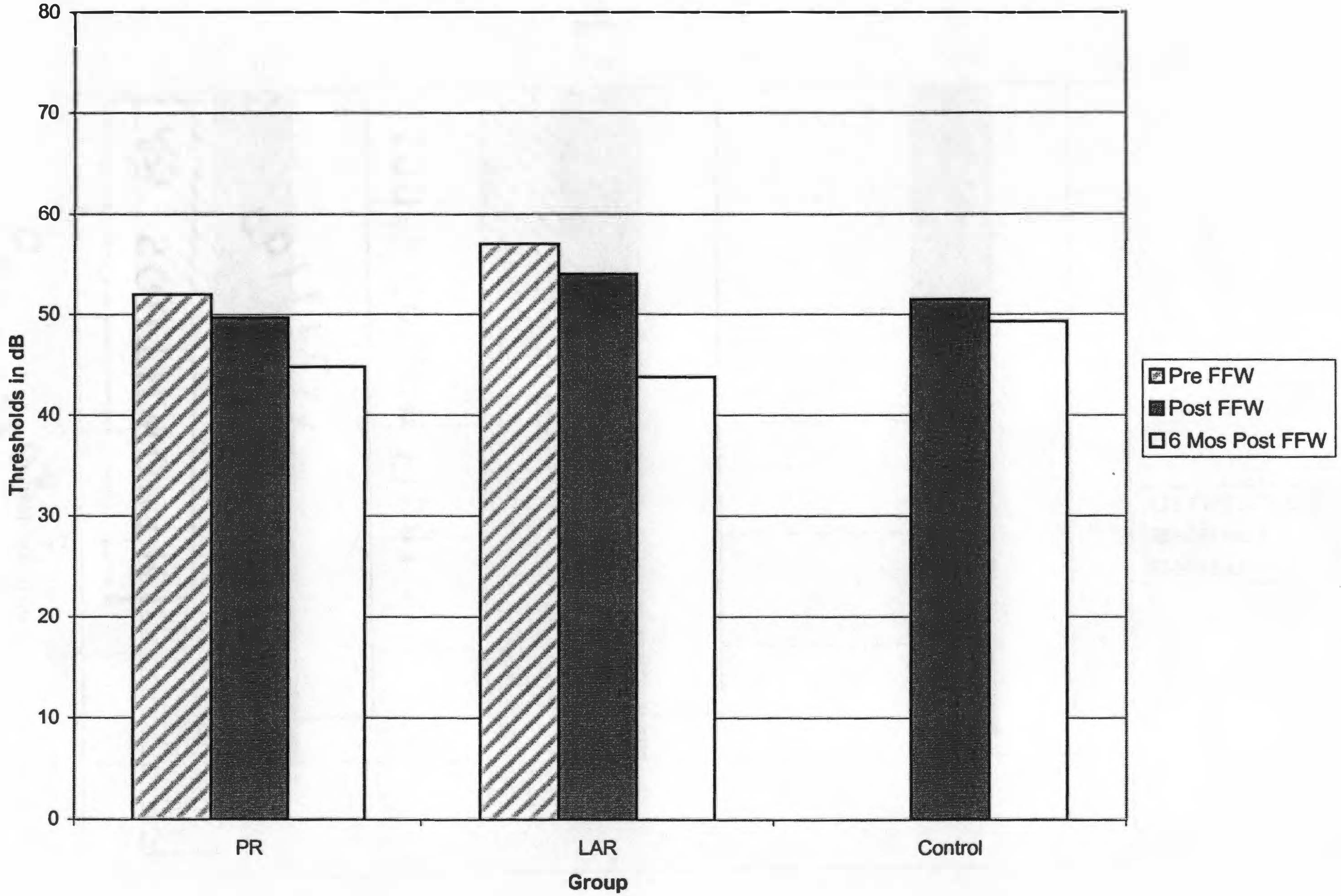

Figure 5. 20-ms gap thresholds for three groups.

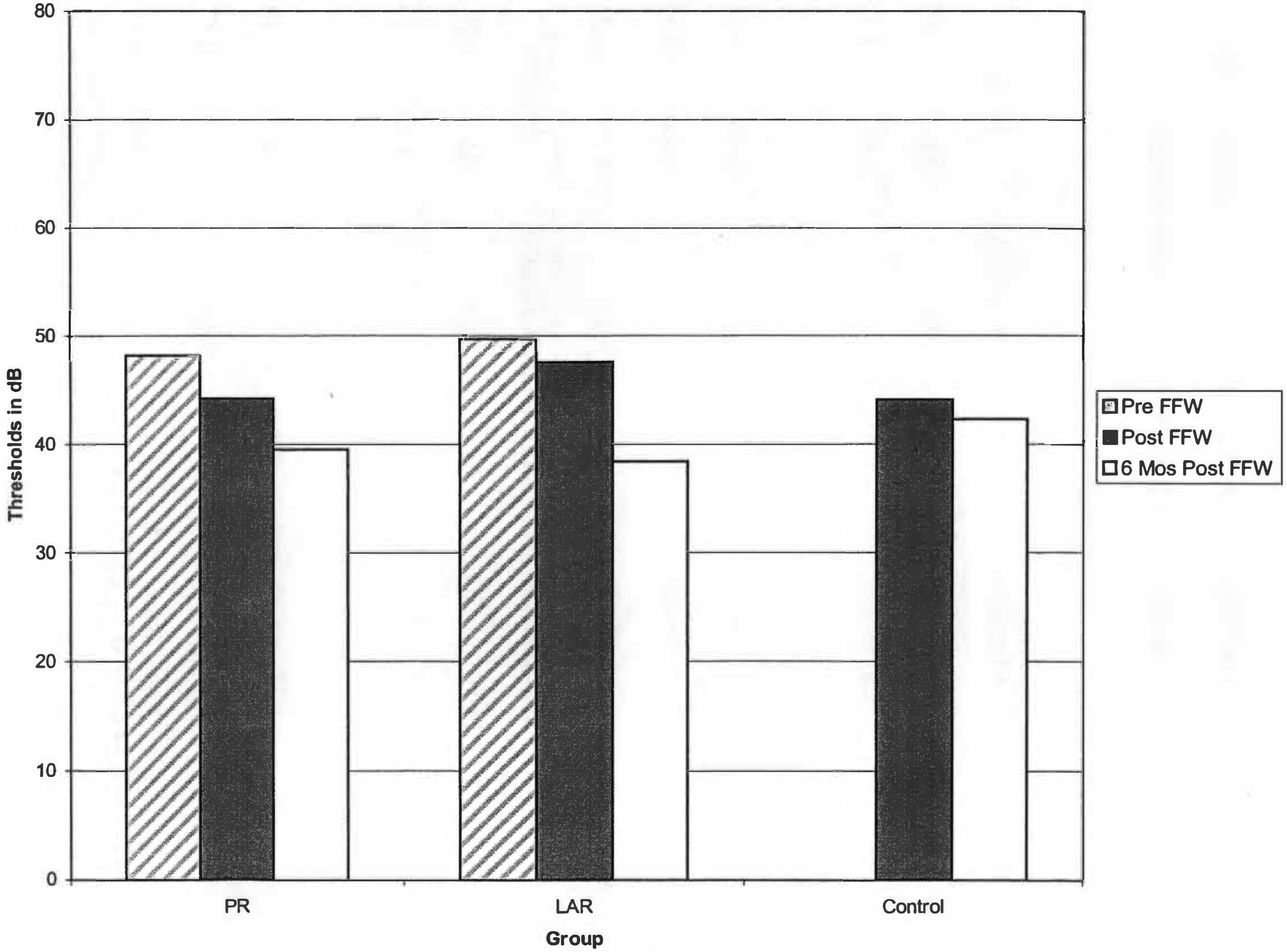

Figure 6. 40-ms gap thresholds for three groups.

Table 21

Means Standard Deviations of Masking Thresholds (dB SPL) for Children in the Poor Reading Group, Low Average Reading Group and Control Group: Post FFW and 6-Months Post FFW

Post FFW	Poor Readers		Low Average Readers		Control	
Condition	M	SD	M	SD	M	SD
Simultaneous	1.48	.71	1.30	.95	1.86	1.57
Backward						
0-ms gap	5.17	5.95	5.93	3.48	6.46	5.45
20-ms gap	7.52	6.66	5.00	6.72	3.88	3.33
40-ms gap	7.13	4.58	8.14	7.30	5.29	9.26
6-Months Post	Poor Readers		Low Average Readers		Control	
Condition	M	SD	M	SD	M	SD
Simultaneous	1.23	1.16	1.70	1.25	1.84	1.89
Backward						
0-ms gap	5.32	3.27	3.16	3.16	4.88	3.48
20-ms gap	5.21	5.46	5.38	6.05	6.70	6.17
40-ms gap	5.93	5.46	5.36	4.16	8.04	6.27

Table 22

ANOVA Table for Standard Deviations of Masking Thresholds and Interactions for Children in the Poor Reading Group, Low Average Reading Group and Control Group: Post FFW and 6-Months Post FFW

Variable	df	Error	F	Significance
Time	1	35	.45	.51
Time X Group	2	35	1.52	.23
Masker	3	105	18.73	<.01
Masker X Group	6	105	.27	.98
Time X Masker	3	105	.45	.72
Time X Masker X Group	5	105	1.01	.42
Group	2	35	.13	.88

Reading Assessments

Mean scores for the WA, WI, and GSRT for post FFW and 6-months post FFW are presented in Table 23. Participants in the three groups did not demonstrate any significant increases for any of the reading assessments six months after FFW. Although children who completed FFW received an intensive auditory program to increase speed and accuracy of discrimination of phonemes, this did not facilitate increases in decoding, sight word recognition, or reading comprehension and their modest increases of mean scores in the WA and WI were not significantly better than children who did not receive FFW training (WA, (F (2,35) = .65, p= .43; WI (F (2,35) = .10, p= .91). Table 24 includes interactions for group and time for each of the reading assessments.

Phoneme Awareness

Unlike the reading assessments, there were significant improvements in phoneme awareness for both the LAC and the NRT. Table 25 shows the means for the two assessments and Table 26 presents the interactions. There were no significant differences among the three groups for the NRT (F (2, 35) = 6.91, p= .30) and all three groups had significant increases six months following FFW (F (1,35) = 9.52, p= .004).

The two groups completing FFW did not demonstrate increases on the LAC immediately following FFW; however, there were increases in this measure six months following FFW (F (1, 35) = 7.04, p= .01). A significant group interaction (F (2,35) =

Table 23

Mean Scores and Standard Deviations for the Word Attack, Word Identification, and the Gray Silent Reading Tests for Children in the Poor Reading Group, Low Average Reading Group and Control Group: Post FFW and 6-Months FFW.

Post FFW	Poor Readers		Low Average Readers		Control	
Test	M	SD	M	SD	M	SD
WA	91	6	102	8	105	9
WI	88	6	101	4	107	7
GSRT	75	13	89	9	98	12
6 Months Post FFW	Poor Readers		Low Average Readers		Control	
Test	M	SD	M	SD	M	SD
WA	92	13	104	10	106	10
WI	87	13	99	3	106	7
GSRT	65	14	91	12	95	17

Note. WA = Word Attack, WI = Word Identification, GSRT = Gray Silent Reading Tests

Table 24

ANOVA Table for Reading Tests Results and Interactions for Children in the Poor Reading Group, Low Average Reading Group and Control Group: Post FFW to 6-Months Post FFW

Test	Variable	df	Error	F	Significance
WA	Time	1	35	.65	.43
	Time X Group	2	35	.13	.88
	Group	2	35	14.87	<.01
WI	Time	1	35	1.12	.30
	Time X Group	2	35	.10	.91
	Group	2	35	24.94	<.01
GSRT	Time	1	35	2.88	.10
	Time X Group	2	35	1.83	.18
	Group	2	35	21.45	<.01

Note. WA= Word Attack, WI= Word Identification, GSRT= Gray Silent Reading Test.

Table 25

Means and Standard Deviations of Phoneme Awareness Results for Children in the Poor Reading Group, Low Average Reading Group and Control Group: Post FFW and 6-Months FFW

Post FFW	Poor Readers		Low Average Readers		Control	
Test	M	SD	M	SD	M	SD
LAC	66	12	77	11	83	13
NRT	87	9	91	5	91	7
6 Months Post FFW	Poor Readers		Low Average Readers		Control	
Test	M	SD	M	SD	M	SD
LAC	76	16	82	12	81	9
NRT	93	5	93	7	95	5

Note. LAC = Lindamood Auditory Conceptualization; NRT = Nonword Repetition Task

Table 26

<u>ANOVA Table for Phoneme Awareness Test Results and Interactions for Children in the Poor Reading Group, Low Average Reading Group and Control Group: Post FFW to 6-Months Post FFW</u>

Test	Variable	*df*	Error	*F*	Significance
LAC	Time	1	35	7.04	.01
	Time X Group	2	35	3.97	.03
	Group	2	35	3.52	.04
NRT	Time	1	35	9.52	.004
	Time X Group	2	35	1.24	.50
	Group	2	35	6.91	.30

Note. LAC= Lindamood Conceptualization Test, NRT= Nonword Repetition Task

7.04, p= .01) revealed that those children in the PR group completing the FFW program exhibited significant increases on the LAC six month after FFW when compared to the LAR and control group. Figures 7 and 8 illustrate improvements on the measures of phoneme awareness.

Expressive and Receptive Language

A prominent research question was whether improvements in language scores would continue six months after FFW. There have been several studies that have demonstrated increases in total language scores and expressive language scores immediately following FFW (Merzenich et al., 1997; Miller et al., 1999). Table 27 contains the mean standard scores of the CELF-3 (total, expressive and receptive scores). There were no significant increases six months after FFW for any of the groups (F (1,35) = .17, p= .68). The interactions are presented in Table 28.

One hypothesis for an increase of standard scores immediately following FFW was familiarity to some of the test items because of the short time interval between administration. Analysis revealed that the only common subtest that increased significantly immediately after FFW training was Recalling Sentences. If increases were a result of familiarity to some of the test items, than it might be assumed that this would be eroded six months after the administration of the test. This, in fact, was the case and there were not significant increases in the Recalling Sentences subtest. The interaction

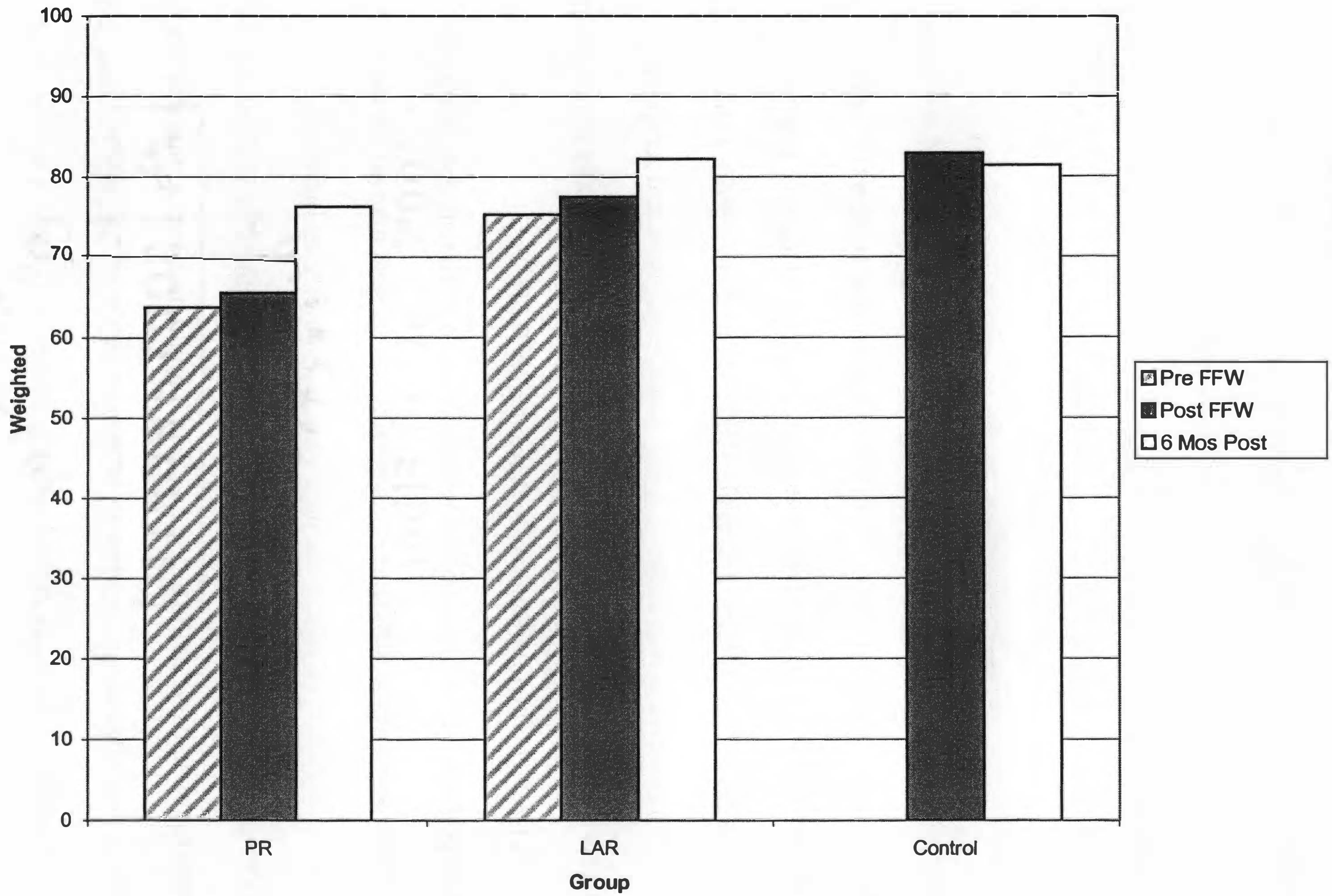

Figure 7. Results of the Lindamood Auditory Conceptualization test for three groups.

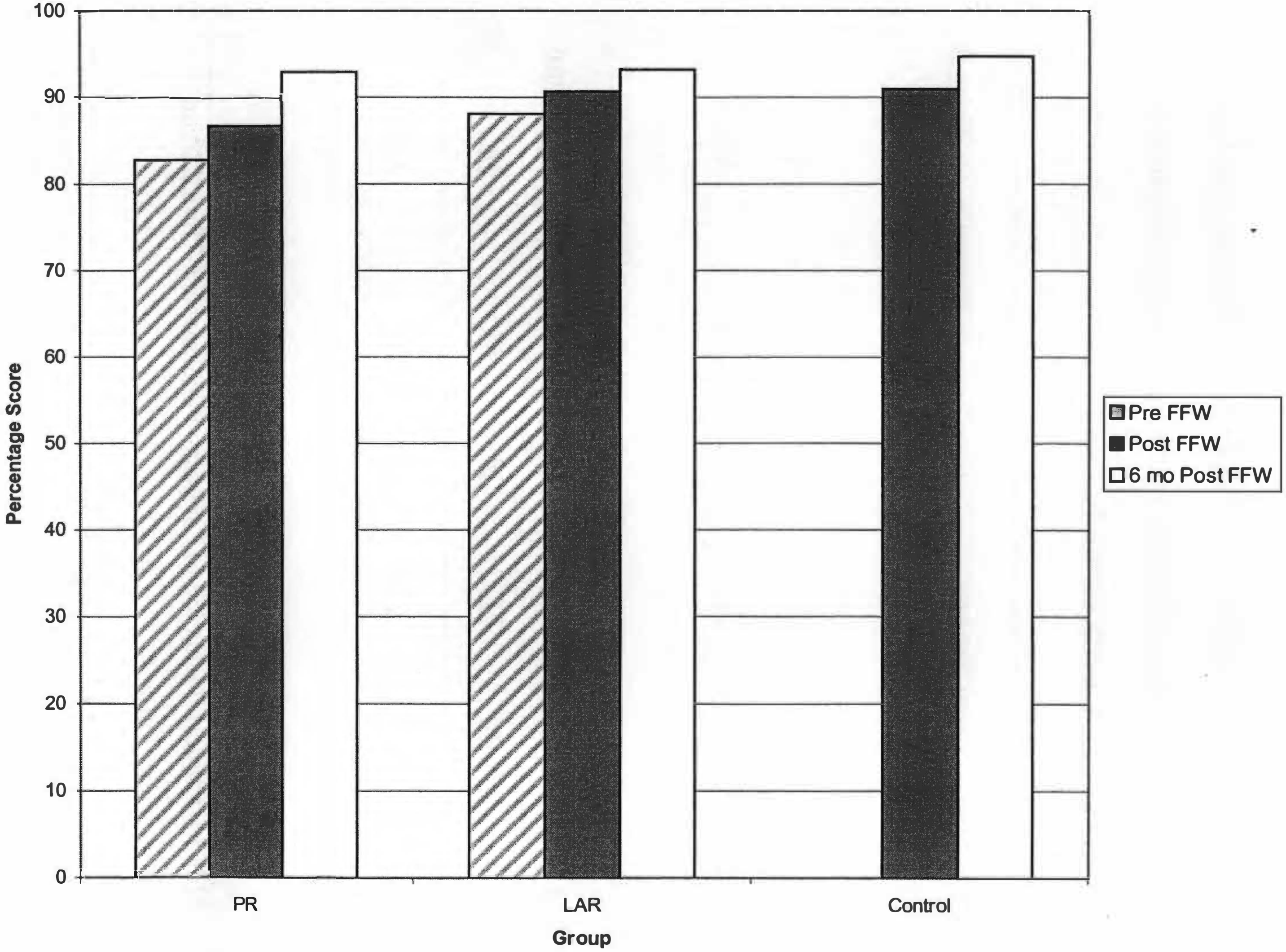

Figure 8. Results of the Nonword Repetition Task for three groups.

Table 27

Means and Standard Deviation of the CELF-3 Summary, Expressive and Receptive Portions for Children in the Poor Reading Group, Low Average Reading Group and Control Group: Post FFW and 6-Months Post FFW

Post FFW	Poor Readers		Low Average Readers		Control	
Test	M	SD	M	SD	M	SD
CELF-3	93	12	102	8	103	11
Expressive	94	13	101	10	102	12
Receptive	94	12	103	8	105	12

6 Months Post FFW	Poor Readers		Low Average Readers		Control	
Test	M	SD	M	SD	M	SD
CELF-3	91	9	101	11	108	11
Expressive	91	11	103	12	107	4
Receptive	93	11	99	10	112	11

Note. CELF-3 = Clinical Evaluation of Language Fundamentals-Third Edition

Table 28

ANOVA Table for Language Abilities and Interactions for Children in the Poor Reading Group, Low Average Reading Group and Control Group: Post FFW and 6-Months Post Months FFW

Test	Variable	df	Error	F	Significance
CELF-3	Time	1	35	.17	.68
	Time X Group	2	35	2.42	.10
	Group	2	35	7.09	< .01
Expressive	Time	1	35	.48	.50
	Time X Group	2	35	1.81	.18
	Group	2	35	4.64	.02
Receptive	Time	1	35	05	.83
	Time X Group	2	35	2.70	.08
	Group	2	35	8.36	< .01

Note. CELF-3 = Clinical Evaluation of Language Fundamentals-Third Edition

identified of Time X Group (F (1, 35) = 4.98, p= .01) represents a significant decrease of mean scores of the PR group. The mean standard scores for the four subtests are presented in Table 29. Six months after FFW there were no significant increase for any of the four subtests (Table 30).

Correlation Between Psychophysical and Behavioral Testing

A Pearson Correlation analysis was performed on the data immediately following FFW training and six months later for the two groups that participated in FFW training in order to investigate whether the psychophysical results correlated with the behavioral testing data. Variable pairs were selected at the $p<.01$ level or beyond. All possible pairs and correlations are found in Appendix F. There were no correlations between the psychophysical data and the behavioral testing results.

Pre FFW and 6 Months Post FFW

Masking Thresholds

A repeated measure of the variance of the masking thresholds and the results of the reading, phoneme awareness, and language assessments was completed to compare changes before FFW training and six months following FFW training. Masking thresholds decreased significantly from the initial testing period to the final testing period (F (1,24) = 37.62, p= <.01). Although the mean thresholds decreased significantly for all

Table 29

Mean Scores and Standard Deviations (in parentheses) for the Four Common Subtests of the CELF-3 for Children in the Poor Reading Group, Low Average Reading Group and Control Group: Post FFW and 6-Months Post FFW

Post FFW	Poor Readers		Low Average Readers		Control	
Test	M	SD	M	SD	M	SD
Recalling Sentences	9.46	2	10.15	2	9.92	3
Word Class	8.85	4	9.70	2	9.83	3
Formulated Sentences	8.38	2	10.08	2	9.68	3
Concepts and Directions	9.38	2	10.62	2	12.50	3

6 Months Post FFW	Poor Readers		Low Average Readers		Control	
Test	M	SD	M	SD	M	SD
Recalling Sentences	7.77	3	11.00	2	10.67	3
Word Class	8.31	4	9.61	2	11.25	3
Formulated Sentences	8.00	2	10.15	3	10.50	3
Concepts and Directions	8.69	2	10.15	2	13.58	3

Table 30

ANOVA Table for Subtests of CELF-3 and Interactions for Children in the Poor Reading Group, Low Average Reading Group and Control Group: Post FFW and 6-Months Post FFW

Subtest	Variable	df	Error	F	Significance
Recalling Sentences	Time	1	35	<.01	.93
	Time X Group	2	35	4.98	.01
	Group	2	35	3.14	.06
Word Class	Time	1	35	.33	.57
	Time X Group	2	35	1.57	.22
	Group	2	35	2.17	.12
Concepts and Directions	Time	1	35	.22	.64
	Time X Group	1	35	.92	.41
	Group	2	35	2.17	.13
Formulating Sentences	Time	1	35	.08	.78
	Time X Group	2	35	.06	.94
	Group	2	35	5.16	.01

conditions, the decrease in simultaneous masking was less than the other conditions. Table 31 presents the interactions among FFW, masking conditions, and group.

Reading Assessments

Pre FFW testing and six months following FFW training did not reveal improvements in any of the three reading assessments. Word attack skills (WA, F (1,24) = 2.71, p= .11), sight-word recognition (WI, F (1,24) = .01, p= .91) and reading comprehension (GSRT, F (1,24) = 1.81, p= .19) did not exhibit any improvements over the entire school year for the participants who completed FFW training. Table 32 displays the interactions for the three reading tests. The participants in the PR group demonstrated the least improvements of mean standard scores for each assessment, and in the case of GSRT, the reading quotient decreased from a score of 77 to 65.

Phoneme Awareness

There were significant increases in both tests of phoneme awareness when comparing the initial assessments and final assessments. Participants in both groups had significant increases in the LAC (F (1,24) = 23.59, p= <.01) and the NRT (F (1,24) = 12.73, p= <.01). Table 33 presents the significant interactions.

Table 31

ANOVA Table for Masking Thresholds and Interactions for Children in the Poor Reading Group and Low Average Reading Group: Pre FFW and 6-Months Post FFW

Variable	df	Error	F	Significance
Time	1	24	37.62	<.01
Time X Group	1	24	.04	.84
Masker	3	72	113.77	<.01
Masker X Group	3	72	.59	.62
Time X Masker	3	72	3.06	.03
Time X Masker X Group	3	72	1 .75	.16
Group	1	24	.01	.93

Table 32

ANOVA Table for Reading Test Results and Interactions for Children in the Poor Reading Group and Low Average Reading Group: Pre FFW and 6-Months Post FFW

Test	Variable	df	Error	F	Significance
WA	Time	1	24	2.71	.11
	Time X Group	2	24	.31	.58
	Group	2	24	15.68	<.01
WI	Time	1	24	.01	.91
	Time X Group	2	24	.03	.87
	Group	2	24	20.22	<.01
GSRT	Time	1	24	1.81	.19
	Time X Group	2	24	7.76	.01
	Group	2	24	20.68	<.01

Note. WA= Word Attack, WI= Word Identification, GSRT= Gray Silent Reading Test.

Table 33

ANOVA Table for Phoneme Awareness Test Results and Interactions for Children in the Poor Reading Group and Low Average Reading Group: Pre FFW and 6-Months Post FFW

Test	Variable	df	Error	F	Significance
LAC	Time	1	24	23.59	<.01
	Time X Group	2	24	1.96	.17
	Group	2	24	3.23	.08
NRT	Time	1	24	12.73	<.01
	Time X Group	2	24	1.43	.24
	Group	2	24	1.57	.22

Note. LAC= Lindamood Conceptualization Test, NRT= Nonword Repetition Task

Expressive and Receptive Language

There was not a significant increase of total standard score of the CELF-3 over the school year (F (1,24) = 3.97, p= .06) for participants in both groups. Table 34 shows that the expressive portion of the CELF-3 did increase over the school year (F (1,24) = 9.91, p= .004) whereas the receptive portion did not (F (1,24) = .06, p= .81). Unlike the analysis of the individual subtests pre and post FFW and post FFW and six months post FFW, the scores from the common subtests from the CELF-3 did not demonstrate any significant increases (see Table 35).

Table 34

ANOVA Table for CELF-3 Results and Interactions for Children in the Poor Reading Group and Low Average Reading Group: Pre FFW and 6-Months Post FFW

Test	Variable	df	Error	F	Significance
CELF-3	Time	1	24	3.97	.06
	Time X Group	2	24	.12	.73
	Group	2	24	8.60	.01
Expressive	Time	1	24	9.91	.004
	Time X Group	2	24	3.15	.09
	Group	2	24	5.60	.03
Receptive	Time	1	24	.06	.81
	Time X Group	2	24	1.12	.30
	Group	2	24	7.32	.01

Note. CELF-3 = Clinical Evaluation of Language Fundamentals-Third Edition

Table 35

ANOVA Table for CELF-3 Subtests Results and Interactions for Children in the Poor Reading Group and Low Average Reading Group: Pre FFW and 6-Months Post FFW

Test	Variable	df	Error	F	Significance
CD	Time	1	24	.04	.84
	Time X Group	2	24	.04	.84
	Group	2	24	4.04	.06
WC	Time	1	24	1.15	.29
	Time X Group	2	24	.87	.36
	Group	2	24	5.57	.03
FS	Time	1	24	.47	.50
	Time X Group	2	24	3.10	.09
	Group	2	24	2.15	.15
RS	Time	1	24	1.57	.22
	Time X Group	2	24	1.57	.22
	Group	2	24	11.65	<.01

Note. CD = Concepts and Directions, WC = Word Class, FS = Formulating Sentences, RS= Recalling Sentences.

Chapter V

Discussion

Summary of Group Results

The purpose of the study was to examine changes in simultaneous and backward masking thresholds on a group of children completing the FFW program. This study expands on previous research which investigated changes in backward masking thresholds on a smaller group of children completing FFW (Marler, et al., 2001; Thibodeau et al., 2001). In addition, similar to Hook et al.(2001), it investigated whether changes in masking thresholds correlated with increases in reading, phoneme awareness, and language abilities. Finally, it investigated if there would be changes in these measures six months after FFW and if any changes would be greater than a group of children who did not complete FFW training.

The 26 children who participated in the FFW training program had differences in reading ability and subgroups were formed based on delays on the WA and WI subtests of the WRMT. The Poor Reading Group (PR) consisted of 13 children with more than a year delay on the two subtests and the children in the Low Average Reading Group (LAR) had age equivalent scores within six months or above. Thirteen children who did not participate in FFW training served as a control group. Performance for the control group on the reading (WA and GSRT), phoneme awareness, and language tests were statistically similar to the children in the LAR group.

Backward and simultaneous masking thresholds did not differ between the children who had significantly lower reading skills. Research has suggested that only children with both reading and oral expressive delays differ significantly on auditory processing tasks (Heath et al., 1999; McArthur & Hogben, 2001; Tallal, 1980). The two groups in this study differed statistically on the reading, phoneme awareness (with the exception of the NRT) and total language assessments. The majority of the participants in this research study did not have both reading and expressive language delays. Only two children who were tested had standard scores below 85 on both the WRMT and the expressive portion of the CELF-3. Both of these children, however, had backward masking thresholds (70.0 and 61.1) that were lower (better) than the group mean. A total of 6 children in the PR group had total language scores below 85. Only 1 out of 6 of these children had backward masking thresholds in the 0-ms gap condition that was greater than the group mean.

Thresholds for the children in the PR group were not as elevated as the mean backward thresholds for children in the impaired language group found in the research by Wright et al. (1997). Again this could be because the majority of children in the PR group did not have a significant language delay. The mean standard score in the Wright et al. study on the CELF-R for the expressive language portion was 70.7, and for this study it was 88.38. The lack of a statistical difference of thresholds between the two groups was consistent, however, with the findings of three other investigations (Bishop et al., 1999; Helzer et al., 1996; Thibodeau et al., 2001). In all three of these studies, there were no group differences in backward masking thresholds between a language-impaired group and a control group. A group of children who did not receive FFW training was tested following FFW and results indicated that backward masking thresholds were not statistically different than the two groups that had FFW training. Findings in this study, therefore, are consistent with previous research that suggests children with reading and language delays do not necessarily have impaired temporal processing.

Threshold levels obtained in this study for both backward and simultaneous masking were similar to the thresholds in Bishop et al. (1999), who also used a 2I2AFC paradigm. Thresholds obtained in the current study are higher than Helzer et al. (1996) and Thibodeau et al. (2001), but these two studies used alternative paradigms. Table 36 reports thresholds in each of these studies. Ideally, it would have been preferable to obtain masking thresholds in a sound booth, but due to infeasibility of transporting almost 40 children 80 miles to a sound booth, testing was done at the school. Even though thresholds in the current study were not obtained in a sound-treated room, levels were very similar to previous research.

Table 36

Mean Backward Masking Thresholds from Current and Previous Studies

Study	Backward (0-ms gap)		Simultaneous		Paradigm
	Impaired	Control	Impaired	Control	
Present Study	71,66,56	58,60	73,70,67	70,70	2I2AFC
Bishop et al. (1999)	67,58,50	71,51,49	N/A		2I2AFC
Thibodeau et al. (2001)	63,59,60	53,54,54	73,73,73	68,69,69	3I3AFC
Helzer et al. (1996)	53	52	N/A		Signal button

Note. Numbers represent thresholds in dB. In the present study thresholds were obtained pre, post and 6 months post FFW. In the Bishop et al., thresholds were obtained three times over a two week testing period. Thibodeau et al. measured thresholds three times within a four-week training period of FFW. Helzer et al. collected masking thresholds only once.

Psychophysical Measures: Pre, Post FFW, and 6 Months Post FFW

Masking Thresholds

The first research question asked whether backward masking and simultaneous masking thresholds would improve immediately following FFW and whether any improvements would continue six months following FFW. The results of this research indicated that masking thresholds decreased (improved) after FFW. As expected, simultaneous masking thresholds were more elevated than backward masking thresholds. Two previous studies measured backward and simultaneous masking thresholds (Marler et al., 2001; Thibodeau et al., 2001) prior to FFW and during the FFW training period. Marler et al. (2001) found a trend for a decrease in masking thresholds that were acquired at three separate intervals during the FFW program. Thibodeau et al. (2001) did not identify significant decreases in masking thresholds that were obtained across five testing sessions. They suggested that one possible reason the children in their two groups did not display lower thresholds was because they did not average in the first trials of backward and simultaneous masking. In the Thibodeau et. al. study (2001) the initial session served as a practice run, unlike in the Marler study where the initial testing period served as baseline. The largest difference of thresholds in both these studies was identified between the first and second testing period.

Because the participants in the experimental group in this study were tested only two times during the FFW training period (prior to FFW and immediately following FFW), it could be argued that one would expect the greatest variability between these two measurements (Thibodeau et al., 2001). In order to compensate for this, the testing protocol for the present study was much more stringent than in previous studies (Bishop et al., 1999; Marler et al., 2001; Thibodeau et al., 2001). Marler et al. (2001) calculated the child's threshold by the arithmetic mean of the last 10 reversals in the initial run. Subsequent testing in their study was brief and only one run for backward and simultaneous masking was completed. In Thibodeau et al. (2001), two runs were averaged in each testing period. In this present study, participants often had to complete several runs of one condition before going on to another. Standard deviations for each run were less than 5 dB and if they were not, the run was discarded and another run was completed until acceptable thresholds were obtained. In addition, threshold levels were closely monitored before presenting the next condition. If thresholds were not within 5 dB on the first two runs, a subsequent run was completed and this threshold had to be within 8 dB, and if this was not obtained, the condition was presented until thresholds were within 10 dB of each other. Consequently, each participant's performance and understanding of the task was very reliable even though backward masking thresholds were measured in a pre and post protocol. Another factor that influenced training in the initial session was that the participants completed four listening tasks; whereas, the previous studies using FFW completed only two (Marler et al., 2001; Thibodeau et al., 2001) . Because participants completed four testing conditions, this aided in obtaining reliable and stable thresholds during the initial and final sessions.

The 26 children who completed FFW training in this study had statistically lower backward masking thresholds following the FFW program. One can speculate that the auditory training the children received during FFW increased their temporal processing abilities and aided in their ability to detect a tone in the presence of a masker. However, similar to Thibodeau et al. (2001), thresholds for children in a control group who did not receive FFW training did not statistically differ from the two groups completing FFW. This finding calls into question whether FFW actually precipitated changes in auditory processing resulting in lower masking thresholds.

The second research question asked whether masking thresholds would continue to improve and if they would improve more than the group of children who did not participate in FFW. It has been speculated that intensive computerized training could play a major role in improving thresholds, independent of possible changes of temporal processing (Marler et al., 2001). If FFW increased temporal processing and precipitated changes auditorally and neurologically, it is logical to expect backward masking thresholds to continue to decrease. However, if the intensive computer training helped develop attention in making quick auditory judgements in computer-related tasks, this skill could fade over a six-month period after the training had ended. Although the 20-ms gap and the 40-ms gap backward masking thresholds were significantly lower, this was the case for children who had FFW and those who did not. 0-ms backward masking thresholds did not significantly decrease six months after FFW. Although there were significant decreases in masking thresholds immediately following FFW, these were not sustained six months later. Also, results of masking thresholds did not exhibit any differences six months following FFW training between the experimental group and the control group who did not receive FFW training. These findings call into question whether FFW increases temporal processing. Because 0-ms backward masking thresholds did not significantly decrease six months following FFW training and because masking thresholds did not differ from a control group who were not exposed to FFW training, there may be alternative explanations for changes in the masking thresholds.

Buss et al. (1999) reported variability and a trend for more adult-like masking thresholds for children between the ages of 8 and 11 years old. Hartley et al. (2000) found that backward masking thresholds begin to plateau and become more adult-like by the age of 11. If changes in backward masking thresholds are independent of FFW training, significant improvement in backward masking threshold before and after FFW and over the course of the school year might represent this trend toward more adult-like masking thresholds.

Standard Deviations

Thresholds decreased in all conditions (simultaneous, 0-ms gap, 20-ms gap, and 40-ms gap backward masking) following FFW training, however, standard deviations did not follow this pattern. The 0-ms backward masking condition was chosen to maximally challenge the participants and the 20 ms and 40 ms were expected to yield easier identification of the tone in the presence of a masker. Results were similar to findings in Helzer et al. (1996) where children in both a language-impaired group and an age-matched group had successively lower thresholds for the 40-ms and 64-ms gap when compared to the 0-ms gap. Children in the language-impaired group required more ascending trial runs than the age-match group to reach thresholds. The authors concluded that children in the SLI group responded more inconsistently. They speculated that SLI children might require longer periods of stimulation to achieve automatic attention to focus on the task or that SLI children have limited capacity to sustain attention. In the current study, rather than use the number of ascending trial runs to reach a threshold as a method to investigate the consistency of the response, the average standard deviation for each condition across all participants in both groups was analyzed. There were no group differences and this may have been because children in the PR, LAR, and control groups in this study had mild or no language delays; whereas, children in previous studies had more moderate to severe language delays (Marler et al., 2001; Thibodeau et al., 2001). Similar to Bishop et al. (1999) and Wright et al. (1997), simultaneous masking had less variability and the standard deviations for this condition were lower than the three backward masking conditions. Helzer et al. (1996) did not analyze differences of ascending trial runs for each condition, but only the total numbers. Our study found that the standard deviation for 0-ms gap backward masking was significantly lower than the

40-ms gap condition, but not for the 20-ms gap condition. This may indicate a point at which the backward masking task becomes more confusing for some children. Although identification of the signal in the presence of a masker may be better, as represented by lower thresholds, there is more variability in this condition across both groups. It is possible that the children had difficulty perceiving the auditory stimulus because the 40-ms gap increased memory demands. Rather than perceiving the stimulus as one auditory object and making a discrimination, the children could have been perceiving the 40-ms gap condition as two auditory objects before making a decision. Demands on auditory memory capacity, consequently, could have been a factor in increased variability of the 40-ms gap condition (Helzer et al., 1996).

Unlike thresholds, there were no differences in standard deviations following FFW. If one assumes that FFW was responsible for decreasing backward masking thresholds because of improving temporal processing, one would expect standard deviations to improve as well. If the FFW program increases temporal processing abilities, one would expect both lower thresholds in backward masking, as well as, lower standard deviations. Increasing the underlying skill presumably should make the task easier. However, standard deviations did not decrease following FFW. Significant differences among the three backward masking conditions were identified, but these differences could have been a result of increased memory demands and not auditory processing abilities. Some researchers have suggested that the 2I2AFC paradigm increases memory demands (Bishop et al., 1999; Marler et al., 2001). It is possible that this paradigm increased demands on memory capacity that could have influenced the variability found among the three different backward masking conditions. Familiarity to the testing protocol and the daily intensive practice on the computer exercises of FFW, might have facilitated their ability to attend to a tone in the presence of a masker. This resulted in modestly lower masking thresholds; however, the ease at achieving lower thresholds was not demonstrated as evidenced by no significant changes in standard deviations. Children who had poor reading ability and those who had low average reading abilities continued to have a great deal of variability as the gap between the tone and masker increased following FFW.

This trend was also found in the children who did not have FFW training. The control group did not have statistically different standard deviations when compared to the experimental groups immediately following FFW. And six months following FFW, there were no significant changes in standard deviations. Again, the lack of a significant difference between the experimental group completing FFW and a control group challenges the effectiveness of FFW to increase temporal processing skills.

Behavioral Testing

Reading and Phoneme Awareness

Twenty-six children who participated in FFW were administered a battery of reading, phonemic awareness, and language assessments before and after FFW. Another research question proposed in this investigation was whether children would increase reading and phonemic awareness skills following the FFW training. There were no immediate gains following FFW for children in the PR or LAR groups on the three tests that measured reading ability (WA, WI, and GSRT). In addition, there were no significant increases in phoneme awareness for either group based on the LAC . However, children in both groups demonstrated significant gains on the nonword repetition task. The lack of improvement on the WA, WI and the GSRT is consistent with Hook et al. (2001) who also did not find immediate gains on the WA, WI, or the Passage Comprehension subtests following FFW.

Participants in neither group demonstrated immediate gains on the LAC, unlike Hook et al. (2001). Differences in findings in this present study and Hook et al. might have been because children in her study had poorer reading ability, but slightly better phonemic awareness skills. The mean LAC scores, pre and post-FFW in Hook et al. were 68.2 and 76, compared to 63.77 and 65.2 in the current study (9 out of 13 children in the PR group, however, were below LAC suggested grade levels). It could be argued that children with better phonemic awareness skills benefit most with FFW training; however, this could not be applied to the children in the LAR group who had higher LAC scores, but showed modest nonstatistical gains. Children in the FFW group in Hook et al. (2001) were tested and administered the program in the summer, so the children did not receive instruction from a school reading program. Likewise, children in our study did not receive individual reading intervention from the reading instructor, however, they were required to complete the reading homework in their regular classroom. Hook et al. found increases for both groups who either received FFW or the Orton Gillingham program. However, children in this present study did not show the same immediate gains in phonemic awareness based on the LAC following the FFW program, although increases in the NRT were identified for both groups completing FFW.

Children did increase scores on the NRT following FFW. Dollaghan and Campbell (1998) suggested that children with lower language abilities perform more poorly on this task. The children in the LAR group had significantly higher total language scores on the CELF-3 than children in the PR group, but group differences on the NRT were not significant ($p=.12$) prior or following FFW. One explanation for not having a greater difference between the mean scores on the NRT is that both groups displayed language scores that were within the low average range. According to Dollaghan and Campbell, a nonword task involves several processing operations which include "transforming the acoustic-phonetic sequence into its constituent phonemes, maintaining the ordered and phonologically coded string in working memory, and organizing the articulatory output" (p. 1145). Four exercises in the FFW program focus on identifying and discriminating phonemic sound changes. The children in both groups trained for approximately 6 weeks on these tasks and improvement in phonemic awareness based on one measure, the NRT, was identified immediately after training.

The FFW program claims to increase abilities in phonemic awareness which can promote better reading skills. In the initial study using FFW (Tallal et al., 1996), children in the FFW group increased abilities to discriminate speech sounds based on pre and post testing using the Goldman-Fristoe-Woodcock Auditory Discrimination Test (GFW, 1974). It can be argued that the exercises the FFW training program used to train phonemic awareness (Phoneme Identification, Old McDonald's Flying Farm, Phonic Match, Phonic Word) are similar, in nature, to the items on the GFW test used by Tallal et al. (1996). It was for this reason that more independent measures such as the LAC and the nonword test were used to identify changes in phonemic awareness. Studies have shown that phonemic awareness is a short-term trainable skill (McGuinness, McGuinness, & Donohue, 1995; Share & Stanovich, 1995), and based on the results of the current study, the FFW program did facilitate improvements in the children's ability to repeat nonsense words. However, the same improvement was not seen for the LAC immediately following FFW. Unlike the reading tests and the LAC that were administered, the NRT did not have an alternative form. Familiarity to some of these items could have been a factor for the improvement, in addition to the FFW program increasing the child's attention to an auditory task. Finally, although increases in the percentage of phonemes correct on the NRT were identified, no significant increases on other measures of reading and phoneme awareness were seen immediately following FFW.

It could be speculated that increases in reading skills, especially word decoding skills, would improve after significant improvements in phoneme awareness were established. Immediately following FFW there were significant increases for both groups on the NRT and a nonsignificant increase of the weighted scores of the LAC. Testing six months following FFW, however, did not identify any improvements on the three tests of reading (WA, WI, or GSRT) for the children completing FFW. This was also true for children in the control group who had statistically similar scores on the WA, GSRT, LAC, and the NRT as those in the LAR group. This finding appears to demonstrate that FFW training does not have a significant contribution in improving reading scores and is no more effective than the traditional classroom reading instruction the control group received in this study.

Whereas reading measurements did not show significant increases following FFW or six months after FFW for any of the groups, the trend was not as clear for phoneme awareness. As previously discussed, improvements on the NRT were identified immediately following FFW for both experimental groups. Six months after FFW training, children in all three groups, however, demonstrated increases on the NRT. Even the children who did not have FFW training had significant gains on the NRT during this testing period. Children who completed FFW, however, did not have any more significant gains on the NRT than children who did not have FFW training. This result questions whether FFW training is a contributing factor in increased phoneme awareness based on the NRT. Comparing results on the LAC six months post FFW is somewhat less conclusive. Only the children in the PR group significantly improved on the LAC . Post FFW and six month post FFW scores did not significantly increase for children in the LAR or the control group.

It can be argued that the FFW program was a significant factor in increasing phoneme awareness and that this training led to increases in phoneme awareness even six months after the children were discharged from FFW. However, even the group that did not receive FFW increased their performance on the NRT and only children in the PR group had a significant increase in LAC six months after FFW. It can be maintained that even though children in the PR group demonstrated significant increases on the LAC, they also had the most to gain towards age-equivalent levels. In addition, it is difficult to assess the influence that children received from their classroom instruction. Most of the children in the PR group received special group and individualized reading instruction from the reading specialist using the Wilson method of instruction during the period following FFW.

Comparison of phoneme awareness over the entire school year for the children who participated in FFW demonstrated significant gains in both measurements, the LAC and the NRT. However, even though there were increases in phoneme awareness, there were no improvements in any of the reading assessments from pre FFW to six months post FFW. It may be argued that increases in phoneme awareness do not immediately affect word attack skills or reading comprehension skills, but would contribute to better reading skills as the child continues to learn and develop reading skills. Tallal has said that FFW "is building the scaffold for reading" (Stanford Report, 2003) and therefore, represents a beginning stage where these skills will lead to better reading. Hook et al. (2001) completed follow-up testing more than a year after FFW, however, these researchers did not find a significant increase in phoneme awareness or in reading skills.

Expressive and Receptive Language

Another research question investigated was whether language abilities would increase immediately following FFW as demonstrated in previous research (Merzenich et al., 1996; Miller et al., 1999). The total language score and the receptive language score were significantly higher for the LAR group than the PR group, but differences in expressive language scores did not meet significance. Language skills varied within groups and were significantly different across the two groups; however, mean language scores were higher for both groups than participants in previous studies using FFW (Marler et al., 2001; Tallal et al., 1996; Thibodeau et al., 2001). As previously discussed, this could have been a factor in lower backward masking thresholds. A primary research question was whether language skills as measured by the CELF-3 would increase following FFW. Children in both groups had increases in total language scores and expressive and receptive language scores following FFW. This is consistent with previous research studies measuring language abilities (Gillam et al., 2001; Hook et al., 2001; Merzenich et al.,1996; Miller, et al., 1999; Tallal et al.,1996).

Subtests for the CELF-3 vary depending on age. Children between the ages of 6 and 8 have 3 different subtests than children between the ages of 9 and 21. In the current study, results were compared on the four common subtests which were Concepts and Directions, Word Class, Recalling Sentences, and Formulated Sentences. Tallal and colleagues (1996) used the Token Test for Children (TTC) (DiSimoni, 1978), to measure language processing pre and post FFW and reported significant gains. One could argue that the subtest, Concepts and Directions is a similar assessment as the TTC because it demands the child to follow spoken commands with picture cues of shapes and colors (black and white in this case). The FFW exercise, Block Commander, bears an uncanny similarity to the TTC and trains the child to listen to a sequence of commands involving the shapes on the computer screen. These shapes are similar to the manipulatives that are part of the TTC. Children in this study did not increase their skills on the Concepts and Direction subtest unlike those in Tallal et al. (1996). One reason for this might be because children in both of our groups did not have unusually low language scores and because they were already performing within normal limits. Consequently, immediate significant gains would not have been expected. An alternative argument, however, may be that the FFW activity, Block Commander, trains the child to the test (Token Test for Children), and immediate gains based on this can be expected. If the FFW program increases language processing which might facilitate the ability to follow 2 and 3 step directions, as demonstrated in the 1996 study, one should expect to see this demonstrated in other standardized tests that purport to measure this skill. Results in this study failed to confirm this.

The only common subtest that children in both groups improved following FFW was Recalling Sentences, and this may account for the significant increase of expressive language post FFW. Children in the FFW group in Hook et al. (2001) also increased in spoken language and this could be evidence that the FFW program improves spoken language function as suggested in Merzenich et al. (1996). However, as Hook et al. (2001) hypothesized, two explanations could account for this immediate gain, and may be especially appropriate for the skills involved in recalling sentences. The first could be a result of the child's increased attention to listening activities after such an intensive auditory program. The second possibility is that there is only one form of most language tests and some children could have increased their performance based on familiarity with some of the items that were presented in just a short time period of approximately 6 weeks. In the current study while administering the CELF-3 after FFW, a number of children expressed remembering certain words, sentences, or pictures, although the examiner did not keep track of these instances.

Test-retest reliability for the CELF-3 was conducted on 152 children who were re-administered the test one to four weeks after the initial testing (Semel, Wiig, & Secord, 1995). Reliability for each of the subtests were acceptably high (> 0.8). Increases found on the CELF-3 in the present study were obtained by a repeated measures analysis of variance on standard scores. However, an alternative to interpret the significance of the gains on the CELF-3 is to use the two standard error criterion as a true index to change and to rule-out possible effects of regression toward the mean. The CELF-3 provides confidence intervals for the six subtests and the cumulative receptive, expressive, and total language scores. If a child scores outside the confidence interval, there is a 95.5% chance that the increase on the test or subtests is real. Although Miller et al. (1999) did not provide results concerning the number of participants who scored outside the test intervals, they reported that "the majority of children trained with Fast ForWord recorded positive score advances on most applied test measures" (p. 10).

In the present study the total number of children who scored outside the confidence interval for the total language score was 11 of 26 participants (six in the PR group and five in the LAR group). Twelve children had gains outside the confidence interval for expressive language abilities (six in the PR group and six in the LAR group) and twelve children demonstrated advances in receptive language abilities (seven in the

PR group and five in the LAR group). This represents less than 50% of the participants who increased language abilities following FFW.

In order to test whether re-administering the CELF-3 in such a short time frame was a factor in the increase of language scores immediately following FFW, another research question posed whether language abilities would continue to increase six months after FFW and the administration of the CELF-3. If familiarity to test items played a factor in significant increases immediately following FFW, perhaps this would fade over a period of six months. Six months after the FFW training, there were no increases for either the participants completing FFW training or those in the control group. Children in the PR group continued to have lower standard scores on the CELF-3 than the children in the LAR group or the control group which did not differ significantly. This finding is consistent with the research of language testing following FFW in Hook et al. (2001). Even though language gains occurred immediately following FFW for both experimental groups, no gains were made six months post FFW. Significantly, the children in the FFW program did not exhibit any greater changes in language scores than the children who did not have FFW training. Likewise, language scores did not improve over the course of the entire school year for the children enrolled in FFW. Comparison of pre FFW testing and six months post FFW testing did not reach significance ($F(1,24) = 3.97$, $p = .06$) and there were no significant changes in the four common subtests of the CELF-3. The lack of sustained increases at the end of the school year, and the lack of significant gains by the two groups completing FFW when compared to a control group challenges the effectiveness of FFW to improve language abilities.

Similar to the lack of significant increases on the CELF-3 six months following FFW training, a few children showed gains outside the confidence interval. Only 4 of 26 children (two in the PR group and two in the LAR group) who completed FFW training increased their total language scores above the confidence interval. Four of 26 increased on the expressive portion (one in the PR group and three in the LAR group) and five children increased standard scores on the receptive portion (three in the PR group and two in the LAR group). Four children in the CG demonstrate gains outside confidence interval for the total, expressive, and reception portions of the CELF-3.

Finally, the results of this study indicated that the short time frame between pre and post FFW testing was indeed a contributing factor for the increases seen in the CELF-3. In addition, because only 42% of the children who completed FFW increased language scores outside the confidence interval, the significant increase may represent a regression toward the mean.

Correlations Between Psychophysical Measures and Behavioral Tests

The seventh research question that was asked was whether there would be any correlations between thresholds and standard deviations of simultaneous and backward masking and the tests of reading, phonemic awareness, and language immediately following FFW and six months after FFW training. Analyses that correlated the psychophysical data with the behavioral test data immediately following FFW did not identify any significant correlations beyond chance. This may be because children in this study demonstrated only mild to moderate delays; however, individual analysis of the children with the most significant language and reading delays showed that these children did not have the most elevated thresholds.

Even though backward masking thresholds decreased immediately following FFW, no reading or phonemic awareness tests improved. The two groups completing FFW differed statistically on all reading, phonemic awareness, and total language skills; however, they did not differ on any of the masking conditions before or following FFW. This is consistent with recent studies (Bishop et al., 1999; McArthur & Hogben, 2001; Thibodeau et al., 2001) that do not support the evidence that all children with language or reading delays have impaired temporal processing.

Children in the control group who were tested in the time period immediately following FFW did not have masking thresholds that significantly differed from the children who had completed FFW. In conclusion, analysis of the psychophysical data and behavioral testing post FFW and six months post FFW did not reveal any significant correlations. These findings are consistent with previous research cited that not all children with reading delays have temporal processing deficits. It also challenges the theory that increasing temporal processing will result in improved reading and language skills.

FFW Activities

The last research question posed whether any specific FFW activities were especially harder for the children in the FFW training, and whether they correlated with any of the psychophysical and behavioral testing. Similar to the 11 subjects studied by Hook et al. (2001), the Circus Sequence activity was the most challenging. This activity trains the ability to identify high and low tones in an increasingly rapid sequence. Thibodeau et al. (2001) also found the Circus Sequence to be the most demanding and suggested that one possible explanation for the increased difficulty was the frequency-sweep thresholds used in that activity. The stimuli frequency-sweep used in FFW is from 1000 Hz to a maximum of 2000 Hz. The subjects in their study required a sweep above 7000 Hz in order to detect a steady 1000 Hz tone. Hook et al. (2001) found that word identification correlated significantly with Circus Sequence. In this current investigation there were no correlations with the reading, phoneme awareness, or language tests and the Circus Sequence activitiy. However, Circus Sequence correlated significantly with simultaneous and 20-ms gap backward masking. Only four children met the 90 percent or greater criterion for Circus Sequence and two of these had the lowest backward masking thresholds of the children participating in this study (each of these children had an average threshold of 37 dB); however, the two other children had backward masking thresholds higher than the group mean (60 dB).

Tallal and associates in previous research (Tallal, 1980; Tallal, 1984; Tallal and Piercy, 1974) have used an auditory paradigm (Rapid Perception Test), which is similar to the activity Circus Sequence, to identify children with temporal processing deficits and reading and language disorders. However, other research investigations have disputed whether this procedure accurately identifies deficits in temporal processing (Mody et al., 1997). More importantly, to date, there is little research to document that extensive training in increasing skills in this activity will lead to improved temporal processing and improvements in language and reading abilities. Because children often struggle with completing the Circus Sequence task, more research is needed to investigate whether using larger frequency sweeps, as Thibodeau et al. (2001) recommended, would meet with greater success in the percentage of completion and possibly lead to improvements in temporal processing.

Similar to previous research (Hook et al., 2001; Thibodeau et al., 2001) the second activity that was the most demanding was Phonic Identification which practiced the ability to discriminate phonemes in nonsense syllables. Increasing skills on this task is designed to lead to improvements in phoneme awareness that might be evidenced on the LAC and the NRT. There were no statistically significant correlations between the FFW activities and the behavioral testing, and analysis of non-statistical trends in the two most difficult activities did not reveal any consistent patterns. For example, eight children met the completion criterion for Phonic Identification. Only 3 of the 8 had scores higher than the mean on the LAC; however, 5 of 8 had higher scores than the group mean for the NRT. On the other hand, analysis of the lowest eight scores revealed very similar results: 4 of 8 had higher scores than the group mean on the LAC and 5 of 8 had higher scores than the group mean on the NRT. Therefore, there does not appear to be a compelling trend that success on this activity leads to better phoneme awareness.

The activity that all children met criterion on was Language Comprehension Builder. The purpose of this activity is to present increasingly complex sentences to reinforce syntactic and morphological language structures. There were no correlations between percentage completion on this activity and changes in language scores after FFW. An analysis of trends of six children who had standard scores on the CELF-3 below 85, however, revealed that 4 of 6 increased in total language scores outside the 90% confidence interval and 2 of 6 had no change. Six children who scored the highest on the CELF-3 displayed different results. Only 1 of 6 had an increase of scores outside the 90% confidence interval, 3 of 6 had no change, and only 1 of 6 had an increase outside the 90% confidence interval. These non-statistical results suggest that further study is needed to investigate whether this language activity is facilitating changes in language abilities. It also suggests that further research is needed for all the FFW activities to help determine what kind of child would benefit the most by FFW training.

Implications for the Theory of Temporal Processing Deficit

Studies by Tallal (1980, 1984) have suggested that temporal processing deficits interfere with the learning of speech sounds and that this can cause delays in language and reading development due to poor phoneme awareness. Tallal used a high/low temporal judgement that varied the ISI paradigm to identify children with temporal processing deficits. Later Wright et al. (1997) employed a 2I2AFC paradigm to measure backward masking threshold. This research suggested that children with language delays have significantly elevated backward masking thresholds and that these children might benefit from an intensive auditory training program similar to FFW. The present investigation did not support the assumption that children with reading delays necessarily have deficits in temporal processing as evidenced by higher backward masking thresholds. Also, it did not support the assumption that by improving temporal processing, reading and language abilities would also improve. The experimental groups that completed FFW were statistically different on reading, phoneme awareness, and language abilities, but the two groups did not demonstrate differences in backward masking thresholds. A control group that did not complete the FFW training also did not have masking thresholds that were significantly different from the experimental groups immediately following FFW or six months following the program. Even though backward masking thresholds improved significantly following FFW and there was a nonstatistical trend for lower thresholds six months post FFW, these changes did not correlate with lower reading and language assessments. Changes in reading assessments were not demonstrated immediately following FFW or six months after FFW. In addition there were no differences in changes of the reading and language assessments between the experimental groups and the control group at the time of the final testing period, six months post FFW.

Some researchers have claimed that the FFW program has demonstrated immediate gains in language scores immediately following the program (Mezernich et al., 1996; Miller et al., 1999; Tallal et al., 1996). This current research, however, found that language scores did improve immediately after FFW, but similar to Hook et al. (2001) the increases were not sustained six months later. This finding suggests a learning effect due to the short testing- time frame between pre and post FFW and challenges the assumption that an intensive auditory training program designed to change the way the brain processes speech could increase language abilities.

Implications for the Dual-Route Theory of Reading Acquisition

DRC theory of reading (Coltheart et al., 1993) postulates that there are two avenues for single word reading. One is a lexical route which, in a cascading fashion, stimulates visual features, letter, and word detectors to access the semantic system to recall a stored word. Concurrently, this generates the phonological output lexicon in order to produce the spoken version of the word. The second route of this system, the nonlexical route, allows the reader to attempt to read a novel word that is mediated by the grapheme-phoneme rule system. Ehri (1992), on the other hand, has argued that a signal route that repeatedly accesses the phonological system is a more reliable model to activate word retrieval. It was hypothesized by Tallal (1980, 1984) that if increases in temporal processing improved basic phoneme awareness, then enhanced word decoding and sight word recognition also should be demonstrated. Such a result would lend support to the single route theory mediated by the phonological system. Over the course of the entire school year, children in the FFW program demonstrated significant increases in phoneme awareness based on measures from the LAC and NRT. However, the children in the PR and LAR groups that completed FFW did not exhibit any significant increases in word attack or sight word recognition abilities.

With the single-route theory mediated by a phonological module, similar to Ehri (1992), one would expect increases in word attack and word identification skills with significant increases in phoneme awareness abilities. This research investigation, however, did not find increases in reading measurements despite increases in phoneme awareness over the course of a school year. The children who completed FFW did not appear to use the increased phoneme awareness skills to improve word recognition. Because there was a lack of improvement on the WA and WI, it could be assumed that this group of children continued to rely on the lexical route to access word retrieval and the phonological output. This evidence provides greater support for the dual-route theory

(Coltheart et al., 1993) where children continue to rely on both a lexical and nonlexical route for word reading.

Research Limitations

One research limitation of this study was not being able to recruit a number of children with reading and language scores of one or more standard deviations below the mean. Walnut Hill is a small elementary school (approximately 350 children, Kindergarten through fourth grade) and so the program did not offer a large sample population. Consequently, the number of children with significant delays in reading was limited. Recruiting children outside the school posed a major problem. Finding a room for the psychophysical testing that provided adequate sound-levels would have been challenging and achieving a similar testing situation at Walnut Hill may not have been possible. Secondly, a disadvantage of recruiting children from another school system would have jeopardized the homogeneity of the group at Walnut Hill. This study set out to assess the performance of children going through the FFW program who all had a similar reading curriculum and instruction.

A second research limitation was not being able to test the control group before the onset of the FFW program. Ideally, this would have been done; however due to time constraints and the need to commence the FFW program, it was not possible.

A third research limitation was that some children in the groups received reading resource instruction following the FFW program while other did not. This may have contributed to greater increases on the phoneme awareness tests for the PR group.

Finally, another research limitation was that language samples from the participants were not obtained. Analysis of oral expression and narrative skills would have provided valuable information on language abilities before and after FFW.

Clinical Implications

No immediate improvements on word attack, word identification, or reading comprehension were seen for either poor readers or low average readers following FFW. Also, no increases in reading or language skills were evidenced six months following the program. Moreover, children in a control group did not show any different changes in these measures when compared to children who completed FFW. Although further study is needed to research the efficacy of FFW and its individual activities, this study immediately calls into question the service delivery model of the program during school class time. FFW did not provided any immediate improvement in reading skills, and in fact, may have concumed time better spent on classroom reading activities or small group instruction with the reading specialist. This criticism was frequently voiced by the teachers and parents who evaluated their students progress during the term they participated in FFW.

Three school districts in the East Tennessee area (Harriman city school, Clinton city schools, and Onieda city schools) provide FFW to students during school hours and none of these schools use a strict criterion to select which students need or do not need the training (Onieda Elementary, Clinton Elementary, and Walnut Hill Elementary). One school has all students in Kindergarten complete FFW training. This current study demonstrated that children with mild to moderate reading deficits do not immediately benefit from FFW. Another study found that children with moderate to severe reading delays also did not immediately benefit from FFW (Hook et al., 2001). Consequently, school programs need to develop stricter criteria to select which students might benefit most from FFW. In order to do this, outcome measures need to be completed and analyzed to help decide on eligibility. This information needs to be shared with other school programs using FFW and, most importantly, shared with the parents of the children in the local school districts. It is critical that parents understand the possible benefits or the lack thereof.

Future Research

Various testing measurements have been used to identify temporal processing deficits. Some of these include competing words or sentences (Keith, 2000), temporal judgements of high and low tones (Tallal, 1980), or backward masking thresholds (Wright et al., 1997, McArthur & Hogben, 2001). More research is needed to investigate optimal methods for assessing temporal processing.

Habib's (2000) theory of temporal processing disorders suggests that processing any kind of rapidly presented sequence of stimuli is delayed for various modalities; auditory, visual or sensory. A large body of research is beginning to emerge suggesting that a general temporal processing problem may be an underlying cause for dyslexia (Bishop & McArthur, 2001; Farmer & Klein, 1995). Although this current research challenged the theory that children with poor reading abilities have auditory temporal processing deficits, it did not investigate whether children with reading deficits have temporal processing deficits in other modalities. Further studies are needed to provided a clearer understanding whether the theory that proposes a causal link between auditory processing deficits and delays in reading development is actually a result of a more general temporal processing disorder.

Researchers have speculated that children with severe reading deficits (dyslexia) have atypical neurological organization (Habib, 2000). Merzenich et al. (1996) suggest that intensive auditory training may increase and reorganize neural connections to improve auditory processing. At this time, research designed to identify regions of the brain that contribute to the reading process and whether neural activity in these regions is different from individuals with and without reading deficits is beginning to grow (Gauger et al., 1997; Shaywitz et al., 2000; Temple et al., 2003). Shaywitz et al. (2000) measured brain activation patterns during tasks that involve orthographic and phonemic judgements. FMRI imaging revealed differences between a group of impaired reading and non-impaired readers. The researchers discovered that impaired readers failed to increase activation in Wernicke's area, the angular gyrus, the extrastriate and striate cortex as the difficulty of the phonemic judgement tasks increased. At the same time, fMRI displayed over-activation during simple phonological tasks in Brodmann's area 46/47/11 and the inferior frontal gyrus. The researchers concluded that reading impaired children demonstrated atypical activation patterns over the posterior cortex which includes regions for both visual and language functioning.

To date, there has been only one research study that used neuroimaging to examine changes in brain activity following FFW (Temple et al., 2003). This study used an experimental group with low reading abilities that completed FFW; however, comparing imaging results and behavioral results to a group that did not complete training would answer questions about test-retest effects.

Secondly, it is unclear what activity in a training program, like FFW, is precipitating greater neural activity. Positive correlations between a particular FFW exercise and an increase in reading scores or in neural activity might be a false-positive. For example, Temple et al. (2003) found a correlation between the percentage of completion score on Phonic Word and neuroimaging in the temporo-parietal region. However, this does not conclusively indicate that the Phonic Word exercise alone was responsible for this increase in neural activation in this region of interest. It might be argued that children in the experimental group found the Phonic Word exercise the easiest and therefore, completed the greatest portion of the activity. Further research is needed to investigate not only differences in kinds of phonological and language tasks in a particular training program, but differences that might be discovered between linguistic and non-linguistic exercises, and those that are acoustically modified and those that are not.

Recent research has attempted to compare the efficacy of different computer formatted learning programs (Gillam et al., 2001) with FFW. However, more research is needed to fully understand not only the efficacy of a particular program, for example, designed to improve reading skills, but whether the optimal medium of instruction is the computer. Instruction in computer labs offers an alternative to traditional classroom teaching which might increase student interest and motivation. It also allows for large group instruction with the capability of individualizing a program according to the student's abilities. However, this current research study did not identify any more significant gains in reading for children who had completed a specialized computer program to increase skills than children who did not have this instruction. Similarly, Hook et al. (2001) did not discover any differences in reading between a group of children with FFW training and a group of children receiving Orton-Gillingham reading instruction. In conclusion, as computer programs designed to increase reading skills expand in the marketplace it is critical that research continue to study their efficacy. For example, Lexia Phonics Based Reading (www.lexialearning.com., 2003) and Sound Reading (www. Soundreading.com., 2003) are recent products who have advertised significant results. The Lexia program has not provided any published results of the effectiveness of their program, however, Sound Reading has produced data that is included in their information brochures describing their program and on their website. Currently, Gillam and colleagues are collecting data to compare the outcomes of computer assisted language intervention programs.

Chapter VI

Summary and Conclusion

Summary

Research has provided evidence that children with reading and language delays have underlying deficits in auditory temporal processing (McArthur & Hogben, 2001; Tallal,1980; Tallal,1984; Tallal et al., 1996; Wright et al., 1997). To date, clinical methods to improve temporal processing have included an intensive auditory training program called Fast ForWord (Scientific Learning Corporation, 1997). Research has demonstrated that children completing this program have increased language skills (Merzenich et al., 1996; Miller et al., 1999; Tallal et al., 1996), however, there has been conflicting research that challenges increases in language abilities and temporal processing abilities as measured by backward masking following FFW (Marler et al., 2001; Thibodeau et al., 2001). The purpose of this research investigation was to examine the efficacy of FFW in improving temporal processing skills as measured by backward masking thresholds on a group of children who were recommended to participate in the FFW program based on poor reading performance. Of primary interest was whether decreases in backward masking thresholds would be found and if increases would then occur in reading, phoneme awareness, and language abilities immediately following FFW and six months following FFW. A second research question was whether children in a control group who did not have FFW training would demonstrate differences in backward masking thresholds. Finally, another primary research question was whether children completing FFW would evidence greater increases in reading, phoneme awareness, and language abilities compared to children who did not participate in FFW.

Twenty-six children participated in FFW training and experimental testing prior to FFW, immediately following FFW, and six months after FFW. Subgroups were identified based on the WI and WA of the WRMT and 13 children were part of a Poor Reading group and 13 children were identified as part of a Low Average Reading Group. These two groups differed significantly on all reading and language assessments. Masking thresholds and assessments in reading, phoneme awareness, and language were obtain before and after FFW and six months following FFW training. A control group of children (n=12) who did not participate in FFW training were tested after FFW and six months after FFW.

Backward masking thresholds increased immediately following FFW, however, thresholds were not significantly different from the control group that did not go through FFW. Although temporal processing abilities increased after FFW, there were no increases in reading skills or phoneme awareness as measured on the LAC. However, both experimental groups increased standard scores on the CELF-3 and on the NRT. Results immediately after FFW, were similar to previous research (Marler et al., 2001; Thibodeau et al., 2001) that demonstrated greater backward masking thresholds as well as other recent research that found increases on the CELF-3 (Hook et al., 2001; Miller et al., 1999). Results from the current study challenges theories that children with reading delays have deficits in temporal processing abilities (Tallal, 1980, Tallal, 1984), and supports other research that questions this hypothesis (Marshall et al., 2001; McAnally et al., 1999; Nittrouer, 1999).

The current investigation re-assessed children six months after FFW in order to examine whether changes in backward masking threshold would be sustained and whether children completing this auditory program would improve significantly better on tests in reading, phoneme awareness, and language than a group of children without this specialized training. 0-ms gap backward thresholds did not improve from the period immediately following FFW and six months after FFW. Testing at the end of the school year did not discover any significant difference between the groups (those that participated in FFW and the control group that did not) in masking thresholds, despite a strong non-statistical trend for 0-ms gap backward masking to continue to decrease for children in the experimental group. Most importantly, there were no gains in reading and language skills six months after the FFW program among the three groups. Only children in the PR group significantly improved phoneme awareness as measured by the LAC, however, this did not impact reading scores.

Conclusions

An intensive program designed to increase auditory processing of nonspeech and synthetic speech stimuli did not result in an increase of language and reading abilities. Even though modest increases in backward masking thresholds were made, this did not result in long-term improvements in reading and language skills.

The lack of improvements in reading skills in the presence of decreased backward masking thresholds challenges the notion that deficits in auditory temporal processing contribute to delays in reading development. In addition, even though increases in phoneme awareness were demonstrated over the course of a school year and following FFW, this did not contribute to increases in reading. Increases in phoneme awareness were achieved by the children in the experimental groups, but significant increases were made over the long-term only by those in the PR group. In spite of this, there were no increases in word attack or word identification skills. This finding may contribute to studies that propose that there are two routes in printed word recognition; a lexical and nonlexical route (Coltheart et al., 1993). Children in the PR group who did increase phoneme awareness did not benefit by improving word attack skills or word identification skills, and likewise, children who had modest non-statistical gains in phoneme awareness also did not increase word attack or word identification skills. This finding may suggest that the children in this study with poor and low average reading skills rely on the lexical route for word recognition rather than the nonlexical route, or one that is solely mediated by the phonological module. This may suggest that even though these children have increased their skills in phoneme awareness, they have yet to learn how to apply them.

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Appendices

Appendix A

Brief Medical History

Date: ____________

Parent Names: ______________________________ Telephone: ____________

Address: ____

Child's Name: ___________________________ Date of Birth: _____________

Related Medical History: Please answer "yes" or "no."

_____ Child is currently free of upper respiratory infection

_____ Child has no middle ear problems at this time

_____ Child has no neurological problems/history of head trauma

_____ Current illness/medication. (If yes, please list medication.)

____

_____ Child has a diagnosis of ADHD (Attention Deficit Hyperactivity Disorder)

_____ Child has received a diagnosis of CAPD (Central Auditory Processing Disorder).

Thank you for filling out this form. Please return it with the Informed Consent Form.

Appendix B

Fast ForWord Parent Questionnaire

1. In what way did the Fast ForWord program affect your child's life?
    a) at home
    b) at school
2. How satisfied are you with the changes in your child resulting from Fast ForWord?
3. How did the length of the Fast ForWord program affect your child?
4. Did your child enjoy using a computer before the Fast ForWord?
5. If your child enjoys computer games, what kinds of games does your child play?
    a) Play Station b) Nintendo c) PC role play games
    d) educational games e) N/A
6. Has your child's attitude changed about computers after the Fast ForWord program?
7. Did your child enjoy the Fast ForWord program?
8. What did your child say was the best thing about the Fast ForWord program?
9. What did your child say was the worst thing about the Fast ForWord program?
10. How would you rate the Fast ForWord program compared to other intervention programs?
11. Would you recommend Fast ForWord to your friends?
12. What were the advantages/disadvantages of having the Fast ForWord program offered through the school system?

Parent's Name: ______________________________
Parent's Signature: ______________________________
Child's Name: ______________________________
Date: ______________________________

Appendix B. Continued.

Parent Questionnaire Responses

Parental Responses to the Fast ForWord Questionnaire

1. In what way did the Fast ForWord program affect your child's life?

   a) at home

   - did homework faster
   - wanted to be on the computer more
   - she had a lot more homework because she missed class time
   - wouldn't do it much at home because he didn't like it

   b) at school

   - completed more work at school so less homework
   - don't know
   - she missed the teacher explaining how to do the work
   - it has helped her with her work and reading

2. How satisfied are you with the changes in your child resulting from Fast ForWord?

   - very satisfied (7)
   - wanted more information about the Fast ForWord program
   - good (2)
   - I am not sure what changes occurred
   - I'm very happy
   - Ok
   - no change
   - satisfied
   - same

3. How did the length of the Fast ForWord program affect your child?

   - he was able to cope with missed class time
   - she grew tired of it
   - it affected her in a good way
   - helped her read
   - she was ready for it to be over

Appendix B. Continued.

- helped him all year
- to learn more things
- it was alright
- ok with it (2)
- no change
- did not like the length
  did not bother him
- I missed some of his work

4. Did your child enjoy using a computer before Fast ForWord?
   - yes (17)
   - she hard ever used one

5. If your child enjoys computer games, what kind of games does your child play?
   - play station (15)
   - nintendo (7)
   - PC role play games (2)
   - educational games (7)

6. Has your child's attitude change about computers after the Fast ForWord prgram?
   - likes it more because his reading has improved
   - no (7)
   - yes (4)
   - some (2)
   - not affected
   - seems to be more interested in computers
   - same

7. Did your child enjoy the Fast ForWord program?
   - yes (14)
   - no (2)
   - yes and no

8. What did your child say was the best thing about the Fast ForWord program?

Appendix B. Continued.

- missing class, but I think he enjoyed his improved reading
- getting to play games (5)
- it was fun
- I liked Mr. Valentine and Miss Amy, she learned how to read better
- she learned a lot
- everything
- helped him in his everyday reading
- when he got thought puzzles and got the right answers
- the cat game (2)
- the circus game
- computers (2)

9. What did your child say was the worst thing about the Fast ForWord program?

- the noises in the video games
- not having time to do classwork at school
- nothing (3)
- doing the circus sea event
- missing class time and instructions and having to bring it home and not understand how to do it
- didn't last long enough
- he didn't like it if he couldn't get through puzzles, some he didn't care for
- stayed too long downstairs
- she had to stay ther for an hour
- the mix matching game
- getting pulled out of class
- the work
- took library time away
- the circus game

10. How would you rate the Fast ForWord program compared to other intervention programs?

- the only other basis for comparison would be the Wilson Reading program - they both helped C.....
- OK

Appendix B. Continued.

- I would give it a 10
  N/A
  good (3)
- 70%
- great
- I am not sure which programs you would compare it to
  7 or 8
- not sure (23
- I think it would work better after school
- very good

11. Would you recommend Fast ForWord to you friends?
    - yes (14)
    - maybe (2)
    - no

12. What were the advantages or disadvantages of having the Fast ForWord program offered through the school system?

Advantages

- it was free and available during class time
- if she needed it we didn't have to drive her some where else to learn
- she was able to enjoy it
- it saved me time and I didn't have to m iss work to have him tested and probably could not afford it with the fees
- concerned individuals teaching students
- to learn more
- advantage was helping him with his reading sounds
- he would do more at school than he did at home
- they did the program at school when they weren't tired, if they were to send it home I don't think all of the children would have done it
- the child leaned new and exciting things
- getting better acquainted with computers
- gave her knowledge where needed
- time for him to enjoy his play time and learn in a structured class

Appendix B. Continued.

- they were able to ask the teacher for help if they needed it
- it was good for the school

Disadvantages

- he got behind in classwork
- took away from classroom time
- didn't last long

Appendix C

Fast ForWord Teacher Questionnaire

1. In what way did the Fast ForWord program affect the child's classroom performance/schedule?
2. How satisfied are you with the changes in this child resulting from Fast ForWord?
3. How did the length of the Fast ForWord program affect the child?
4. Did the child enjoy using a computer before the Fast ForWord?
5. Has the child's attitude changed about computers after the Fast ForWord program?
6. Did the child enjoy the Fast ForWord program?
7. What did the child say was the best thing about the Fast ForWord program?
8. What did the child say was the worst thing about the Fast ForWord program?
9. How would you rate the Fast ForWord program compared to other intervention programs?
10. Would you recommend Fast ForWord to coworkers?
11. What were the advantages/disadvantages of having the Fast ForWord program offered through the school system?
12. What were the advantages/disadvantage of having the Fast ForWord program delivered during school hours?

Teacher's Name: ________________________________
Teacher's Signature: ________________________________
Child's Name: ________________________________
Date: ________________________________

Appendix C. Continued.

Teacher Responses from Fast ForWord Questionnaire

1. In what way did the Fast ForWord program affect the child's classroom performance/schedule?
   - The children were out of class during the time we covered reading and math - they were behind on the skills we went over in class
   - I didn't see much change
   - The students missed out on the skills we covered while they were out of the classroom – had to cover these individually with them
   - Hectic! Too much interruption - missed out on too much instruction
   - My students missed classroom instruction; therefore, they had to do much of the classroom work they missed on their own or be behind when they returned to class
   - It took approximately 2 hours out of the regular academic program making it difficult to arrange teaching time for those students in the program

2. How satisfied are you with the changes in the child resulting from Fast ForWord?
   - I didn't notice a significant improvement
   - Some progress
   - I didn't notice much of a change
   - I've not seen a difference
   - Not very satisfied – I've seen very little progress in the classroom as a result of using the program
   - I didn't see much change
   - Not

3. How did the length of the Fast ForWord program affect the child?
   - The students began to get bored with the program before it ended
   - I did my best to work around the program, but the students still missed instructional time
   - They were ready for it to be over
   - Too long to be pulled out of regular classroom
   - The students complained – the students missed a lot of instructional time

Appendix C. Continued.

- Taking a child out of a regular classroom.
- Too much time out of class

4. Did the child enjoy using a computer before the Fast ForWord program?
    - Yes (5)
    - They liked using the computer at first, but got bored
    - Unsure, I never really had a chance to know whether they did or not

5. Has the child's attitude changed about computers after the Fast ForWord program?
    - They continue to enjoy computers (2)
    - They have not said
    - No – they love working on computers
    - Unsure
    - Not really
    - No

6. Did the child enjoy the Fast ForWord program?
    - They did at first and then they began to miss being in class
    - Yes (3)
    - Some did, others didn't
    - One of my 6 did
    - No, most complained about having to work on the program

7. What did the child say was the best thing about the Fast ForWord program?
    - The game format
    - Playing the games
    - At first they enjoyed the program because of playing what they called games on the computer
    - Getting rewards and getting to play games on computer
    - I liked the Block Commander program where they had to listen and follow directions
    - The music and games, especially the bee game
      No class work

Appendix C. Continued.

8. What did the child say was the worst thing about the Fast ForWord program?

- They got tired while in there
- It was too long
- Out of class too much, program was boring
- Length of time each day on the program, total length of time to finish the program, programs were not fun
- The cat and the circus, the lessons took too long
- Too long

9. How would you rate the Fast ForWord program compared to other intervention programs?

- I would rate the program lower than that of other programs offered through the school
- Not very high
- I wouldn't rate it as highly as other programs
- I prefer direct teacher instruction to computer programs
- I would rate it below a small group remediation focused group directed by a teacher – I'm not sure that the results from Fast ForWord can be seen yet
- Not as good

10. Would you recommend Fast ForWord to coworkers?

- I'm not sure at this point
- Yes, as an after school or summer program
- No (2)
- No, for the amount of time the students were involved, I didn't feel like the improvement was high enough
- Not as a "cure all" program for reading, but maybe as a supplement to a program
- I'm not sure yet

Appendix C. Continued.

11. What were the advantages/disadvantages of having the Fast ForWord program offered through the school system?

Advantages
- The students were familiar with the people who administered the program
- More students could take advantage of the program
- It's another style of teaching that could reach some children who could not be reached with other styles
- Good experience, helpful to some

Disadvantages
- Students missing instructional time two hours per day is too long
- I didn't see the improvement I had hoped for compared to the time they were out of class

12. What were the advantages/disadvantages of having the Fast ForWord program delivered during school hours?

Advantages
- The students were already here
- More students could take advantage of the program

Disadvantages
- The students missed out on instructional time (3)
- It could be better used through summer school, after school tutoring, during scheduled computer times, etc.
- It was difficult to fit all academic subjects into the time left over after Fast ForWord used its time

Appendix D

Correlations for Pre and Post FFW: Psychophysical Measures and Behavioral Testing

Note. Sim= simultaneous masking, 0-ms= 0-ms gap, 20-ms= 20-ms gap, 40-ms= 40-ms gap, Sim SD= simultaneous masking standard deviations, 0-ms SD= 0-ms gap standard deviations, 20-ms SD= 20-ms gap standard deviations, 40-ms SD= 40-ms gap standard deviations. WA=Word Attack, WI=Word Identification, GSRT= Gray Silent Reading Tests, LAC=Lindamood Conceptualization Test, CELF-T- Clinical Fundamentals Evaluation of Language-Total, CELF-E=Clinical Fundamentals Evaluation of Language-Expressive, CELF-R=Clinical Fundamentals Evaluation of Language-Receptive, TONI-3= Test of Nonverbal Intelligence-Third Edition.

	WA	WI	GSRT	LAC	NRT	CELF-T	CELF-E	CELF-R	TONI-3
Sim	-.27	.10	.34	.25	-.04	.33	.40*	.34	.29
0-ms	-.20	.05	.13	.22	.12	.15	.26	.01	.28
20-ms	-.18	.14	.20	.40*	-.30	.03	.13	-.05	.27
40-ms	-.03	.13	.15	.27	-.04	.03	.09	-.03	.19
Sim SD	-.32	-.18	.14	.21	-.08	.10	.08	.11	-.36
0-ms SD	-.07	.18	.32	.26	-.07	.08	.20	-.07	-.35
20-ms SD	-.10	-.02	.18	.26	-.15	.17	.14	.18	-.14
40-ms SD	-.33	-.04	.03	.26	.07	-.01	.09	-.09	.07

* Correlation is significant at the .05 level (2-tailed).

Appendix E

Correlations Pre and Post FFW: Percentage Completed on FFW Activities and Behavioral Testing

Note. CS = Circus Sequence, PI = Phoneme Identification, OM = Old MacDonald's Flying Farm, PW = Phonic Words, PM = Phonic Match, BC = Block Commander, LC = Language Comprehension Builder, WA=Word Attack, WI=Word Identification, GSRT= Gray Silent Reading Tests, LAC=Lindamood Conceptualization Test, CELF-T- Clinical Fundamentals Evaluation of Language-Total, CELF-E=Clinical Fundamentals Evaluation of Language-Expressive, CELF-R=Clinical Fundamentals Evaluation of Language-Receptive, TONI-3= Test of Nonverbal Intelligence-Third Edition.

	WA	WI	GSRT	LAC	NRT	CELF -T	CELF -E	CELF-R	TONI-3
CS	-.02	-.24	-.09	-.46*	.06	-.14	-.13	-.06	-.24
PI	-.03	-.18	-.15	-.37	-.07	01	-.03	.01	-.11
OM	.22	-.01	-.06	-.21	-.09	-.14	-.10	-.16	.31
PW	-.01	.10	.12	-.15	-.30	.03	.12	-.10	.20
PM	.04	-.19	-.28	-.30	-.09	-.12	-.16	-.09	-.16
BC	-.29	-.16	-.16	-.18	-.16	-.01	.02	-.06	.18
LC	.06	-.04	-.01	-.34	-.04	.06	.05	03	.17

* Correlation is significant at the .05 level (2-tailed).

Appendix F

Correlations of Pre and Post FFW: Psychophysical Measures and Percentage Completion of the FFW Activities

Note. Sim= simultaneous masking, 0-ms= 0-ms gap, 20-ms= 20-ms gap, 40-ms= 40-ms gap, Sim SD= simultaneous masking standard deviations, 0-ms SD= 0-ms gap standard deviations , 20-ms SD= 20-ms gap standard deviations, 40-ms SD= 40-ms gap standard deviations, CS = Circus Sequence, PI = Phoneme Identification, OM = Old MacDonald's Flying Farm, PW = Phonic Words, PM = Phonic Match, BC = Block Commander, LC = Language Comprehension Builder.

	CS	PI	OM	PW	PM	BC	LC
Sim	-.53**	-.45**	-.28	-.01	-.53**	-.06	.05
0-ms	-.46*	-.45*	-.28	-.01	-.53	.07	-.01
20-ms	-.57**	-.59**	-.04	. 27	-.49*	-.05	-.21
40-ms	-.32	-.42*	.07	.34	.26	-.02	.05
Sim SD	-.19	-.03	-.09	-.18	-.15	-.17	-.29
0-ms SD	-.02	-.22	.12	-.20	-.14	.05	.01
20-ms SD	-.42*	-.34	-.06	.18	.15	.26	.15
40-ms SD	-.01	-.12	-.18	.07	-.57**	.23	-.04

** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).

Appendix G
Results of Behavioral Testing and Psychophysical Measures

Note. Grp=Group, Subj=Subject, WA=Word Attack, WI=Word Identification, GSR=Gray Silent Reading Tests, LAC=Lindamood Conceptualization, CFT=Clinical Evaluation of Language Fundamentals-3 Total, CFR=Clinical Evaluation of Language Fundamentals-3 Receptive, CFE=Clinical Evaluation of Language Fundamentals-3 Expressive, S=Simultaneous masking, B0=0-ms gap Backward masking, B2=0-ms gap Backward masking, B4=40-ms gap Backward masking, SD=simultaneous masking standard deviations, B0D=0-ms gap Backward masking standard deviations, B2D=20-ms gap Backward masking standard deviations, B4D=40-ms gap Backward masking standard deviations, TONI=Test of Nonverbal Intelligence-3, CS=Circus Sequence, PI=Phonic Identification, OM=Old MacDonald's Flying Farm, PW=Phonic Words, PM=Phonic Match, BC=Block Commander, LC=Language Comprehension, PR=Poor Reading Group, LAR=Low Average Reading Group, CG=Control Group,1=pre Fast ForWord, 2=post Fast ForWord, 3=six months post Fast ForWord.

Appendix G. Continued.
Poor Reading Group

Sub	WA 1	WI1	GS R1	LA C1	NR T1	CF T1	CF R1	CF E1	S1	B01	B21	B41	SD1	B0 D1	B2 D1	B4D 1
1	85	86	70	55	82	77	86	72	81	70	64.5	61.3	5.7	5.2	2.1	13.7
2	92	92	76	69	79	83	82	86	72.5	74.7	56.8	55.3	5	2.4	12.7	9.3
3	80	82	67	51	80	86	80	94	79.8	73.5	53.9	35.3	7.4	2.1	2.5	3.5
4	93	95	89	58	85	101	100	102	66.8	65.5	59.2	57.8	1.2	7.8	2.9	3.1
5	93	90	65	61	93	92	86	100	66	71.3	67.9	57.8	3.7	7.8	9.9	14.2
6	95	91	84	87	53	78	75	84	73.7	61	37.8	48.3	0	15.5	2.1	18.4
7	91	86	90	39	84	84	90	80	65.3	63.3	28.8	31.8	.9	.9	2.5	.4
8	94	95	92	64	82	112	108	116	76.6	90.7	71.9	69.3	.2	1.9	13.6	15.6
9	94	92	84	85	80	89	94	86	63.3	33.8	39.6	28.8	.9	.2	1.5	.2
10	83	77	61	50	89	67	78	61	63.7	61.6	42.8	32.3	0	4.4	3.5	.5
11	81	75	74	70	98	88	88	90	78.4	76.9	63.8	45.4	2.3	5.5	15.3	18.1
12	90	85	74	58	94	94	80	90	68.8	68.6	41.8	45.7	1.2	1.9	1.1	12.6
13	95	93	74	82	78	98	110	88	73.5	73	49.5	56.9	3.5	1.9	1.6	11

Appendix G. Continued.
Poor Reading Group

Sub	WA2	WI2	GSR2	LAC2	NRT2	CFT2	CFR2	CFE2	S2	B02	B22	B42	SD2	B0D2	B2D2	B4D2
1	86	89	60	64	89	81	78	86	67.5	57	54.8	45.1	.2	.5	10.5	2.6
2	87	92	81	64	91	92	92	94	67.6	64.6	47.3	52.8	1.9	11.4	6.7	14.8
3	85	83	60	62	94	90	96	86	66.8	68.7	48.2	37.3	1.9	8.3	17.4	7.9
4	98	94	70	72	93	93	90	98	67.8	63.7	55.7	38.1	2.1	2.4	9.4	6
5	93	87	76	51	91	96	84	110	70.8	63.4	50.5	43.3	1.2	2.9	1.2	1.9
6	91	88	86	82	71	87	84	92	70.7	61.9	70.2	71.8	2.4	21.7	18.3	8.9
7	99	90	74	46	90	86	96	78	62.5	37.2	32.5	31.2	.7	.2	1.4	4
8	94	95	96	82	94	115	116	114	80.7	84	58.7	56	1.4	4.2	16.6	12.7
9	97	91	81	82	80	110	118	102	63.2	39.2	33	33.5	2.1	1.1	2.6	.7
10	91	80	57	58	88	70	78	65	67.3	51.2	34	33.2	.5	2.1	.7	8.1
11	83	72	55	58	99	89	84	96	66	64.2	50.8	48.3	1.9	2.6	2.6	14
12	95	94	69	55	92	95	94	88	67.3	59.3	42.5	44.4	.9	7.2	.7	3.9
13	91	90	88	79	77	104	98	110	71.8	75.2	68.5	40.2	2.1	2.6	9.7	7.2

Appendix G. Continued.
Poor Reading Group

Sub	WA 3	WI3	GS R3	LA C3	NR T3	CF T3	CF R3	CF E3	S3	B03	B23	B43	SD3	B0 D3	B2 D3	B4D 3
1	86	93	55	88	89	84	78	92	68	58	54	59	.2	8.7	2.6	9.5
2	101	99	80	79	93	92	94	92	69	64	52	44	1.9	3	3.8	14.5
3	54	47	77	52	88	96	108	86	69	57	34	36	.5	1.9	.7	4.2
4	105	94	67	82	92	98	98	100	68	56	45	36	.7	8.7	13.4	3.8
5	90	84	55	75	96	88	88	90	65	42	40	32	.5	9,2	.1	2.8
6	98	92	55	85	99	94	102	88	65	70	66	57	1.9	6	10.3	18.7
7	94	89	62	46	99	88	98	80	64	27	34	30	1.4	.4	5.8	1.9
8	101	95	98	94	96	113	106	120	67	72	43	46	.7	3.1	2.8	3.5
9	95	93	55	88	84	95	104	92	64	37	34	25	.5	3.9	.5	5.3
10	95	83	55	76	93	76	78	78	62	49	32	28	.7	11.3	0	1.6
11	87	77	55	85	99	80	82	80	69	69	48	41	4.2	2.8	13.5	.6
12	94	94	73	54	89	84	80	90	66	67	51	36	.2	5.2	13.4	2.1
13	95	93	55	88	91	91	94	90	62	58	50	44	2.6	5	.9	8.6

Appendix G. Continued.
Poor Reading Group

Sub	TONI	CS	PI	OM	PW	PM	BC	LC
1	97	4	39	22	98	94	98	97
2	86	99	99	96	99	91	99	99
3	85	94	62	96	98	91	95	99
4	92	71	100	95	99	90	95	99
5	110	82	53	73	99	92	92	98
6	85	34	28	97	99	94	96	99
7	89	99	79	73	99	92	92	92
8	107	18	46	97	99	94	96	99
9	92	85	92	55	98	51	98	99
10	92	86	95	22	98	93	76	97
11	99	71	97	35	97	94	96	98
12	97	54	100	97	98	93	96	98
13	115	42	79	91	99	93	97	99

Appendix G. Continued.
Low Average Reading Group

Sub	WA 1	WI1	GS R1	LA C1	NR T1	CF T1	CF R1	CF E1	S1	B01	B21	B41	SD1	B0 D1	B2 D1	B4D 1
1	99	102	70	64	99	105	112	98	71.2	44.3	44.7	49.5	1.2	2.9	1.9	2.1
2	108	99	107	88	90	108	112	104	70.7	66.9	63.7	48	.9	5	6.6	6.1
3	97	97	72	75	82	90	98	84	77.8	74.8	73.5	75.1	9	12.8	2.1	12.5
4	95	102	81	76	96	95	82	110	72.3	79.5	48.1	46.2	2.4	8.4	15.3	9.2
5	91	97	70	57	93	91	102	82	66.5	62.4	49.7	47.3	1.6	2	3.9	1.9
6	99	98	81	67	82	91	92	92	78.1	65.6	65.3	53.8	12.6	5.5	13.9	3.2
7	98	96	107	58	93	95	92	100	79.1	70.3	77.7	57.4	8.6	2.7	2.4	8.6
8	100	95	90	88	75	87	108	88	66.7	70.9	65.7	37	1.4	6.7	1.4	0
9	96	99	72	81	90	96	102	92	70.3	70.3	66.6	59.3	0	.9	2.8	3.3
10	101	101	104	81	94	89	84	96	67.3	64.3	59.2	62.5	1.4	1.4	1.6	20
11	112	103	98	76	82	103	102	104	58	44.1	44.2	28.5	2.8	7.4	10.2	.7
12	108	95	80	88	88	91	88	96	68.9	63.2	44.5	34.7	.8	2.1	2.1	3.1
13	96	102	94	80	83	106	118	94	73	59.7	42.3	47	.4	2.4	.5	25.3

Appendix G. Continued.
Low Average Reading Group

Sub	WA 2	WI2	GS R2	LA C2	NR T2	CF T2	CF R2	CF E2	S2	B02	B22	B42	SD2	B0 D2	B2 D2	B4D 2
1	101	105	102	52	87	113	114	112	68	44.2	47.8	37.6	.5	5.6	.2	1.3
2	110	104	101	76	98	106	106	106	68	79.2	50.3	47.7	1.9	8.6	17.2	6
3	103	99	71	69	89	93	100	88	68.3	63	53.3	51.2	1.9	.5	3.3	2.1
4	96	102	100	70	94	116	110	122	70.2	61	35.9	45.7	.2	9.6	5.1	16.4
5	99	99	86	70	93	100	108	92	65.3	60.9	54	55.2	1.9	2.6	.8	8.9
6	110	100	91	67	94	95	96	96	65.2	63.9	58.5	55.7	3.2	.7	3.7	.7
7	86	96	93	82	90	96	96	98	76.3	75.8	77.8	45.4	3.3	11.5	.6	20.8
8	101	102	74	93	80	91	94	90	68.2	72.5	74.2	60.7	0	.2	1.6	.7
9	99	99	95	82	85	106	116	96	71.7	56.7	61.8	43.2	1.4	2.4	20.8	1.2
10	117	113	86	88	93	111	108	114	69	64	52.5	42.6	1	7.7	8.7	7.8
11	105	97	86	88	84	93	90	98	63	37.5	35.5	31.5	.7	0	7.8	.7
12	102	99	90	88	99	102	102	102	63.7	46.1	36.1	34	1.9	6.4	4.6	0
13	96	99	89	82	93	102	102	102	71	59	64.5	68.3	1.9	9.2	1.6	14.9

Appendix G. Continued.
Low Average Reading Group

Sub	WA 3	WI3	GS R3	LA C3	NR T3	CF T3	CF R3	CF E3	S3	B03	B23	B43	SD 3	B0D 3	B2 D3	B4D 3
1	101	106	109	52	98	116	110	122	63	46	43	38	.9	.7	1.9	5.9
2	99	100	100	93	97	102	94	110	70	53	51	35	.7	.2	1.4	3.3
3	99	98	85	88	73	90	90	92	70	63	50	44	3.9	1.2	2.4	9.7
4	100	102	100	76	88	124	118	128	68	60	42	36	.7	2.4	10.1	4.1
5	98	100	71	73	95	81	84	80	71	61	34	37	1.9	6.6	.7	7.8
6	105	100	82	79	88	96	86	96	64	59	54	52	.7	.9	9.8	7.8
7	98	98	108	70	89	97	96	100	72	66	60	40	1	6.8	13.4	6.7
8	132	100	85	91	98	96	98	96	72	78	58	57	1.6	10.1	19.2	15
9	105	98	85	88	95	96	96	98	72	50	48	38	.5	2.5	7.2	5.3
10	120	99	85	94	99	106	108	104	68	64	35	29	3.8	.2	1.2	.4
11	104	93	94	88	96	106	106	106	70	37	34	33	.7	.6	2.1	1.2
12	100	94	100	94	100	100	98	102	62	40	32	30	2.4	5.8	.4	2.1
13	98	99	77	82	95	110	106	110	64	48	29	30	3.3	3.1	.2	.5

Appendix G. Continued.
Low Average Reading Group

Sub	TONI	CS	PI	OM	PW	PM	BC	LC
1	115	85	100	77	99	95	98	99
2	100	52	55	92	98	93	97	99
3	102	28	46	95	98	91	74	97
4	95	87	82	23	98	69	97	98
5	94	83	65	81	98	94	98	99
6	89	71	51	58	99	50	33	97
7	88	29	14	9	98	90	71	95
8	127	43	51	98	99	53	93	98
9	95	30	54	71	98	94	97	98
10	89	29	63	51	98	91	96	98
11	85	99	100	95	99	93	97	99
12	92	36	46	65	97	92	54	96
13	92	70	76	45	99	92	96	99

Appendix G. Continued.
Control Group

Sub	WA 2	WI2	GS R2	LA C2	NR T2	CF T2	CF R2	CF E2	S2	B02	B22	B42	SD 2	B0 D2	B2 D2	B4 D2
1	117	117	88	85	94	104	110	98	63.7	46.1	36	34	1.6	1.9	1.2	4
2	102	106	109	82	94	120	120	118	71	59	64.5	68.3	.7	8.9	1.9	1.9
3	100	99	109	100	96	115	120	110	66	46	39	37	.5	9.5	3.2	.7
4	111	107	110	76	95	94	90	100	72	63	46	51	5.6	1.8	.7	3.3
5	103	95	82	88	88	88	92	86	70	49	47	37	1.6	4.4	4	1.3
6	101	106	100	88	87	98	102	96	65	44	44	32	1.4	7.2	4.6	3.3
7	106	113	96	82	73	102	108	96	74	65	45	46	.5	.7	3.4	.7
8	105	115	102	51	99	93	98	90	705	53	33	32	1.2	17.8	8.3	10.3
9	99	99	112	81	85	95	90	102	69	67	56	53	.5	3.8	3.6	1.9
10	102	99	74	104	91	97	98	98	74	69	68	41	2.1	14.7	12.3	1.2
11	110	115	91	76	93	117	118	116	76	73	60	50	4.1	1.2	2.5	33.. 5
12	113	110	110	82	97	120	120	120	67	67	80	48	2.6	5.7	1	1.4

Appendix G. Continued.
Control Group

Sub	WA 3	WI3	GS R3	LA C3	NR T3	CF T3	CF R3	CF E3	S3	B03	B23	B4 3	SD 3	B0D 3	B2 D3	B4D 3
1	111	117	84	82	92	111	112	91	66	46	39	37	.2	1.4	12.1	10.5
2	117	112	112	79	97	130	122	106	72	63	46	51	1.6	2.1	.7	2.4
3	99	96	121	88	99	114	122	105	70	49	47	37	.7	4.9	13.5	2.5
4	97	105	89	61	94	114	131	102	65	44	44	32	.7	7.4	.7	3.2
5	99	103	90	88	94	88	92	84	74	65	45	46	.2	3.9	.7	13.6
6	129	114	100	88	95	103	110	88	70	53	33	32	3.1	3.5	16.8	15.9
7	107	109	92	87	85	101	104	95	69	67	56	53	1.9	9.5	3.8	1.1
8	99	111	109	82	95	106	108	92	74	69	68	41	3.3	8.1	14.7	2.1
9	96	95	57	88	97	118	104	97	76	73	60	50	2.6	7.3	5.7	10.1
10	102	98	82	88	96	96	100	88	67	67	80	48	3.1	0	8.9	5.2
11	113	102	92	76	94	109	118	90	70	73	34	46	1.6	9.9	1.4	9.6
12	106	108	110	70	98	113	118	93	65	54	40	35	3.1	.7	1.4	20.3

Appendix G. Continued.
Control Group

Sub	TONI							
1	91							
2	106							
3	105							
4	102							
5	85							
6	88							
7	95							
8	92							
9	97							
10	88							
11	90							
12	93							

Vita

Daniel Valentine graduated with a B.A. and M.A. degree in English from Michigan State University. Following graduation, he spent two years as a Peace Corps Volunteer teaching English as a foreign language in Taza, Morocco. After repatriation, he taught English literature and English as a second language in Kansas, Indiana, and Tennessee before returning overseas to Saudi Arabia. For two years he served as the Director of the English as a Foreign Language Program at the Ministry of Interior in Riyadh. During this time, he and his family traveled extensively throughout Africa and Asia.

When he returned from Saudi Arabia, he began studies in speech-language pathology at the University of Tennessee, Knoxville. After graduation he worked as a speech-language pathologist in hospitals and long-term health care facilities in Florida and Tennessee. In 1994 he joined the clinical faculty of the Hearing and Speech Center at the University of Tennessee. His areas of clinical specialization have been in reading disorders, school-age language disorders, and fluency, which he has held the Certificate of Special Recognition in Fluency Disorders since 2000.

Mr. Valentine has been an active presenter at ASHA and state conferences. He hopes to continue to research issues in reading disorders and stuttering.