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Clinical Forum

Auditory Processing Disorder and Auditory/Language Interventions: An Evidence-Based Systematic Review

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Purpose: In this systematic review, the peer-reviewed literature on the efficacy of interventions for school-age children with auditory processing disorder (APD) is critically evaluated.

Method: Searches of 28 electronic databases yielded 25 studies for analysis. These studies were categorized by research phase (e.g., exploratory, efficacy) and ranked on a standard set of quality features related to methodology and reporting.

Results: Some support exists for the claim that auditory and language interventions can improve auditory functioning in children with APD and those with primary spoken language disorder. There is little indication, however, that observed improvements are due to the auditory features of these programs. Similarly, evidence supporting the effects of these programs on spoken and written language functioning is limited.

Conclusion: The evidence base is too small and weak to provide clear guidance to speech-language pathologists faced with treating children with diagnosed APD, but some cautious skepticism is warranted until the record of evidence is more complete. Clinicians who decide to use auditory interventions should be aware of the limitations in the evidence and take special care to monitor the spoken and written language status of their young clients.

Key Words: auditory processing disorder, auditory intervention, spoken language disorder, primary language disorder

As Richard (2011) indicated in her prologue to this clinical forum, there is a long, contentious history involving both the identification and treatment of children with auditory processing disorder (APD) by professionals in communication sciences and disorders. Despite this history of debate and disagreement, children with APD are regularly identified and treated by audiologists and speech-language pathologists (SLPs), and claims of success for treatments of many types abound. However, no systematic reviews of the treatment literature in this area have been published to date. The purpose of this systematic review is to examine and critically evaluate the literature on interventions that target the spoken and written language problems, as well as the possibly even more basic auditory processing problems, of children and youths with diagnosed APD.

Because of the disagreement that exists concerning the diagnosis of APD, we cast a broad net for our review by considering all treatment studies involving school-age children with diagnosed APD, regardless of the criteria used to make the diagnosis. Auditory interventions are often used to treat children with spoken language disorder who have not been diagnosed with APD. Therefore, we also included studies in which auditory interventions were used to address the spoken and written language abilities of children with primary language disorders.

There is no consensus in the field of speech-language pathology regarding criteria for distinguishing auditory interventions from language interventions, and many available

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tools have features of both types of treatments. For our review, auditory treatments were identified by their principled and progressive manipulation of the auditory components of speech and nonspeech stimuli, such as rate, interstimulus interval, frequency, intensity, and presence of background noise. This contrasted with programs judged to be spoken language interventions, which manipulate language form, content, and use rather than acoustic features of speech and nonspeech stimuli. Using this basic distinction, Fast ForWord (Scientific Learning Corporation, 1998), a popular computer-based intervention, was considered to be an auditory intervention because it manipulates the rate and intensity of various speech components of a circumscribed set of frequently repeated linguistic and nonlinguistic stimuli. On the other hand, even though two of its computer-based games increase complexity primarily by manipulating background noise and the duration and intensity of formant transitions, Earobics (Cognitive Concepts, 1997), another popular computer-based intervention, was considered to be a language rather than an auditory intervention. This is because its other four games predominantly manipulate language components such as consonants, vowels, syllables, and their written analogues as parts of words rather than the acoustic features of the stimuli (Diehl, 1999).

To conduct the systematic review, five clinical questions were developed using the PICO (patient, intervention, comparison, outcome) format that is commonly used in evidence-based searches (Dollaghan, 2007; Sackett, Straus, Richardson, Rosenberg, & Haynes, 2000). All questions deal with the effects of auditory or language interventions on auditory, language, and academic outcomes for school-age children.

1. What are the effects of auditory interventions on children with a diagnosis of APD?
2. What are the effects of auditory interventions on children with diagnoses of both APD and spoken language disorder?
3. What are the effects of language interventions on children with a diagnosis of APD?
4. What are the effects of language interventions on children with diagnoses of both APD and spoken language disorder?
5. What are the effects of auditory interventions on children with a diagnosis of spoken language disorder?

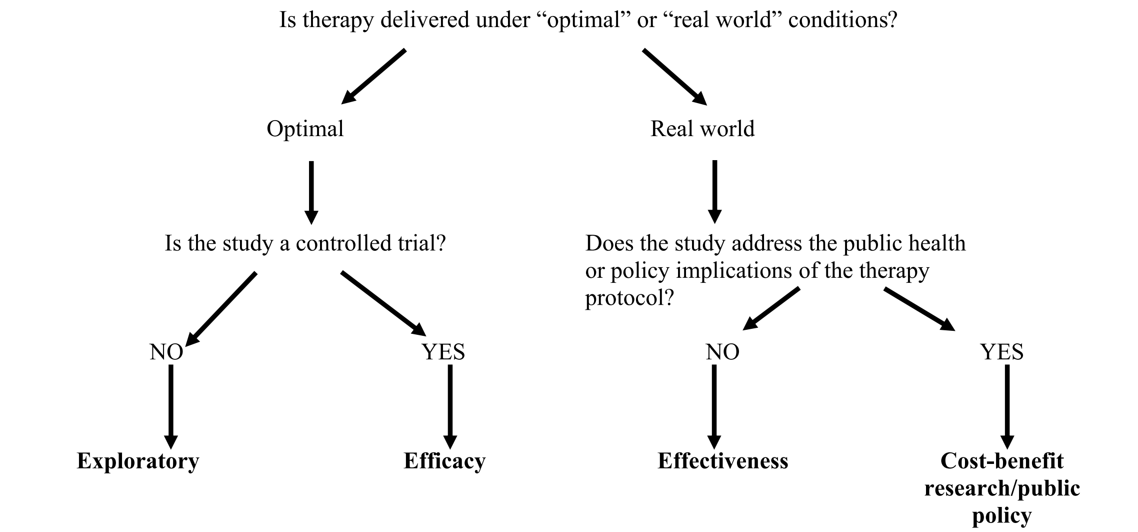
METHOD

A systematic search of 28 electronic databases was conducted by the American Speech-Language-Hearing Association's (ASHA's) National Center for Evidence-Based Practice in Communication Disorders (N-CEP) from March 2008 to June 2008 using key words related to central auditory processing or auditory processing interventions (see Appendix A). Studies were considered for review if they were published in a peer-reviewed journal from 1978 to 2008, were written in English, and contained original data pertaining to one or more of the five clinical questions. We included studies of school-age children, 6 to 12 years old, with the diagnosis of APD and/or primary spoken language disorder. We excluded studies of auditory interventions with participants described simply as having reading or learning disabilities (i.e., without APD or spoken language disorder) or if the participants had autism or autism spectrum disorder, hearing loss, or cognitive disability as defined by an IQ < 70. Only studies of active, direct treatment approaches designed to influence children's ability to process speech and language were considered; passive methods that compensate for children's auditory processing problems, such as preferential seating and the use of frequency modulated (FM) systems, were excluded from the search. We also excluded studies of mixed treatment regimes, vestibular interventions, and pharmacological interventions.

Accepted studies were categorized into one of four stages of clinical research—exploratory, efficacy, effectiveness, or cost-benefit research/public policy—using the decision tree depicted in Figure 1. *Exploratory* studies generally involve relatively few participants and have purposes such as assessing the feasibility of a treatment or evaluating the sensitivity of measurement instruments. They contain few or no controls to infer a relationship (or nonrelationship) between the treatment and outcomes. This contrasts with *efficacy* studies, which are controlled, quasi-experimental or experimental attempts to determine whether the treatment causes an outcome. They are generally carried out under conditions unlike those of most clinical contexts, so the investigators can keep a watchful eye on controlled parameters of the study. *Effectiveness* studies may contain pre–post or between-group designs, but they usually take place after efficacy studies have already determined that the tested intervention is efficacious, and they are expressly designed to assess the effects and/or efficacy of the approach under more typical clinical conditions. *Cost-benefit research/public policy* studies also typically occur following efficacy studies. They are designed to calculate the costs of the target intervention, often in comparison with the costs of standard care.

Each eligible study was evaluated for methodological quality and was classified by stage of research using ASHA's levels-of-evidence scheme (Mullen, 2007). The initial review was conducted by two N-CEP reviewers (TF and TS), blinded from one another's results, who appraised each study independently. Another author was then assigned to review the initial N-CEP evaluation. Any discrepancies between the N-CEP reviews and the other author's evaluations were discussed and resolved by consensus. The studies accepted were evaluated by the entire group of authors on seven

Figure 1. The decision tree for determining the study stage of research.



quality indicators: study protocol, blinding, sampling/allocation, treatment fidelity, statistical significance, precision, and intention to treat. A point was awarded for the specific quality indicator if it met the following criteria:

- *Study protocol*—The design of the study was described in sufficient detail that it could be replicated.
- *Blinding*—Testers and/or test scorers–coders were masked with respect to the child's experimental group assignment.
- *Sampling/allocation*—Participants were selected at random or were assigned randomly to groups, with a clear description of the blinding procedures.
- *Treatment fidelity*—The manner for determining that the described intervention was actually implemented throughout the study was clearly described.
- *Statistical significance*—A statistical test of either pre–post or between-group gains following treatment was reported, or data that allowed statistical tests to be performed were provided.
- *Precision*—An effect size, such as *d,* was reported along with confidence limits surrounding *d* or data sufficient to calculate *d* and confidence limits around it (e.g., a *t* or *F* statistic).
- *Intention to treat*—There were no dropouts from the original group assignments, or it was clear that all analyses were performed using data with the participants in their originally assigned groups.

Efficacy studies could obtain a maximum quality score of seven. However, exploratory studies, which have designs in which intention-to-treat analysis is not relevant, could receive a maximum quality score of six.

The presence and direction of statistical effects are reported in the appendices. Studies that included at least one statistically significant outcome ($\alpha = .05$) favoring the experimental treatment condition were awarded a plus sign (+). Studies reporting one or more nonsignificant statistical tests, indicating no treatment comparison effects, were awarded a zero (0). Finally, studies that observed one or more negative outcomes, indicating significantly weaker posttreatment performance relative to controls, were awarded a minus sign (–). Studies in which the experimental hypotheses were tested using more than one dependent variable were eligible for all three signs.

Treatment effects are reported in the appendices in the form of *d* and confidence limits surrounding *d* when they were either presented in the report or calculable. When not reported by the investigators, effect sizes were calculated either from group means and standard deviations or from the report of a statistical test of the contrast at issue (e.g., *t*) using D-Stat (Johnson, 1997). Confidence limits surrounding *d* also were calculated, where possible, to illustrate the precision of the estimate of effect size. The lower boundary of this confidence interval is its most important feature. If this boundary is above zero, the investigator can conclude with confidence that the true treatment effect is indeed positive. Studies reporting one or more such effects received a plus sign in the appendix. If the lower boundary of the confidence interval was below zero for one or more tests, a treatment non-effect could not be reliably ruled out. In these cases, a zero was entered in the table. Finally, it is possible for the entire confidence interval to fall below zero, indicating that the true treatment effect is highly likely to be negative, giving the advantage to the control group. One or more such findings resulted in the entry of a minus sign in the table.

RESULTS

The findings from the systematic search are provided in Figure 2. The two N-CEP reviewers independently evaluated a total of 192 citations based on their titles and abstracts. Of those, 32 were preliminarily accepted based on the inclusion criteria. Upon review of the full text of these articles, nine articles were rejected principally for three reasons: Six studies did not target the population or intervention under review, two did not provide sufficient or original data for analysis, and one was not published in a peer-reviewed journal. This left a total of 23 articles that referenced 25 studies included in the final analysis.

Outcomes of Interventions for Children With APD

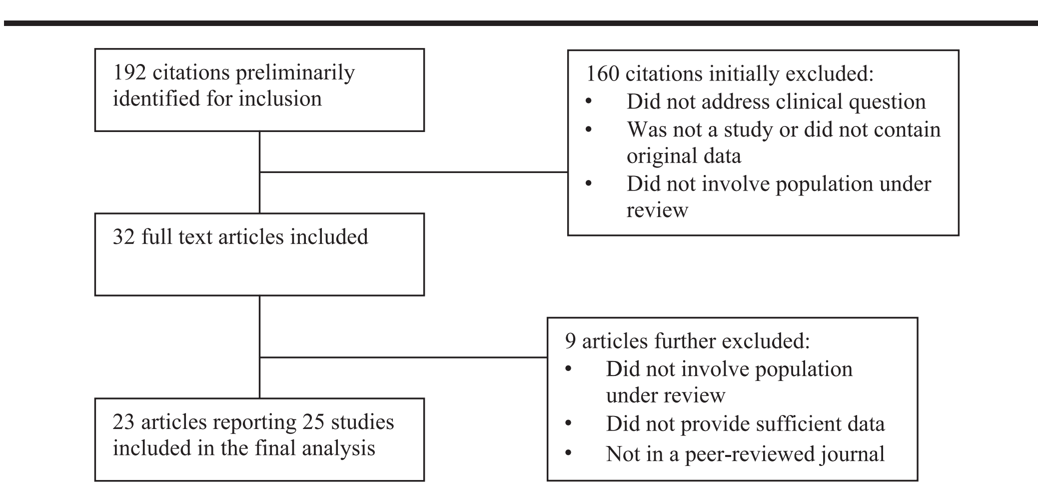
The literature search yielded only six studies that reported the outcomes of auditory or language interventions for children who had been diagnosed as having APD, with or without comorbid spoken language disorder (clinical questions 1–4). Therefore, these studies are considered together as a group.

Appendix B provides a summary of the type of treatment evaluated along with the type of outcome measured (i.e., auditory, written language and achievement, spoken language), research phase represented by the study, numbers and ages of participants (including experimental and control groups), details of intervention intensity, and study outcomes. The bases for diagnosis of APD in these studies generally was teacher concern for listening and related academic abilities or low overall performance on one or a battery of tests, usually including the Staggered Spondaic Word Test (SSW; Katz, Basil, & Smith, 1963), the SCAN-C Test for Auditory Processing Disorders in Children—Revised (Keith, 1999), and tests of speech in noise. The six studies included 121 children, with the largest share participating in Jirsa's (1992) efficacy trial of a traditional auditory intervention ($N = 40$) and Yencer's (1998) trial of auditory integration training (AIT; $N = 36$).

The interventions, in the order of their presentation in Appendix B, included "traditional listening" treatments, AIT, Fast ForWord, and Earobics. Detailed descriptions of these approaches are beyond the scope of this review. Briefly, traditional listening treatments include speech-in-noise training, auditory recognition, and auditory discrimination to improve comprehension. AIT uses filtered music to stimulate the auditory system to enhance listening skills. Fast ForWord is a set of computer-delivered games that use acoustically modified stimuli to improve spoken language processing. Earobics is a set of computer-delivered games that are designed to improve children's listening, memory, and phonological awareness skills.

Traditional listening treatments. Four articles presented studies that evaluated the effects of traditional listening interventions on children identified as having APD. Each article reported auditory outcomes, such as those measured by the SSW and SCAN-C, or auditory neurophysiological responses, like the P300. Three articles—English, Martonik, and Moir (2003), Putter-Katz et al. (2002), and Miller et al. (2005)—were exploratory studies that did not contain control groups or other features to enable clear inferences of treatment efficacy. All three of these research articles had positive auditory outcomes. Only one efficacy study (Jirsa, 1992) evaluated the effects of a traditional auditory training approach on the participants' behavioral and auditory electrophysiological responses. Outcomes were positive for P300 amplitudes and latencies and on several behavioral measures, but this study received a quality score of only 2 points, rendering claims of efficacy tentative. The only assessments of treatment gains on written language or

Figure 2. Identification of articles included in the evidence-based systematic review.



achievement scores were reported in the Miller et al. series of case studies. Participant 3 made no gains in these areas, but Participant 6 exhibited significant improvements in spelling.

AIT. A single study, the efficacy trial reported in Yencer (1998), evaluated the effects of AIT on school-age children with APD. Statistical tests involving 26 dependent behavioral and physiological variables yielded no differences to distinguish the experimental group from the controls following the intervention. It should be pointed out that the AIT method provided in the Yencer study differed from the AIT method proposed by Berard (1982), and the participants' APD were relatively mild. For this group of children with APD, the study indicated that the AIT approach did not yield significant improvement of auditory function.

Fast ForWord. Only two articles (Deppeler, Taranto, & Bench, 2004; Miller et al., 2005), both of which were exploratory by design, reported studies of Fast ForWord for children with APD with or without spoken language disorder. Six of the eight children studied by Deppeler et al. (2004; age 6–9 years) showed significant improvement on at least one of the auditory measures (SSW or AB words in noise [Boothroyd, 1968]), but only one child maintained the improvement after 1 year. Two children exhibited reliable positive gains on spoken language measures, but three children showed significant negative changes. The significant auditory gains in the absence of improvement in language and academic performance were consistent with the findings for Participants 1, 4, and 8 in Miller et al. (2005).

Earobics. The only article to report on the outcomes of a language intervention on school-age children with identified APD is that of Miller et al. (2005; Participants 5 and 9). For Participant 5, no significant improvement was observed on either reading or spelling, both of which were areas of pretreatment weakness, or on a nonword repetition task, which was within the typical range before the intervention. Participant 9 showed significant improvement on spelling and nonword repetition tests, both of which were areas of pretreatment weakness. No improvement was observed on the reading tests, although performance was within normal limits on these tests before intervention.

Appendix C provides details of the methodological quality and stage of research of the six studies addressing the first four questions, none of which earned more than 4 quality points. The most common quality issues were failure to keep testers and coders blind to the children's treatment condition; failure to assign participants randomly to treatment condition; and failure to report on the methodological strategies for monitoring and improving the reliability and validity interventions, referred to as treatment fidelity. Exploratory studies that used predetermined statistical criteria for identifying reliable outcomes were assigned a point for statistical significance. For example, Miller et al. (2005) calculated 90% confidence intervals based on available psychometric information for each standardized test they used. Changes that exceeded the 90% limits were considered statistically reliable. Thus, studies reported in this article were assigned a point for reporting on the statistical significance of their outcomes.

Outcomes of Auditory Interventions for Children With Spoken Language Disorder

The most productive searches for this systematic review concerned the effects of auditory interventions on children who had been identified with spoken language disorder but no identified auditory disorders (i.e., Group 5 questions). Seventeen of the 23 total articles included in the review addressed these questions. Note that the Merzenich et al. (1996) and Tallal et al. (1996) articles each included two studies. Of the 17 articles, one was a single case study exploring the outcomes from a traditional listening program. The vast majority of articles in this area examined the effects of Fast ForWord or early Fast ForWord prototypes. Six articles, involving 266 different children, examined the auditory outcomes of Fast ForWord. Ten articles, including a total of 443 children, evaluated the effects of Fast ForWord on children's spoken language. Two more articles, including an additional 82 children, reported studies of interventions that were inspired by Fast ForWord and included Fast ForWord-like acoustic modifications. This breakdown by intervention type and study methodology is represented in the summary of articles found in Appendices D and E.

Participants with spoken language disorder in these studies were identified using a broad range of tests, but children generally met predetermined criteria for language impairment, such as ≥ 1 *SD*s below the mean on at least one subtest of a standardized language test. Two studies required the participants to have significant deficits in language comprehension (Bishop, Adams, & Rosen, 2006; Cohen et al., 2005). Most participating children had already been diagnosed as having language impairments and were receiving services from an SLP and/or a reading specialist. Children did not have general cognitive impairments, but some studies included children with nonverbal IQ scores between 70 and 85, qualifying them as having "nonspecific" language impairments rather than specific language impairment (Weismer et al., 2000). Most studies involved English-speaking American children; however, Bishop et al. (2006), Cohen et al. (2005), and Crosbie and Dodd (2001) included English-speaking children from England, Scotland, and Australia, respectively, and Segers and Verhoeven's (2004) participants spoke Dutch.

Traditional auditory discrimination training. Only one study, the case report of Crosbie and Dodd (2001), reported on the results of a traditional auditory discrimination approach with a school-age child with language disorder without a diagnosis of APD. This child made significant improvements on sound discrimination tasks but exhibited no noteworthy gains on measures of language. This was an exploratory case study that provided only preliminary information on treatment efficacy.

Fast ForWord: Auditory effects. As shown in Appendix D, there were five exploratory studies that evaluated the auditory outcomes of Fast ForWord and its early prototypes. These studies ranged in quality from 1 to 5. In addition, two efficacy articles met the criteria for Question 5. One of these, Alexander and Frost (1982), was an auditory intervention that involved acoustic modifications of syllable stimuli in a discrimination training task. It was included as a Fast ForWord study because it clearly was inspired by the experimental work and theory that underlies Fast ForWord (e.g., Tallal & Piercy, 1973a, 1973b, 1974), and because it used the Tallal Repetition Test (Tallal & Piercy, 1973b) as its outcome measure of temporal processing. The second efficacy article reporting on the effects of Fast ForWord on auditory abilities, Gillam et al. (2008), was one of only two articles evaluated that received 7 of 7 quality points. It was a direct comparison of Fast ForWord to another computer-based intervention, a traditional language intervention, and an attention control group.

All but one of the five exploratory studies observed some positive auditory outcomes from Fast ForWord. The early studies of Merzenich et al. (1996) reported dramatic gains in the processing of rapidly presented auditory stimuli. The one study that did not find a positive outcome, Thibodeau, Friel-Patti, and Britt (2001), had the highest quality rating of the six exploratory studies (5 out of 6 available points). The two participants with the lowest scores in language and the poorest results on the frequency sweep detection and backward masking tasks exhibited the smallest gains on these measures following the intervention.

In the efficacy study of Alexander and Frost (1982), the authors reported a significant improvement in syllable sequencing at two testing points. However, in both cases, one-tailed tests revealed outcomes only at the .15 level. In addition, the similarity of stimuli used in the training and the outcome measure cast further doubt on the authors' interpretation of the results.

In a more recent, high-quality study of Fast ForWord, Gillam et al. (2008) reported statistically reliable pre–post gains on a backward masking task that requires temporal processing of the sort targeted by Fast ForWord. Yet the gains in backward masking were no greater for Fast ForWord than for two other language interventions or an attention control condition containing no special auditory or language manipulations. Furthermore, there were no interactions involving backward masking threshold and treatment, indicating that the children with lower backward masking scores did not exhibit greater improvement in backward masking if they received Fast ForWord rather than one of the other treatments.

Fast ForWord: Spoken language and phonology effects. Eleven studies examined the language outcomes associated with Fast ForWord. The Fast ForWord implementations of Loeb, Stoke, and Fey (2001) and Cohen et al. (2005) differed in a key way from typical administrations. Both of these interventions were implemented in the children's homes with their parents as monitors and assistants, rather than at school or in the laboratory.

Six of the 11 studies were classified as exploratory. The Stevens, Fanning, Coch, Sanders, and Neville (2008) study, although designed as a quasi-experimental efficacy trial, was rated as an exploratory study because the comparison group included only typically developing children. These six studies had quality scores of 3 or 4 (see Appendices D and E). Most of these studies reported one or more positive outcomes from the Fast ForWord intervention. Two pre–post group studies (Stevens et al., 2008; Tallal et al., 1996, Study 1) reported large gains on standardized measures of receptive language. Other studies found limited or no significant gains on receptive and expressive measures for some children (e.g., Agnew, Dorn, & Eden, 2004; Loeb et al., 2001), and some studies observed significant decrements in performance on one or more standardized measures for some children (e.g., Friel-Patti, DesBarres, & Thibodeau, 2001; Loeb et al., 2001).

The five efficacy studies, with quality scores from 3 to 7, exhibited sharp contrasts in their outcomes (see Appendices D and E). Tallal et al. (1996, Study 2) showed the most positive outcome but had a quality score of only 3 out of 7. The study by Pokorni, Worthington, and Jamison (2004) was slightly higher in quality due to its blinding of testers from the children's experimental condition assignments. After participating in a summer program of either Fast ForWord, the Lindamood Phoneme Sequencing program (LiPS; Lindamood-Bell Learning Center, 1999) or Earobics, children in the LiPS group had higher scores on the Blending Phonemes subtest of the Phonological Awareness Test (Robertson & Salter, 1997) than children in the other two groups. No across-group differences were found on any of the remaining four phonological awareness and language tests. Furthermore, the Fast ForWord group exhibited no statistically reliable gains over time on any of the five language measures.

The two most rigorous studies included in this review, Cohen et al. (2005) and Gillam et al. (2008), reported large gains on standardized measures of phonological awareness and language following the treatment period. The gains made by the Fast ForWord groups were no different, however, from the gains made by groups receiving equally intensive language interventions or groups who did not receive language intervention. Of nine secondary measures assessed by Cohen et al., the Fast ForWord group outperformed controls (who received no experimental language intervention) on only one measure (rhyming) at the 6-month posttest. Similarly, the Fast ForWord group studied by Gillam et al. outperformed the academic enrichment control group on only one measure, the Blending Phonemes subtest from the

Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen, & Rashotte, 1999) immediately after the test and again 6 months later, at which time they also significantly outperformed the traditional language intervention group.

Fast ForWord: Written language effects. Three studies of Fast ForWord, Loeb et al. (2001), Agnew et al. (2004), and Pokorni et al. (2004), examined written language outcomes associated with the intervention. In the exploratory study of Loeb et al., three of the four children completed Fast ForWord and received pre- and postassessments of reading skill using the Woodcock Reading Mastery Tests—Revised (Woodcock, 1987). Looking at data across subjects, there was no consistent pattern of change and little evidence to suggest any significant effect on prereading and reading skills. Similarly, Agnew et al. observed no gains in nonword reading despite having found evidence for a positive auditory treatment effect.

The results of the efficacy study of Pokorni et al. (2004) were consistent with the lack of effects reported by Loeb et al. (2001) and Agnew et al. (2004). None of the three interventions tested—Fast ForWord, Earobics, and LiPS—yielded any significant group changes in the children's passage comprehension, word attack, or spelling, as evaluated by the Woodcock Language Proficiency Battery—Revised (Woodcock, 1991).

Language-oriented interventions with acoustic modifications. Two interventions studied by Bishop et al. (2006) and Segers and Verhoeven (2004) were designed to directly influence children's performance in grammatical comprehension and phonological awareness, respectively. In this respect, they could be considered language interventions. They are included in this section of this review as auditory interventions because for each intervention, speech stimuli were presented with graded, experimenter-manipulated acoustic modifications, using algorithms similar to that of Fast ForWord. Each study was designed to evaluate the impact of the graded acoustic manipulations of the speech signal on the children's auditory processing and language performance. The treatment regimens were also much less intensive than Fast ForWord.

The intervention of Bishop et al. (2006) was designed to facilitate children's rapid responses to increasingly more grammatically complex sentences. In the acoustic modification condition, the stimuli were presented with increasingly less acoustic modification. Therefore, Bishop et al. anticipated possible effects on two auditory processing and five language tests. They found no significant treatment-related group differences on either a measure of speech discrimination or nonspeech frequency sweep discrimination or on any of the measures of grammatical and narrative production/comprehension. Similarly, Segers and Verhoeven (2004) reported no posttreatment differences between treatment (acoustic modification) and control groups (no acoustic modification) on their five phonological awareness tasks. In fact, when the scores for all five phonological awareness tasks were combined into a single outcome variable at the end of the treatment period, it was the group who received training with natural speech rather than the group with the acoustic modifications that statistically significantly outperformed the no-treatment control group.

DISCUSSION

We initiated this systematic review by seeking all published, peer-reviewed articles that reported on evaluations of defined auditory or language interventions from any phase of investigation (i.e., exploratory, efficacy, or effectiveness) for school-age children who had been diagnosed with APD, using a broad, inclusive definition of APD. Because auditory interventions often are recommended for children with spoken language disorder, we also included investigations of the effects of auditory interventions with this population. This section summarizes our efforts to address a set of four clinical questions targeting auditory and language interventions for children with APD and a fifth question pertaining to auditory interventions for children with spoken language disorder. Additionally, future research and clinical directions are recommended.

Interventions for Children With APD

The search to address the four questions about intervention for school-age children with APD yielded only six studies. Four of these studies were exploratory, and two focused on treatment efficacy. None of the six studies received more than 4 points in the 6- or 7-point quality appraisal system. All six studies reported outcomes for auditory measures, but only two reported on spoken or written language outcomes.

From this small set of studies, there is weak evidence to suggest that intensive, short-term interventions (i.e., traditional auditory interventions, Fast ForWord, and Earobics) may be associated with improved auditory functioning among school-age children who meet broad criteria for APD, with or without accompanying spoken language disorder. There is less evidence that these same interventions affect the spoken and written language performance of children with APD. In fact, the only two articles that reported language outcomes of intervention with this group of children both presented sets of case studies and observed a mixture of significant positive and negative results across case study participants.

Although only a single qualifying efficacy study on AIT was identified, the results of that study indicate that AIT is not efficacious for school-age children with APD. In a recent systematic review of AIT studies, Sinha, Silove, Wheeler, and Williams (2006) came to a similarly negative conclusion regarding the use of this treatment for children with autism. This evaluation is consistent with ASHA's position statement on AIT, which states that "AIT has not met scientific standards for efficacy that would justify its practice by audiologists and speech-language pathologists" (ASHA, 2004, p.1).

Auditory Interventions for Children With Spoken Language Disorder

The search for studies of auditory interventions for school-age children with spoken language disorder (Question 5) yielded 17 articles. These articles included 19 studies that examined the outcomes of a listening/auditory discrimination program (1 study), Fast ForWord (16 studies), and language-based interventions that used Fast ForWord-like acoustic modifications of all language stimuli (2 studies). No firm conclusions can be made concerning the listening/auditory discrimination program (Crosbie & Dodd, 2001), although findings of positive auditory outcomes and limited language outcomes are compatible with the results of the previously described studies evaluating outcomes of traditional auditory interventions for children with APD.

The results of seven exploratory and efficacy studies on the auditory effects of Fast ForWord led to the conclusion that children with spoken language disorder who receive Fast ForWord may generally be expected to improve their performance on various auditory processing tasks; however, the relationship of these gains to the auditory intervention is not clear (see Gillam, Crofford, Gale, & Hoffman, 2001; Gillam et al., 2008; Marler, Champlin, & Gillam, 2001; Thibodeau et al., 2001). The Gillam et al. (2008) study, in particular, provides high-quality evidence that the positive auditory outcomes associated with Fast ForWord can be achieved with interventions that do not specifically target auditory abilities. In addition, children with deficits in temporal processing, as measured by backward masking thresholds, did not profit more from Fast ForWord than from any other intervention. These studies provide little evidence that Fast ForWord's acoustic modifications of speech and nonspeech stimuli are responsible for improvements in children's auditory function.

Similarly, there is little support for the effects of Fast ForWord's acoustic modifications when the goal is to facilitate language learning among children with language disorders who have not been identified as having APD. The largest and most rigorous efficacy studies of Fast ForWord have found either no improvements on language measures (Pokorni et al., 2004) or gains similar to other, equally intensive language interventions and control conditions with no auditory or language manipulations (Cohen et al., 2005; Gillam et al., 2008). The evidence suggests that the acoustic modifications found in Fast ForWord and similar speech modification interventions generally are not responsible for improved spoken language performance for children with language disorders.

Similar outcomes were obtained for two interventions that presented language stimuli with Fast ForWord-like graded acoustic modifications (Bishop et al., 2006; Segers & Verhoeven, 2004). Neither of these studies observed gains associated with the treatment that exceeded improvements of participants serving in the no-treatment control condition.

The effects of Fast ForWord on the academic outcomes of children with spoken language disorder had not been examined adequately at the time this review was performed. The three existing studies that were included, however, showed that Fast ForWord did not consistently yield significant changes in the reading profiles of children with spoken language disorder.

Future Research and Clinical Directions

To fill the precipitous gaps in understanding APD and its treatment, programs of thematically coherent research are needed. These programs should begin with small-scale but rigorous studies within which participants are carefully evaluated using a comprehensive battery of conventional tests of APD as well as more sophisticated neurophysiological indices, including Bio-Mark (see Cunningham, Nicol, Zecker, Bradlow, & Kraus, 2001; Russo, Nicol, Zecker, Hayes, & Kraus, 2005; Warrier, Johnson, Hayes, Nicol, & Kraus, 2004), and psychoacoustic measures, such as the backward masking and frequency discrimination threshold tests used by Bishop et al. (2006), Thibodeau et al. (2001), and others.

It is well known that children who have been diagnosed with APD frequently have spoken and written language disorders (Sharma, Purdy, & Kelly, 2009) that may or may not be causally associated with the APD. When the language characteristics of children in APD study samples are unknown, as was the case in four of the six studies of children with APD examined in this review, study results are confounded and difficult to interpret. Therefore, it is critical that the language skills of children are carefully and comprehensively evaluated before and after intervention is provided in APD treatment studies. This will make it possible to examine treatment-related gains in language ability and evaluate the moderating and mediating influences that language disorder could have on various types of auditory treatment outcomes.

With detailed information from high-quality exploratory studies of well-described samples, researchers can develop hypotheses about which auditory training approaches are most appropriate for children who are exhibiting specific auditory, spoken and written language, and learning profiles. Ultimately, interventions that appear to be efficacious in smaller studies must be tested in larger, well-controlled and hypothesis-driven experimental trials that compare their efficacy with that of other auditory and language interventions

(Robey, 2004). Ideally, these studies would include relatively homogeneous samples of school-age children with APD. A more realistic alternative may be to allow language and auditory characteristics to vary at baseline and to account for these differences using statistical techniques such as multiple regression and analysis of covariance.

Currently available evidence on the efficacy of interventions for school-age children with APD provides little direction for clinicians who are working with children with identified APD. However, in light of the demand for addressing this population, a few recommendations seem warranted at this time. Because language disorders are so common among children with APD (Sharma et al., 2009), it is critical that clinicians administer comprehensive language evaluations to children with APD to rule out or identify specific aspects of language disorders. When language problems exist, intervention targeting the deficits should be implemented, with an awareness of how language deficits change over time. Research on such treatments for school-age children with language disorders is also limited, although the available evidence is generally encouraging (Cirrin & Gillam, 2008).

In conclusion, in this systematic review, we found no compelling evidence that existing auditory interventions make any significant contributions to auditory, language, or academic outcomes of school-age children who have been diagnosed with APD or language disorder. We were in unanimous agreement, however, that this finding should not be taken as the final word about the effectiveness of auditory interventions. Future studies will hopefully fill the gaps in the literature and provide more definitive conclusions and recommendations. In the meantime, clinicians who choose to continue using auditory interventions should do so in conjunction with interventions that target specific language, communication, and academic goals. Ideally, clinicians and researchers should work together, sharing ideas and experiences, to develop and evaluate the efficacy of interventions that make real differences in the lives of children with APD and their families.

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APPENDIX A. KEY WORDS AND DATABASES USED IN THE SEARCH

Key Words

auditory processing disorder
central auditory processing disorder
auditory perception
central deafness
auditory perceptual disorder
acoustic perceptual disorder
auditory comprehension disorder
psychoacoustic disorders
auditory inattention

Databases

Centre for Reviews and Dissemination
Cochrane Library
Cumulative Index to Nursing and Allied Health Literature (CINAHL)
Deutsches Institut für Medizinische Dokumentation und Information
Education Abstracts
ERIC
Evidence Based Medicine Guidelines
Exceptional Child Education Resources (ECER)
Health Source – Consumer Edition
Health Source: Nursing/Academic Edition
HighWire Press
Linguistics Language Behaviour Abstracts (CSA)
Medline
National Library for Health
National Rehabilitation Information Center
Neuroscience Abstracts (CSA)
OT seeker
PsycARTICLES
Psychology and Language Sciences Collection
PsycINFO
PubMed
Science Citation Index Expanded (ISI)
Science Direct
Social Sciences Citation Index (ISI)
Social Services Abstracts (CSA)
SUMSearch
Teacher Reference Center
Translating Research Into Practice Database – Clinical Research Engine

APPENDIX B. INTERVENTION DESCRIPTIONS AND OUTCOME SUMMARIES FOR STUDIES EXAMINING AUDITORY AND LANGUAGE TREATMENTS FOR CHILDREN WITH AUDITORY PROCESSING DISORDER (APD), WITH OR WITHOUT LANGUAGE DISORDER (CLINICAL QUESTIONS 1–4)

Intervention type	*Outcome type research phase*	*Citation*	N	*Age (years; months)*	*Intervention session length/ frequency/duration*	*Outcome summary*
Dichotic listening	A Exploratory	English et al. (2003)	10	5;0–10;9	1 hr 1× per week 10–13 weeks	All participants' left ear scores on the dichotic test improved at least 1.5 *SD*s; 9 participants improved their left ear scores to be within age norms.
Comprehension in noise and dichotic listening	A Exploratory	Putter-Katz et al. (2002)	20	7;11–14;4	45 min 1× per week 4 months 13–15 sessions	Significant increase in speech recognition in degraded and dichotic listening conditions, especially in the more severe group.
Informal auditory training	A, W Exploratory	Miller et al. (2005) Participants 3 and 6	2	7;0, 7;4	100 min 5× per week 4 weeks 20 sessions	Both participants improved significantly on the SSW, but only Participant 3 improved on the SCAN-C. Participant 3 showed no reading or achievement test gains. Participant 6 improved in spelling.
Intensive listening auditory memory – competing noise	A Efficacy	Jirsa (1992)	40	9;5–12;5	45 min 2× per week 14 weeks	Significant changes in P3 latency and amplitude measures for the treatment group. The treatment group also showed intragroup improvement on some of the other measures (e.g., 5 of the 7 TAPS subtests).
Modified auditory integration training	A Efficacy	Yencer (1998)	36	Grades 1–4	30 min 2× per day 10 days	No significant differences between experimental and control participants.
Fast ForWord (Scientific Learning Corporation, 1998)	A, S Exploratory	Deppeler et al. (2004)	8	Grades 6–9	100 min 5× per week 4 weeks	6 participants showed improvement on at least one of the SSW or the AB Words in Competing Noise. Only 2 participants made positive changes in receptive or expressive language; 3 made significant *negative* changes.
Fast ForWord	A, W Exploratory	Miller et al. (2005) Participants 1, 4, and 8	3	8;0, 8;0, 9;0	100 min 5× per week 4 weeks 20 sessions	All participants improved on the SSW and/or on the SCAN–C. No effects on tests of reading or achievement, but scores on these tests for Participant 8 were within normal limits before treatment.
Earobics (Cognitive Concepts, 1996)	A, W Exploratory	Miller et al. (2005) Participants 5 and 9	2	8;0, 8;1	100 min 5× per week 4 weeks 20 sessions	Both participants made significant gains on the SSW and/or the SCAN-C. Participant 5 made no gains in reading or spelling, but Participant 9 improved in spelling.

Note. Studies are grouped by general intervention type. A = auditory; W = written language and achievement; S = spoken language and phonological awareness; SSW = Staggered Spondaic Word Test (Katz, Basil, & Smith, 1963); SCAN–C = SCAN–C Test for Auditory Processing Disorders in Children—Revised (Keith, 1999); TAPS = Test of Auditory–Perceptual Skills (Gardner, 1985); AB Words in Competing Noise (Boothroyd, 1968).

APPENDIX C. RESEARCH STAGE AND CRITICAL APPRAISAL RATINGS FOR STUDIES REPORTING OUTCOMES OF AUDITORY AND LANGUAGE TREATMENTS FOR CHILDREN WITH APD

Intervention type	*Outcome type*	*Citation*	*Research phase/quality score*	*Study protocol*[a]	*Blinding?*[a]	*Random sampling/ allocation*[a]	*Treatment fidelity*[a]	*Statistically significant?*[a,b]	*Significant effect?*[a,c,d]
Dichotic listening	A	English et al. (2003)	Exploratory 1/6	Adequate	No	No	No	Not tested	Not provided
Comprehension in noise and dichotic listening	A	Putter-Katz et al. (2002)	Exploratory 2/6	Inadequate	No	No	No	Group 1: +, 0 Group 2: +, 0	Group 1: Not provided Group 2: +, 0
Informal auditory training	A, W	Miller et al. (2005) Participants 3 and 6	Exploratory 3/6	Adequate	No	No	No	A = +, 0 W = +, 0	Not provided
Intensive listening auditory memory – competing noise	A	Jirsa (1992)	Efficacy 2/7	Inadequate	No	No	No	+, 0	+, 0
Modified auditory integration training	A	Yencer (1998)	Efficacy 4/7	Adequate	Yes	No	No	0	0
Fast ForWord	A, S	Deppeler et al. (2004)	Exploratory 3/6	Adequate	No	No	Yes	A = +, 0 S = +, 0, –	Not provided
Fast ForWord	A, W	Miller et al. (2005) Participants 1, 4, and 8	Exploratory 4/6	Adequate	No	No	Yes	A = +, 0 W = 0	Not provided
Earobics	A, W	Miller et al. (2005) Participants 5 and 9	Exploratory 3/6	Adequate	No	No	Yes	A = +, 0 W = +, 0	Not provided

[a]One quality point was given for attaining the highest score in each category. No studies were assigned a point for performing intention-to-treat analyses. [b]One point was scored if significance was reported or calculable, regardless of outcome. [c]Effects measured for exploratory studies are pre–post, within-participant comparisons, whereas those for efficacy studies are standardized mean differences across study groups. + indicates that one or more effects favored the treatment, 0 indicates one or more nonsignificant treatment effects, and – indicates one or more effects favoring the pretest measurement or controls. [d]Significant effects have lower confidence limits that do not cross zero.

APPENDIX D (P. 1 OF 3). **INTERVENTION DESCRIPTIONS AND OUTCOME SUMMARIES FOR STUDIES EXAMINING AUDITORY TREATMENTS FOR CHILDREN WITH SPOKEN LANGUAGE DISORDER (CLINICAL QUESTION 5)**

Intervention type	*Outcome type/research phase*	*Citation*	*N*	*Age*	*Intervention session length/frequency/duration*	*Outcome summary*
Monitoring skills and auditory discrimination	A, S Exploratory	Crosbie & Dodd (2001)	1	7;0	8 sessions 2× week 4 weeks	Auditory discrimination training led to lasting improvement on auditory tasks. No improvements were noted on tests of language.
Fast ForWord	A Exploratory	Marler et al. (2001)	7	6;10–9;3	100 min 5× per week 4 weeks	2 children with language disorders received Fast ForWord, and 2 received a computerized language intervention with no acoustic modification. All children showed reduced signal thresholds over time. 1 child with language disorder who received Fast ForWord improved in backward masking threshold, but so did a child who received the language treatment. Temporal processing improvements did not appear to be related to Fast ForWord acoustic modifications.
Early Fast ForWord games	A Exploratory	Merzenich et al. (1996) Study 1	7	5;8–9;1	20 min 5× per week 4 weeks 19–28 sessions	Participants demonstrated improved ability to sequence stimuli of shorter durations and stimuli separated by shorter interstimulus intervals.
Early Fast ForWord games	A Exploratory	Merzenich et al. (1996) Study 2	11	5;2–10;0	20 min 5× per week 4 weeks 20 sessions	Participants demonstrated improved ability to sequence stimuli of shorter durations and stimuli separated by shorter interstimulus intervals.
Fast ForWord	A, S, W Exploratory	Agnew et al. (2004)	7	$M = 8.07$	100 min 5× per week 4–6 weeks	Participations showed improved accuracy on a test of auditory duration judgment. There were no pre–post gains in phoneme deletion or nonword reading.
Fast ForWord	A Exploratory	Thibodeau et al. (2001)	5	5;10–9;2	100 min 5 days per week 6 weeks up to 32 sessions	There were no group gains over time for backward masking threshold or for frequency sweep threshold. 2 participants with the greatest problems made the smallest gains.
Syllable sequencing with slowed CV transitions	A Efficacy	Alexander & Frost (1982)	24	7;2–11;7	30 min 1× per week 7 weeks	Improved speed of temporal processing of speech-like sounds, but only at the $p = .15$ level.
Fast ForWord vs. computer-assisted language intervention vs. literacy-based language intervention vs. attention control	A, S Efficacy	Gillam et al. (2008)	216	6;0–8;11	100 min 3.5 hr total 5× per week 6 weeks	All groups improved similarly in backward masking. There was no evidence that children who were poor in backward masking responded best to Fast ForWord. All groups improved similarly in spoken language, as measured by the CASL. Sound blending scores improved more for children with computerized language treatment or Fast ForWord than for other groups at 6-month follow-up.

APPENDIX D (P. 2 OF 3). INTERVENTION DESCRIPTIONS AND OUTCOME SUMMARIES FOR STUDIES EXAMINING AUDITORY TREATMENTS FOR CHILDREN WITH SPOKEN LANGUAGE DISORDER (CLINICAL QUESTION 5)

Intervention type	*Outcome type/research phase*	*Citation*	*N*	*Age*	*Intervention session length/frequency/ duration*	*Outcome summary*
Fast ForWord	S Exploratory	Friel-Patti et al. (2001)	5	5;10–9;2	100 min 5× per week 6 weeks up to 32 sessions	3 of the 5 children made significant gains on standardized language composites, but 2 also showed significant declines on the Token Test (Tallal & Piercy, 1973b). Limited changes were observed on six language sample measures.
Fast ForWord vs. computer-assisted language intervention	S Exploratory	Gillam et al. (2001)	4	6;11–7;6	100 min 5× per week 4 weeks	2 children who received Fast ForWord made significant gains on the language test, and 1 increased mean length of utterance (MLU). Both children who received language intervention made gains on both the language test and MLU. Children with longer MLUs after treatment made more errors.
Fast ForWord	S Exploratory	Stevens et al. (2008)	33	Language disorder treatment *M* = 7;2 Typical treatment *M* = 7;6 Typical control *M* = 7;7	100 min 5× per week 6 weeks	The group with language disorders, who received Fast ForWord, made improvements in receptive but not expressive language. They also made significant changes in selective attention based on an electrophysiological measure. The typical Fast ForWord group and typical controls made no significant language gains.
Early Fast ForWord prototype	S Exploratory	Tallal et al. (1996) Study 1	7	5;8–9;1	Lab: 3 hr 5× week Home: 1–2 hr 7× per week 4 weeks	Children with Fast ForWord made dramatic improvements on the Token Test (memory and grammar) and the CYCLE–R (grammar comprehension).
Fast ForWord in the home with parents	S, W Exploratory	Loeb et al. (2001)	4	5;8–8;1	100 min 5× per week 6 weeks	Of 595 items tested, significant positive change occurred on only 10%. None of the measures of grammatical production consistently detected improvements related to Fast ForWord.
Fast ForWord	S Exploratory	Turner & Pearson (1999) Participants 1, 2, and 4	3	6;3–12;4	100 min 5× per week 4–9 weeks	All 3 children below 12 years of age made significant improvements on at least one composite language measure.
Early Fast ForWord prototype	S Efficacy	Tallal et al. (1996) Study 2	22	5;9–9;1	Lab: 3 hr 5× per week Home: 1–2 hr 7× per week 4 weeks	Dramatic improvements were observed on the Token Test and the CYCLE-R.

APPENDIX D (P. 3 OF 3). **INTERVENTION DESCRIPTIONS AND OUTCOME SUMMARIES FOR STUDIES EXAMINING AUDITORY TREATMENTS FOR CHILDREN WITH SPOKEN LANGUAGE DISORDER (CLINICAL QUESTION 5)**

Intervention type	*Outcome type/research phase*	*Citation*	*N*	*Age*	*Intervention session length/frequency/ duration*	*Outcome summary*
Fast ForWord/ LiPS/Earobics	S Efficacy	Pokorni et al. (2004)	54	7;5–9;0	3 hr 5× per week 4 weeks	Contrary to the LiPS and Earobics groups, the Fast ForWord group showed no evidence of significant pre–post gains in phonemic awareness. None of the groups improved their CELF–3 scores.
Fast ForWord provided at home vs. computer-based language intervention vs. no-treatment controls	S Efficacy	Cohen et al. (2005)	77	6–10	90 min 5× per week 4–6 weeks	Significant gains by children with receptive–expressive specific language impairment who received Fast ForWord were no greater than gains of other groups on the primary measures. Of 9 secondary measures, the Fast ForWord group had higher scores than controls on only 1, rhyming at 6-month posttest.
Fast ForWord-like modifications of natural speech in a computerized phonemic awareness program vs. a phonemic awareness program without modifications vs. attention controls	S Efficacy	Segers & Verhoeven (2004)	36	4;10–6;11	15 min 2–3× per week 5 weeks	There were significant differences in phonological awareness over time but not as a function of group participation. With phonemic awareness task performance combined, performance at posttreatment was better for the group *without* acoustic modifications.
Sentence comprehension with Fast ForWord-like acoustic modifications vs. speech with pauses vs. no-treatment controls	A, S Efficacy	Bishop et al. (2006)	33	8–13	15 min 1–3× per week *M* = ~15 weeks	There were no gains on either speech discrimination or nonspeech frequency sweep detection tasks for either treatment group compared to controls. The group with Fast ForWord-like acoustic modifications never outperformed the other treatment or control groups on any of 5 language measures.

Note. Studies are grouped by general auditory intervention type. CASL = Comprehensive Assessment of Spoken Language (Carrow-Woolfolk, 1999); CYCLE–R = Curtiss-Yamada Comprehensive Language Evaluation: Revised (Curtiss & Yamada, 1988); LiPS = Lindamood Phoneme Sequencing Program (Lindamood-Bell Learning Center, 1999); CELF–3 = Clinical Evaluation of Language Fundamentals, Third Edition (Semel, Wiig, & Secord, 1995).

APPENDIX E (P. 1 OF 2). RESEARCH STAGE AND CRITICAL APPRAISAL RATINGS FOR STUDIES REPORTING OUTCOMES OF AUDITORY AND LANGUAGE TREATMENTS FOR CHILDREN WITH SPOKEN LANGUAGE DISORDER

Intervention type	*Outcome type*	*Citation*	*Research stage/ quality score*	*Study protocol*[a]	*Blinding*[a]	*Sampling/ allocation*[a]	*Treatment fidelity*[a]	*Statistically significant?*[a,b,c]	*Significant effect?*[a,b,c,d]
Speech discrimination training	A, S	Crosbie & Dodd (2001)	Exploratory 1/6	Adequate	No	No	No	Not tested	Not provided
Fast ForWord	A	Marler et al. (2001)	Exploratory 1/6	Adequate	No	No	No	Not tested	Not provided
Early Fast ForWord games	A	Merzenich et al. (1996) Study 1	Exploratory 3/6	Adequate	No	No	No	+	+, 0
Early Fast ForWord games	A	Merzenich et al. (1996) Study 2	Exploratory 3/6	Adequate	No	No	No	+	+
Fast ForWord	A, S, W	Agnew et al. (2004)	Exploratory 4/6	Adequate	No	No	Yes	A = + S, W = 0	A = 0 S, W = 0
Fast ForWord	A	Thibodeau et al. (2001)	Exploratory 5/6	Adequate	No	No	Yes	0	0
Sentence processing with slowed CV transitions	A	Alexander & Frost (1982)	Efficacy 3/7	Adequate	No	No	No	0	Not provided
Fast ForWord/computer-assisted language intervention/literacy-based language intervention/attention control	A, S	Gillam et al. (2008)	Efficacy 7/7	Adequate	Yes	Yes	Yes	A = 0[e] S = +, 0	A = 0[e] S = +, 0
Fast ForWord	S	Friel-Patti et al. (2001)	Exploratory 3/6	Adequate	No	No	Yes	+, 0, –	Not provided
Fast ForWord	S	Gillam et al. (2001)	Exploratory 3/6	Adequate	No	No	Yes	+, 0, –	Not provided
Fast ForWord	S	Stevens et al. (2008)	Exploratory 3/6	Adequate	No	No	Yes	+, 0	Not provided
Early Fast ForWord prototype	S	Tallal et al. (1996) Study 1	Exploratory 3/6	Adequate	No	No	No	+	+
Fast ForWord at home	S, W	Loeb et al. (2001)	Exploratory 4/6	Adequate	Yes	No	Yes	S = +, 0, – W = +, 0, –	Not provided
Fast ForWord	S	Turner & Pearson (1999) Participants 1, 2, and 4	Exploratory 4/6	Adequate	No	No	Yes	+, 0	Not provided
Fast ForWord	S	Tallal et al. (1996) Study 2	Efficacy 3/7	Adequate	No	No	No	+	+

APPENDIX E (P. 2 OF 2). **RESEARCH STAGE AND CRITICAL APPRAISAL RATINGS FOR STUDIES REPORTING OUTCOMES OF AUDITORY AND LANGUAGE TREATMENTS FOR CHILDREN WITH SPOKEN LANGUAGE DISORDER**

Intervention type	*Outcome type*	*Citation*	*Research stage/ quality score*	*Study protocol*[a]	*Blinding*[a]	*Sampling/ allocation*[a]	*Treatment fidelity*[a]	*Statistically significant?*[a,b,c]	*Significant effect?*[a,b,c,d]
Fast ForWord vs. LiPS vs. Earobics	S/W	Pokorni et al. (2004)	Efficacy 4/7	Adequate	Yes	No	No	0	0
Fast ForWord at home vs. computer-based language intervention	S	Cohen et al. (2005)	Efficacy 7/7	Adequate	Yes	Yes	Yes	0[g]	0
Fast ForWord-like modifications of natural speech in a computerized phonological awareness program vs. the same phonological awareness program without modification vs. attention controls	S	Segers & Verhoeven (2004)	Efficacy 3/7	Adequate	No	No	Yes	0, –	Not provided
Sentence comprehension with Fast ForWord-like acoustic modifications vs. slowed speech vs. controls	A, S	Bishop et al. (2006)	Efficacy 5/7	Adequate	Yes	Yes	No	A = 0 S = 0	A = 0 S = 0

[a]One quality point was given for attaining the criteria in each category. [b]One point was scored if significance was reported or calculable, regardless of outcome. [c]Effects measured for exploratory studies are pre–post, within-participant comparisons, whereas those for efficacy studies are standardized mean differences across study groups. + indicates that one or more effects favored the treatment, 0 indicates one or more nonsignificant treatment effects, and – indicates one or more effects favoring the pretest measurement or controls. [d]Significant effects have lower confidence limits that do not cross zero. [e]Gillam et al. (2008) found no between-group effects, but all treatment groups and the active control group made relatively large gains in backward masking. Gillam et al. interpreted this to mean that all groups made real and substantial gains in the processes underlying the backward masking task.

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