Comorbidity of Auditory Processing, Language, and Reading Disorders

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Purpose: The authors assessed comorbidity of auditory processing disorder (APD), language impairment (LI), and reading disorder (RD) in school-age children. Method: Children (N = 68) with suspected APD and nonverbal IQ standard scores of 80 or more were assessed using auditory, language, reading, attention, and memory measures. Auditory processing tests included the Frequency Pattern Test (FPT; F. E. Musiek, 1994; D. Noffsinger, R. H. Wilson, & F. E. Musiek, 1994); the Dichotic Digit Test Version 2 (DDT; F. E. Musiek, 1983); the Random Gap Detection Test (R. W. Keith, 2000); the 500-Hz tone Masking Level Difference (V. Aithal, A. Yonovitz, & S. Aithal, 2006); and a monaural low-redundancy speech test (compressed and reverberant words; A. Boothroyd & S. Nittrouer, 1988). The Clinical Evaluation of Language Fundamentals, Fourth Edition (E. Semel, E. Wiig, & W. Secord, 2003) was used to assess language abilities (including auditory memory). Reading accuracy and fluency and phonological awareness abilities were assessed using the Wheldall Assessment of Reading Passages (A. Madelaine & K. Wheldall, 2002) and the Queensland University Inventory of Literacy (B. Dodd, A. Holm, M. Orelemans, & M. McCormick, 1996). Attention was measured using the Integrated Visual and Auditory Continuous Performance Test (J. A. Sandford & A. Turner, 1995).

Results: Of the children, 72% had APD on the basis of these test results. Most of these children (25%) had difficulty with the FPT bilaterally. A further 22% had difficulty with the FPT bilaterally and had right ear deficits for the DDT. About half of the children (47%) had problems in all 3 areas (APD, LI, and RD); these children had the poorest FPT scores. More had APD-RD, or APD-LI, than APD, RD, or LI alone. There were modest correlations between FPT scores and attention and memory, and between DDT scores and memory.

Conclusions: LI and RD commonly co-occur with APD. Attention and memory are linked to performance on some auditory processing tasks but only explain a small amount of the variance in scores. Comprehensive assessment across a range of areas is required to characterize the difficulties experienced by children with APD.

KEY WORDS: auditory processing disorder, language processing disorder, reading disorder, Children’s Auditory Processing Performance Scale (CHAPPS), attention, memory

Some school-age children appear to have hearing difficulties, despite having normal hearing sensitivity. Teachers and parents describe them as children who are distracted by background sounds, do not follow multiple instructions, take longer to comprehend simple auditory directions, occasionally misconstrue what is being said, or appear to have “selective” hearing (Benson, Seaton, & Johnson, 1997). Anecdotally, it appears that these children could be diagnosed as having an auditory processing disorder (APD), a language impairment (LI), or attention deficits, depending on which professional first assesses the child.

APD has been defined by the American Speech-Language-Hearing Association (ASHA) Task Force on Central Auditory Processing Consensus...
Development (1996) as problems in one or more of the following auditory behaviors: sound localization and lateralization, auditory discrimination, auditory pattern recognition, temporal aspects of audition, and auditory performance decrements with competing acoustic signals and degraded acoustic signals. Because of the complexity of auditory processing and the heterogeneity of APD, the ASHA Task Force on Central Auditory Processing Consensus Development (1996) recommended that clinical tests for APD include temporal processing, localization and lateralization, perception of low-redundancy monaural speech, dichotic listening, and binaural interaction.

The technical report of the ASHA Working Group on Auditory Processing Disorders (2005) suggests that APD can coexist with other disorders, such as LI and learning disability. LI has been defined as significantly poor language (receptive or expressive) when intelligence and hearing sensitivity are within normal limits, and there are no other physical or emotional difficulties (Bishop, 1992). Definitions of LI vary; however, they are typically based on a discrepancy between receptive and/or expressive language and nonverbal IQ, when nonverbal IQ scores are within the normal range (Bishop, Bishop, et al., 1999; Kamhi, 1998; Weismer et al., 2000). Although there is evidence that LI can coexist with APD (e.g., Benasich, Thomas, & Leppanen, 2002; McArthur & Bishop, 2004a, 2004b; Tallal & Stark, 1981; Wible, Nicol, & Kraus, 2005), this has been questioned by some authors (e.g., Bishop, Carlyton, Deeks, & Bishop, 1999; Helzer, Champlin, & Gillam, 1996; Rosen, 1999). The Bishop et al. (1999) and Rosen (1999) studies found no difficulty on auditory tasks in children with specific LI.

Similarly disparate results have been found for children with reading disorder (RD). Children with RD have problems with written language in the presence of average nonverbal intelligence and having received adequate instruction to acquire written and spoken language (McArthur & Bishop, 2001). A number of studies have found that some children with RD have auditory processing deficits (Ahissar, Protopapas, Reid, & Merzenich, 2000; Amitay, Ahissar, & Nelken, 2002; Heiervang, Stevenson, & Hugdahl, 2002; Rosen & Manganari, 2001; Sharma et al., 2006), whereas others have questioned whether children with RD have auditory difficulties (McAnally & Stein, 1996; Schulte-Körne, Deimel, Bartling, & Remschmidt, 1998). The literature is rife with research investigating causes of RD. Much of this work has focused on the link between temporal auditory processing and RD (for a review, see Ramus et al., 2003). These studies have used a range of tasks, such as backward masking, gap detection, and auditory pitch discrimination (Rosen, 2003). Ramus et al. (2003) concluded that a percentage of children with RD do have difficulties on auditory processing tasks. Only a few studies in the reading literature (Bishop, Carlyton, et al., 1999; King, Lombardino, Crandell, & Leonard, 2003; Watson & Miller, 1993) have used a range of auditory processing measures to assess children with reading or language problems (McArthur & Bishop, 2001). Of these studies, only King et al. (2003) used tests recommended for APD diagnosis by the ASHA Task Force on Central Auditory Processing Consensus Development (1996).

The current study investigated the reading and language status of school-age children diagnosed with APD on the basis of the results of a range of APD assessments to determine (a) whether children with a clinical diagnosis of APD have coexisting reading and/or language disorder and (b) whether different types of auditory processing difficulties are associated with reading and/or language disorders.

Reading and language disorders have been reported as simultaneously present in some children (Anderson, Brown, & Tallal, 1993; Bishop, 2001; Snowling, Bishop, & Stothard, 2000). However, at least some children with LI demonstrate age-appropriate reading abilities (Bishop & Adams, 1990; Catts, 1993). Richard (2007, p. 400) referred to an “auditory processing continuum” whereby (central) auditory, phonemic, and language processing are regarded as the primary differential aspects, with APD occurring in isolation or in combination with other disorders. Phonemic awareness is the ability to isolate and manipulate subsyllabic sounds, and it is regarded as a component of phonological awareness (Scholes, 1998).

People with auditory, language processing, and/or RDs are heterogeneous (Aram & Nation, 1980; Bellis, 2007, p. 127; Ramus et al., 2003; Reed & Baker, 2005, p. 85), and there is some existing evidence for comorbidity (King et al., 2003; M. M. Walker, Shinn, Cranford, Givens, & Holbert, 2002). Few studies have conducted comprehensive evaluations of a wide range of auditory, language, and reading skills in the same group of children, and hence the overlap between deficits in these areas is not clear. The aim of the current study was to determine the percentage of children with APD who have coexisting language and/or RD, and to characterize the nature of the auditory processing difficulties in children with language and/or reading difficulties. The link between auditory processing, sustained attention, and short-term auditory memory was also investigated.

**Method**

**Participants**

Sixty-eight children 7–12 years of age participated. Children had either (a) APD suspected by teachers and/or parents or (b) a diagnosis of APD by an audiologist, a speech-language therapist, or an educational psychologist. Children who agreed to participate were screened to
ensure that (a) they had Type-A tympanograms, (b) their nonverbal intelligence score was 80 or higher on the Test of Nonverbal Intelligence (TONI-3; Brown, Sherbenou, & Johnsen, 1997), and (c) their pure-tone hearing thresholds were 15 dB HL or better.

Participants included 44 boys (65%) and 24 girls (35%). Average age was 9.8 and 9.7 years for boys and girls, respectively (SD = 1.6; range = 7.0, 12.8). In general, none of the children had any formal prior diagnoses other than APD (n = 9; 13%) and, in some cases, RD (n = 20; 29%). A small number of children had other diagnoses, such as dyspraxia (n = 3; 4%), Asperger’s syndrome (n = 2; 3%), attention-deficit/hyperactivity disorder–attention deficit disorder (n = 4; 6%), or tinnitus (n = 1; 1%). Parents of some children reported speech and language concerns; however, none of the children had a formal diagnosis of speech or LI.

Ten children (15%) who participated because of parental concern had no formal diagnosis. At the time of their participation in the study, none of the children were undergoing any treatment for language or reading difficulties, and none were using any form of classroom amplification or personal frequency modulated devices. Nearly half of the children participating in the study had a prior history of multiple middle ear infections (49%), and at least 43% had another family member—such as a parent, sibling, or first cousin—who had a diagnosis of Asperger’s syndrome, autism, APD, attention-deficit/hyperactivity disorder–attention deficit disorder, or reading/learning disorder.

Handedness was informally measured by offering a pen/pencil and asking the children to write their name on a piece of paper. The children were also asked whether they always or sometimes used the same hand for all tasks, such as sports. Seven children (10%) were classed as having mixed handedness, as they used different hands and feet for different tasks. Ten children were left handed (15%).

Procedure

Peripheral hearing was tested using pure-tone, speech, and immittance audiometry, as well as transient click-evoked otoacoustic emissions (OAEs). All participants had (a) pure-tone thresholds of 15 dB HL or better at octave frequencies ranging from 250 Hz to 8000 Hz, (b) Type-A tympanograms (Jerger, 1970), (c) ipsilateral 1000-Hz acoustic reflex thresholds less than 100 dB HL (Silman & Gelfand, 1981), (d) left and right ear CVC phoneme scores of 90% or better for speech presented in quiet (Boothroyd & Nittroer, 1988), and (e) OAE strength within the normal range on the basis of the pass/refer criteria in the transient evoked OAE protocols of the Scout Sport System (Bio-Logic Systems Corporation, Mundelein, IL) that were adopted from Hall (2000). If all measures of peripheral hearing were normal, participants proceeded to the psycho-educational, language, hearing, and auditory processing test battery (see description of tests in Table 1). The tests were undertaken in four sessions, each approximately 2 hr in length. Session duration was reduced when the child’s attention and motivation were problematic. A few children required an additional 1–2 test sessions.

Case History

Parents completed a case history providing details of birth history, early speech and language milestones, as well as language and reading progress to the time of participation in the study. Parents also completed the Children’s Auditory Processing Performance Scale (CHAPPS) questionnaire developed by Smoski, Brunt, and Tannahill (1998). The CHAPPS has 36 items concerning listening behavior in a variety of listening conditions and functions. Children are rated on a 7-point scale ranging from –5 (cannot function at all) to 1 (less difficulty than peers) on items relating auditory memory/sequencing and attention and listening to speech in noise, in quiet, in ideal conditions, and with multiple inputs. CHAPPS questionnaire results were compared with findings for the APD test battery; however, the diagnosis of APD was not based on CHAPPS scores.

Auditory Processing Test Battery

Five behavioral tests were used to test a range of auditory processes: (a) Dichotic Digit Test Version 2 (DDT-2; Musiek, 1983), (b) Frequency Pattern Test (FPT; Musiek, 1994; Noffsinger, Wilson, & Musiek, 1994), (c) Random Gap Detection Test (RGDT; Keith, 2000), (d) compressed (45%) and reverberant (0.3-s) CVC words (Boothroyd & Nittroer, 1988), and (e) 500-Hz tone Masking Level Difference (MLD; Aithal, Yonovitz, & Aithal, 2006). Pure-tone audiometry and behavioral auditory processing tests were administered using a Grason-Stadler (Milford, NH) clinical audiometer and TDH-39 earphones (Tucker-Davis Technologies, Alachua, FL). Test materials were presented at 60 dB HL using a CD player (BassXPander, P882). For FPT and monaural low-redundancy tests, stimuli to right and left ears were presented separately, with starting ear randomized. For DDTs and RGDTs, right and left ears were tested simultaneously. The FPT and DDT scores were considered to be a “pass” if the scores were within 2 Sds of the mean for the normative sample (for norms, see Kelly, 2007). For the RGDT, a gap detection threshold of 20 ms or lower was regarded as a pass (Keith, 2000). Compressed and reverberant speech scores were compared with locally developed norms (Kelly,
2007), and scores more than 2 SDs on two tests or 3 SDs below the mean for one test were regarded as abnormal (ASHA Working Group on Auditory Processing Disorders, 2005).

The MLD is the difference in threshold of the signal (in dB) for the case in which the signal and the noise have the same phase and level relationships at the two ears, and the case in which the interaural phase and/or level relationships of the signal and noise are different. The MLD is a measure of the improvement in detectability of a signal that normally occurs under binaural listening conditions. For the MLD task, an 11-dB or greater 500-Hz threshold difference between the $S_PN_0$ (tone presented to the two ears in opposite phase, noise presented in the same phase) and $S_0N_0$ (tone and noise presented to the two ears in the same phase) conditions was regarded as normal (Aithal et al., 2006). Diagnosis of APD was based on FPT, DDT, RGDT, MLD, and/or compressed and reverberant speech scores.

### Cognition and Language

The TONI-3 measures the child’s reasoning ability with minimum language influence (Brown et al., 1997). It is a norm-referenced measure of cognitive ability that assesses intelligence aptitude, abstract thinking, and problem solving for individuals 6–89 years of age. For each item, the child selected one of six options to complete the pattern. In the current study, the lower cutoff for nonverbal intelligence scores of 80 was selected on

<table>
<thead>
<tr>
<th>Measure</th>
<th>Test</th>
<th>Test details</th>
</tr>
</thead>
<tbody>
<tr>
<td>APD</td>
<td>FPT</td>
<td>Frequency discrimination and temporal sequencing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>State the sequence of pitch in a series of three high- or low-pitch tones.</td>
</tr>
<tr>
<td></td>
<td>DDT-2</td>
<td>Binaural integration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repeat the four numbers heard simultaneously in the two ears (two per ear).</td>
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<tr>
<td></td>
<td>RGDT</td>
<td>Temporal resolution</td>
</tr>
<tr>
<td></td>
<td></td>
<td>State whether one or two tones or clicks are heard.</td>
</tr>
<tr>
<td></td>
<td>(Compressed and reverberant words)</td>
<td>Monaural low-redundancy tests</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repeat the words heard separately in the two ears.</td>
</tr>
<tr>
<td></td>
<td>MLD</td>
<td>Binaural integration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Detect a tone in noise with and without an inter-ear phase difference.</td>
</tr>
<tr>
<td>Cognition</td>
<td>TONI-3</td>
<td>Nonverbal cognitive assessment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>State which figure (out of a choice of six) comes next to complete a pattern.</td>
</tr>
<tr>
<td>Language tasks</td>
<td>CELF-4</td>
<td>Receptive and expressive language</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Complete language tasks, some of which are picture based.</td>
</tr>
<tr>
<td>Reading tasks</td>
<td>WARP</td>
<td>Reading accuracy and fluency</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Read short passages; number of words spoken correctly in 1 min is scored.</td>
</tr>
<tr>
<td></td>
<td>QUIL</td>
<td>Phonological task with 10 subtasks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Complete phonological awareness tasks, some of which are picture based.</td>
</tr>
<tr>
<td>Memory</td>
<td>CELF-4 forward digits task</td>
<td>Auditory memory at digit level</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repeat number sequence.</td>
</tr>
<tr>
<td>Attention</td>
<td>Integrated Visual and Auditory Continuous Performance Test</td>
<td>Sustained auditory and visual attention</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mouse click when the number “1” is seen or heard.</td>
</tr>
</tbody>
</table>

Note. FPT = Frequency Pattern Test; DDT-2 = Dichotic Digit Test Version 2; RGDT = Random Gap Detection Test; MLD = Masking Level Difference; TONI-3 = Test of Nonverbal Intelligence-Version 3; CELF-4 = Clinical Evaluation of Language Fundamentals, Fourth Edition; WARP = Wheldall Assessment of Reading Passages; QUIL = Queensland University Inventory of Literacy.
the basis of Fey, Long, and Cleave’s (1994) finding that gains in grammatical skills made by children with the scores of 70–84 were comparable with those meeting a nonverbal IQ criterion of 85 and above.

The Clinical Evaluation of Language Fundamentals, Fourth Edition (CELF-4; Semel, Wiig, & Secord, 2003) was used to assess children’s receptive and expressive language scores. The receptive language score is a cumulative score from subtests such as Concepts and Following Directions, and Receptive Word Classes (semantic relationships). The expressive language score is the cumulative score from subtests such as Formulating Sentences, Recalling Sentences, and Expressive Word Classes.

Reading and Phonological Tasks

Children were tested using (a) the Wheldall Assessment of Reading Passages (WARP; Madelaine & Wheldall, 2002), which measures reading fluency and accuracy, and (b) the Castles’s Word/Nonword Test (Castles & Coltheart, 1993), which measures reading accuracy for regular/irregular words and nonwords. WARP and Word/Nonword Test norms were adopted from Madelaine and Wheldall (2002) and Edwards and Hogben (1999), respectively.

The Queensland University Inventory of Literacy (QUIL; Dodd, Holm, Orelemans, & McCormick, 1996) is a phonological awareness assessment that has been standardized on Australian schoolchildren 2–7 years of age. The QUIL has the following 10 subtasks: (a) reading of nonwords, (b) spelling of nonwords (e.g., lont, sheve, etc.), (c) segmentation of syllables (to determine the number of syllables in a given word), (d) identification of syllables, (e) visual rhyming, (f) auditory rhyming (judgment of pairs of words, such as “shell” and “bell” or “bou” and “bait”), (g) spoonerisms (swapping the first sound from a pair of words and making new words, such as “felt” and “make” swapped to “melt” and “fake”), (h) phoneme detection (identifying the odd word out, which may be different because of first/second or third sound), (i) phoneme segmentation, and (j) phoneme manipulation (identify and remove a sound from the given word and then say the word; e.g., “frog” without “r” is “fog”).

Auditory Memory

Auditory memory was measured using the CELF-4 forward digits task. The task requires the child to recall numbers in correct serial order after hearing the numbers. The numbers are spoken slowly in a monotone voice, and the child is asked to repeat them in the exact order. The length of the series keeps increasing until the child can no longer repeat the series in the correct order.

Sustained Attention: Auditory and Visual

Children were tested on the Integrated Visual and Auditory Continuous Performance Test (Sandford & Turner, 1995), which assesses the children's performance on a combined visual and auditory task. The test was presented on a laptop computer, and the child was instructed to click the mouse whenever the number 1 was seen or heard and to ignore the number 2. Numbers 1 and 2 were seen and heard in pseudorandom order. There were 500 trials, and the task took about 15 min to complete. Feedback was provided only during practice trials.

Results

APD

On the basis of the clinical test battery and the criterion of APD scores falling 2 SDs below the mean on two tests, or 3 SDs below the mean on any one test (ASHA Working Group on Auditory Processing Disorders, 2005), 49 children (72%) were diagnosed as having APD. CHAPPS questionnaires were completed by 65 parents. Smoski et al. (1998) suggested that CHAPPS ratings less than –11 indicate that a child is “at risk” for an auditory processing problem, on the basis of summed ratings across the 36 items in the questionnaire. On average, CHAPPS scores were –10.4 (SD = 5.4; range = –21.3, 2.3), and only 43% of the children (n = 29) whose parents had completed the questionnaire met the criterion of scores less than –11, indicating that their child may be at risk of APD. Twenty-five children (37%) were identified with APD by both the questionnaire and the test battery. Twenty-two children with APD did not have CHAPPS scores less than –11 and, hence, would have been missed if diagnosis was based on the CHAPPS. Four children were identified as being at risk for APD on the basis of the CHAPPS but passed the APD test battery. Of these children, 3 had RD and/or LI but did not meet criteria for APD. These findings do not support the use of the CHAPPS as a screening or diagnostic tool for APD because many children with APD were not identified on the basis of their CHAPPS scores, and some were incorrectly identified. The CHAPPS questionnaire may still be a valuable component of the case history, however, for children with suspected APD because it highlights areas of difficulty in the classroom and, hence, could be used to guide intervention in combination with other test findings.

None of the children showed significant difficulties on the compressed and reverberant speech task; however, the scores for this test indicate that it was quite an easy task. Average scores for right and left ears were 88.8% (SD = 7.1; range = 66%, 100%) and 88.3% (SD = 6.6; range = 62%, 100%), respectively. Although none of the children were below the norm on this task, a repeated
measures analysis of variance—with test ear and noise condition as main effects and age as a covariate—showed a significant decline in phoneme scores, $F(1, 66) = 14.4, p < .001$, for the distorted speech condition compared with the nondistorted speech condition. As expected, speech scores were also affected by participant age, $F(1, 66) = 4.1, p = .047$.

Table 2 shows the average scores of children on the APD test battery. Of the 49 children with a diagnosis of APD, 41 (82%) failed the FPT bilaterally (see Figure 1). Of these 41 children who had difficulty bilaterally with the FPT, 12 (25%) failed on the FPT only, 11 (22%) also failed on the DDT (right ear), 6 (12%) had problems bilaterally on both FPT and DDT, and the other 10 children had a range of different results. For the DDT, it was more common for children to fail in the right ear only ($n = 15, 31\%$) than bilaterally ($n = 11, 22\%$). Twelve children (25\%) failed on RGDT, and 3 children (6\%) failed on the MLD task. None of the children failed all four tasks (FPT, DDT, RGDT, and MLD).

In general, patterns of APD results were quite variable across participants. Table 2 shows that, as expected, children with LI and RD (no APD) and those who passed everything had the best scores across APD measures. For the FPT test, children with APD and LI and no RD had better scores than other groups with RD. Interestingly, the 3 children with APD only (no LI or RD) had RGDT scores that were at least 50% poorer than that of any other group in the analysis, and this group also had the smallest standard deviation. This group overlapped with the other groups for the other APD measures. Auditory processing test performance was compared for the four groups with sufficient numbers to be included in an analysis of variance (ANOVA; APD—LI, APD—RD, and APD—LI—RD), with age included as a covariate. Age had a significant influence on FPT scores, $F(1, 49) = 11.7, p = .001$; DDT scores, $F(1, 49) = 5.4, p = .024$; and RGDT scores, $F(1, 49) = 5.5, p = .023$. However, age did not have a significant influence on MLDs. There were significant group differences for FPT scores, $F(1, 49) = 12.8, p < .001$, but not for DDT, RGDT, or MLD scores. As shown in Figure 2, FPT scores were best for the group with no APD (LI—RD) and poorest for the two groups with reading delay (APD—RD and APD—LI—RD). Planned comparisons showed that the APD—LI group performed significantly better on the FPT task than the APD—LI—RD group ($p = .005$).

### Language Impairment

Figure 3 shows the average scores across subtests of the CELF-4. Most children showed difficulty with following directions, recalling sentences, formulation of sentences, and forward number repetition. The inclusion criteria for children to be labeled as LI were as follows: (a) language scores (receptive and/or expressive) below the 10th percentile (standard score of 80; Bishop, Bishop, et al., 1999; Bishop, Carlyton, et al., 1999; Catts, Fey, Tomblin, & Zhang, 2002; Tomblin, Records, & Zhang, 1996), and/or (b) language scores within the expected range for typically developing children (80 or above) but receptive and/or expressive scores below the Test of Nonverbal Intelligence—Version 3 (TONI-3) scores by 1 SD or more (Catts et al., 2002), and/or (c) language scores within the expected range but receptive language scores at least 1.25 SDs (20 points) below expressive language scores (Fey, 1986; Kamhi, 1998). Fifty-two children (76\%) had LI on the basis of these three criteria. Thirty-five children met the first criterion for LI, with language scores below 80. Within Criterion a, 17 children had poor

### Table 2. Average scores and standard deviations of the total group and different groupings of the children with diagnoses of APD, LI, and/or RD for different tests of auditory processing.

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>FPT (%)</th>
<th>DDT (%)</th>
<th>MLD (dB)</th>
<th>RGDT (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>M SD</td>
<td>Right</td>
<td>Left</td>
<td>Right</td>
</tr>
<tr>
<td>All</td>
<td>68</td>
<td>9.8 1.6</td>
<td>46.6 29.3</td>
<td>46.2 28.7</td>
<td>76.4 13.9</td>
</tr>
<tr>
<td>All APD*</td>
<td>49</td>
<td>9.8 1.6</td>
<td>34.3 21.3</td>
<td>34.7 22.7</td>
<td>73.9 14.5</td>
</tr>
<tr>
<td>APD (no RD or LI)</td>
<td>3</td>
<td>9.1 1.7</td>
<td>44.6 36.7</td>
<td>59.8 22.9</td>
<td>68.0 10.8</td>
</tr>
<tr>
<td>APD and LI</td>
<td>39</td>
<td>9.9 1.7</td>
<td>33.8 20.7</td>
<td>32.4 22.5</td>
<td>74.0 15.1</td>
</tr>
<tr>
<td>APD and LI (no RD)</td>
<td>7</td>
<td>10.6 1.9</td>
<td>51.4 27.2</td>
<td>58.1 34.2</td>
<td>69.6 12.6</td>
</tr>
<tr>
<td>APD and RD (no LI)</td>
<td>7</td>
<td>9.5 1.2</td>
<td>32.9 20.9</td>
<td>36.6 19.2</td>
<td>76.1 13.6</td>
</tr>
<tr>
<td>APD, LI, and RD</td>
<td>32</td>
<td>9.7 1.7</td>
<td>30.0 17.2</td>
<td>26.8 14.7</td>
<td>74.9 15.6</td>
</tr>
<tr>
<td>LI and RD (no APD)</td>
<td>8</td>
<td>9.7 1.4</td>
<td>67.1 26.5</td>
<td>69.2 24.8</td>
<td>78.8 11.4</td>
</tr>
<tr>
<td>Passed all tests</td>
<td>3</td>
<td>9.6 0.9</td>
<td>92.1 1.8</td>
<td>85 13.2</td>
<td>87.2 13.0</td>
</tr>
</tbody>
</table>

*Irrespective of whether the children have LI or RD. **Irrespective of whether the children have RD.
receptive and expressive language scores, 8 had poor receptive language, and 10 had poor expressive language. Sixteen children met Criterion b for LI, with language scores below their nonverbal IQ. Six children showed this discrepancy for both receptive and expressive language, 3 children showed poor receptive language scores, and another 7 showed poor expressive language scores.

Figure 1. Number of children with specific auditory processing difficulties out of the 49 diagnosed with auditory processing disorder. All children having difficulties on the Frequency Pattern Test (FPT) had bilateral problems, and hence ears are not specified. DDT-2 = Dichotic Digit Test Version 2; RGDT = Random Gap Detection Test; MLD = Masking Level Difference; R = right ear.

Figure 2. Average FPT scores for the children in the language impairment (LI)–reading disorder (RD), auditory processing disorder (APD)–LI, APD–RD, and APD–LI–RD groups. Scores for the LI–RD group are the highest and are significantly better than those for the other three groups. The APD–LI group has significantly higher scores than the APD–LI–RD group. Error bars show 95% confidence intervals. FollowDirect = Following Directions; ReSent = Recalling Sentences; FormSent = Formulating Sentences; ReWord = Receptive Semantic Relationships; ExWord = Expressive Semantic Relationships; FamSeq = Familiar Sequences; FRept = Forward Digits Repetition; BRept = Backward Digits Repetition.

Figure 3. Average standard scores of all participants (N = 68) across the eight Clinical Evaluation of Language Fundamentals, Fourth Edition (CELF-4) subtests. Scores within the range of 7–10 (shaded area) are regarded as normal (M – 1 SD). Error bars show 95% confidence intervals. FollowDirect = Following Directions; ReSent = Recalling Sentences; FormSent = Formulating Sentences; ReWord = Receptive Semantic Relationships; ExWord = Expressive Semantic Relationships; FamSeq = Familiar Sequences; FRept = Forward Digits Repetition; BRept = Backward Digits Repetition.
Only 1 child met Criterion c for LI. This child’s expressive language score was 20 points better than his receptive language score. Figure 4 shows the number of children meeting these various criteria for having LI.

**Reading and Phonological Awareness Disorders**

RD was defined as having accuracy and fluency 1 SD or more below age peers (Pogorzelski & Wheldall, 2002), plus standard scores 1 SD or more below the mean on at least two of the QUIL phonological awareness tasks (such as nonword reading, rhyming, phoneme detection, phoneme segmentation, phoneme manipulation, and syllable identification). Fifty-two children (77%) had poor reading accuracy and fluency. Forty-four children (65%) had problems on reading accuracy and fluency as well as phonological awareness and, hence, were defined as RD. Figure 5 shows the average scores (with standard deviations) across the 10 QUIL subtasks. All children had difficulty on nonword spelling and reading, as well as on spoken and visual rhyme.

Seven (nonword reading, syllable identification, syllable segmentation, spoken rhyme, phoneme detection, phoneme segmentation, and phoneme manipulation) of the 10 QUIL measures of phonological awareness and Castles and Coltheart’s (1993) word lists were used to identify a phonological processing problem. Three tasks—nonword spelling, visual rhyme, and spoonerisms (which assess skills such as memory and reading in addition to phonological awareness)—were excluded.

**Overlap of Auditory, Language, and Reading Processing Disorders**

Figure 6 shows the distribution of APD, LI, and RD occurring in isolation or in combination. More children had a combination of difficulties (n = 32; 47%) than a “pure” diagnosis of a single disorder. Three children did
well on all auditory, language, and reading measures. Table 3 shows the average TONI-3 nonverbal IQ standard scores, CELF-4 receptive and expressive language standard scores, and WARP reading scores (words per minute) of the total group and different groupings of the children with diagnoses of APD, LI, and/or RD. The 7 children with LI and APD and no RD were slightly older than the other groupings, and the 8 children with LI and RD had slightly higher TONI-3 scores. Otherwise, there were no clear differences between groupings.

**Attention, Memory, and Cognition**

Of the children, 61 (90%) had TONI-3 scores of 85 or higher (range = 85, 142). Only 7 children had nonverbal standard scores in the range of 80–84. Across all children, the average TONI-3 score was 99.5 ($SD = 13.3$; see Table 3). TONI-3 scores for children with problems on auditory and/or visual sustained attention were 97.6 on average ($SD = 13.4$). Thirty-six children had poor sustained auditory attention (53%), and 27 children (40%) had poor sustained visual attention (Integrated Visual and Auditory Continuous Performance Test standard scores of 1 $SD$ or more below the mean). More children had problems on both sustained auditory and visual attention ($n = 28$; 41.2%) than auditory attention alone ($n = 9$; 13.2%) or visual attention alone ($n = 1$; 1.5%). Of the 68 children, 26 (30%) had normal auditory attention and a diagnosis of APD, and 9 children (8%) had poor auditory attention but did not have APD. Thus, APD and auditory attention problems did not necessarily present together.

Forty children (59%) had standard scores on the CELF-4 digit repetition auditory memory task that were 1 $SD$ or more below the mean, and 28 children (41%) had difficulty on the sentence recall (language-based) CELF-4 memory task. Twenty-three children (34%) showed problems on both forward digits and sentence recall; these children had an average TONI-3 score of 98.0 ($SD = 12.8$). There were 7 children (12%) with poor auditory memory who passed all the APD tests, and there were 16 children (32%) who showed no problems on the auditory memory tasks but who had APD. Thus, as was the case for auditory attention, poor auditory memory and APD could present separately or together.

**Influence of Auditory Attention and Auditory Memory on APD Tests**

Multiple regression analyses were undertaken to investigate the effects of auditory memory (digit span) and

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**Table 3.** Average TONI-3 nonverbal IQ standard scores, CELF-4 receptive and expressive language standard scores, and WARP reading scores (words per minute) of the total group and different groupings of the children with diagnoses of APD, LI, and/or RD.

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Age (years)</th>
<th>Male/female</th>
<th>TONI-3</th>
<th>Receptive language</th>
<th>Expressive language</th>
<th>WARP (reading)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>SD</td>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>All</td>
<td>68</td>
<td>9.8</td>
<td>1.6</td>
<td>44/24</td>
<td>99.5</td>
<td>13.3</td>
<td>85.6</td>
</tr>
<tr>
<td>All APD</td>
<td>49</td>
<td>9.7</td>
<td>1.6</td>
<td>30/19</td>
<td>97.1</td>
<td>12.0</td>
<td>83.7</td>
</tr>
<tr>
<td>APD (no RD or LI)</td>
<td>3</td>
<td>9.1</td>
<td>1.7</td>
<td>2/1</td>
<td>99.0</td>
<td>1.7</td>
<td>91.3</td>
</tr>
<tr>
<td>APD and LI</td>
<td>39</td>
<td>9.8</td>
<td>1.7</td>
<td>25/14</td>
<td>97.7</td>
<td>13.1</td>
<td>81.4</td>
</tr>
<tr>
<td>APD and LI (no RD)</td>
<td>7</td>
<td>10.6</td>
<td>1.9</td>
<td>3/4</td>
<td>98.7</td>
<td>11.0</td>
<td>88.0</td>
</tr>
<tr>
<td>APD and RD (no LI)</td>
<td>7</td>
<td>9.5</td>
<td>1.2</td>
<td>4/3</td>
<td>92.3</td>
<td>6.0</td>
<td>92.1</td>
</tr>
<tr>
<td>APD, LI, and RD</td>
<td>32</td>
<td>9.7</td>
<td>1.7</td>
<td>21/11</td>
<td>97.6</td>
<td>13.7</td>
<td>80.2</td>
</tr>
<tr>
<td>LI and RD (no APD)</td>
<td>8</td>
<td>9.7</td>
<td>1.4</td>
<td>7/1</td>
<td>112</td>
<td>17.3</td>
<td>85.9</td>
</tr>
<tr>
<td>Passed all tests</td>
<td>3</td>
<td>9.6</td>
<td>0.9</td>
<td>0/3</td>
<td>104.3</td>
<td>7.5</td>
<td>100.7</td>
</tr>
</tbody>
</table>

*Irrespective of whether the children have LI or RD. †Irrespective of whether the children have RD.
sustained auditory attention on APD results for four of the APD assessments (FPT, DDT, RGDT, and MLD). As there were no significant effects of test ear on FPT and DDT, scores for the two ears were averaged. Age, auditory memory, and auditory attention explained 21.6% of the variance in FPT scores. Partial correlations with FPT scores were .32 and .30 for auditory memory and auditory attention, respectively. Age, auditory memory, and auditory attention explained 28.5% of the variance in DDT scores. Partial correlations showed significant links between DDT scores and age ($r = .34$), and between DDT scores and auditory attention ($r = .44$). Attention and memory had no significant effect on RGDT or MLD scores.

**Discussion**

**Diagnosis of APD, LI, and RD**

Unfortunately, there are no widely recognized “gold standards” for identifying APD, RD, and LI; therefore, the extent of comorbidity of these conditions will depend on the specific diagnostic tests used to assess these different areas of difficulty as well as test sensitivity and specificity. Only two of the APD tests used in the current study, FPT and DDT, are extremely well-established measures of auditory processing with good sensitivity and specificity (Musiek & Chermak, 1994).

As noted earlier, there is considerable variation in the criteria used to diagnose RD and LI; consequently, the overlap between APD, RD, and LI groups is likely to vary between studies. Many definitions of LI require nonverbal IQ scores within the normal range; however, the criterion for nonverbal intelligence standard scores varies from 75 to 85 across studies (Kamhi, 1998). Stark and Tallal (1981) recommended using a representative set of language tasks to diagnose LI, rather than using one task (Plante, 1998). Despite these variations in definitions between studies, the overlap in APD, LI, and RD is consistent with Bishop, Bishop, et al. (1999) and Ramus et al. (2003).

Bishop, Bishop, et al. (1999) compared auditory processing abilities (on the basis of Tallal and Stark’s, 1981, auditory repetition task) in children with and without LI. All the children had nonverbal intelligence scores of 80 or above; however, the children with LI had a 15-point discrepancy between their receptive language and nonverbal intelligence scores. The auditory processing findings were equivalent between groups. In the current study, children with APD with and without LI had similar mean scores on FPT, DDT, MLD, and RGDT measures of auditory processing (see Table 2). Thus, children with similar profiles of auditory processing difficulties may or may not have LI; therefore, it is not possible to predict the presence of LI in children with APD on the basis of the APD tests used in the current study. This is consistent with the recommendations of the ASHA Task Force on Central Auditory Processing Consensus Development (1996) and the ASHA Working Group on Auditory Processing Disorders (2005) that children with suspected APD have both audiological and speech-language assessments.

Thirteen children with LI had no APD on the basis of the measures used in the current study. The 39 children with both LI and APD (with and without RD) all had difficulty with auditory processing tasks that required temporal processing (FPT, RGDT, and/or MLD). There is evidence that temporal processing performance very early in life predicts later language performance (Benasich et al., 2006; Benasich & Tallal, 2002; Guttorm et al., 2005), and there is considerable support for the view that temporal processing disorders are causally linked to LI and RD (see review by Tallal, 2004). At first glance, the finding that not all children with LI had APD in the current study appears to contradict this view; however, this ignores the potential long-lasting impact of APD early in life on language and reading development, even if APD goes on to resolve. An older child could have LI and/or RD but no concurrent APD, even when there is an auditory basis to the LI/RD, if the APD has resolved as a result of maturation, the learning and/or home environment, and so forth. This highlights one of the main limitations of cross-sectional studies. Longitudinal studies that begin early in life are needed to be able to draw conclusions about causality as well as comorbidity.

There is objective evidence from a longitudinal study of 109 typically developing children for a link between early auditory processing and later reading ability (Espy, Molfese, Molfese, & Modglin, 2004). Espy et al. (2004) measured auditory evoked potentials (AEPs) to speech and nonspeech sounds and found that the rate of maturation of AEP amplitudes from 1 to 4 years and from 4 to 8 years was predictive of word-level reading at 8 years. Sharma et al. (2006) found significant differences in AEPs between school-age children who had never experienced reading difficulties versus children with a history of reading difficulties who had reading scores within the normal range at the time of testing (“compensated” readers). Thus, even though reading performance was normal, there was electrophysiological evidence for different underlying auditory processing in children with previous reading difficulties. It is also possible that the children with LI and no evidence of APD in the current study might have electrophysiological evidence of altered auditory processing. Thus, longitudinal studies using both electrophysiological and behavioral measures of auditory processing, language, and reading would help our understanding of the causal links between these conditions.

Pogorzelski and Wheldall (2002) defined reading accuracy and fluency as poor when scores were more
than 1 SD below the mean for typically developing age peers. The same criterion was used to define a problem on phonological awareness tasks. There were 10 QUIL subtasks, all of which produced a wide range of performance. The subtasks producing the highest average scores were phoneme segmentation and syllable segmentation. Performance was poorest overall for non-word reading and spoken rhyme. For 5 of the QUIL tasks—nonword reading, syllable segmentation, syllable identification, phoneme detection, and rhyming—only 16 children passed. Previous studies have used some of these tasks to identify a phonological awareness deficit. For example, Heath and Hogben (2000) measured phoneme detection; Leitao, Hogben, and Fletcher (1997) measured phoneme segmentation and nonword reading; and Rack, Snowling, and Olson (1992) measured nonword reading. Unfortunately, there is no clear consensus in the literature regarding which phonological awareness tasks are most reliable and valid.

To determine the link between phonological awareness and auditory processing, correlations were calculated for APD and QUIL test results for the seven QUIL measures used in conjunction with WARP scores to identify children as RD. The strongest relationship between auditory processing and phonological awareness was for the FPT. Although a number of correlations were statistically significant (see Table 4), the size of the correlations was weak to moderate. Sharma et al. (2006) found a similar correlation between FPT and nonword reading in children with RD.

Comorbidity of Auditory, Language, and Reading Processing Disorders

This study used a comprehensive battery of tests from a range of disciplines to determine how often children with suspected APD have a pure disorder as compared with APD comorbid with reading or LI. Only 4 of the participants had come to the study with a diagnosis of APD; the remainder had come from different sources (on the recommendation of teachers, educational psychologists, special educators, and parents) with suspected APD.

Nearly half of the children (47%) had problems in all three areas (APD, LI, and RD), whereas only 4% had pure APD. One possible explanation for this overlap between disorders is that currently available assessment tools are not adequately able to distinguish between auditory, language, and reading dysfunction. It is possible that failed results on multidisciplinary assessments reflect a single, global disorder that manifests itself in multiple areas rather than individual, comorbid disorders. Bishop, Bishop, et al. (1999) wondered whether this common link was auditory attention. In the current study, significant correlations \((p \leq .04)\) were noted between auditory processing, language, and reading abilities and auditory attention and auditory memory. Though significant, the correlations were at best modest \((r \leq .50; \text{see Tables 4 and 5})\). Thus, auditory attention and memory may be contributing to performance on the auditory processing, reading, and language tasks; however, these explain a minimal amount of the variance in the data. Also, in a few children, attention deficits occurred in the absence of auditory, reading, or language deficits. Thus, the data from the current study do not clearly support attention or memory as the key underlying link between the auditory processing, reading, and language dysfunction. If there is an underlying ability that links auditory processing, reading, and language, another possible candidate is perceptual learning (Moore, Amitay, & Hawkey, 2003). As noted by Moore et al. (2003, p. 83), there is evidence that the language abilities of children with LI can improve after training that is based on the principles of perceptual learning (Kujala et al., 2001; Merzenich et al., 1996; Tallal et al., 1996).

Table 4. Pearson’s correlations \((r)\) between the APD test scores (FPT, DDT, MLD, and RGDT), sustained auditory attention, auditory memory (Digit Span Subtest and CELF-4), and seven of the QUIL subtasks used to identify phonological awareness difficulties (nonword reading, syllable identification, syllable segmentation, rhyme, phoneme detection, phoneme segmentation, and phoneme manipulation).

<table>
<thead>
<tr>
<th>Test</th>
<th>Nonword reading</th>
<th>Syllable</th>
<th>Identification</th>
<th>Segmentation</th>
<th>Rhyme</th>
<th>Detection</th>
<th>Segmentation</th>
<th>Manipulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPT</td>
<td>.625**</td>
<td>.292*</td>
<td>.373**</td>
<td>.387**</td>
<td>.321*</td>
<td>.281*</td>
<td>.439*</td>
<td></td>
</tr>
<tr>
<td>DDT</td>
<td>.242</td>
<td>.381*</td>
<td>.215</td>
<td>.124</td>
<td>.115</td>
<td>.281*</td>
<td>.439*</td>
<td></td>
</tr>
<tr>
<td>MLD</td>
<td>.067</td>
<td>.271</td>
<td>.365*</td>
<td>.051</td>
<td>.253</td>
<td>.139</td>
<td>.195</td>
<td></td>
</tr>
<tr>
<td>RGDT</td>
<td>-.263</td>
<td>-.204</td>
<td>-.033</td>
<td>-.443</td>
<td>-.005</td>
<td>-.178</td>
<td>-.175</td>
<td></td>
</tr>
<tr>
<td>Attention</td>
<td>.384**</td>
<td>.333**</td>
<td>.347**</td>
<td>.287*</td>
<td>.460**</td>
<td>.033</td>
<td>.340**</td>
<td></td>
</tr>
<tr>
<td>Memory</td>
<td>.344**</td>
<td>.377**</td>
<td>.157</td>
<td>.198</td>
<td>.252</td>
<td>.143</td>
<td>.281</td>
<td></td>
</tr>
</tbody>
</table>

Note. Scores averaged across ears were used for the FPT and DDT tests. Values in bold indicate significant links.

\(^{*}p \leq .025. **p \leq .002.\)
Perceptual learning abilities have generally not been explored in studies investigating the link between APD, LI, and RD in children; therefore, this is an area for future research.

Regardless of the underlying basis—because of the high likelihood of auditory, language, and reading difficulties co-occurring in children with suspected APD—professionals should be aware of the need for these children to have a range of assessments. Richard (2007) suggested that APD should not be diagnosed without language being assessed. The tests used in the current study to assess auditory processing were chosen because of their good sensitivity and specificity, minimal linguistic loading, and simplicity of the instructions. There are many other auditory processing assessments available clinically that use more complex speech stimuli that are likely to tap into both auditory and language abilities. The test battery needs to be selected carefully for areas of specific strengths and difficulties to be correctly diagnosed across areas using a multidisciplinary approach.

### Auditory Processing Characteristics of Children With APD

Figure 7 shows the language and reading patterns for children with different types of difficulties on the APD test battery. The purpose of examining the data in this way was to determine whether different types of APD results are associated with specific difficulties on the other tasks. For example, do children who have problems only on FPT have a distinctive pattern of reading or language difficulty that is different from children who have difficulty on both FPT and DDT? As Figure 7 shows, the differences in reading and language results between groups of children with different outcomes on the APD test battery were not clear. Bishop, Carlyton, et al. (1999, p. 1295) concluded that APD is “not necessary nor sufficient for causing LI in children,” on the basis of their study of auditory processing abilities of twin pairs 8–10 years of age. Unfortunately, the current study and previous studies—such as Bishop, Carlyton, et al.—are limited by the lack of information on the auditory processing status of the children very early in life.

Auditory processing abilities of children with different comorbidities (APD–LI–RD, APD–LI, APD–RD, and LI–RD) were compared using an ANOVA, with test ear as a within-subject factor and age as a covariate. Age had a significant effect on FPT, DDT, and RGDT scores. K. M. Walker, Hall, Klein, and Phillips (2006) reported similar maturational effects on auditory processing. FPT performance differed significantly across groups. Children with all three areas of difficulty (APD–LI–RD) performed most poorly on the FPT task. The FPT task is quite complex, requiring a number of auditory skills, including frequency discrimination and temporal pattern perception; therefore, it is not surprising that performance on this task was problematic for the children in the APD–LI–RD group.

K. M. Walker et al. (2006) found a correlation between gap detection and language/reading performance. In the current study, RGDT scores did not differ between groups. This may be due to the small number of participants in some of the subgroups in the current study and also to differences between the RGDT and K. M. Walker et al.’s gap detection tasks. The finding that the 3 children with APD only had very poor gap detection is of interest. Because there are few children in this group, it is difficult to draw conclusions; however, it would be useful in future research to find a larger group of children with poor temporal processing and age-appropriate language and reading to determine factors that may have contributed to these children compensating for or being resilient to language and reading difficulties.

### Attention and Memory

The presence of auditory attention problems in 30 of the 49 children with APD (58.6%) was not surprising because comorbidity of APD and attention disorders has been reported previously (Ricco, Hynd, Cohen, Hall, & Molt, 1994). Although attention and APDs overlap, they are recognized as separate diagnostic entities (Keller & Tillery, 2002), as they do not necessarily occur together, as demonstrated here. There was a very small number of children who showed attention or memory problems in the absence of APD.

The link between sustained auditory attention and auditory memory (see Table 5) and FPT and DDT scores is not surprising. The FPT task was the most complex of the auditory processing measures in the current study.
Figure 7. Distribution of difficulties on reading and language tasks among children grouped together on the basis of their areas of difficulty on the APD test battery (FPT; FPT and DDT-R; FPT and DDT; FPT and RGDT; FPT, DDT, and RGDT; FPT, DDT, and MLD; no APD). The six columns denote the number of children within each APD group who showed difficulties on the Wheldall Assessment of Reading Passages (WARP; word accuracy and fluency) and phonological awareness (PA), showed difficulties on the WARP only, showed difficulties on the PA only, had overall language scores (receptive and expressive) below 80 (horizontal lines), had overall language scores below TONI scores, and had no RD or LI.

- **WARP & PA**
- **WARP**
- **PA**
- **Language Scores < 80**
- **Language Scores > TONI**
- **NO RD or LI**
requiring children to attend to instructions, discriminate tones of different frequencies, and remember and label an auditory sequence. Scores on the DDT task were not correlated with memory but were correlated with sustained attention. Care was taken to ensure children were performing optimally, with session times shortened if necessary. Ideally, assessment sessions should be short with adequate practice to make sure that the child has understood the task and reinforcement to ensure that the child remains on task (Silman, Silverman, & Emmer, 2000). This flexibility is possible in a research setting but may not always be possible clinically. Unfortunately, if auditory attention is extremely poor, an inaccurate diagnosis of APD could occur (Sutcliffe, Bishop, Houghton, & Taylor, 2006). Motivation is another important consideration. Chermak (2005) suggested that if performance is poor for all APD tasks, then the audiologist should suspect global deficits, such as poor attention, memory, language, or motivation.

Another question of interest in the current study was whether children with lower nonverbal intelligence scores have the most coexisting problems. Table 2 presents the average TONI-3 scores for the different groupings of the children, showing considerable overlap in the scores. An ANOVA—with age as a continuous predictor—comparing the TONI-3 scores of the children with APD, LI, and RD (n = 32) versus children with fewer difficulties (n = 36) showed no significant difference, F(1, 63) = 0.4, p = .538. Therefore, children with lower cognitive scores did not necessarily have more problems across tasks.

**Conclusions**

More than half of the participating children showed comorbidity of APD, LI, and RD. Scores for two of the APD tasks were linked to auditory attention (FPT) and/or memory (FPT and DDT); however, only weak correlations were obtained, indicating that these abilities only had a minor effect on scores. There were only modest correlations between auditory attention, auditory memory, reading, and language performance. Children in the APD–LI–RD group had the poorest FPT scores. Children presented with a number of different combinations of difficulties, however, highlighting the importance of assessing language, reading, attention, and memory in addition to auditory processing. There is consensus that interventions for children with APD should be customized and deficit focused (ASHA Working Group on Auditory Processing Disorders, 2005). To achieve this, audiologists need to carefully consider the choice of assessments and ensure that children are performing optimally; in addition, they need to ensure that they work collaboratively with related professionals, such as speech-language pathologists and educational psychologists.

**References**


