

## Use of the California Consonant Test with Children

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**The potential advantages of using the California Consonant Test (CCT) (Owens & Schubert, 1977) with children are discussed, followed by reports of two exploratory investigations. In the first investigation, the CCT was administered in classrooms to second, third and fourth graders with normal hearing. The children scored within 13% of an adult control group, suggesting that the CCT was not too difficult for them. In the second investigation, the CCT was administered to 11 children with hearing loss in classrooms with various amplification combinations. Their scores were lower and more variable than the scores of the children with normal hearing, but all scored above chance, suggesting that the CCT was within their capabilities as well. Additional areas of research and uses of the CCT with children are discussed.**

The purposes of this study were twofold: (1) To present the characteristics of the California Consonant Test (CCT), a test designed for adults with high-frequency hearing loss (Owens & Schubert, 1977), that make it well-suited both for assessing the speech discrimination abilities of young children and for comparing the efficacy of amplification systems; and (2) to explore the feasibility of using the CCT with young children with and without hearing loss in assessing speech discrimination under various conditions.

Assessing speech recognition/discrimination in children is challenging. Children often lack the vocabulary and the metalinguistic skills that adults bring to a speech understanding task. Individuals are more likely to respond correctly when the stimulus is a familiar word (Brandy, 2002; Kirk, Pisoni & Osberger, 1995). Because children's vocabularies are smaller than adults', they are more likely to err in an open-set task. For example, to the phrase "Amphibians come from eggs," a young child may volunteer "My Aunt Vivian (read amphibian) comes from Ohio." Also, children's articulation may be faulty, leaving unresolved the question of whether a response was incorrect or misarticulated. A sign, fingerspelling or use of the word in a sentence may clarify the response, but this process increases test time and potential fatigue. Requesting clarification also may complicate or preclude the use of recorded materials, thereby reducing test reliability (Brandy, 2002).

Picture selection tests, such as the Word Intelligibility by Picture Identification Test [(WIPI); Ross & Lerman, 1970] and the Northwestern University Children's Perception of Speech [(NU-CHIPS); Elliot & Katz, 1980] are closed-set tasks, reducing the number of possible errors and eliminating the issue of articulation problems. However, the contrasts between the targets and foils on these tests involve gross discriminations in that items differ on more than one consonant, on the vowel, or the consonant contrasts differ on multiple distinctive features.

### Rationale for CCT Use with Children

A speech discrimination test that may be a useful addition to the battery of pediatric tests is the CCT (Owens & Schubert,

1977). Potential advantages of the use of the CCT with children are that it is a closed-set test and that it focuses on high-frequency sounds in the final position of words, the sounds most easily lost in classrooms (Boothroyd, 2005). The CCT is a written test consisting of 100 consonant-vowel-consonant items, each item consisting of a target and three foils. There are 64 items with final consonant contrasts and 36 items with initial consonant contrasts (Owens & Schubert, 1977). Although the CCT was designed for adults with high-frequency hearing loss, the reading level required theoretically is not above that of children in second grade (Illinois State Board of Education, 2000). In addition to requiring finer discriminations than other closed-choice tests, the CCT has other characteristics that make it a good choice for use with young children. Commercial recordings of the CCT are available (Auditec of St Louis) which provide control of the variables associated with live-voice delivery. There are two equivalent 100-item lists and the halves of List 1 are also equivalent (Owens & Schubert, 1977), allowing testing under different conditions. Using half lists, each of which take six minutes to administer, seems a reasonable demand on young children's attention. Also, the CCT targets are mostly high-frequency, low-energy consonants (80 voiceless versus 20 voiced) and most contrasts (64 of 100) are in the final position of words where the consonant is less stressed. These sounds are probably least available to young children in most listening situations (Flexer, 2005). Another advantage is that the structure of the CCT focuses attention on the acoustics of the task. Whether the children know the words is irrelevant. Each written item differs on either the initial consonants or the final consonants. The children need only determine which end of the words differ, and attend to that part of the stimulus given.

### Rationale for CCT Use in Comparing Amplification Systems

One use of the CCT with young children is in comparing classroom amplification systems. Classroom amplification systems are designed to provide a fairly equal and improved signal-to-noise ratio (S/N) throughout a classroom, reducing the effects of distance and noise on the students' ability to perceive as much

of the speech signal as possible no matter where in the classroom they are (Flexer, 2005). However, a good S/N does not ensure a good speech signal; high-frequency energy must be preserved for optimal speech understanding (Boothroyd, 2005). Consonant sounds have less energy than vowels at the source and that energy is lost more quickly with distance than is vowel energy (Flexer, 2005). To ensure that access to auditory information provided by classroom amplification is optimal, one must deliver high-frequency information throughout the listening space. Preserving high-frequency information at angles other than 0° azimuth is a challenge with traditional speakers (Mapp & Collums, 1997).

Because the CCT focuses on high-frequency phonemes, mostly in the final position of words where the consonant is less stressed, it is ideally suited to determining if one speaker configuration or speaker type is preserving the information most critical to speech understanding. Preservation of high-frequency information can be measured with equipment, such as a sound level meter with an octave band filter, but whether and how that preservation translates into better speech understanding in any particular group of listeners is not known. For example, Prendergast (2001) showed that a bending wave speaker preserved 3.4 dBA more energy in the 2000 Hz octave band and 15.1 dBA more in the 4000 Hz band than did a traditional speaker and children scored significantly better on the CCT with the former. However, what degree of high-frequency preservation in which bands accounted for the improved speech discrimination is unknown.

Manipulating high-frequency preservation while measuring speech discrimination is a means of exploring that variable. Again, the equivalent lists and half lists of the CCT make it a suitable instrument for such studies.

### Comparisons of Classroom Amplification Systems Using Closed Set Materials

The WIPI has been used to compare word discrimination performance of Kindergarten through third-grade children in classrooms using different classroom amplification speaker configurations (Prendergast, 1999). Although statistically significant differences were found between the different speaker configurations, a ceiling effect was evident (i.e., a large proportion of children scored at or near 100% under each condition). Larger differences between conditions may have been masked because the level of discrimination required by the WIPI was not sufficiently difficult.

The CCT also has been used to compare classroom amplification systems with third- and fourth-grade children (Prendergast, 2001). A statistically significant difference was found, but the children's scores were low (58.06% for traditional speaker and 65.68% for bending wave speaker). This may suggest that the speech discrimination or reading skills required by the CCT were too difficult for this age group. However, there are other plausible explanations for the low scores. These include the quality of the CCT recording, the response time demands of the recorded test, and the potential confusion due to the unconventional order of test items. The CCT recording used was of poor quality. A compact disk recording was ordered for the investigation, but when it arrived shortly before scheduled data collection, it was

clearly a damaged disk. Several adults with normal hearing were unable to differentiate many of the targets from the foils under ideal listening conditions. Therefore, an audiotaped version of the CCT was transferred to another CD. Although the tape-to-CD version was somewhat more intelligible than the damaged CD, it presented a more difficult listening task than a well-recorded CD would have provided. Data collection proceeded despite the poor recording because all conditions were equally disadvantaged and rescheduling would have been a hardship on the students and teachers. The low scores also may have been due to the time demands of the test, or the possible confusion in following the test order, as the items are numbered down columns rather than being numbered from left to right. Thus, the CCT has characteristics that theoretically make feasible its use with young children. It has been used with older primary-aged children, but their scores were fairly low. Several variables may have contributed to the low scores and some of those can be altered for investigation. Additional data collection is necessary to determine the actual utility of the CCT with young children.

### Investigation #1: Feasibility of Using the CCT with Young Children

The purposes of the first exploratory investigation were to determine (1) if the relatively poor performance of third and fourth graders seen previously would improve with a good quality recording and more detailed instruction, (2) if it is feasible to use the CCT with second-grade children, and (3) to determine if the performance of the grade-school students was comparable to that of young adults.

### Methods

*Participants.* Subjects included 67 students in second grade, 80 in third grade, 71 in fourth grade and 44 students in their junior or senior year in college (Table 1). Many of the fourth-grade students had been tested as third graders. However, because the second data collection was 6 months after the first, it is unlikely that any practice effect existed (Owens & Schubert, 1977). The students were recruited from the University Lab School and from undergraduate audiology classes. All of the grade-school students whose data are included had passed their mandated school pure tone hearing screenings. They also passed distortion product otoacoustic emission (DPOAE) screening (Maico ERO-SCAN) at 1500 Hz, 2000 Hz, 3000 Hz, 4000 Hz, 5000 Hz, and 6000 Hz, with +5dB signal-to-noise ratio (S/N) at 3 of 6 frequencies or more within a week of data collection. If a child failed the DPOAE screening, immittance screening was done (Madsen Electromedics Model RCT). A failure was a Jerger Type B or C tympanogram (Jerger, 1970). The majority of immittance failures subsequently passed both immittance and DPOAEs immediately before data collection. Data from those who did not pass both were not included in the results. All of the college students underwent hearing testing within the year as a class project. All reported hearing within normal limits, bilaterally.

*Classroom arrangement and data collection schedule.* Data collection with the children was accomplished as part of four graduate-student projects, each of which had a different research question. However, all used the same inclusion criteria for subjects and the same data collection methods. The college students participated as part of a class project. Data collection was carried out at three times over 9 months (May, November and February) and a fourth time, 15 months later, in May.

The instrument set-up and signal delivery level were the same as described for the bending wave classroom amplification condition in Prendergast (2001) for all but one group of subjects. A LightSpeed 500C classroom amplification system with an ARQ1 picture panel speaker was used. The speaker was positioned according to manufacturer's instructions. In both classrooms, placement was 6 feet 6 inches above the floor in the center of the north wall of the classroom, behind the typical instructional position. A Compact Disc (CD) player (Sony CFD-S38) was placed to simulate typical teacher instructional position. The CD player was on top of a 4-foot, 8-inch cart placed where the teachers generally lectured and the center of the CD speaker was 5 feet, 2 inches above the floor, at approximately the height of the teacher's mouth. The flexible-collar teacher microphone from the CA system (LightSpeed Model LS4/TMP) was affixed two inches in front of the CD player speaker to simulate placement relative to the teacher's mouth. The volume control of the cassette player was adjusted so that the CCT 1000 Hz calibration tone was 58 dBA (the average of one teacher's unamplified voice during instruction) measured at 3 feet in front of the teacher instructional position. The classroom amplification system was then adjusted so that the amplified calibration tone measured 68 dBA at the same position. This +10 S/N was chosen because it is typically what is achieved with classroom amplification (Crandell, Smaldino & Flexer, 2005). A commercially available CD recording (Auditec of St. Louis) of the CCT list 1 was used. The classroom amplification system was used with all of the subjects except the last group tested (second group of second graders). The level of signal delivery for them was the same (68 dBA), but amplification was not used because that was not part of the research question. Occupied classroom noise and speech signal levels were taken at child ear level (Quest M215 Sound Level Meter, A scale) at six to eight sites throughout the children's group instructional seating area. The signal to noise ratios (S/N) were recorded preceding each data collection session, averaged and rounded to the nearest whole decibel.

The first data collection session was with third- and fourth-grade children in May when the heating, ventilation and air conditioning system (HVAC) was not on and the average S/N was +18 dB, above the +15 dB recommended for children with hearing loss (ASHA, 1995; Crandell & Smaldino, 2000). In November, a new cohort of third graders and fourth graders, most of whom had been tested as third graders in May, were tested with the HVAC on. The average S/N ratio was +9 dB, less favorable, but still better than that found in many elementary classrooms (Crandell & Smaldino, 2000). The third data collection session was done with second graders and college students in February with HVAC on and an average S/N of +10 dB. The fourth data collection session involved second graders tested 15 months later in May without HVAC and without classroom amplification (S/N

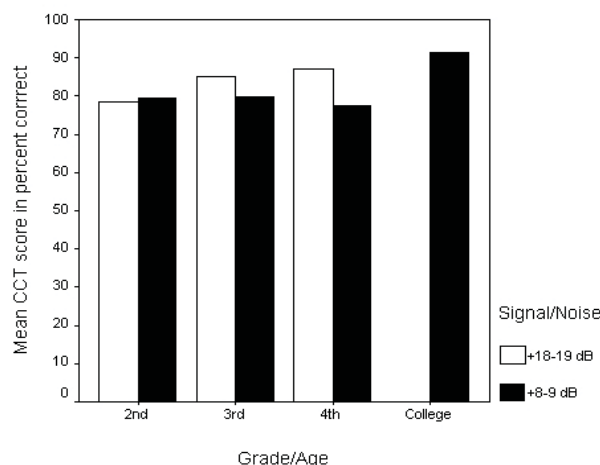
averaged +19 dB). This good S/N was due to closed windows, a fortuitous lack of hall and vehicular traffic noise, and the addition of some carpet pieces on the classroom floor.

All of the second-grade and college students were tested in the same second grade classroom, whereas the third- and fourth-grade students were tested in the same fourth grade classroom. Both classrooms were 30' X 30' with 9' ceilings and had reverberation times of .713 seconds as estimated by the procedure recommended by Smaldino and Crandell (1995). The actual reverberation times were not likely to be the same due to the effects of various items in each classroom, but the rooms were identical otherwise (e.g. size and placement of windows, doors, white boards, etc.) The seating arrangements were determined by the host classroom teachers and differed for the four data collection times. The college students were given standard instructions (Owens & Schubert, 1977) and provided with recorded practice items. The grade-school children were given group and/or individual instruction, written practice items, and instruction on how to mark their test forms (see Appendix).

Children's CCT forms were shielded by two file folders stapled together to form a visual barrier on three sides. Children were encouraged to attend only to their own test form. Three to six adult monitors were present to encourage independent work, replace broken pencils, and help children who lost their place (item numbers are not articulated on the recording).

Two graduate students or a graduate student and the principal investigator scored the CCT forms. Interscorer reliability exceeded 95% for all groups. Most disagreements were due to ambiguous markings between two choices. Disagreements were numbered consecutively on the answer sheets. Even-numbered disagreements were scored as the choice above the ambiguous mark and odd-numbered disagreements were scored as the choice below an ambiguous mark. Because the purpose of the investigation was to explore the feasibility of CCT use with children and because there were many uncontrolled variables, only descriptive statistics were used for analysis (Statistical Package for the Social Sciences, 1999)

**Figure 1. California Consonant Test (CCT) scores for various aged students under favorable and unfavorable signal-to-noise ratios (S/N)**



**Table 1. Subject information, signal to noise ratio (S/N) and results of the California Consonant Test for second, third, and fourth graders and college students.**

Grade of subjects (Month tested)	# of subjects	Male	Female	Mean % Correct	Range	s.d.	Mean S/N
2nd Grade (Feb)	34	16	18	79.53	68% - 90%	5.99	+10 dB*
2nd Grade (May)	34	14	19	78.36	66% - 90%	6.39	+19 dB**
3rd Grade (May)	35	18	17	85.14	70% - 96%	6.10	+18 dB
3rd Grade (Nov)	45	22	23	79.73	64% - 92%	6.35	+9 dB*
4th Grade (May)	36	15	21	87.17	76% - 94%	4.91	+18 dB
4th Grade (Nov)	35	19	16	77.60	68% - 86%	5.41	+9 dB*
College (Feb)	44	11	33	91.35	78% - 98%	4.42	+10 dB*
Total	262	115	147				

\* Data collection with HVAC system operative. S/N could not be improved without distortion.

\*\* Classroom amplification not used.

## Results

Results are reported in Table 1 and graphically depicted in Figure 1. The third and fourth graders did nearly as well as the college students when the S/N was very favorable. Second-grade children with the HVAC system operating scored within 12% of the college students' scores under similar circumstances. With no HVAC and no classroom amplification, second graders scored about the same as their age peers with HVAC and classroom amplification. The older elementary students under excellent conditions scored within 4 to 6 % of the college students, but their scores were similar to the second graders' when conditions were less favorable. Results showed a general improvement in performance with increasing age under favorable conditions: The third grade students' mean score (85.14) was better than the second graders' score (78.36), but poorer than the fourth graders' mean score (87.17). Under less favorable conditions, the scores for the elementary students were similar across grades and no pattern was apparent. There were no ceiling or floor effects; no subject scored 100% and all students scored well above chance.

## Investigation #2:

### Comparing Devices with Children with Hearing Loss

The previously described investigation suggested that the CCT is an appropriate instrument to use with young children. Prendergast (2001) demonstrated that the CCT can be used to compare classroom amplification systems. It may be reasonable, therefore, to consider using the CCT in the investigation of the effects of personal and classroom amplification in various combinations on speech discrimination of children with hearing loss. Prendergast (2001) found that, with the introduction of classroom amplification into regular division classrooms, several students with hearing loss who were mainstreamed in those rooms claimed that they did as well with their hearing aids and the classroom amplification system as they did with a personal FM system. The superiority of personal FM systems over hearing aids alone has been established (Ross & Giolas, 1971) and there is no reason to expect that classroom amplification systems can replace personal

FMs (Smaldino, Crandell & Flexer, 2005). However, results from group research cannot determine the best system combination for an individual. Because objective verification may be required to support recommendations for individual students, the second investigation was designed to determine the feasibility of using the CCT to compare children's speech discrimination performance using classroom and personal amplification and/or personal FM.

## Method

*Participants.* Subject data are reported in Table 2. Subjects were 11 students with hearing loss who participated for at least part of each day within a regular division classroom that was equipped with classroom amplification. They ranged in age from 9 years, 5 months to 13 years, 6 months and exhibited hearing losses in the better ear ranging from moderate to profound. They wore a variety of behind-the-ear (BTE) personal amplification devices and each had been fitted with a Telex Select 2-40 BTE FM. All devices were adjusted by the educational audiologist to maximize speech audibility using real ear measures and the DSL i/o method with an Audioscan (Model RM 500, software 3.2). These adjustments were performed on the FM equipment at the beginning of the school year. Devices were monitored frequently. All of the children were receiving aural rehabilitation (AR) therapy twice a week. At the beginning of each session, each child was given the Ling six sound test (Ling, 1976; Koch, 1999) with silent foils and device problems were reported promptly to the educational audiologist. The children usually announced to their AR therapist that their hearing aid or FM was not working as they entered the therapy room. The children typically were reliable reporters on the condition of their equipment.

*Procedures.* It was determined that all of the children's devices were working properly before data collection, first by asking the children. If they responded negatively and if battery replacement did not correct the problem, data collection was postponed until electroacoustic analysis indicated the unit was functioning ap-



appropriately. The children also were given the Ling six sound test (Koch, 1999) with silent foils immediately before data collection. If any doubt existed regarding the functioning of any device, data collection was rescheduled. The children were given instructions as outlined in the Appendix.

All children were given the CCT under two conditions: With and without personal FM equipment. The order of conditions and CCT half lists were counterbalanced. For some children, the two conditions were (1) binaural hearing aids with classroom amplification only and (2) a hearing aid in one ear, a BTE FM in the other ear (the better ear if there were one) with classroom amplification. There were five children in this group, ranging in age from 10 years 1 month to 13 years (Group 1). Six other children were tested with monaural personal amplification and classroom amplification (Group 2). Two children wore only one hearing aid because they had a “dead” ear that had never been fit with amplification. These two children were 11 years, 11 months and 13 years, 6 months of age. Four other children had been fit with binaural amplification, but for a variety of reasons, one aid was unavailable or in disrepair. All of these four children had been

functioning with a unilateral fitting for several weeks to several months. They ranged in age from 9 years, 5 months to 11 years, 3 months. For all six children with monaural amplification, the conditions were (1) classroom amplification plus hearing aid and (2) classroom amplification plus BTE FM in the aided ear.

The children were tested in the fourth-grade classroom and with the classroom amplification described in the first investigation. Data collection was accomplished in December over several sessions. A Telex teacher microphone was interfaced with the classroom amplification receiver/transmitter. Each subject’s BTE-FM was matched to the frequency of the teacher microphone by changing a receiver crystal. The CCT calibration signal was set at the same level as for the first investigation (68 dBA measured at 3 feet in front of the teacher instructional position). S/N levels were not measured due to the limited time that the classroom was available. Because there were fewer children in the room for any data collection session, it may be that the S/N was better than that measured the month before (+9 dB) with third and fourth graders.

**Table 2. Subject data and results on the Californial Consonant Test (CCT) for children using combinations of personal hearing aids (HA), classroom amplification (CA) and personal FM systems (FM).**

Group & Subject ID	Age	Better Ear PTA (dB HL)	Type of BTE	% CCT CA+HA	% CCT CA+FM	% CCT CA+HA+FM (difference)	% correct In sound suite-better ear (test used)
1a	10;1	73	Resound	52		72 (+20)	88% (CID-W22)
1b	11;2	50	Danavox	52		82 (+30)	88% (CID-W22)
1c	11;3	66	S.Prisma	46		68 (+22)	84% (CID-W22) Aided SF at 40 dB HL
1d	12;11	95	AVR Impact	30		58 (+28)	DNT
1e	13;0	93	Personic	60		72 (+12)	84% (LNT 1)
2a	11;11	88	Multifocus *	36	46	(+10)	32% (CID-W22)
2b	13;6	73	S.Music*	76	72	(-4)	88% (CID-W22)
2c	9;5	93	Pico Forte+	30	36	(+6)	28% (PBK List 3) Aided SF at 75dB HL
2d	9;6	68	Personic+	52	58	(+6)	84% (PBK)
2e	10;5	66	S.Music+	42	42	(0)	80% (LNT 1)
2f	12;7	76	Peronic+	34	44	(+10)	88% (CID-W22)

\* One aidable ear + Recommended binaural fitting - only one aid functioning/available.

## Results

Subject information and results on the CCT are reported in Table 2. CCT forms were scored as described previously. Interscorer reliability was 99.27%. There was great variability in the children’s scores, ranging from 30% to 82% in the binaural group (Group 1) and 30 to 76% in the monaural group (Group 2). All scored above chance. Group 1 averaged 48.0% and Group 2 averaged 45.0% without personal FM. All but two children had improved scores with the use of personal FM. Interestingly, the two who showed no improvement with FM (subjects 2b and 2e) were aided monaurally with a Siemens Music hearing aid, one because of an unaidable ear and the other because of disrepair.

Group 1 showed more improvement from the addition of personal FM with an average gain of 22.4% (to 70.4%), while the mean improvement for Group 2 was 4.7% (to 49.7%). Also included in Table 2 is the best speech recognition score obtained in an IAC booth during the same school year for each child. Most were obtained with insert earphones. Several instruments were used, ranging from the Lexical Neighborhood Test, Level 1 (Kirk et al., 1995) to CID-W22 word lists (Brandy, 2002). All of the tests used were open-set tests and, except for subjects 2a and 2c, percent correct scores were in the 80’s, suggesting excellent speech recognition in quiet. Only one child scored in the 80’s under the best conditions in the classroom with the CCT.

## Discussion

The CCT is particularly well-suited to comparing classroom amplification systems: It is weighted toward high-frequency, final consonant sounds (Owens & Schubert, 1977), the sounds most necessary for speech understanding and those most likely to be lost as speech moves into a space (Boothroyd, 2005; Flexer, 2005). These sounds are lost whether the source is unamplified voice (Boothroyd, 2005) or amplified voice delivered via traditional speakers (Mapp & Colloms, 1997). Determining that a classroom amplification system preserves high-frequency information well enough for young children to perceive critical elements of speech seems essential if students are to receive maximum benefit from these systems.

Results from the first preliminary investigation suggest that CCT use is feasible with children as young as second grade when they are given detailed instructions on how to attend to the items. No ceiling or floor effects were seen with any of the children and their scores ranged from 77.60% to 87.17%. The CCT scores of all of the children in this study were 15 to 20% better than those of the third and fourth graders reported earlier (Prendergast, 2001). Although the differences cannot be attributed with absolute certainty to the better recording and more detailed instructions, the magnitude of the differences suggests that this is probable. In addition, the children in the previous study were from the same school, had the same teachers and were admitted to the Laboratory school under the same demographic and socioeconomic guidelines as the children in the current study. In other words, ethnicity, educational opportunity, and socioeconomic status were not factors in the differences seen.

Results of Investigation #1 demonstrated that scores tended to increase with grade level under favorable S/N, but not under unfavorable S/N conditions. Increased speech discrimination ability with age has been demonstrated previously (Elliott & Katz, 1980; Prendergast, 1999), but the failure of the youngest students to benefit the most with improved S/N is contrary to other findings (see Crandell, Smaldino & Flexer, 2005 for a review). A possible explanation is that the children were not randomly assigned to groups within each grade level nor matched on salient variables such as reading level, developmental level, listening or attending skills, or related factors. Similarly, although it is not unexpected to see higher scores with better S/Ns with the same children tested under both conditions, the higher scores seen here with better S/N may be due to differences between the groups of children. The same can be said for the essentially identical scores achieved by the two groups of second-grade children under different S/Ns: The group with the more favorable S/N may have been poorer readers, or had poorer attending, listening, or related skills than the group with the less favorable S/N. It also is not surprising that the college students scored somewhat better than the younger children not only because of their age advantage, but also because they are upper classmen in college, not representative of people their age and presumably more experienced in test taking than grade school children and other young adults not in college. The time demands of the CCT recording and the nontraditional item ordering may have impacted the younger children more than the college students. However, the children did not ap-

pear to be rushed by the allotted response time: Most made their selection quickly and waited for the next item. The placement of the test items in columns confused a few children, despite reminders before the session, but help from an adult during data collection resolved the problem.

Additional research is needed to determine what high-frequency preservation is required for optimal speech understanding in the classroom for children with normal hearing. This could be accomplished using the CCT and comparing scores across various modifications in high-frequency emphasis/ preservation. Also, it is possible to do distinctive feature scoring of the CCT (Feeny, 1990). In distinctive feature scoring, more credit is given for responses that are almost correct (+2 for correct responses, +1 point for responses differing by one distinctive feature) than for those that are far from the target (-1 point for differences of 2 to 5 distinctive features). Because an additional point can be taken off for the response least like the target, it is possible to obtain a negative score if many of the responses are far from the mark. This finer scoring is ideal for comparing systems because it more clearly reflects how much auditory information is being perceived. If higher scores result from distinctive feature scoring than from traditional scoring, chances are that the responses are not random, but are near misses. Error analyses of CCT results are also possible (Prendergast, 2004) so that relationships between error patterns and particular frequency modifications can be explored and used to improve system output.

In the second investigation, no ceiling or floor effects were seen with the children with hearing loss: None of the children scored 100% and all of the children scored above 25% (the level of chance) although it could be argued that scores in the low 30% range may be due to chance. However for most of the children with hearing loss, the CCT appears to be a feasible instrument for measuring efficacy of amplification systems and combinations thereof.

It was not surprising that the subjects fitted with a personal aid and a BTE FM in a classroom also equipped with classroom amplification did better than those with only one hearing aid with classroom amplification. However, the very modest gains seen for those fit with only the BTE FM are noteworthy. It is likely that classroom amplification and any advanced circuitry in the hearing aid each provided some benefit for those fit monaurally. Both possible sources of benefit were lost with the switch to the BTE FM. Comparison of aided CCT scores with and without classroom amplification would address the amount of benefit from classroom amplification alone. Comparison of CCT scores obtained with BTE FM units and small, self-contained FM receivers booted to hearing aids would address the benefit of the advanced circuitry (provided that the advantages of advanced circuitry were maintained with the boot). The relatively poor performance of the monaurally fitted children (mean scores of 45.0% and 49.7%) underscores the importance of binaural fitting, where possible, in classroom listening. The lack of improvement or minimal gain seen in the FM condition for this group also seems to justify individual determination of benefit from amplification system combinations. The theoretically preferred configuration (if binaural personal booted FM is not possible due to budget

constraints) is a hearing aid plus hearing aid booted with FM in a classroom with a good classroom amplification system.

Only two of the children with hearing loss scored as well or better on the CCT under both classroom conditions as they did on the open-set speech recognition tests that were administered during their annual audiological evaluations. This may be due to the challenging nature of the CCT for children whose hearing losses are greater in the high frequencies than in the lows, the classroom listening conditions, or both. However, a score of 88% on an adult speech recognition test in an evaluation suggests fairly good skills, while scoring 34% on the CCT in the classroom suggests otherwise (subject 2f). Comparing the CCT performance of children with hearing loss in the classroom and in the test suite would address the impact of the listening environment for that test in that population. Similarly, comparing the CCT performance of children and college students with normal hearing under the same two conditions would indicate differential effects, if any, of the listening environment on the different populations. The large differences between CCT scores in the classroom and the scores on the annual evaluation tests for most of the children with hearing loss in this study underscores the need for caution in generalizing performance from the test suite to the classroom.

Reluctance to generalize performance in the sound suite to performance in the classroom led to the development of The Functional Listening Evaluation (Johnson & Von Almen, 1997). This procedure is intended to determine the effects of noise, distance and visual input on a child's listening ability in the classroom using sentence and/or single word stimuli. Currently, the recommended single word tests are the WIPI, NU-CHIPS and PBK (Phonetically Balanced Kindergarten tests, [Brandy, 2002]), the limitations of which have already been enumerated. CCT items could be selected carefully for use under the various conditions. Results could be scored using the distinctive feature system (Feeney, 1990) and error analysis, yielding very specific targets for intervention or device adjustment as well as more general suggestions for classroom support (e.g., desk top amplifier, preferential seating).

Finally, an interesting feature of the recording of the CCT (Auditec of St. Louis) is the use of a man with a deep voice as the speaker. Because the test was designed to highlight problems that individuals with high-frequency hearing loss experience, it is curious that a woman with a high fundamental frequency was not selected to record the test. A recording with a female speaker would seem to be a more accurate reflection of children's classroom listening experience. Also, if the test were to be recorded again, it would be helpful to include item numbers preceding the delivery of each target to reduce the chance of losing one's place during the test.

The majority of targets on the CCT are high-frequency consonants in the final position of words. As such, the CCT is a useful instrument for determining if those elements critical to speech comprehension are delivered to children via various amplification systems. It can be used with children with rudimentary reading skills if appropriate instruction is given. Future modifications of the CCT recording and research findings may increase the utility of CCT use with children.

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## Appendix

Special instructions for the elementary students, with and without hearing loss, for taking the California Consonant Test.

The children were shown practice items from List 1 of the CCT. Overhead

BACK \_\_\_\_\_  
 BAG \_\_\_\_\_  
 BATCH \_\_\_\_\_  
 BATH \_\_\_\_\_

“Here are 4 words. How are they alike? (If not answered, ask the next question) Are the first or last sounds different? Right! The last sounds are different. So listen for the last sound. Does it matter if you know all the words to pick one? (No!) Now tell me which one I say, “Mark the word “batch.” Is that this one (pointing to the first two and getting negatives), Is it this one (pointing to “batch.”) Right, it’s this one, so I’ll put an X on the line after the word you heard. It does not matter if you know the words or not, you can hear the sounds and know which one I said. Now let’s try another list.” Overhead with

RICE \_\_\_\_\_  
 DICE \_\_\_\_\_  
 NICE \_\_\_\_\_  
 LICE \_\_\_\_\_

“How are these words alike or different? (Yes, the ends are the same and the beginning sounds are different). If not answered: Are the first or last sounds different? Right! The first sounds are different. So listen for the first sound. Now tell me which one I say, “Mark the word “dice.” Is that this one (pointing to the first one and getting negatives, Is it this one (pointing to “dice”). Right, it’s this one, so I’ll put an X on the line after the word you heard. On the test, you will know most of the words, but remember, it does not matter if you know the words or not, you can hear the sounds and know which the man says. Put an X on the line after the word you hear. I’m going to give you each a paper to do some more practice. “

The 7 practice items from list 1 of the CCT were duplicated and distributed to each student. The target for each was given and each student’s performance in marking the items was monitored by the author, classroom teacher, and two or more graduate students participating in the data collection. Subjects were reinstructed until each unambiguously made an X on the line to the right of one of the items.

It was also pointed out to the subjects that the items were numbered down the 5 columns rather than from left to right.