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Development and Standardization of SCAN-C Test for Auditory Processing Disorders in Children

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Abstract

This paper reports on the development and standardization of SCAN-C: Test for Auditory Processing Disorders in Children-Revised. The revisions include new test instructions that have been reworded to make them easier for young children, aural stimuli presented on a compact disc, a revision of the Competing Words subtest, and the addition of a Competing Sentences subtest. Normative data on the new test were obtained on 650 children age 5 years, 0 months, to 11 years, 11 months. Analysis of new standardization data revealed systematic improvement in performance with increasing age. A new method of calculating the composite standard score gives equal weighting to each subtest of SCAN-C. Subtest test–retest reliability was substantially improved over the original SCAN, with SCAN-C correlations ranging from .65 to .82 for 5 to 7 year olds. Concurrent validity tests found that SCAN-C test results can be viewed with the same confidence as SCAN.

Key Words: Auditory Figure-Ground, central auditory processing disorder, Competing Sentences subtest, Competing Words, dichotic speech tests, Filtered Words

Abbreviations: AFG = Auditory Figure-Ground, CD = compact disc, COMP = composite score, CS = Competing Sentences, CW = Competing Words, FW = Filtered Words

The SCAN-C Test for Auditory Processing Disorders in Children-Revised (Keith, 2000) is a revision of the original SCAN (Keith, 1986) that was published in 1986. The original test was designed for use with children, ages 3 to 11 years. It was normed on a standardization sample representative of the general U.S. population. SCAN raw scores are converted to standard scores, percentile ranks, and confidence intervals. The standardization enables a comparison of the relative ranking of performance on SCAN to other tests of language and intelligence standardized on the same population. Such comparison offers more objective and rational methods for guiding the audiologist in making recommendations for educational placement, management, and remediation of children diagnosed as having central auditory processing disorders. The test has been used to study auditory processing, language, and learning problems in children. It has also been used to study auditory processing in children with academic and reading problems (Stromberg, 1988; Spafford, 1990), as well as the effects of attention deficit disorders (Keith and Engineer, 1991), the effects of temporal lobectomies (Cranford et al, 1996), and the effects of lead exposure on child development (Dietrich et al, 1992).

Although there are generally positive responses to SCAN, authors have raised questions on various issues. Emerson et al (1997) did test and retest measurements on six children in a quiet school setting and an audiometric booth. They reported that five of six children performed more poorly on the SCAN Composite (COMP) and Auditory Figure-Ground (AFG) subtests when tested in a school setting versus an audiometric booth. Amos and Humes (1998) report that normally developing first- and third-grade children scored lower on the first administration of SCAN than the second. From test 1 to test 2 for the Filtered Words (FW), Competing Words (CW) subtests, standard scores and COMP scores improved significantly, using a 6- to 7-week retest interval. The data indicate that, for the

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COMP score, 48.9 percent of children had test 2 scores outside of the established 95 percent confidence intervals, with all scores better on test 2 than test 1. Amos and Humes (1998) noted that the 6-month test–retest interval reported in the SCAN standardization study was "probably an inappropriately long test–retest interval." Finally, Humes et al (1998) expressed concern about the rationale for the computation of the SCAN composite score, which gives heavier weighting to the CW score over the FW or the AFG subtest scores by virtue of the greater number of CW subtest items than the FW and AFG subtest items.

These and other factors provided motivation to accomplish a revision and restandardization of SCAN. The following changes were made in the revised edition:

- Test instructions were reworded to make them easier for young children.
- The audiocassette has been replaced with a compact disc (CD) for SCAN-C. CDs are more durable than audiocassettes (that stretch and wear) and maintain quality playback for the life of the CD.
- The CW subtest of SCAN was revised. There are now 15 word pairs for each directed ear listening task, making test administration more efficient without sacrificing accuracy of diagnosis. The pairs were chosen based on item analysis of word pairs that were the most discriminating in SCAN-A (Keith, 1994).
- The Competing Sentences (CS) subtest was added to increase the diagnostic utility of the dichotic test battery.
- Normative data for children 5 years, 0 months, to 11 years, 11 months, were collected based on U.S. census figures for the general population (with better representation of regions of the country and racial/ethnic groups).

In keeping with the need for documentation of central auditory test batteries, the purpose of this article is to describe SCAN-C, its design, and results of standardization procedures.

METHOD

SCAN-C Subtests

The SCAN-C includes four subtests: FW, AFG, CW, and CS.

Filtered Words Subtest

The test stimuli consist of monosyllabic words that were low-pass filtered at 1000 Hz with a rolloff of 32 dB per octave. Three practice and 20 test words are presented to the right ear. Then two practice words and 20 test words are presented to the left ear. The FW test items are the same as those used in SCAN (Keith, 1986). Filtering causes a perceived difference in loudness between test instructions and test items. To adjust for this perceived difference in loudness, the practice items and test items were recorded 3 dB higher than the test instructions.

Auditory Figure-Ground Subtest

Monosyllabic words were recorded in the presence of multitalker speech babble noise at +8 dB signal-to-noise ratio (SNR) (i.e., the stimulus words are 8 dB louder than the multitalker speech babble). No single speaker and no background messages are identified in the multitalker background noise. Peak compression of the background noise also was done to eliminate acoustic peaks that naturally occur during spontaneous speech. The final variations in acoustic peaks are within +1 dB and –2 dB at the 0-dB level.

The child is asked to repeat the stimulus words in the presence of background noise. Two practice words and 20 test words are presented to the right ear, and then two practice and 20 test words are presented to the left ear. The AFG test items are the same as those used in SCAN (Keith, 1986).

Competing Words Subtest

The test stimuli consist of monosyllabic word pairs presented to the right and left ears. Word pairs were recorded at equal intensities on both channels of the stereo CD and were digitally compressed to achieve equal duration. The maximum deviation in duration of word pairs on the final version was no more than ±10 msec.

The child hears two words simultaneously—one word presented to each ear. First, two practice word pairs and 15 test word pairs are presented. As a directed listening task, the child is instructed to repeat both words, repeating the word heard in the right ear first. Then, a second set of two practice word pairs and 15 test word pairs are presented. The child is instructed to repeat both words, repeating the word heard in the left ear first. The CW test items are the same as those used in SCAN-A (Keith, 1994).

Competing Sentences Subtest

Pairs of sentences that are unrelated in topic are presented to the right and left ears. The sentence pairs have simultaneous onset and offset times, with no more than a 10-msec difference. The CS subtest also consists of a directed ear listening task, but, in this case, the child is instructed to direct attention to the stimuli presented in one ear while ignoring stimuli presented to the other ear. First, two practice items and 10 test sentence pairs are presented. The child is instructed to repeat only the sentence heard in the right ear. Then, two practice items and 10 test sentence pairs are presented. This time, the child is instructed to repeat only the sentence heard in the left ear. The CS test items are the same as those used in SCAN-A (Keith, 1994). They were adapted from the Bamford-Kowal-Bench Standard Sentence Lists (Bench and Bamford, 1979).

Technical Specifications and Recording

A male speaker with clear articulation and General American dialect recorded the test instructions and items. The speaker said the carrier phrases "Say the word" or "Say" and the stimulus words and sentences in a natural manner and at the same effort level. Stimuli were recorded with approximately 4-second intervals between stimuli on subtests 1 through 3 (FW, AFG, and CW) and 5-second intervals between sentences on subtest 4, CS. This rate allows adequate time for children ages 5 to 11 years old to respond and does not prolong the test unnecessarily.

Standardization Studies

One hundred and fourteen examiners participated in the SCAN-C standardization and validation studies. Examiners were speech-language pathologists, audiologists, and professionals with dual degrees in speech-language pathology and audiology, as well as graduate students in audiology. Examiners were given the option of two test environments. They could test the child in either an audiometric sound-proofed test booth or a quiet room. Examiners were given detailed administration and scoring procedures for standardization. They also were instructed to transcribe all responses that were not repeated exactly.

Subjects

Six hundred and fifty children between the ages of 5 years, 0 months, and 11 years, 11 months, were studied. This sample is based on the general U.S. population and stratified by age, gender, race/ethnicity, region, and parent education level. There were 100 children in each age group, age 5 years, 0 months, to 9 years, 11 months. There were 150 children in the age group 10 years, 0 months, to 11 years, 11 months, for whom data were collapsed into one age group after 50 percent of the cases were collected when it became apparent that performance between the two age groups was similar. There were 51.2 percent male and 48.8 percent female subjects. The standardization sample by race/ethnicity included 15.7 percent African American, 15.2 percent Hispanic, 64.8 percent Caucasian, and 4.3 percent representing other races/ethnicities. Subjects were tested from four geographic regions of the United States with 21 percent from the west, 24 percent from the north central, 37 percent from the south, and 18 percent from the northeast. The parent education level of the standardization sample included 13.7 percent with 11 years or less of formal education, 30.5 percent with 12 years, 30.8 percent with 13 to 15 years, and 25.1 percent with 16 or more years of formal education. The parent who spent the most time with the child was considered to be the primary caregiver.

The children in the standardization sample were required to:

- Be able to take the test in English in the standard fashion without modification;
- Have normal and symmetric peripheral hearing as tested by air-conduction pure-tone audiometry at 500, 1000, 2000, and 4000 Hz; and
- Have intelligible speech with few articulation errors.

Children were not excluded from the standardization sample if they were receiving special education services or services as gifted and talented. Of the standardization sample, 1.5 percent of the children were classified as having an attention deficit disorder, 2.2 percent were diagnosed as having an attention deficit with hyperactivity disorder, 1.25 percent were classified as having a learning disability, and 3.8

percent were diagnosed as having a speech and language disorder. Less than 0.6 percent of the standardization sample consisted of children who had one of the following disorders: behavior disorder/emotionally disturbed, developmental delay, dyslexia, and other health impaired. Children receiving services as gifted and talented made up 2.2 percent of the standardization sample. All children with severe disabilities were excluded from the standardization research.

The rationale for the standardization sample is as follows. A standardization sample can be defined in a variety of psychometrically sound ways. Although it is fairly common for the sample to be defined as "normals," this is not the only valid definition. If normative information is used to compare a subject to the "normal" population, then a standardization sample of "normals" would be appropriate. Often, however, the comparison to be made is to a "general" population, which may be defined more broadly. The rationale for the standardization sample used here is that children who could take the test without accommodation were part of the general population for whom the test is designed, and so they were included. Children who could not take the test without accommodation were excluded. In this study, the standardization population included children with minor developmental disabilities. They were admitted into the standardization sample to avoid a truncated sample. That is, if a standardized study develops normative data based on a certain number of standard deviations below the mean, and the sample excludes all disordered children, then normal children who fall in the lower end of the bell curve will be labeled as disordered. It is common psychometric practice to include a certain percentage of children with mild disorders to avoid the problem of truncated norms when a standard deviation derived score is used to classify children.

Administration and Scoring

SCAN-C was standardized on a sample of children who were administered the test in exactly the same manner. The test was administered in either an audiometric sound-proofed test booth or a well-ventilated and quiet room, removed from auditory or visual distractions. Equipment included either a CD player or a two-channel audiometer. The CD player was required to have a frequency response between 20 and 20,000 Hz with equal-quality stereo earphones. Children were not provided reinforcement or encouragement during administration of the test, and the test was never interrupted between items within a subtest. If a break was needed, the CD was stopped between subtests, at which time reinforcing statements also could be provided. Staff members at The Psychological Corporation were trained to review and score all responses provided by the examiners.

RESULTS

Development of Norms

Normative data for SCAN-C are reported at 1-year intervals from 5 years, 0 months, to 9 years, 11 months, and one combined age group for 10 and 11 year olds (10 years, 0 months, to 11 years, 11 months). Raw score means and standard deviations by subtest for each whole-year age group in the SCAN-C standardization sample are reported in Table 1. Raw score means increased and the standard deviations decreased with increasing age as expected, reflecting maturation of the central auditory nervous system.

The resultant z scores were then converted to subtest standard scores with a mean of 10 and standard deviation of 3, which resulted in a range of standard scores from 1 to 19. Some

Table 1 Raw Score Means and SDs for the SCAN-C Subtests by Age

		Subtest 1: Filtered Words		*Subtest 2: Auditory Figure-Ground*		*Subtest 3: Competing Words*		*Subtest 4: Competing Sentences*	
Age	*n*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
5.0–5.11	100	25.9	6.4	27.9	4.9	24.3	8.4	6.1	3.7
6.0–6.11	100	29.3	5.1	30.3	4.7	31.9	9.6	9.0	3.9
7.0–7.11	100	31.3	4.9	31.9	4.4	34.5	8.8	11.1	4.0
8.0–8.11	100	31.9	4.6	32.8	3.4	37.6	8.4	12.9	3.6
9.0–9.11	100	33.7	3.8	33.5	3.4	41.5	8.1	15.1	3.6
10.0–11.11	150	34.1	3.4	34.3	3.4	43.1	6.7	16.4	3.1

smoothing of score distributions was completed to adjust for small irregularities of scores across ages.

The SCAN-C COMP standard scores were developed for the entire sample. A distribution of scores was created by summing the four subtest standard scores. Percentile ranks for each age group were converted to normalized z scores and then to COMP standard scores with a mean of 100 and a standard deviation of 15. Summing the subtest standard scores to create the composite standard score gives equal weight to each subtest and eliminates the problem pointed out by Humes et al (1998) of heavier weighting of one subtest over another. Finally, subtest standard scores and COMP standard scores may be converted to a percentile rank using the tables presented in the appendices of the *Examiner's Manual* (Keith, 2000). Percentile ranks are based on a normally distributed sample. The advantage of standard scores is that it is a scoring scale common to psychoeducational batteries. It enables examiners to directly compare relative ranking of performance across tests (e.g., standardized language and intelligence tests) standardized on the same populations and provides information about test–retest performance. Using standard scores, examiners can determine normal, borderline, and disordered performance by setting their own criteria.

Ear Advantage

The ear advantage scores are obtained by subtracting the right from the left ear scores (RE – LE = EA for right ear first task and vice versa for the left ear first task) under each directed ear listening condition for the CW subtest. Results of ear advantages were converted to a cumulative prevalence for each age group. For example, the typical right ear advantage for the directed right condition at each age group was in the range of 0 to 7 at age 5, 1 to 7 at age 6, 1 to 6 at age 7, 1 to 7 at age 8, 1 to 4 at age 9, and 1 to 4 at ages 10 to 11. The typical right ear advantage for the directed left condition at each age group was in the range of 0 to 5 at ages 5 and 6, 0 to 4 at ages 7 and 8, and 0 to 2 at ages 9 to 11 years. These results show the typical right ear advantage showing left hemisphere dominance for language.

It is clinically important to determine whether a discrepancy in the subject's right and left ear advantage is typical of children of similar age or highly unusual. For example, an ear advantage that falls in the cumulative frequency range above the 35th percentile is typical and normal. However, ear advantage scores in the 2nd percentile or below are highly unusual and indicate the possibility of damage to or abnormal development of the auditory pathways. The cumulative prevalence of ear advantage is provided for each age group in the standardization sample. For example, an 8-year-old child with a right ear advantage of 12 or above on the directed right condition of the CW subtest has a cumulative prevalence of 2 percent. This finding indicates that the child's performance is highly unusual and provides evidence of a central auditory processing disorder.

Test–Retest Reliability

The reliability of each SCAN-C subtest and the COMP score was estimated by retesting 145 children from the original standardization sample who were between the ages of 5 and 11. Each child was tested twice by the same examiner. The study was divided into two age groups: 65 children were between 5 and 7 years old and 80 children were between 8 and 11 years old. The children took the test on two separate occasions with a testing interval between 2 days and 6 weeks (42 days). The mean testing interval was 6.5 days. Table 2 presents the means and standard deviations for the test and retest and the

Table 2 Means and SDs for Test–Retest Reliability

	First Administration		*Second Administration*	
	Mean	*SD*	*Mean*	*SD*
Ages 5–7 (n = 65)				
Filtered Words	10.17	2.88	11.63	2.95
Auditory Figure-Ground	10.26	2.45	11.77	2.63
Competing Words	10.82	2.67	11.99	3.06
Competing Sentences	10.54	2.44	11.55	2.49
Composite	103.08	12.74	112.55	15.39
Ages 8–11 (n = 80)				
Filtered Words	9.71	3.12	10.79	2.68
Auditory Figure-Ground	9.49	3.00	11.13	3.03
Competing Words	9.65	3.00	11.43	3.01
Competing Sentences	9.38	3.13	10.33	3.39
Composite	96.89	14.93	106.56	14.85

corrected stability coefficients (R^{ae}) between the test and retest and the mean differences. (These correlations were corrected for variability differences between the sample and population.) The stability coefficients were calculated using Pearson correlation coefficients between the test and retest standard scores for both the subtest and the COMP scores (Guilford and Fruchter, 1978). SCAN-C subtest test–retest reliabilities (corrected r) range from .65 to .82 for the 5 to 7 year olds and from .67 to .78 for the 8 to 11 year olds.

Confidence Intervals

SCAN-C provides 95 percent confidence intervals for each subtest and for the COMP standard score. These confidence intervals provide a range of scores within which the examiner can be 95 percent confident that the child's "true score" actually lies, taking measurement error into account. Confidence intervals are inversely related to the standard errors of measurement (SEM), which are provided in Table 3. For the subtests, which have a mean of 10 and a standard deviation of 3, the SEM range from 0.99 to 1.99. For the COMP standard score, which has a mean of 100 and a standard deviation of 15, the SEM is 5.02.

Validity

Concurrent validity of SCAN-C was evaluated by comparing the scores obtained on SCAN-C with the scores obtained on the original version, SCAN. The two tests were administered to 80 children between the ages of 5 years, 0 months, and 11 years, 0 months, in counterbalanced order. Forty of the children in the study were a subsample of the standardization group that was administered SCAN-C first and then SCAN. The other 40 children were administered the original SCAN first and then SCAN-C (and were not part of the standardization research). The tests were administered within 2 to 20 days of each other by the same examiner. The correlations between the SCAN and SCAN-C subtests were as follows: FW = 0.55, AFG = 0.31, CW = 0.72, (the CS subtest is not part of SCAN), and COMP score = 0.79.

These correlations represent moderately low to moderately high correlations between the SCAN and SCAN-C subtests. The lowest correlation was the AFG subtest. The SCAN-C COMP standard score is comparable to the SCAN COMP standard score, with a correlation of 0.79.

Gender Effects

An analysis of gender differences was conducted with matched pairs of males and females selected from the SCAN-C standardization sample. One hundred and eighty-one males and 181 females (181 pairs) were matched on the basis of age, race/ethnicity, parent education level, and region. This study found no significant difference in performance between males and females in the 5 years, 0 months, to 11 years, 0 months, age range on any subtest or COMP standard score. The results indicate that SCAN-C yields similar results for males and females. Table 4 reports the mean, SD, and t-tests of standard score differences for the matched sample.

Effect of Test Environment on Results

To examine the effect that the test environment might have on a child's performance, a small study was conducted on a matched sample of 27 children. Twenty-seven children in the standardization sample (N = 650) who were administered SCAN-C in an audiometric soundproofed test booth were matched with 27 children in the standardization sample who were administered SCAN-C in a quiet room. The children were matched on age, gender, race/ethnicity, and parent education level. Paired t-tests were

Table 3 Standard Error of Measurement

Age	*N*	*Filtered Words*	*Auditory Figure-Ground*	*Competing Words*	*Competing Sentences*	*Composite*
5	100	1.27	1.72	1.12	1.38	
6	100	1.48	1.52	0.99	1.45	
7	100	1.47	1.58	1.11	1.26	
8	100	1.55	1.99	1.11	1.40	
9	100	1.58	1.76	1.22	1.39	
10–11	150	1.73	1.78	1.31	1.52	
All	650					5.02

Table 4 SCAN-C Mean, SD, and t-Tests of Standard Score Differences for the Matched Sample (Ages 5–11 Years; n = 181 Pairs) of Males and Females

		Males		*Females*		
Ages 5–11	*n Pairs*	*Mean*	*SD*	*Mean*	*SD*	*t*
Filtered Words	181	10.16	3.03	9.83	2.89	1.13
Auditory Figure-Ground	181	10.01	3.13	9.93	2.9	0.25
Competing Words	181	10.04	3.01	10.17	2.89	−0.40
Competing Sentences	181	9.88	2.79	10.32	3.19	−1.39
Composite	181	100.25	15.51	100.46	14.67	−0.14

conducted on the matched sample and no significant differences were found on any mean subtest or composite standard scores.

DISCUSSION

In summary, the standardization of SCAN-C, a revision of SCAN: A Screening Test for Auditory Processing Disorders (Keith, 1986), is presented. The results of the SCAN-C standardization sample indicated that:

1. The raw scores for each age group increased with age as the standard deviation decreased. In a departure from SCAN, the COMP standard score was computed by summing the four subtest standard scores. In the original SCAN, the COMP standard score was computed by adding the raw scores of each subtest. The calculation gave more weight to the CW subtest because of the greater number of test words. Summing the subtest standard scores gives equal weight to each subtest and eliminates the problem pointed out by Humes et al (1998) of heavier weighting of one subtest over another.
2. The ear advantage scores are calculated to determine the cumulative prevalence for each age group. With these data, it is possible to determine whether the obtained ear advantage scores are typical for a child of equivalent age or whether the scores are atypical and fall within the 2nd, 5th, 10th, or 15th percentile. The obtained data indicate the expected right ear advantage for both directed right and left ear testing using monosyllable words, with the predicted decrease in the right ear advantage on directed left ear testing. At no time did the typical child show a left ear advantage greater than 1 for any condition. These data allow inference of possible developmental delays in the auditory system, reversed hemispheric dominance for language, or other damage to the central auditory pathways.
3. The test–retest reliability correlations ranging from .65 to .82 for the 5 to 7 year olds and from .67 to .78 for the 8 to 11 year olds were substantially better than reported for SCAN. The findings seem to answer the concerns expressed by Amos and Humes (1998) that the 6-month test–retest interval reported in the SCAN standardization study was "probably an inappropriately long test–retest interval."
4. Concurrent validity testing comparing SCAN-C to SCAN results found moderately high correlations except for the AFG subtest. The COMP standard score correlation of .79 indicates that the revised test produces an overall equivalent test finding to SCAN, with the additional information provided by the CS subtest. According to newly released guidelines published by the American Educational Research Association (1999), validity is now considered a unitary concept integrating all evidence that is available. That is, information is provided here as evidence that SCAN-C is a valid measure, and, according to the guidelines, it is the responsibility of the users to decide if they agree.
5. Analysis of gender effects found no difference between performance of boys and girls taking this test. This finding verifies the assumption that separate norms based on gender are not required.
6. The study by Emerson et al (1997), although conducted on few children, raised concern about the effect of testing children in a quiet room versus a sound-proofed audiometric test booth. The data reported in the SCAN-C standardization study, comparing results in these two environments, indicate that there was no difference in test results. These findings indicate that the type of testing environment will not affect the SCAN-C scores as long as the test room is reasonably

quiet and free of distraction. The findings reported here are more complete than data published by Emerson et al (1997), who tested only six children in the two environments. The results are consistent with findings reported by Bradham and Smith (1999), who found no difference in performance of SCAN scores on 16 children tested twice, in a treatment room and a sound-proofed booth.

The other changes in SCAN-C, including reworded test instructions, availability of the test on CD, the revision of the CW subtest, and the addition of a CS subtest, should improve the usefulness of this central auditory test battery. The standardization data presented here indicate that normative data for children 5 years, 0 months, to 11 years, 11 months, is consistent with expected findings, with improved performance and decreased variability as children age. Standardization data on children between the ages of 3 years, 0 months, and 4 years, 11 months, were not provided in SCAN-C. Experience with this age group indicates that they are generally unable to complete the testing, and the results are inconsistent. We did obtain preliminary data on 21 3 year olds and 36 4 year olds who were able to complete the test. Twenty-two percent of 3 year olds and 5.3 percent of 4 year olds were unable to complete the test for a variety of reasons. The data on 3- and 4-year-old children who were able to complete the test are presented in the SCAN-C *Examiner's Manual* for general comparison.

As always, the diagnosis of a central auditory processing disorder is best accomplished using a team approach to assessment and a variety of measures. SCAN-C is only one of several measures that can be used in the diagnosis of this complex disorder.

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