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CLINICAL REPORT

Development and Use of Auditory Compact Discs in Auditory Evaluation

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Abstract—Two audio compact discs have been developed by the Department of Veterans Affairs for use in the assessment of auditory function. This report focuses on 1) the development of the first compact disc, which contains speech materials used in routine audiologic evaluations, and 2) an introduction to the second compact disc, which contains tonal and speech materials used in more elaborate auditory evaluations. The first disc (*Speech Recognition and Identification Materials, Disc 1.1*), which is in its second generation, contains spondaic words, several monosyllabic word tests (Rush Hughes PB-50s, CID W-22, Maryland CNCs, and Northwestern University [NU] No. 6), and the Synthetic Sentence Identification materials. The second disc (*Tonal and Speech Materials for Auditory Perceptual Assessment*), which was produced in conjunction with the Dartmouth-Hitchcock Medical Center, contains spondaic words in the MLD paradigm, dichotic materials (chords, nonsense syllables, digits, and sentences), segmented/alternated CNCs, high-pass and low-pass NU No. 6 materials, 45% and 65% compressed NU No. 6 materials, the same 45% and 65% compressed materials compounded with 0.3-s reverberation, frequency tone patterns, and duration tone patterns.

Key words: *auditory assessment, auditory compact discs, auditory evaluation.*

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INTRODUCTION

For several centuries, speech has been used to assess hearing abilities. Advances in the use of speech to evaluate hearing are tied directly to advances in instrumentation. For example, the phonograph was invented by Edison in 1877; shortly thereafter, Lichtwitz developed a phonograph that contained speech materials at various levels (1). In 1924, Jones and Knudsen developed an audiometer that contained an electronic circuit that could vary the level of speech presentations. Today, recorded speech materials and circuits on audiometers for speech are an everyday occurrence.

During the past 40–50 years, one of the major activities of audiologists within the Department of Veterans Affairs has been the conduct of auditory compensation and pension (C&P) examinations. In the 1950s, a major problem with these examinations was to ensure that the performance of a veteran on an auditory C&P examination would be the same, regardless of the site at which the testing was conducted. When properly calibrated, pure-tone stimuli are identical from one site to another. The real dilemma was with speech stimuli. The psychometric characteristics of speech stimuli delivered by monitored live voice are different from time to time with the same speaker, and certainly are different among speakers.

The solution to the problem of the same speech materials spoken by the same speaker was the development of the CID W-1 (spondaic words), and

CID W-22 (monosyllabic words) on audio (vinyl) records (2). The records were not a perfect medium in that the records deteriorated rapidly because of the mechanical action of the stylus on the records; records also were susceptible to physical damage from other sources. To avoid problems with deterioration, the records were replaced after 25 uses. An inconvenience of the records was that the records had to be changed for different speech stimuli and for different randomizations.

In the 1970s, because of the problems and inconveniences of the vinyl records, the recording medium was changed to audio tape, initially reel-to-reel, then cassette. Because of the mechanical nature of audio tape and tape recorders, deterioration continued to be a problem due to the mechanical action of the tape crossing the tape heads, the tape being stretched and broken, and other physical abuses. The problem of tape deterioration was overcome by replacing the tapes every 6 months, which was a big advancement over the replacement schedule of the vinyl records after 25 uses. Even the audio tapes involved the time-consuming inconveniences of advancing, rewinding, and changing tapes to access different materials.

Many of the problems encountered with audio tape were overcome with the development of the audio compact disc technology in the mid-1980s. Compared with audio record and audio tape analog technology, the audio compact disc (CD) digital technology offers the following advantages:

1. high-fidelity recordings with enhanced signal-to-noise ratio, virtually infinite channel separation, and no "print-through";
2. identical recordings from one disc to another;
3. a recording medium that does not deteriorate as a function of use and time, and, therefore, does not need replacing;
4. almost instantaneous access to any one of 100 tracks (i.e., no winding or rewinding to access a particular word list); and,
5. 144 minutes of recorded materials per disc.

Additionally, compact disc players offer an extremely favorable "quality-value ratio" (i.e., the players are relatively inexpensive). Because the "light amplification by stimulated emission of radiation" (laser) read mechanism does not contact the disc, there is no wear on either the disc or the recorder. The following are some useful features for compact disc players used in auditory evaluation: 1) random, not sequential, track selection; 2) display of track and time remaining while playing; 3) AB segment define and play; 4) remote control; and, 5) variable output level.

The following two sections detail the development of the two audio compact discs developed by the Department of Veterans Affairs for use in the assessment of auditory function. The first disc, entitled *Speech Recognition and Identification Materials, Disc 1.1,* contains speech materials that for the most part are used in routine audiologic evaluations. The second disc, entitled *Tonal and Speech Materials for Auditory Perceptual Assessment,* which was produced in conjunction with the VA Medical Center (VAMC), West Los Angeles (Doug Noffsinger, PhD) and with Dartmouth-Hitchcock Medical Center (Frank Musiek, PhD), contains tonal and speech materials used in more sophisticated evaluations of the auditory system.

METHOD AND MATERIALS

Speech Recognition and Identification Materials, Disc 1.1

Material Selection

The basic auditory evaluation performed during a C&P examination by the Department of Veterans Affairs (VA) includes pure-tone thresholds for air conduction and bone conduction, aural acoustic immittance measurements, speech-recognition thresholds, and word-recognition performance at multiple presentation levels. Guidelines mandate that word recognition be assessed using an approved recording of six of the Maryland CNC word lists (3). Thus, the guidelines for the C&P examination dictated that spondaic words and the Maryland CNC word lists be included on the compact disc. The question then became, What other speech materials should be included on the compact disc? For obvious reasons, we wanted to include speech materials that: 1) had an existing literature, and 2) were in the public domain or could be donated. Because the compact disc was being developed primarily for use within the Department of Veterans Affairs, it was important to get opinions from other VAMCs concerning what speech materials audiologists would like to have. Thus, the Compact Disc

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Survey was sent to 97 VA Audiology Clinics to determine the speech recognition/identification materials that VA audiologists would prefer to have on the compact disc. Of the 88 survey responses that were returned (91 percent), the 10 most often-requested speech materials were as follows:

1.	CID W-22	61%
2.	Spondaic words	49%
3.	Northwestern University No. 6	43%
4.	Synthetic Sentence ID (SSI)	35%
5.	Staggered Spondiac Words (SSW)	26%
6.	California Consonant Test	18%
7.	Continuous discourse	15%
8.	Speech Perception in Noise (SPIN)	15%
9.	MAC Battery	12%
10.	Multitalker babble	11%

The first four materials listed were included on the compact disc, along with several other sets of speech materials.

Material Preparation

For each of the seven speech materials selected for inclusion on the compact disc, analog copies of the master analog tapes were acquired. Each word was digitized and placed in a unique file. Then each file was edited to minimize the silence before and after the stimulus item and to eliminate noises, such as clicks. The majority of the monaural files for the two channels were interleaved into one stereo file so that the onsets of the two channels were concurrent. The stereo files, including a 1000-Hz calibration tone, then were recorded onto digital audio tape (DAT) (Sony, PCM-2500A) with nominal 4- to 6-s interstimulus intervals (ISI). The audio mastering studio then recorded the materials from the DAT along with the appropriate time code onto Sony 1630 format tape, from which the glass master of the compact disc was made. Details of this process are provided later in this section.

Finally, a Macintosh IIci was used to design and produce the art work for the compact disc, for the jewel box insert, and for the booklet that was to be included in the jewel box. A script detailing the materials on the compact disc was prepared as a 24-page booklet. The following section, which was taken from the booklet that accompanies each disc, details the contents of the compact disc.

The *Speech Recognition and Identification Materials, Disc 1.1* compact disc is a revision of the *Speech Recognition and Identification Materials, Disc 1* that was produced by the VA Medical Center, Long Beach, in 1989 for use by VA audiologists who use the six Maryland CNC word lists in the assessment of the word-recognition performance of patients undergoing C&P examinations. The remaining recognition and identification materials contained on the disc (see **Table 1**) were selected based on 1) the results of a survey of the VA audiology clinics, and 2) the availability of the materials through the generosity of the individuals responsible for the materials, including G. Donald Causey, PhD (spondaic words, Maryland CNC lists, and NU No. 6), Bob Brose (Technisonic Studios, St. Louis: Charles E. Harrison, producer of the CID W-22 lists, and the Rush Hughes recordings of the PB-50 lists), and James Jerger, PhD (Synthetic Sentence Identification materials).

The speech materials contained on Version 1.1 of the *Speech Recognition and Identification Materials* are identical to the speech materials contained on the initial Version 1.0 disc. The differences between the two compact discs are related to the digital characteristics used to process the materials. With *Disc 1,* the materials were processed digitally with a 12-bit A/D and D/A converter (20,000-Hz rate and a 5,000-Hz filter cutoff with a 115-dB/octave rejection). With *Disc 1.1,* tracks 1–26 were processed using a 16-bit A/D and D/A converter and the following characteristics: 1) tracks 1–18 were processed with a 44,100-Hz rate and a 19,800-Hz filter cutoff (96 dB/octave); 2) tracks 19–26 were processed with a 20,000-Hz rate and an 8,800-Hz filter cutoff (96 dB/octave); and, 3) tracks 27–35, which were unchanged from *Disc 1,* were processed on a 12-bit converter with a 20,000-Hz rate and a 5,000-Hz cutoff.

The text that follows describes briefly the materials that are contained on each track of the *Speech Recognition and Identification Materials, Disc 1.1* compact disc. A detailed script of each track and references are provided in the booklet that accompanies each disc. Several characteristics of the recordings should be noted. First, the ISI with the various materials are the times between successive stimulus onsets. Second, with all of the 50-item

Table 1.
An index of the audio compact disc *Speech Recognition and Identification Materials, Disc 1.1*, produced in 1991.

Track	Left Channel	Right Channel	Time
1	1000-Hz Calibration Tone	1000-Hz Calibration Tone	0:30
2	Spondaic Words (72, 4-s, ISI)[1]	Spondaic Words (144, 2-s, ISI)	4:51
3	Maryland CNC List 1 (1-25)[1]	CID W-22 List 1A (1-25)[2]	1:47
4	Maryland CNC List 1 (26-50)	CID W-22 List 1A (26-50)	1:47
5	Maryland CNC List 3 (1-25)	CID W-22 List 2A (1-25)	1:47
6	Maryland CNC List 3 (26-50)	CID W-22 List 2A (26-50)	1:47
7	Maryland CNC List 6 (1-25)	CID W-22 List 3A (1-25)	1:46
8	Maryland CNC List 6 (26-50)	CID W-22 List 3A (26-50)	1:46
9	Maryland CNC List 7 (1-25)	CID W-22 List 4A (1-25)	1:46
10	Maryland CNC List 7 (26-50)	CID W-22 List 4A (26-50)	1:46
11	Maryland CNC List 9 (1-25)	Rush Hughes PB-50 List 8B (1-25)[2]	1:47
12	Maryland CNC List 9 (26-50)	Rush Hughes PB-50 List 8B (26-50)	1:47
13	Maryland CNC List 10 (1-25)	Rush Hughes PB-50 List 9B (1-25)	1:46
14	Maryland CNC List 10 (26-50)	Rush Hughes PB-50 List 9B (26-50)	1:46
15	Picture ID Task List 1A (1-25)[3]	Rush Hughes PB-50 List 10B (1-25)	2:32
16	Picture ID Task list 1A (26-50)	Rush Hughes PB-50 List 10B (26-50)	2:32
17	Picture ID Task List 2A (1-25)	Rush Hughes PB-50 List 11B (1-25)	2:31
18	Picture ID Task List 2A (26-50)	Rush Hughes PB-50 List 11B (26-50)	2:31
19	NU No. 6 CNC List 1A (1-25)[1]	Competing Sentences	1:55
20	NU No. 6 CNC List 1A (26-50)	Competing Sentences	1:58
21	NU No. 6 CNC List 2A (1-25)	Competing Sentences	1:56
22	NU No. 6 CNC List 2A (26-50)	Competing Sentences	1:56
23	NU No. 6 CNC List 3A (1-25)	Competing Sentences	1:56
24	NU No. 6 CNC List 3A (26-50)	Competing Sentences	1:56
25	NU No. 6 CNC List 4A (1-25)	Competing Sentences	1:56
26	NU No. 6 CNC List 4A (26-50)	Competing Sentences	1:56
27	Synthetic Sentence ID Random #1[4]	Competing Message Story	1:43
28	Synthetic Sentence ID Random #2	Competing Message Story	1:41
29	Synthetic Sentence ID Random #3	Competing Message Story	1:39
30	Synthetic Sentence ID Random #4	Competing Message Story	1:40
31	Synthetic Sentence ID Random #5	Competing Message Story	1:41
32	Synthetic Sentence ID Random #6	Competing Message Story	1:42
33	Synthetic Sentence ID Random #7	Competing Message Story	1:39

(Continued on next page)

Table 1. (*Continued*)
An index of the audio compact disc *Speech Recognition and Identification Materials, Disc 1.1*, produced in 1991.

Track	Left Channel	Right Channel	Time
34	Synthetic Sentence ID Random #8	Competing Message Story	1:39
35	Synthetic Sentence ID Random #9	Competing Message Story	1:41

[1]Spondaic words, Maryland CNC lists, and NU No. 6 CNC lists reproduced compliments of G. Donald Causey, Ph.D., Consultant in Audiology, VA Medical Center, Washington, DC.
[2]CID W-22 lists and PB-50 lists (Rush Hughes) reproduced from the original recordings produced by Charles E. Harrison at Technisonic Studios, St. Louis, MO.
[3]Picture Identification Task lists reproduced compliments of Audiology Section, VA Medical Center, Long Beach, CA.
[4]Synthetic Sentence Identification materials reproduced compliments of James Jerger, Ph.D., Baylor College of Medicine, Houston, TX.

word lists recorded on this compact disc, words 1–25 are recorded on one track; words 26–50 are recorded on the subsequent track. Third, the beginning of tracks 2 through 35 are indexed for access under software control.

Track 1. Both channels contain a 30-s, 1000-Hz calibration tone that reflects the peaks of the speech materials as monitored on a calibrated VU meter (4,5). It should be noted that many meters used on audiometers are not "true" VU meters and/or are not properly calibrated (6). The 1000-Hz calibration tone, therefore, may not reflect accurately the peaks of the speech materials on non-VU meters and on non-calibrated VU meters.

Track 2. The left channel (A) contains two randomizations of the 36 CID W-1 spondaic words spoken by a female with 4-s interstimulus intervals; the right channel (B) contains four randomizations of the 36 CID W-1 spondaic words spoken by a female with 2-s ISI. Normative data for these materials are given in Cambron, Wilson, and Shanks (7). Total time is 291 s.

Tracks 3 and 4. The left channel contains List 1 of the Maryland CNC materials recorded by a male (3), whereas the right channel contains a copy of the CID W-22 List 1A materials recorded by Technisonic Studios (2). Track 3 has words 1–25 and track 4 has words 26–50. Both channels have 4.2-s ISI; the total time/track is 107 s.

Tracks 5 and 6. The left channel has List 3 of the Maryland CNC words; the right channel has List 2A of the CID W-22 words. The ISI is 4.2 s with 107 s/track.

Tracks 7 and 8. The left channel has List 6 of the Maryland CNC words; the right channel has List 3A of the CID W-22 words. The ISI is 4.2 s with 106 s/track.

Tracks 9 and 10. The left channel has List 7 of the Maryland CNC words; the right channel has List 4A of the CID W-22 words. The ISI is 4.2 s with 106 s/track.

Tracks 11 and 12. The left channel has List 9 of the Maryland CNC words; the right channel has the Rush Hughes recording (8) of List 8B of the Harvard PB-50 words (9). (For the Rush Hughes recordings, slight modifications [one to six words/list] were made in the original PB-50 lists.) The ISI is 4.2 s with 107 s/track.

Tracks 13 and 14. The left channel has List 10 of the Maryland CNC words; the right channel has the Rush Hughes recording of List 9B of the PB-50 words. The ISI is 4.2 s with 106 s/track.

Tracks 15 and 16. The left channel has List 1A of the Picture Identification Task materials (10,11); the words on both tracks are indexed. The right channel has the Rush Hughes recording of List 10B of the PB-50 words. The ISI is 6.0 s with 152 s/track.

Tracks 17 and 18. The left channel has List 2A of the Picture Identification Task materials; the right channel has the Rush Hughes recording of List 11B of the PB-50 words. The ISI is 6.0 s with 151 s/track.

Tracks 19 and 20. The left channel has List 1A of the NU No. 6 recorded by a female; the right channel has competing sentences—modified Bell Telephone Sentences—recorded by a male (12). Normative data for these materials in quiet, in broadband noise, and in the competing message (ipsilateral) are given in Wilson, Zizz, Shanks, and Causey (13). The ISI is 4.6 s with 115 (Track 19) and 118 (Track 20) s/track.

Tracks 21 and 22. The left channel has List 2A of NU No. 6; the right channel has competing sentences. The ISI is 4.6 s with 116 s/track.
Tracks 23 and 24. The left channel has List 3A of NU No. 6; the right channel has competing sentences. The ISI is 4.6 s with 116 s/track.
Tracks 25 and 26. The left channel has List 4A of NU No. 6; the right channel has competing sentences. The ISI is 4.6 s with 116 s/track.
Tracks 27 through 35. The left channel of each track contains a randomization of the 10 sentences that comprise the Synthetic Sentence Identification materials (14,15); the right channel contains the Davy Crockett competing message story. The 10 sentences were digitized and reconfigured for each of the 9 segments of the competing message story. Thus, the temporal alignment between the sentences and competing message is not the same as in the original recordings. The ISI is 9.5 s with nominally 100 s/track.

Tonal and Speech Materials for Auditory Perceptual Assessment, Disc 1.0

The *Tonal and Speech Materials for Auditory Perceptual Assessment, Disc 1* compact audio disc was produced to provide a collection of high-quality auditory materials for use in assessing auditory perceptual (central) abilities. The tonal and speech materials contained on the disc were selected based on the availability of the materials either through the public domain or through the generosity of the individuals responsible for the materials, including G. Donald Causey, PhD (NU No. 6), Bob Brose (Technisonic Studios, Inc., St. Louis, Charles E. Harrison, producer of the CID W-1 lists), Kresge Hearing Research Laboratory of the South, New Orleans (dichotic CVs), and James Jerger, PhD (Dichotic Sentence Identification).

The speech materials contained on the *Tonal and Speech Materials for Auditory Perceptual Assessment* disc were digitized from analog master tapes using an analog-to-digital converter (Antex, Model SX10) with the following characteristics: 16-bit, 20,000 samples/s, 8,800-Hz filter cutoff (96 dB/octave rejection). The tonal materials were generated digitally using in-house routines. All materials were compiled on digital audio tape (Sony, Model PCM-2500A) from which the Sony 1630 format master was made.

The text that follows describes briefly the materials that are contained on each track of the compact disc (see **Table 2**). The ISI with the various materials are the times between successive stimulus onsets.

Track 1. Both channels contain a 300-ms, 1000-Hz tone burst, followed by a 1-s silent interval and a 30-s, 1000-Hz calibration tone that reflects the peaks of the speech materials as monitored on a calibrated VU meter (4,5). The tone burst can be used to check the ballistic characteristics of a VU meter. The needle on a calibrated VU meter will swing from −20 vu to 0 vu with minimal overshoot when a 300-ms tone burst is placed across the meter. For a variety of reasons, the materials on several tracks do not peak at 0 vu. These exceptions are noted in the text that follows.
Track 2. This stereo track contains spondaic words embedded in bursts of broadband noise in the SπNo paradigm; that is, the spondaic words (S) are 180° out-of-phase on the two channels and the bursts of broadband noise (N) in-phase on the two channels. The 10 spondaic words that are used repetitively are from the Technisonic Studio recording of the W-1 lists (2) and were selected based on earlier masking-level difference data (16). The words start 500 ms into the 2000-ms noise bursts that have 200-ms rise-fall times. Four words are recorded at each of 16 signal-to-noise ratios in 2-dB decrements from 0 dB to −30 dB. To avoid "pegging" the VU meter on the noise/word composite signals at 0 dB S/N, the levels are calibrated to −1 vu with reference to the 1000-Hz calibration tone. Because the words are 180° out-of-phase, monitoring the words will be difficult if both channels are fed to one loudspeaker at the same levels. To avoid this problem, monitor only one channel. The ISI is 5 s with a 318-s total time. For relative phase calibration purposes, Track 18 contains 100-Hz tone bursts recorded 180° out-of-phase on the two channels (17,18,19).
Track 3. This 296-s stereo track contains 30 dichotic chords with simultaneous onsets (20,21). The 1-s target chords, which are different in each ear, are followed by a 1-s silent interval, and in turn are followed by four simultaneous response chords that are the same in each ear. The response chords are 500 ms with a 500-ms silent interval between response chords. The chords peak at about 0.5 vu. The task of the subject is to indicate which of the two response chords correspond to the two target

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Table 2.
An index of the audio compact disc *Tonal and Speech Materials for Auditory Perceptual Assessment, Disc 1.0*, produced in 1992.

Track	Left Channel	Right Channel	Time
1	1000-Hz Calibration Tone	1000-Hz Calibration Tone	0:32
2	Spondaic Words SπNo MLD[1]	Spondaic words SπNo MLD	5:18
3	Dichotic Chords	Dichotic Chords	4:56
4	Dichotic Chords (90-ms lag)	Dichotic Chords	4:57
5	Dichotic Nonsense Syllables[2]	Dichotic Nonsense Syllables	3:02
6	Dichotic Nonsense Syllables (90-ms lag)	Dichotic Nonsense Syllables	3:04
7	Dichotic Digits	Dichotic Digits	3:39
8	Dichotic Sentence Identification[3]	Dichotic Sentence Identification	4:59
9	Consonant Segments CNCs List 5A	Vowel Segments CNCs List 5A	3:54
10	Consonant Segments CNCs List 5B	Vowel Segments CNCs List 5B	3:55
11	NU No. 6, High-Pass Filtered List 3C[4]	NU No. 6, Low-Pass Filtered List 3C	4:00
12	NU No. 6, High-Pass Filtered List 4C	NU No. 6, Low-Pass Filtered List 4C	4:04
13	Frequency Tone Patterns	Duration Tone Patterns	7:03
14	NU No. 6, 45% Compress + Reverb List 5	NU No. 6, 45% Cmpressed List 5	3:59
15	NU No. 6, 45% Compress + Reverb List 6	NU No. 6, 45% Compressed List 6	4:01
16	NU No. 6, 65% Compress + Reverb List 7	NU No. 6, 65% Compressed List 7	4:02
17	NU No. 6, 65% Compress + Reverb List 8	NU No. 6, 65% Compressed List 8	4:02
18	100-Hz, Pulsed Phase Cal. Tone	100-Hz, Pulsed Phase Cal. Tone	0:18

[1]CID W-1 Spondaic Words were reproduced from the original recordings produced by Charles E. Harrison at Technisonic Studios, Inc., St. Louis, MO.
[2]Dichotic Nonsense Syllables (CVs) provided by Kresge Hearing Research Laboratory of the South, New Orleans, LA.
[3]Dichotic Sentence Identification materials reproduced compliments of James Jerger, Ph.D., Baylor College of Medicine, Houston, TX.
[4]The NU No. 6 recordings used for the degraded speech tasks were with the compliments of G. Donald Causey, Ph.D., Consultant in Audiology, VA Medical Center, Washington, DC.

chords. The six chords are composed of the following sinusoids with the respective crest factors (CF):

1.	512 Hz	640 Hz	768 Hz	CF = 2.36
2.	550 Hz	682.7 Hz	825 Hz	CF = 2.38
3.	576 Hz	733.3 Hz	880 Hz	CF = 2.42
4.	618.7 Hz	768 Hz	896 Hz	CF = 2.38
5.	640 Hz	825 Hz	990 Hz	CF = 2.38
6.	682.7 Hz	880 Hz	1024 Hz	CF = 2.36

Track 4. This 297-s stereo track is identical to track 3, except the target chord in the left channel lags by 90 ms the target chord in the right channel. Again, the response chords are simultaneous.

Track 5. This 182-s stereo track contains the 30 possible pairings of 6 nonsense (CV) syllables (BA, DA, GA, PA, TA, and KA) in a dichotic format (22). The syllables were digitized (from the right channel of an analog tape produced by Kresge Hearing Research Laboratory, New Orleans), edited, and aligned at the VA Medical Center, Long Beach. The levels of the syllables do not reach 0 vu because the duration of each syllable is less than the integration time of a VU meter. The task of the subject is to repeat the dichotic nonsense syllables.

Track 6. This 184-s stereo track is identical to track 5, except the nonsense syllable in the left channel lags by 90 ms the nonsense syllable in the right channel.

Track 7. This 219-s stereo track contains the 36 possible pairings of 9 digits (1, 2, 3, 4, 5, 6, 8, 9, and 10) in a dichotic format. The levels of the digits do not reach 0 vu because the duration of each digit is less than the integration time of a VU meter. The task of the subject is to repeat the dichotic digits (23,24).

Track 8. This 299-s stereo track contains the 30 possible pairings of 6 synthetic sentences (25) in a dichotic format. This version of the Dichotic Sentence Identification Test was produced (digitized, compressed and expanded as needed, and aligned) at the VA Medical Center, Long Beach. The task of the subject is to identify the dichotic sentences in a list of six sentences.

Track 9. This 234-s stereo track contains 50 CVC words that are segmented at the approximate phoneme boundaries and are alternated such that the carrier phrase ("Show me") is in both channels, the initial consonant segment is in the left channel, the vowel segment is in the right channel, and the final consonant segment is in the left channel (26). Because the carrier phrases on the two channels are recorded 180° out-of-phase (to prevent the patient from experiencing a mid-line image with the carrier phrase), the materials will sound "rough" when both channels are monitored in a single loudspeaker. The task of the subject is to repeat the monosyllabic word. Minimal correct recognition of the words is obtained from either channel individually; maximum correct recognition of the words is obtained when both channels are presented simultaneously.

Track 10. This 235-s stereo track is identical to track 9, except that the 50 CVC words are in a different randomization.

Track 11. This 240-s track contains monosyllabic words from List 3 of the NU No. 6 (N.U. No. 6) spoken by a female (13). The words on the left channel (1) are high-pass filtered (2100-Hz cutoff; 115 dB/octave rejection), whereas the words on the right channel (2) are low-pass filtered (1500-Hz cutoff; 115 dB/octave). The high-pass words on the left channel peak at −15 to −10 vu; the low-pass words on the right channel peak at −3 to 0 vu. The materials sound normal if both channels are fed to a single loudspeaker. Because the words are simultaneous on the two channels, a binaural fusion task can be created by presenting the words in the stereo mode (27,28,29).

Track 12. This 244-s track is identical to track 11, except that the materials are List 4 of the NU No. 6.

Track 13. The left channel (1) contains 60 frequency-pattern sequences (6 patterns by 10 randomizations). The low-frequency tone (L) is 880 Hz and the high-frequency tone (H) is 1122 Hz. Both tones are 150 ms with 10-ms rise-fall times (cosine squared). The frequency-pattern sequences have 200-ms ISI and 6-s interpattern intervals. Because the frequency pattern tones are shorter than the integration time of a VU meter, the VU meter peaks at −2 to −3 vu with reference to the 1000-Hz calibration tone (30,31,32,33). The right channel (B) contains 60 duration-pattern sequences (6 patterns by 10 randomizations). The tones are 1000 Hz with 10-ms rise-fall times (cosine squared). The long tone (L) is 500 ms, the short tone (S) is 250 ms, the ISI is 300 ms, and the interpattern interval is 6 s (32,34). The task of the subject is to repeat (mimic) the tonal pattern. The track time is 423 s. The following are the various combinations of pattern sequences:

Frequency Patterns	Duration Patterns
LLH = 880 Hz, 880 Hz, 1122 Hz	LLS = 500 ms, 500 ms, 250 ms
LHL = 880 Hz, 1122 Hz, 880 Hz	LSL = 500 ms, 250 ms, 500 ms
LHH = 880 Hz, 1122 Hz, 1122 Hz	LSS = 500 ms, 250 ms, 250 ms
HLH = 1122 Hz, 880 Hz, 1122 Hz	SLS = 250 ms, 500 ms, 250 ms
HLL = 1122 Hz, 880 Hz, 880 Hz	SLL = 250 ms, 500 ms, 500 ms
HHL = 1122 Hz, 1122 Hz, 880 Hz	SSL = 250 ms, 250 ms, 500 ms

Track 14. The right channel (2) contains 50 carrier phrase and word stimuli from the NU No. 6 pool of 200 words that are compressed 45 percent (i.e., 45 percent of the carrier phrase and word has been removed). This list is designated List 5 because it contains a composite of words from the original four NU No. 6 lists. The left channel (1) contains the same 50 carrier phrases and words that are compressed 45 percent and reverberated 0.3 s. The task of the subject is to repeat the word that follows the carrier phrase. The track time is 239 s (35,36,37).

Track 15. This track is identical to track 14, except that a different group of 50 words from the NU No. 6 pool of 200 words is used; hence, the designation is List 6. The track time is 241 s.

Track 16. The right channel (2) contains 50 carrier phrase and word stimuli from the NU No. 6 pool of 200 words that are compressed 65 percent (i.e., 65 percent of the carrier phrase and word has been removed). This list is designated List 7 because it contains a composite of words from the original four NU No. 6 lists. Because the words have been compressed so much, the words peak at less than 0 vu. The left channel (1) contains the same 50 carrier

phrases and words that are compressed 65 percent and reverberated 0.3 s. The task of the subject is to repeat the word that follows the carrier phrase. The track time is 242 s.

Track 17. This track is identical to track 16, except that a different group of 50 words from the NU No. 6 pool of 200 words is used; hence, the designation is List 8. The track time is 242 s. NOTE: Tracks 14 and 15 contain 100 words; similarly, Tracks 16 and 17 contain 100 words. The two groups of 100 words contain 52 common words.

Track 18. This 18-s stereo track contains 100-Hz tone bursts that are 50-ms on and 50-ms off recorded 180° out-of-phase on the two channels. These tone bursts are for the relative phase calibration of the two channels of audiometers. The procedure for phase calibration requires an NBS-9A, 6 cm^3 coupler, a microphone, a microphone amplifier or sound-level meter, and an oscilloscope. The output of the amplifier or meter is fed to the oscilloscope. If the earphones are in-phase with each other, then the tone bursts will be out-of-phase at the oscilloscope (i.e., the onset of the waveform through one earphone will be positive whereas the onset of the waveform through the other earphone will be negative). If these results are not obtained, then reversing the leads to one earphone will produce the correct phase relation.

CONCLUSION

In summary, the auditory compact disc medium has enhanced the quality of materials available to audiologists for use in diagnostic and rehabilitation procedures. In addition to the materials described in this report, several other compact discs have been produced, including: 1) three discs from the Massachusetts Eye and Ear Infirmary (Aaron Thornton, PhD) that contain both traditional and unique speech materials; 2) one disc from Brigham Young University (Richard Harris, PhD) that contains traditional and specialized word lists; and, 3) one disc from Auditec of St. Louis (William Carver, PhD) that contains traditional materials for adults and children. This first generation of compact discs has simply replicated the format contained on analog tapes (i.e., word lists with 5-s or so ISI). In this format, the majority of the compact disc is occupied by the silent intervals between stimulus items. In all probability, the next generation of compact disc will use a format similar to the CD-ROM on which the stimulus items will be packed tightly and a computer used to access the materials. Materials from many first-generation compact discs will fit on one disc using the CD-ROM format. Finally, for special applications, a niche will be developed for the digital audio tape (DAT).

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