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Dichotic Listening to Speech: Background and Preliminary Data for Digits, Sentences, and Nonsense Syllables

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Abstract

Three tests of dichotic listening utilizing speech signals as stimuli are included on the VA-CD *Tonal and Speech Materials for Auditory Perceptual Assessment, Disc 1.0.* They include a dichotic monosyllabic digits task, a dichotic synthetic sentences task, and a dichotic nonsense syllable (CV) task. Since the materials were specially recorded or created and recorded for use on the VA-CD, normative data were collected at nine universities/medical centers in the United States involving 120 young listeners. Data revealed that these listeners had little difficulty correctly identifying digits or synthetic sentences when they were presented at 50–70 dB HL in a dichotic format requiring two responses to each trial. At the same presentation levels and under two onset-time conditions (0- and 90-msec onset stagger), correct responsiveness was less frequent when the stimuli were dichotic CVs. However, scores fell in ranges consistent with previous studies and useful for seeking lesion effects. Although careful definition of stimuli, standardization of materials, and the relative stability offered by audio compact disc technology were prime reasons for making the VA-CD, another goal was to offer the clinician-researcher a range of difficulty among the procedures on the disc. Data from the normative trials using dichotic speech signals suggest that the goal has been accomplished.

Key Words: Compact disc, dichotic CV, dichotic speech

Three tests of dichotic listening are included on the VA-CD known as *Tonal and Speech Materials for Auditory Perceptual Assessment, Disc 1.0*, which is discussed in this issue of *JAAA*. These tests, namely, dichotic digits (Broadbent, 1956; Kimura, 1961; Musiek, 1983), dichotic sentences (Fifer et al, 1983; Beck et al, 1985), and dichotic nonsense syllables (Berlin et al, 1973; Olsen, 1983), are procedures that are known or thought to exercise areas of the brain that deal with hearing. These particular tests were chosen from many such tests available for one or more of these reasons:

1. They target areas of the two brain hemispheres known to be particularly responsible for processing auditory signals.
2. Their processing is known to be adversely affected by lesions of those brain areas.
3. In conjunction, the tests provide a range of difficulty from an easy task for normal listeners (digits) to a difficult task for normal listeners (nonsense syllables).

The term "dichotic listening" refers to a condition in which both ears receive signals in a roughly simultaneous fashion. In a laboratory setting, this is usually done by having a subject listen through earphones to signals that are different at the two ears, although the signals may be closely related to one another, often differing in only a few critical features. The signals are delivered by independent chan-

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nels, so that the events at each ear can be manipulated separately. The subject is asked to give two responses to each dichotic pair. The signals are never the same at the two ears, and the set of stimuli from which the targets are drawn is small. For the materials on the VA-CD, the possible choices are nine digits, six sentences, or six nonsense syllables (CVs).

For dichotic materials that are carefully aligned in time so that they are essentially simultaneous and that are constructed so that they differ in only a few features (e.g., a consonant burst and formant transition), a series of trials allows the establishment of a percentage of correct responses for each ear and thus the identification of the ear that is better at recognizing the stimuli in question. This ear is said to have an "advantage" for the stimuli and thus the commonly occurring notation in the dichotic listening literature such as "the subject had a right-ear advantage for dichotic ..." (see Noffsinger, 1985). This is considered important, since an ear advantage is thought to mean that the opposite brain hemisphere is dominant for the materials in question (Kimura, 1961, 1967; Shankweiler and Studdert-Kennedy, 1967; Lowe et al, 1970; Sidtis, 1982).

If this were all one could conclude from dichotic listening trials, then it would hardly be worth the effort. The ear advantages revealed by such tasks are often quite small; they require many stimulus presentations to establish, and the listening task required of the subject is quite demanding and not particularly pleasant (Lauter, 1982, 1983). Additionally, if the only unusual quality found in one test session about a patient or a subject is the absence of an ear advantage for some obscure stimuli, then one has learned nothing of importance about hemispheric dominance or anything else.

There is more to it, of course. Normative studies and, more critically, studies of patients with lesions at specific parts of the central auditory nervous system have made apparent an important fact. Stringently controlled dichotic stimuli, such as the dichotic nonsense syllables used on the compact disc, force the auditory system to work in ways that it would probably not ordinarily do, so that each ear has only one way to route signals to the brain. Under routine listening circumstances, each ear has both ipsilateral and contralateral pathways available to transmit signals upward, thus assuring a widespread, duplicative representation of signals in both halves of the brain. Dichotic listening, under conditions of precise signal control and with proper signals, appears to suppress the ipsilateral route of access to the brain for each ear. The contralateral pathway predominates. In addition, some data from patients with known brain lesions suggest that after reaching the right hemisphere, left ear signals must cross the corpus callosum to the left hemisphere, where they compete for processing with right ear signals (Milner et al, 1968; Sparks and Geschwind, 1968; Sparks et al, 1970; Cullen et al, 1975).

The ability of the dichotic listening technique to force a signal presented to one ear to be initially represented only in the contralateral hemisphere's auditory field is what makes the procedure so important in the study of hemispheric asymmetries. This ability provides to audition a technique of similar importance to that of tachistoscopic techniques in vision. Such ability also makes dichotic listening critical to the study of the effects of disease, damage, and/or other dysfunction of parts of the auditory brain. It is this last realm, lesion effects, that prompted inclusion on the VA-CD of the three dichotic procedures mentioned earlier.

In general, studies of the effects of brain lesions on correct understanding of difficult speech, including dichotically presented digits, sentences, and CVs, conclude that the ear contralateral to temporal lobe lesion shows clear breakdown in performance (e.g., Bocca et al, 1955; Berlin et al, 1972; Baran and Musiek, 1991). For difficult materials such as nonsense syllables, both ears may show breakdown when the hemisphere dominant for processing the syllables, usually the left one, is damaged.

Another consideration in choosing the dichotic speech tests for the disc was their difficulty. The abilities of patients to attend, listen, and respond vary, and so must the tasks available for use in testing such patients.

METHOD

General

Several experimental methods are covered earlier in an introductory article (Noffsinger et al, 1994) in this journal. These include the digitization techniques for creating the speech materials, the exact contents of each track on the VA-CD, the general calibration stimuli available on the compact disc, a general picture of the strategies used in data collection, and details about the hearing sensitivity, ages, and handedness of the 120 young adults who comprised the subject pool.

Digits

The materials were created for the VA-CD and feature a male speaking one of nine monosyllabic digits (i.e., digits 1–10 minus digit 7). The digitized files were manipulated to produce the 36 possible pairs of digits. These are not dichotic digit strings as are often used (Musiek, 1983). They were aligned precisely at the onset of any energy beyond baseline voltage. Durations of the signals ranged from 353–561 msec. (Because of their peak durations, the digits may not register at 0 VU, given the integration time of VU meters.) The same digit was never both parts of a pair. Examples of test materials are seen in Figure 1 as amplitude/time displays.

The dichotic digit task was administered at 50, 60, and 70 dB HL (ANSI, 1989). Groups of 40 of the normal listeners heard each level condition. They were given practice with items from the test materials before the compact disc trials. They were instructed to listen to the pairs of digits and to give two responses for each pair on a check-off answer sheet. The set of possible stimuli was known to the subject, and so was the fact that the same digit never occupied both halves of a pair.

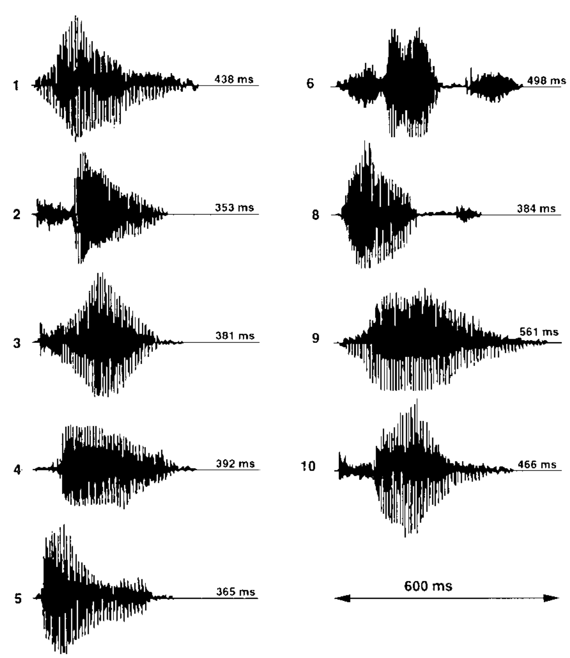

Figure 1 Amplitude (Y) by time (X) displays of the digital waveforms of the nine digits (1–10 without 7). Actual durations of the digits are listed.

Sentences

The materials, which use a male talker, were provided by James Jerger, Ph.D. (see Fifer et al, 1983). They feature six meaningless strings of meaningful words (i.e., 6 of the original 10 synthetic sentences described by Fifer et al). The 30 possible pairings of the six "sentences" were onset aligned and digitally manipulated (at the VA-Long Beach laboratory) to match their durations at 2 sec (see examples in Fig. 2). Members of a pair were never the same sentence. This was known to the normal subjects who listened and tried to identify them by number from a closed set of six possible responses.

Presentation levels of either 50, 60, or 70 dB HL were used. Three groups of 40 listeners from the 120-member subject pool heard each

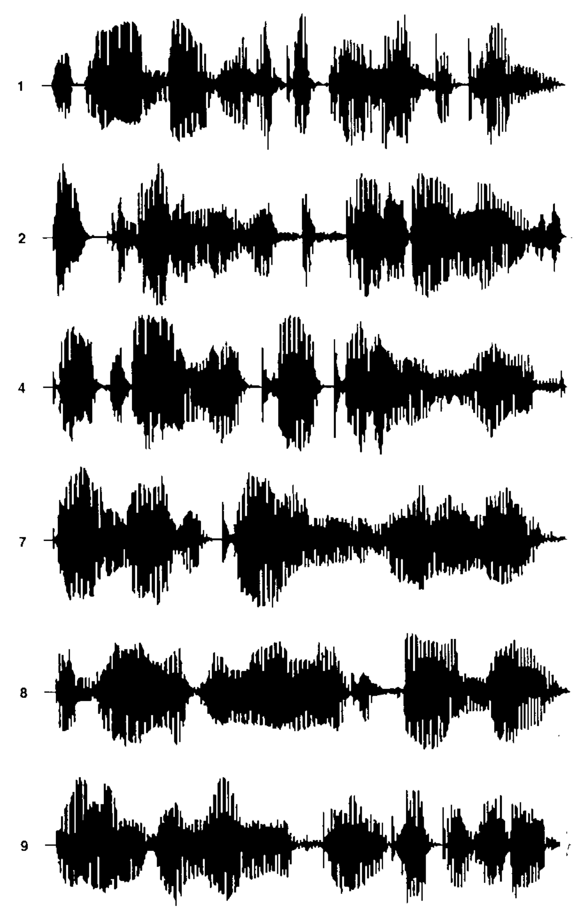

Figure 2 Amplitude (Y) by time (X) displays of the digital waveforms of the six sentences. All have 2-sec durations. The sentences are: (1) small boat with a picture has become; (2) built the government with the force almost; (3) go change your car color is red; (3) down by the time is real enough; (5) agree with him only to find out; and (6) women view men with green paper should.

presentation level. They were given practice before the VA-CD trials. They knew the set of possible responses and that the same sentence would not appear in both ears simultaneously. A check-off answer sheet was used to record responses.

Nonsense Syllables (CVs)

The materials use a male talker. They were digitized from one channel of an analog tape recording furnished by the Kresge Hearing Research Laboratory-New Orleans (see Berlin et al, 1973). They feature the set of six syllables formed by combination of a stop plosive and the vowel /a/: pa, ta, ka, ba, da, ga. For one test condition, the 30 possible pairings of these syllables were precisely aligned at the onset of any energy deviation from baseline voltage. (See Fig. 3 for an illustration of the waveforms of each syllable.) Durations of the syllables ranged from 241–284 msec. (Because of their peak and overall durations, the syllables do not register at 0 VU, given the integration time of VU meters.) For a second test condition, the onset times on the two channels of the compact disc track were staggered by 90 msec (Gelfand et al, 1980) and a different randomization of the 30 pairs was used. This configuration of stimuli on the VA-CD allowed both simultaneous onset trials and 90-msec time-staggered onset trials with either ear leading/lagging in time.

The compact disc trials involved three onset time conditions — simultaneous, 90-msec right ear lag, 90-msec left ear lag — and three presentation levels — 50, 60, and 70 dB HL.

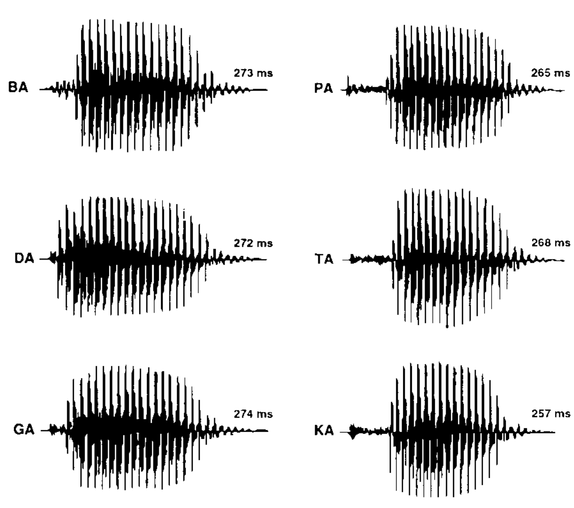

Figure 3 Amplitude (Y) by time (X) displays of the digital waveforms of the six CVs (/ba/, /pa/, /da/, /ta/, /ga/, /ka/). Actual durations of the nonsense syllables are listed.

Groups of 40 normal listeners from the master subject pool listened to each condition. They knew the set of possible responses, were given several practice items, and were forced to give two responses to each trial on a check-off answer sheet. They understood that one syllable would never be both halves of a pair.

RESULTS

Digits

The results from 40 listeners (80 ears) on the dichotic digit task (36 digit pairs) at each of three presentation levels can be simply capsulized: (1) at 50 dB HL, 100 percent of 80 ears scored 97 percent or better; (2) at 60 dB HL, 100 percent of 80 ears scored 94 percent or better; and (3) at 70 dB HL, 100 percent of 80 ears scored 94 percent or better. In brief, virtually all listeners understood everything. Correct responsiveness from the 40 listeners involved in each of three listening conditions was 94 percent or better. These "ceiling" performance levels from young adults with good hearing listening to single digit pairs were expected.

Sentences

Performance by 40 listeners (80 ears) on the dichotic sentence task (30 sentence pairs) at each of three presentation levels — 50, 60, and 70 dB HL — was straightforward. As with the digits, correct responsiveness was the rule. Performance was 90 percent accurate or better from each of the 40 listeners participating in each of the three presentation conditions. Such accuracy was expected.

Nonsense Syllables (CVs)

The dichotic CVs were not such a simple task for the young, normal-hearing subjects. Table 1 summarizes results that are also shown graphically in Figures 4–6.

Correct responsiveness for the 40 subjects for the left ear lag condition is shown in Figure 4. Small ear differences of 3 percent or less are seen across the three presentation levels, with scores somewhat better at lower presentation levels.

Similar data for the right ear lag condition are given in Figure 5. Again, mean differences between ears did not exceed 3 percent for any presentation level, and scores were better at lower presentation levels.

Table 1 Performance (% Accurate) by Normal Listeners on Dichotic Nonsense Syllables under Various Listening Conditions

	Presentation Level (dB HL)					
	50		*60*		*70*	
Condition	*RE*	*LE*	*RE*	*LE*	*RE*	*LE*
Left Ear Lag (90 msec)						
Mean	86	88	78	80	69	72
SD	8	12	16	14	14	20
Minimum Score	67	57	33	40	33	23
Maximum Score	100	100	100	100	100	100
Right Ear Lag (90 msec)						
Mean	84	87	77	80	71	70
SD	16	12	15	19	16	16
Minimum Score	47	43	40	17	33	33
Maximum Score	100	100	100	100	97	100
Simultaneous						
Mean	75	76	63	75	61	60
SD	12	14	15	15	15	17
Minimum Score	53	40	37	20	30	23
Maximum Score	100	100	90	100	100	100

n = 40 persons (80 ears) for each condition. RE = right ear, LE = left ear.

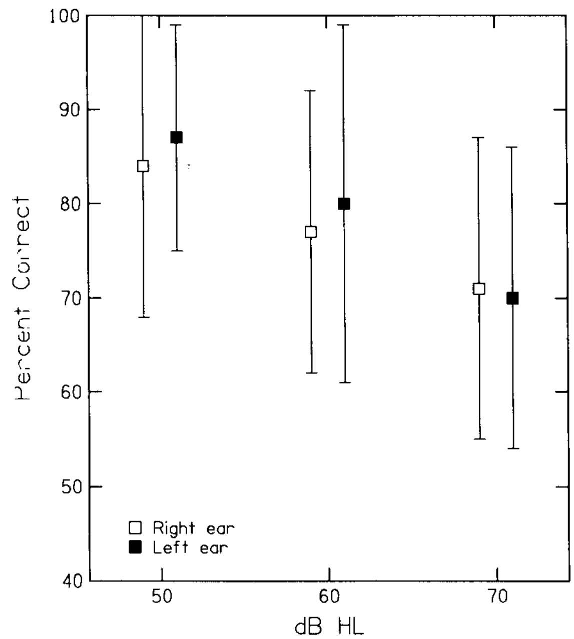

Figure 5 Mean performance (% correct) with one standard deviation for the right ear (open squares) and left ear (closed squares) of 40 subjects at each of three presentation levels (n = 120). The dichotic condition featured a 90-msec lag in onset of the right ear syllable.

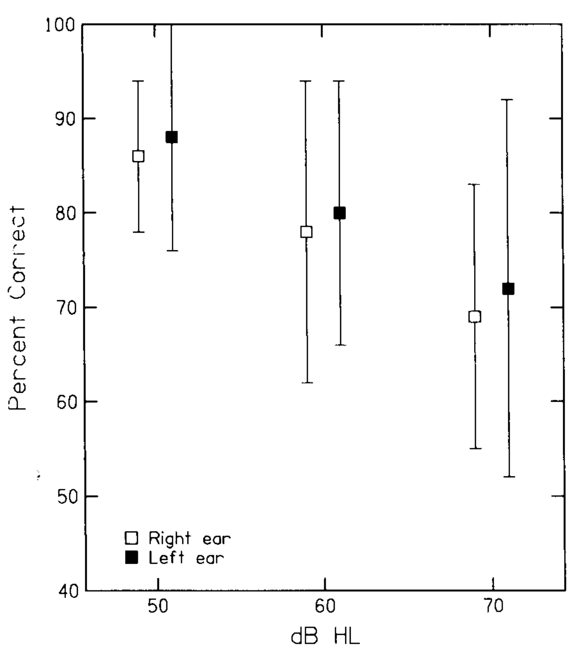

Figure 4 Mean performance (% correct) with one standard deviation for the right ear (open squares) and left ear (closed squares) of 40 subjects at each of three presentation levels (n = 120). The dichotic condition featured a 90-msec lag in onset of the left ear syllable.

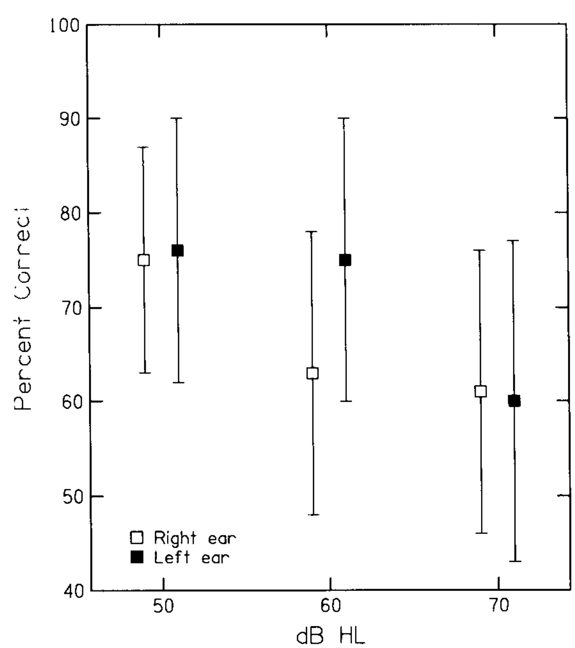

Figure 6 Mean performance (% correct) with one standard deviation for the right ear (open squares) and left ear (closed squares) of 40 subjects at each of three presentation levels (n = 120). The dichotic condition featured a simultaneous onset of syllables to each ear.

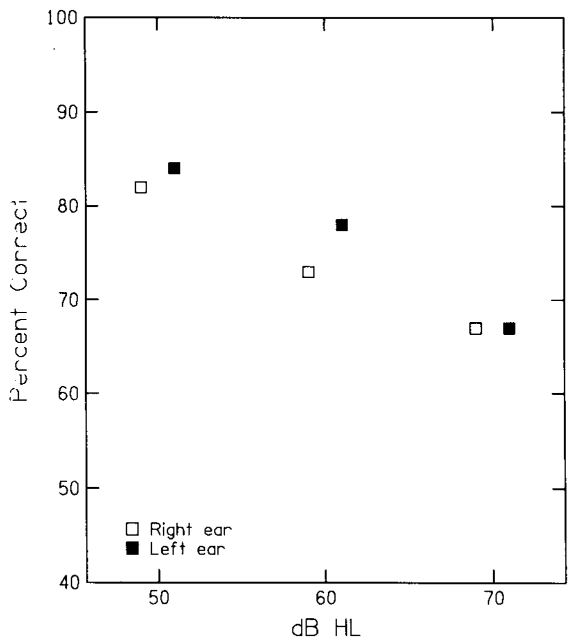

Figure 7 Mean performance (% correct) for the right ear (open squares) and left ear (closed squares) of 40 subjects at each of three presentation levels (n = 120). The data are collapsed across the onset-time conditions shown in Figures 4–6.

Scores from the simultaneous-onset condition (Fig. 6) at 50, 60, and 70 dB HL were generally lower than for the time-staggered onset conditions. In addition, the scores for the 60 dB HL presentation showed an ear difference of 12 percent that was not apparent for any other dichotic nonsense syllable condition, a circumstance that is not understood and different from earlier findings (Berlin and McNeill, 1976; Noffsinger, 1985).

If data from the various nonsense syllable onset-time conditions are collapsed, as is shown in Figure 7, then the two ears' performances are similar, differing by no more than 5 percent. Across all presentation-level and onset-time conditions, the right and left ears score 74 percent and 76 percent, respectively. These scores are comparable to those obtained by others for similar conditions (see Berlin et al, 1973; Noffsinger, 1985) but do not show the 6–8 percent right ear advantage reported in those studies. Although this is speculation, the lack of a right ear advantage in the dichotic CV, compact disc trials reported here may reflect the clinical conditions under which trials were conducted, the particular stimuli chosen for the VA-CD, and/or influences of unknown character.

DISCUSSION

A useful aid in judging normal performance is description of confidence areas for the dichotic tasks. For the most difficult test, nonsense syllables, 93 percent of all ears tested scored 50 percent or better at 50, 60, and 70 dB HL. The 90th percentile was at 56.7 percent. For digits and sentences, scores below 90 percent accurate were not found for any subjects. Thus, scores below 90 percent accurate for digits and sentences and below 50 percent accurate for nonsense syllables are rare, leaving a clinician or clinical investigator the reasonable conclusion that scores worse than these usually do not occur in a population of the sort tested in this study.

Another way to look at the data from the nonsense syllable test is to examine ear differences, regardless of the absolute scores. Across presentation levels, 90 percent of the normal subjects had differences in performance between ears of 27 percent or less (interear differences of 8 syllables correct) for both 90-msec lag conditions and 33 percent or less (interear differences of 10 syllables correct) for the simultaneous condition. These indices may be a useful guide to making decisions about when one ear's score is meaningfully different from the other ear's score.

People who study dichotic listening are usually interested in two major things: lesion effects and dominance effects. In general, lesion effects are seen as one of two varieties. The first is poor performance by the ear on the side opposite that of a temporal lobe lesion. The second is poor performance by both ears when there is damage to the temporal lobe that is primarily responsible (dominant) for processing events like the test stimuli (Sparks et al, 1970).

Dominance effects/ear advantages reflect the fact that one ear (usually of normal listeners) can listen to and understand something better than the other ear. An ear advantage is not an easy thing to find. It may be, in fact, normally distributed over a large population tested once or over repeated trials for a single subject (Speaks and Niccum, 1977).

The data reported here from the dichotic digit, sentence, and nonsense syllable VA-CD trials do not suggest that the materials will be particularly useful in teasing out hemispheric specialization in even normal listeners. They were not chosen or intended to do so. The data do provide evidence that the materials provide a range of complexity that should be useful to the clinician and/or clinical investigator who needs or wants to study lesion effects and who wants to use materials that are carefully produced and described and that should withstand aging and repeated-use deterioration. How useful they will be awaits further investigation with older listeners and with listeners having abnormal peripheral and central auditory systems.

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