J Am Acad Audiol 23:522–533 (2012)

The Effects of Energetic and Informational Masking on the Words-in-Noise Test (WIN)

DOI: 10.3766/jaaa.23.7.4

Richard H. Wilson*†
Cristine P. Trivette*†
Daniel A. Williams*†
Kelly L. Watts*†

Abstract

Background: In certain masking paradigms, the masker can have two components, energetic and informational. Energetic masking is the traditional peripheral masking, whereas informational masking involves confusions (uncertainty) between the signal and masker that originate more centrally in the auditory system. Sperry et al (1997) used Northwestern University Auditory Test No. 6 (NU-6) words in multitalker babble to study the differential effects of energetic and informational masking using babble played temporally forward (FB) and backward (BB). The FB and BB are the same except BB is void of the contextual and semantic content cues that are available in FB. It is these informational cues that are thought to fuel informational masking. Sperry et al found 15% better recognition performance (~3 dB) on BB than on FB, which can be interpreted as the presence of informational masking in the FB condition and not in the BB condition (Dirks and Bower, 1969). The Words-in-Noise Test (WIN) (Wilson, 2003; Wilson and McArdle, 2007) uses NU-6 words as the signal and multitalker babble as the masker, which is a combination of stimuli that potentially could produce informational masking. The WIN presents 5 or 10 words at each of seven signal-to-noise ratios (S/N, SNR) from 24 to 0 dB in 4 dB decrements with the 50% correct point being the metric of interest. The same recordings of the NU-6 words and multitalker babble used by Sperry et al are used in the WIN.

Purpose: To determine whether informational masking was involved with the WIN.

Research Design: Descriptive, quasi-experimental designs were conducted in three experiments using FB and BB in various paradigms in which FB and BB varied from 4.3 sec concatenated segments to essentially continuous.

Study Sample: Eighty young adults with normal hearing and 64 older adults with sensorineural hearing losses participated in a series of three experiments.

Data Collection and Analysis: Experiment 1 compared performance on the normal WIN (FB) with performance on the WIN in which the babble segment with each word was reversed temporally (BB). Experiment 2 examined the effects of continuous FB and BB segments on WIN performance. Experiment 3 replicated the Sperry et al (1997) experiment at 4 and 0 dB S/N using NU-6 words in the FB and BB conditions.

Results: Experiment 1—with the WIN paradigm, recognition performances on FB and BB were the same for listeners with normal hearing and listeners with hearing loss, except at the 0 dB S/N with the listeners with normal hearing at which performance was significantly better on BB than FB. Experiment 2—recognition performances on FB and BB were the same at all SNRs for listeners with normal hearing

*James H. Quillen VA Medical Center, Mountain Home, TN; †Department of Audiology and Speech-Language Pathology, East Tennessee State University, Johnson City, TN

Richard H. Wilson, Ph.D., VA Medical Center, Audiology (126), Mountain Home, TN 37684; Phone: 423-979-3561; Fax: 423-979-3403; E-mail: richard.wilson2@va.gov

The Rehabilitation Research and Development Service, Department of Veterans Affairs supported this work through a Merit Review, the Auditory and Vestibular Dysfunction Research Enhancement Award Program (REAP), and a Senior Research Career Scientist award to the first author.

Portions of this paper were presented at the annual convention of the American Auditory Society, March 2011, Scottsdale, AZ, and at the annual convention of the Association of VA Audiologists, March 2011, San Diego.

The content of this article does not represent the views of the Department of Veterans Affairs or the United States Government.

Delivered by Ingenta to: James H. Quillen VA Medical Center
IP : 152.130.8.8 On: Wed, 11 Jul 2012 20:15:06

using a slightly modified WIN paradigm. Experiment 3—there was no difference in performances on the FB and BB conditions with either of the two SNRs.

Conclusions: Informational masking was not involved in the WIN paradigm. The Sperry et al results were not replicated, which is thought to be related to the way in which the Sperry et al BB condition was produced.

Key Words: Audiogram, energetic masking, hearing loss, informational masking, signal-to-noise ratio, speech perception, words/speech-in-noise, words/speech-in-quiet

Abbreviations: BB = temporally backward babble; CRM = Coordinate Response Measure; FB = temporally forward babble; HFPTA = high-frequency, pure-tone average (1000, 2000, and 4000 Hz); NU-6 = Northwestern University Auditory Test No. 6; PTA = pure-tone average (500, 1000, and 2000 Hz); rms = root-mean-square; SNR, S/N = signal-to-noise ratio; SSI = Synthetic Sentence Identification; SSN = speech-spectrum noise; WIN = Words-in-Noise Test

When masking is introduced in a listening paradigm, the recognition performance on the listening task is altered. In a typical speech-in-noise paradigm in which the masker is a random noise, the spectra of the speech and masker signals and the amplitude or energy relation between the speech and masker signals are the important determinants of recognition performance (Miller, 1947). The energy relation between the two signals is expressed as the signal-to-noise ratio (S/N; SNR) and is referred to as *peripheral* or *energetic masking*, which within certain limits is linear when plotted as a function of presentation level (Hawkins and Stevens, 1950). With speech-in-noise paradigms, at high SNRs the speech waveform dominates the noise waveform (amplitude wise), and because of minimal stimulus uncertainty the listener can easily segregate the speech signal from the masker signal and achieve excellent recognition performance. In contrast to the high SNR paradigm, when the SNR is low, the noise waveform dominates the speech waveform, and because of increased stimulus uncertainty, the listener has difficulty segregating the speech signal from the masker signal that leads to poor recognition performance.

When speech is both the target signal and the masking signal, factors in addition to energetic masking can operate. The similarities between the target and masking signals in terms of the acoustic properties, contextual and semantic content, and so on create stimulus uncertainties for the listener that make it difficult to segregate the target signal from the masking signal. On this continuum of similarity (Kidd et al, 2002), as the stimulus/listener uncertainty increases, the performance on the listening task decreases. This inability of the listener to distinguish between similar acoustic signals, which can be speech or nonspeech signals, is referred to as *informational masking* and is rooted in a literature that over the years searched for descriptors of the phenomenon. In discussing the "cocktail party problem," Cherry (1953) observed that when two messages with similar semantic content are spoken by the same speaker, listeners are not able to separate the two messages. Egan et al (1954) distinguished "between two kinds of interference in the reception of simultaneous messages: *masking* and *confusion*" (p. 774). In the Egan et al definitions, masking referred to "the accepted theory of peripheral masking," whereas confusion occurred when the listeners had difficulty distinguishing between two similar, synchronous messages. Likewise, Webster and Thompson (1954) observed that "It is quite apparent that competing messages both mask and divide attention, and the decrement in performance must be attributed to both" (p. 397). Subsequently, Carhart et al (1968) used *semantic interference* to describe the masking of speech by speech in contrast to the use of "perceptually nondescript" to describe the "semantically void" characteristic of a white noise that was modulated (four interruptions/sec with a 10 dB interburst ratio or modulation depth). After studying the effects on spondaic-word thresholds of modulated white noise, competing sentences, and modulated noise combined with competing sentences, Carhart et al (1969) used the terms *perceptual interference* and *perceptual masking* to describe the "excess" masking (~3 dB) that was found with the combined masking condition with respect to either of the two masking conditions alone. Dirks and Bower (1969) used the term *disruptive factors* as a possible contributor to the overall masking that is achieved when the speech signal and competing message masker are spoken by the same speaker. Stimulus uncertainty was paramount to Watson et al (1976), who observed that in contrast to peripheral masking, *recognition masking* (Massaro, 1972), which was a term used interchangeably with *informational masking* (apparently introduced by Pollack, 1975), was unchanged when routed to the contralateral ear and could be minimized with training. Since those early days of investigation, it is becoming commonplace to recognize the influences that both energetic and informational masking may have on both speech and nonspeech auditory perceptual masking paradigms (Watson, 2005). As suggested by Lutfi (1990), total masking

Delivered by Ingenta to: James H. Quillen VA Medical Center
IP : 152.130.8.8 On: Wed, 11 Jul 2012 20:15:06

is the sum of the energetic and informational masking components.

In summary, the more similar the speech signal and the masker signal are, the more of an opportunity there is for informational masking to occur. The extreme example of speech and masker similarity or listener uncertainty is the same speaker speaking two similar messages at the same sound-pressure level through one transducer (Cherry, 1953; Egan et al, 1954). Similar listener uncertainty involves the Coordinate Response Measure (CRM; Bolia et al, 2000; Brungart, 2001) that uses the same semantic and syntactic structure in the target and masking sentences (e.g., the simultaneous presentation of "Ready Charlie go to blue one now" [target] and "Ready Baron go to green five now" [masker]). In these CRM examples that maximize stimulus similarity and listener uncertainty, there are few, if any, cues to help the listener segregate the speech and masker signals. The effects of informational masking can be decreased by introducing differential listening cues that can be incorporated simply by creating a disparity in, for example, the presentation level of either signal. As the differential listening cues increase (e.g., with different speakers for the speech and masker signals, different levels, etc.), stimulus similarity and listener uncertainty decreases, signal segregation becomes easier, and performance on the task increases. Thus, just as with the energetic component of masking, the informational masking component can be manipulated to varying degrees by a multitude of variables in the stimulus paradigm.

An ideal speech perception paradigm that can be used to study informational masking is one in which the speech masker is reproduced normally in the temporal domain (forward) and temporally backward or reversed. In comparison to normal speech, backward speech eliminates the contextual and semantic content cues of the signal but maintains the spectral content and many of the temporal characteristics (Meyer-Eppler, 1950; Dirks and Bower, 1969; Summers and Molis, 2004). Kellogg (1939) provides an interesting and entertaining introduction to the attributes of backward speech as it was being explored in the early days of recording devices. He pointed out that the sustained sounds for the most part are unaltered when played backward. Likewise, Kellogg observed that the (ex)plosive consonants are much the same when played backward with the final consonants less "conspicuous" than the initial consonants. The onsets and offsets of many sounds, however, are substantially different in the two temporal playback directions. For these reasons in the study of informational masking, the use of a normal speech masker and that same speech masker played backward are quintessential conditions.

Several studies have used speech signals and speech maskers to study energetic and informational masking using the speech maskers played forward and backward. The Synthetic Sentence Identification (SSI) materials (Speaks and Jerger, 1965) were used by Dirks and Bower (1969) to study "the effect of semantic content or meaning of a competing speech message" (p. 229). The SSI has 10 third-order approximation sentences with a story competition about Davy Crockett. The speaker of the sentences and story are the same.[1] There was no difference between identification performances obtained on the SSI when the competing story was played temporally forward or backward.

Multitalker babble also has been used as a speech masker. The classic Miller study (1947) demonstrated that as the number of talkers in the competing speech masker increases above one, the effectiveness of the masker increases. In that study (Miller, 1997, fig. 9, p. 119), 50% correct recognition was achieved at ~105 dB SPL with one talker, at ~96.5 dB SPL with two talkers, and stabilized at 94 to 95 dB SPL with four, six, or eight talkers. The finding that the masking effectiveness of babble stabilizes around six talkers has been substantiated with a variety of masking paradigms (Pollack and Pickett, 1958; Bronkhorst and Plomp, 1992; Simpson and Cooke, 2005; Brungart et al, 2009). The amplitude modulation characteristic of the one-talker competitor, which includes the natural silent intervals in the speech stream, provides favorable SNRs during which time speech perception is easy. As the number of talkers increases from one to two and then four or more, the amplitude modulation characteristic and the silent intervals in the waveform envelope are increasingly diminished and the speech masker increasingly becomes more like a conventional "random" speech-spectrum noise (SSN). Perceptually with multitalker babble, as the number of talkers is increased, the talker speech streams become increasingly entangled and the intelligibility of any particular talker is increasingly diminished. The link between a babble masker and a random noise masker is exemplified in a recent study that compared recognition performances with a six-talker babble and a SSN (Wilson et al, 2007). When the two maskers were at the same root-mean-square (rms), listeners with normal hearing performed 2 dB better in the babble than in the SSN; listeners with sensorineural hearing loss only had a 0.5 dB difference between the two maskers. The better performance on the babble condition was attributed to the valleys in the amplitude modulations of the babble providing "windows of opportunity" during which time the SNR was briefly improved. Such amplitude valleys were not available in the SSN envelope.

Garstecki and Mulac (1974) studied the effects of forward multitalker babble (FB) and backward multitalker babble (BB) on recognition performance with the CID W-22 words, the CID Everyday Speech Sentences, and the SSI materials, all of which were recorded by the same speaker. FB and BB were played continuously during the listening tasks. Listeners with normal hearing and two groups of listeners with hearing loss were studied. Performances on both CID materials were 5–7% better for

Delivered by Ingenta to: James H. Quillen VA Medical Center
IP : 152.130.8.8 On: Wed, 11 Jul 2012 20:15:06

BB than for FB, whereas performances on the synthetic sentences in babble were 20–25% better for BB than for FB. The differences were attributed to the "semantic content of the [FB] competing message" (p. 175), which today would be termed *informational masking*.

Hornsby et al (2006) reported with the HINT sentences (Nilsson et al, 1994) presented in sound field that as the number of talkers in spatial multitalker babble increased from two to seven, "both informational and energetic masking effects can be observed" (p. 446). Further, Hornsby et al reported for listeners with normal hearing that performance improved as the number of talkers decreased, whereas the number of talkers did not alter performance for listeners with hearing loss. The results from several studies using a variety of experimental paradigms indicate that informational masking is more pronounced in listeners with normal hearing than in listeners with hearing loss. Arbogast et al (2005) found that their different-band sentence masker produced about twice as much informational masking on listeners with normal hearing compared to listeners with hearing loss. A recent study used "speech-in-speech-in noise" paradigms in which the masking components were combinations of speech-shaped noise signals and speech signals (Agus et al, 2009). The speech-shaped noise provided the energetic masking component, and the speech provided the informational masking component, which mimicked the paradigm used earlier by Carhart et al (1968). Simple sentences with three keywords from the Audiovisual Sentence List (MacLeod and Summerfield, 1990) served as the target speech. When noise and speech were mixed as the masker, the maximum masking effect (3 to 5 dB) was observed with both listeners with normal hearing and older listeners with hearing loss. This was interpreted as evidence of informational masking, which was a slightly smaller effect for the listeners with hearing loss. A similar observation was made by Summers and Molis (2004) with sentence materials using a single-talker competing message played forward and backward.

This project explored the effects that energetic and informational masking have on the Words-in-Noise Test (WIN) that incorporates speech signals in a multitalker babble masker (Wilson, 2003; Wilson and Burks, 2005; Wilson and McArdle, 2007). The WIN involves two 35-word lists of monosyllabic words and 7 SNRs from 24 to 0 dB in 4 dB decrements. Five unique words are presented at each SNR with the metric of interest being the SNR at which the 50% point occurs as computed with the Spearman-Kärber equation (Finney, 1952). The words are from the Northwestern University Auditory Test No. 6 lists (NU-6; Tillman and Carhart, 1966) spoken by a female speaker (Causey et al, 1983; Department of Veterans Affairs, 2006). The six-talker, multitalker babble (three females and three males) was compiled by mixing the recordings of the six talkers after the silent gaps had been deleted (J.D. Causey, pers. comm, 1979).

Interestingly, the effects that energetic and informational maskers have on the same NU-6 recordings presented in the same six-talker babble described in the previous paragraph were studied earlier in a slightly different paradigm (Sperry et al, 1997). In that study of 18 young adults with normal hearing, 30 min babble samples were made for the forward babble (FB) and backward babble (BB).[2] Each listener was presented a 50-word list randomly in FB and BB at each of 5 SNRs from −8 to 8 dB in 4 dB steps. As depicted in Figure 1, except at the highest SNR, recognition performance on the BB condition was consistently 15% better than performance on the FB condition. At the 50% point, there was a 3.3 dB difference between the mean recognition performances the two conditions with BB at −1.2 dB S/N and FB at 2.1 dB S/N. The 3.3 dB difference suggests that an informational masking component was operating in this speech-in-noise paradigm.

Because the WIN incorporates the identical speech signals and multitalker babble materials used by Sperry et al (1997), it is easy to argue that the WIN also should demonstrate an informational masking component. Thus, the purpose of this study was to determine the degree of involvement that energetic and informational masking have in the WIN, which could guide future application of the WIN in domains of auditory function involving the two types of maskers. There are, however, differences between the WIN paradigm and the paradigm used by Sperry et al that prompt questioning an informational masking component with the WIN. First, the WIN uses a fixed level babble and a variable level speech signal, whereas Sperry et al employed a variable level babble and a fixed level speech signal. This is probably not a factor that would contribute to performance differences as Yost and Soderquist (1981) and Weber (1986) both demonstrated that which of the two variables (signal and masker) is fixed and which is varied has no consequence on the outcome. Second, the WIN uses unique 4.3 sec

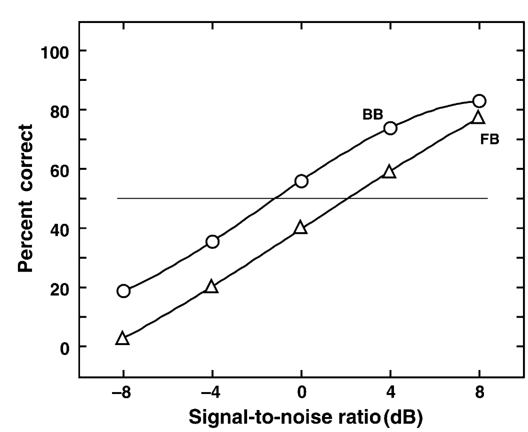

Figure 1. The mean percent correct obtained on the NU-6 materials when the competing babble was played normally or temporally forward (FB, triangles) and played temporally backward (BB, circles). The data are from Sperry et al (1997, table 1, p. 75).

Delivered by Ingenta to: James H. Quillen VA Medical Center
IP : 152.130.8.8 On: Wed, 11 Jul 2012 20:15:06

babble segments with each word that over the course of the test are randomly interspersed, whereas Sperry et al used a continuous 30 min loop of babble whose continuity was not interrupted over the course of the 50-word presentations. The random 4.3 sec snippets of babble used with the WIN are thought to minimize or negate any perceptual continuity of the babble. Three experiments were conducted primarily on listeners with normal hearing in pursuit of informational masking first in the WIN paradigm progressing to the paradigm used by Sperry et al. The hypothesis in Experiment 1 was that the WIN would provide equivalent results when the babble was played forward and backward thereby demonstrating little or no involvement of informational masking. Because the WIN is intended to evaluate listeners with hearing loss, such participants were included in this experiment. Experiment 2 pursued informational masking in a WIN-type paradigm that used the WIN words in the descending presentation level scheme but with continuous multitalker FB and BB segments as opposed to the 4.3 sec babble segments used in Experiment 1. Experiment 3 reverted to the stimulus paradigm used by Sperry et al in a partial replication of their study at two SNRs.

EXPERIMENT 1

Methods

Materials

The following three speech paradigms were incorporated: (1) the traditional WIN with the multitalker babble played temporally forward (FB), (2) the WIN with the multitalker babble played temporally backward (BB), and (3) the WIN words presented in quiet at each of the presentation levels used in the two babble paradigms. As indicated in the introduction the WIN consists of two 35-word lists of NU-6 materials with five unique words in each list presented at SNRs from 24 to 0 dB in 4 dB decrements (Wilson, 2003; Wilson and Burks, 2005; Wilson and McArdle, 2007). Each of the 70 words is companioned with a unique, 4.3 sec segment of six-talker babble (recorded by G.D. Causey, pers. comm., 1979). Thus, each of the WIN words was frozen temporally with its companion babble segment and was only used at one SNR. To avoid abrupt changes at the boundaries of the babble segments, the beginning and end of each babble segment were edited at the negative-going zero crossings, which provided a smooth transition between babble segments. Each of the 70 words was contained in a separate file with the carrier phrase and target word on the left channel and the multitalker babble on the right channel. The appropriate SNRs were set in each of these individual word files.

For the traditional WIN paradigm (FB), the files were concatenated to form two randomizations of each of the two lists, the channels were mixed with a monitor channel added to the second channel, and the files were recorded on CD (Hewlett-Packard, Model GWA-4162B). For the BB paradigm, several steps were required with a waveform editor. First with each of the 70 files, the beginning and end points of the target words were identified and the rms of the words and corresponding babble segments computed. The word lengths ranged from 233 to 689 msec (mean = 508 msec; SD = 79 msec). Second, the 4.3 sec babble waveform was reversed temporally. Third, the rms of the reversed babble segment that temporally corresponded to the target word was computed and adjusted to the rms level obtained for that word in the first step. In this manner the SNR over the duration of the target word was the same for both FB and BB. The rms adjustments to the BB segments were minimal with 84% (59 words) involving changes of ≤1 dB. Fourth, the two channels were mixed, and two randomizations of each list were compiled and recorded on CD as previously described. Finally, the words in each of the two WIN lists were recorded in quiet using the same 24 dB amplitude range incorporated in the WIN.

Participants

Sixteen young adult listeners (mean = 23.9 yr; SD = 2.6 yr) with normal hearing at the octave frequencies between 250 and 8000 Hz (≤20 dB HL; American National Standards Institute [ANSI], 2004) participated. The mean three-frequency (500, 1000, and 2000 Hz) pure-tone average (PTA) was 8.8 dB HL (SD = 5.4 dB), and the mean high-frequency, pure-tone average (HFPTA; 1000, 2000, and 4000 Hz) was 6.0 dB HL (SD = 5.5 dB). The 64 older listeners (mean = 65.6 yr; SD = 7.1 yr) met the following inclusion criteria for the test ear: (1) 55 to 85 yr of age, (2) 500 and 1000 Hz thresholds ≤40 dB HL, (3) PTA ≤40 dB HL, and (4) word recognition in quiet on the NU-6 materials >40% correct. The mean PTA was 27.8 dB HL (SD = 8.6 dB), and the HFPTA was 40.8 dB HL (SD = 8.4 dB). The mean audiograms for the test ears of both groups are shown in Figure 2.

Procedures

Each participant listened to List 1 and List 2 of the WIN words three times, once for each of the three conditions (WIN with FB, WIN with BB, and WIN words in quiet). The first four lists presented were for the two babble conditions with the conditions alternated and the lists and randomizations counterbalanced so that each participant received both lists for both conditions. Each list randomization was administered an equal number of times to each group of listeners. After the babble data were obtained, the quiet data were collected, alternating the list order among the listeners.

The materials in the three experiments were reproduced by a CD player (Sony, Model CDP-CE375) and fed through an audiometer (Grason-Stadler, Model

Delivered by Ingenta to: James H. Quillen VA Medical Center
IP : 152.130.8.8 On: Wed, 11 Jul 2012 20:15:06

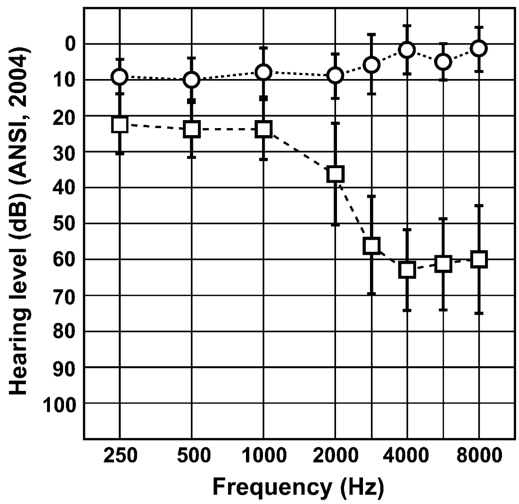

Figure 2. The mean audiograms for the 16 listeners with normal hearing (circles) and the 64 listeners with hearing loss (squares) in Experiment 1. The wide vertical lines are ±1 SD.

61) to an ER-3A insert earphone. A dummy insert earphone was in the nontest ear. The level of the babble was 80 dB SPL with the level of the words both in babble and in quiet varying from 104 to 80 dB SPL in 4 dB decrements. For the three experiments, the left ear was the test ear for the odd numbered listeners and the right ear was the test ear for the even numbered subjects. The testing was conducted in a sound booth with the verbal responses of the listeners recorded into a spreadsheet.

Results and Discussion

The mean results and standard deviations for the various listening conditions are listed in Tables 1 and 2 with the psychometric functions for the three conditions illustrated in Figure 3. Of primary interest were the recognition performances by the two groups of listeners on the WIN in the FB and BB conditions. As seen in Table 1, for the listeners with normal hearing there was a 0.3 dB mean difference between recognition performances on the FB and BB conditions (4.2 and 3.9 dB S/N, respectively) with performance on BB better than performance on FB. Likewise, for the listeners with hearing loss there was a 0.3 dB difference, albeit in the opposite direction, between performances on the FB and BB conditions (11.7 and 12.0 dB S/N, respectively). Neither of the 0.3 dB differences was significant (listeners with normal hearing, $p = 0.45$; listeners with hearing loss, $p = 0.50$). Comparable 50% points for each of the conditions were obtained from the individual data with the Spearman-Kärber equation and from the polynomial equations used to describe the mean data in Figure 3.

The similarities between performances on the FB and BB conditions by each of the two groups of listeners not only occurred at the 50% points but also were observed throughout the SNR ranges (Fig. 3 and Table 2). With one exception, the difference between corresponding mean performances for the forward and backward babble conditions was ≤4%. Considering the ∼7%/dB slopes of the functions (Table 1), 4% is equivalent to about a 0.5 dB difference. The one exception involves the listeners with normal hearing at the 0 dB S/N at which the mean performance on BB was 12% better than the mean performance on FB. Of the 16 listeners, only one listener had poorer performance on BB than on FB. This 12% difference, which on the rationalized arcsine transformed data (Studebaker, 1985) was significant ($t = -2.69$, df = 15, $p = .017$), can be interpreted as the lone indication in Experiment 1 of informational masking.

Finally, the individual data that are presented in Figure 4 as a bivariate plot of the 50% points obtained with FB (abscissa) and BB (ordinate) further emphasize the similarity in recognition performances obtained with the two conditions. First, all the data points are clustered closely about the diagonal line that represents equal performance on the two conditions. Data points above the diagonal line indicate better performance on the forward babble condition; thus, 25% of the listeners with normal hearing and 55% of the listeners with hearing loss had better performance on the FB condition, whereas 62.5% of the listeners with normal hearing and 31% of the listeners with hearing loss had better performance on the BB condition. The dashed line, which is a linear regression fit to the data from the listeners with hearing loss ($R^2 = 0.86$), has a slope that approaches unity (0.996 dB/dB) indicating a one-to-one relation between the two variables.

The recognition performances on the WIN words presented in quiet also are depicted in Figure 3 (triangles) and listed in Table 2. Two relations are noteworthy. First, for both groups of listeners at the highest two presentation levels, performances on the WIN words in quiet and in babble were essentially the same. For the listeners with normal hearing this relation was maintained over the 92 to 104 dB SPL range, whereas for the listeners with hearing loss it was maintained only at the two highest levels. Second, performance in quiet by both groups of listeners clearly demonstrates that the degraded performance on the WIN at the poorer SNRs was owing to the effects of the babble and not to audibility issues in quiet.

In summary, the data from Experiment 1 indicate that the WIN paradigm exhibits the same word-recognition performance regardless of temporal direction of the multitalker babble. As hypothesized, informational masking does not contribute in any substantial way to the overall masking effects that are observed with the WIN. Clinically, the WIN should be considered an energetic masking instrument. To evaluate if this lack of informational masking were owing to the random snippets of babble that are used in the WIN, a follow-up experiment was conducted.

Delivered by Ingenta to: James H. Quillen VA Medical Center
IP : 152.130.8.8 On: Wed, 11 Jul 2012 20:15:06

Table 1. Mean 50% Points (and standard deviations) Calculated from the Individual Listeners for the Forward (FB) and Backward Babble (BB) Conditions and the 50% Points Calculated from the Functions and the Slopes of the Functions at the 50% Points from Figures 3 and 5 for Experiments 1 and 2, Respectively

	Spearman-Kärber 50% Point		Polynomial	
Experiment/Condition	Mean (dB S/N)	SD (dB)	50% Point (dB S/N)	Slope (%/dB)
Experiment 1				
Normal Hearing				
FB	4.2	0.8	3.8	7.5
BB	3.9	1.0	4.0	6.4
Hearing Loss				
FB	11.7	2.6	10.8	7.5
BB	12.0	2.8	11.3	7.1
Experiment 2				
Normal Hearing				
FB	4.5	1.7	4.3	6.7
BB	4.2	1.4	3.9	6.2

EXPERIMENT 2

The purpose of this experiment was to determine if the lack of informational masking observed in Experiment 1 was attributable strictly to the effects of the randomized, 4.3 sec segments of babble. In Experiment 2, continuous babble segments were used throughout the course of each WIN list of 35 words, not the randomized, 4.3 sec segments of babble used in Experiment 1. Based on the Sperry et al (1997) data, the hypothesis for Experiment 2 was that a continuous, multitalker babble would produce better performance on the BB condition than on the FB condition (i.e., an informational masking component), which in turn would provide discriminant validity for the results obtained in Experiment 1.

Methods

Materials

The same eight lists of WIN words used in Experiment 1 were used in Experiment 2 (2 lists × 2 randomizations × 2 babble directions). Only the multitalker babble was different in the two experiments. For Experiment 2, a 69 min segment of babble was adjusted

Table 2. Mean Recognition Performances (%) for the Two Groups of Listeners (upper panel) and Corresponding Standard Deviations (bottom panel) for the Forward Babble (FB), Backward Babble (BB), and Quiet Conditions for the Two Groups of Listeners in Experiment 1

	Signal-to-Noise Ratio (dB)/Word Presentation Level (dB SPL)						
Group/Condition	0/80	4/84	8/88	12/92	16/96	20/100	24/104
Means							
Normal Hearing (n = 16)							
FB	18.1	51.3	78.1	99.4	100.0	100.0	99.4
BB	30.6	50.0	77.5	97.5	99.4	98.8	99.4
Quiet	96.3	99.4	96.9	99.4	100.0	100.0	99.4
Hearing Loss (n = 64)							
FB	0.9	5.5	24.8	67.3	76.4	91.4	91.4
BB	0.8	6.7	21.7	63.3	74.2	90.2	92.7
Quiet	76.4	81.3	83.3	91.1	93.0	96.9	96.4
Standard Deviations							
Normal Hearing							
FB	12.2	12.6	10.5	2.5	0.0	0.0	2.5
BB	11.8	7.3	8.6	5.8	2.5	3.4	2.5
Quiet	5.0	2.5	4.8	2.5	0.0	0.0	2.5
Hearing Loss							
FB	2.9	11.0	22.0	19.7	15.5	11.1	11.7
BB	3.7	9.9	19.9	21.7	16.3	11.3	10.9
Quiet	19.4	18.8	11.7	10.6	10.8	6.4	6.5

Delivered by Ingenta to: James H. Quillen VA Medical Center
IP : 152.130.8.8 On: Wed, 11 Jul 2012 20:15:06

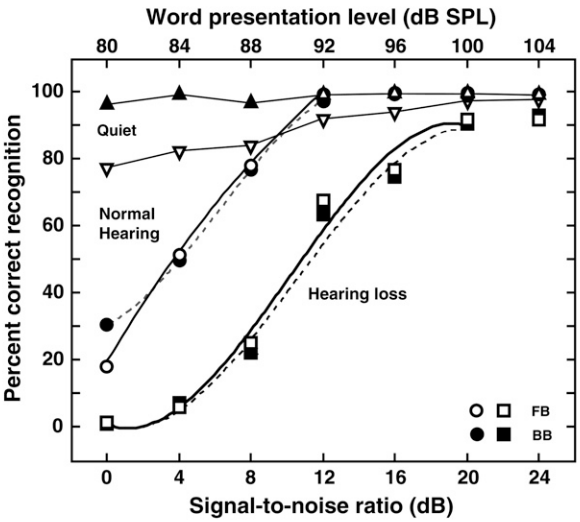

Figure 3. Psychometric functions are shown for the 16 listeners with normal hearing (filled triangles and circles) and from the 64 listeners with hearing loss (open triangles and squares) in Experiment 1 for the WIN materials in quiet (triangles), in forward babble (FB, open circles and squares), and in backward babble (BB, filled circles and squares). Third-degree polynomials are used to describe the masking data for the two groups of listeners.

in amplitude using rms to match the overall amplitude of the babble segments used in Experiment 1. The 69 min babble segment was copied on the second channel and temporally reversed. Then sequentially, (1) forty-eight 151 sec segments of FB and BB were edited from the master file; (2) the rise and fall characteristics of the 48 segments were shaped linearly over 500 msec; (3) 1 sec silent intervals were added to the beginning and end of each file; and (4) the two channels were copied into separate FB and BB files. Because of the randomness of the SNRs with each word and babble segment, no attempt was made to equalize the SNRs of each word in the FB and BB conditions. The order of the files was randomized with 32 FB and 32 BB segments paired and mixed with the WIN lists and recorded on CD. In this manner, 32 of the 48 FB and 32 of the 48 BB segments were used in Experiment 2. Each of the 16 participants was assigned 2 of the FB and 2 of the BB segments. Thus, each list presented to each listener was in a unique babble segment with no repetitions, which duplicated within limits the continuous 30 min babble used by Sperry et al (1997). The words for the quiet condition were as described in Experiment 1.

Participants

Sixteen young adult listeners (mean = 24.1 yr; SD = 3.0 yr), who were new to the study, participated. The PTA was 6.9 dB HL (SD = 5.8 dB), and the HFPTA was 5.4 dB HL (SD = 5.3 dB). Listeners with hearing loss were not included in Experiment 2.

Procedures

Again, each participant listened to List 1 and List 2 of the WIN words three times, once for the FB condition, once for the BB condition, and once in quiet. The FB and BB conditions were alternated and counterbalance among the participants with the quiet condition being administered last. The level of the babble was 80 dB SPL with the level of the words both in babble and in quiet varying from 104 to 80 dB SPL.

Results and Discussion

The data from Experiment 2 are listed in Tables 1 (bottom section) and 3 and are illustrated in Figures 5 and 6. As listed in Table 1, there was a minimal difference between the 50% points for the FB (4.5 dB S/N) and BB (4.2 dB S/N) conditions that was nonsignificant (p = 0.40). Except at the two poorest SNRs, the functions for the two conditions in Figure 5 are essentially superimposed with slopes of 6.7%/dB and 6.2%/dB for FB and BB, respectively. At 0 dB S/N, performance was 4.4% better on BB than on FB with six listeners better on BB, six listeners better on FB, and four listeners equal; this difference was not significant (p = 0.62) on the rationalized arcsine transformed data. At 4 dB S/N, performance was 3.8% better on BB than on FB with nine listeners better on BB, four listeners better on FB, and three listeners equal; this difference was not significant (p = 0.41) on the rationalized arcsine transformed data. The data

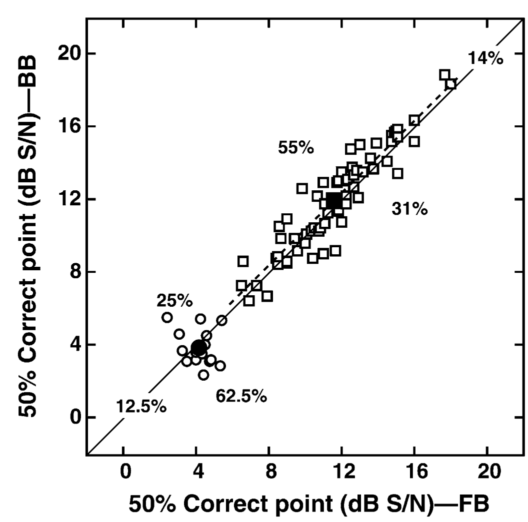

Figure 4. A bivariate plot of the WIN 50% points obtained in Experiment 1 from the 16 listeners with normal hearing (circles) and from the 64 listeners with hearing loss (squares) for forward babble (FB, abscissa) and backward babble (BB, ordinate) is shown. The large filled symbols represent the mean data, and the percentage numbers indicate the portion of performances above, on, and below the diagonal line that represents equal performance. The dashed line is a linear regression fit to the data from the listeners with hearing loss.

Delivered by Ingenta to: James H. Quillen VA Medical Center
IP : 152.130.8.8 On: Wed, 11 Jul 2012 20:15:06

Table 3. Mean Recognition Performances (%) for the 16 Listeners with Normal Hearing (upper panel) and Corresponding Standard Deviations (bottom panel) for the FB, BB, and Quiet Conditions in Experiment 2

	Signal-to-Noise Ratio (dB)/Word Presentation Level (dB SPL)						
Group/Condition	0/80	4/84	8/88	12/92	16/96	20/100	24/104
Means							
FB	20.6	46.9	78.1	99.4	96.9	98.8	97.5
BB	25.0	50.6	78.8	98.1	97.5	98.1	98.1
Quiet	95.6	98.8	97.5	99.4	100.0	98.1	98.8
Standard Deviations							
FB	12.9	19.9	14.7	2.5	4.8	3.4	4.5
BB	15.9	17.3	16.7	4.0	4.5	4.0	4.0
Quiet	7.3	3.4	4.5	2.5	0	4.0	3.4

in Figure 6 show the fairly equal distribution of the 16 individual 50% points about the diagonal line of equal performance. The findings from Experiment 2 demonstrate that when the WIN paradigm was modified to accommodate continuous segments of babble over the duration of the word presentations, there is no evidence of informational masking involvement. Further, the data indicate that the FB and BB maskers can be used interchangeably in the WIN paradigm with equivalent results.

There is an interesting comparison between the data from the young listeners with normal hearing in Experiments 1 and 2. To reduce variability, the WIN was designed using a paradigm in which the words were always fixed in a unique sample of babble. This was done so that each word would always have the identical signal and masker relation that in turn was theorized to reduce variability. A comparison of the standard deviations from Experiments 1 and 2 supports this line of reasoning. The average standard deviations at 0, 4, and 8 dB S/N, which is where variability with the WIN is observed on young listeners with normal hearing, were 10.5 dB in Experiment 1 and 16.2 dB in Experiment 2, a 5.7 dB difference. Thus, the randomness between the coincidences of the target words and the babble that characterized Experiment 2 increased intersubject variability by about 30%.

In view of the Sperry et al (1997) findings of an inferred informational masking component that was observed with the identical speech and babble materials used in the current experiments, the results of Experiment 2 were somewhat unanticipated, which prompted Experiment 3.

EXPERIMENT 3

The paradigm used in Experiment 2 approached but did not exactly duplicate the paradigm used by Sperry et al (1997) that produced 15% higher word recognition when the babble was temporally backward compared to temporally forward. Thus, in Experiment 3, the Sperry et al paradigm was replicated within limits at two SNRs in an attempt to duplicate the differing performances on the FB and BB conditions. Because informational masking is most likely to manifest itself under those conditions in which the signal and the masker have the most similarities, SNRs of 0 and 4 dB were studied. The "within limits" replication involved both similarities and differences. As previously noted, the two studies both involved the identical speech and multitalker babble materials and utilized young adults with normal hearing. The studies were different in two main respects. First, Sperry et al fixed the level of the speech at 40 dB SL (sensation level re the pure-tone average at 1000, 2000, and 4000 Hz) and presented 50 words to participants in each of 15 masking conditions that included 5 SNRs for FB and 5 SNRs for BB. In contrast, the Experiment 3 protocol fixed the level of the multitalker babble at 70 dB SPL and presented 100 different words to each participant in the FB and BB conditions. As mentioned previously, Yost and Soderquist (1981) and Weber (1986) demonstrated the same result is achieved by varying the level of the signal and fixing the level of the masker and by varying the level of the masker and fixing the level of the signal. Second, the 18 participants in the

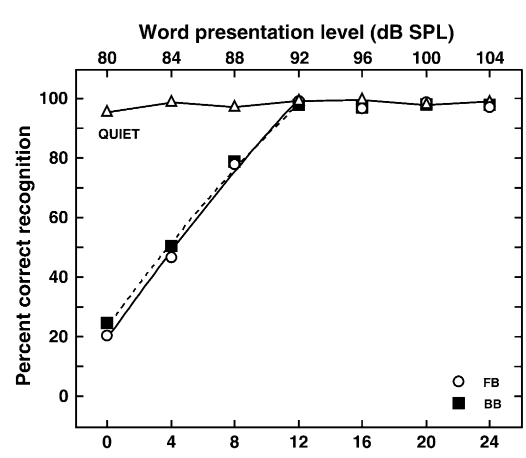

Figure 5. Psychometric functions are shown for the 16 listeners with normal hearing from Experiment 2 for the WIN materials in quiet (triangles), in forward babble (FB, circles), and in backward babble (BB, squares). Second-degree polynomials are used to describe the masking data.

Delivered by Ingenta to: James H. Quillen VA Medical Center
IP : 152.130.8.8 On: Wed, 11 Jul 2012 20:15:06

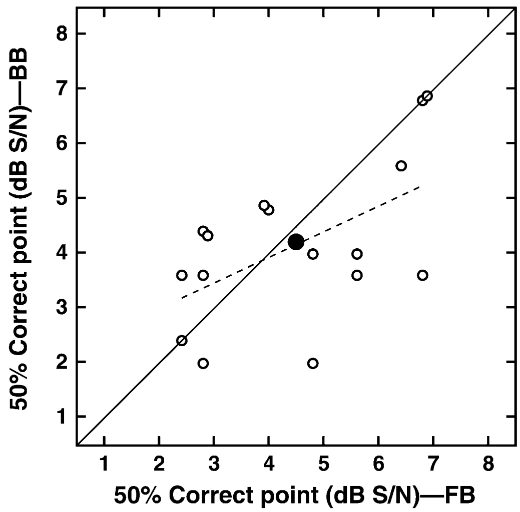

Figure 6. A bivariate plot of the WIN 50% points obtained in Experiment 2 from the 16 listeners with normal hearing for forward babble (FB, abscissa) and backward babble (BB, ordinate) is shown. The large filled symbols represent the mean data.

Sperry et al study listened to the materials at five SNRs in each of three masking conditions; the five SNRs (−8 to 8 dB in 4 dB steps) involved the range of listening difficulty from easy to difficult. The current experiment used 24 listeners for each of two SNRs (48 total participants); the range of listening difficulty for the two SNRs (4 and 0 dB) was on the difficult end of the listening continuum where presentation level cues are minimal.

Methods

Materials

For this experiment, each of the four NU-6 lists (Department of Veterans Affairs, 2006) was divided into two 25-word lists that were ~120 sec. The 151 sec babble segments (48 forward and 48 backward) available for Experiment 2 were shortened to 125 sec, which was several seconds longer than the 25-word lists. For each subject, four of the 25-word lists were uniquely paired with FB segments (100 words), and the remaining four 25-word lists were uniquely paired with BB segments (100 words). The words and babble were mixed on the left channel with the words retained in quiet for monitoring purposes on the right channel. As in Experiment 2, no attempt was made to equalize the SNRs for each word in the FB and BB conditions. Because each word list and babble segment were unique, the eight lists for each participant were recorded on individualized CDs.

Participants

Two groups of 24 young adult listeners participated, one group for each SNR. These 48 listeners were new to the study. For the 4 dB S/N condition, the 24 listeners (mean = 21.6 yr; SD = 3.3 yr) had a mean PTA of 4.6 dB HL (SD = 3.1 dB) and a HFPTA of 4.2 dB HL (SD = 3.3 dB). For the 0 dB S/N condition, the 24 listeners (mean = 22.2 yr; SD = 4.1 yr), who were new to the experiment, had a mean PTA of 4.7 dB HL (SD = 4.3 dB) and a mean HFPTA of 3.3 dB HL (SD = 4.6 dB).

Procedures

For both the 0 and 4 dB S/N conditions, each listener was presented eight 25-word lists (all 200 NU-6 words) with four lists for the FB condition and four lists for the BB condition. The babble was presented at 70 dB SPL. For each participant the order of the lists was quasirandomized, and the two conditions were alternated across the eight lists. Each 25-word list was given an equal number of times at each SNR. Thus, with each of the two SNRs, each of the eight 25-word lists was presented 12 times in each of the two conditions, each time using a unique segment of babble. No list and babble segment combinations were repeated. The data were collected in a 1 hr session.

Results and Discussion

The mean percent correct recognition on the NU-6 words presented in FB and BB at 0 and 4 dB S/N are presented in Table 4. Each mean in Experiment 3 was based on 2400 words or 100 words/listener. For both SNRs in Experiment 3, the differences between recognition performances on the FB and BB conditions were ~0.5%; both differences between FB and BB were not significant (0 dB S/N, $p = 0.55$; 4 dB S/N, $p = 0.68$). These relations substantiate the findings from Experiments 1 and 2 that these particular materials (female recording of NU-6 and the six-talker babble) are immune to the effects of informational masking as evaluated with FB and BB.

The data from Experiment 3 are in contrast to the Sperry et al (1997) data that demonstrated a 15% informational masking effect with the same materials (Fig. 1 and Table 4). There are two comparisons between the Experiment 3 and the Sperry et al data that can be made in Table 4. First, the percent correct recognitions in the Sperry et al study are somewhat higher in three of the four mean comparisons, a relation that is attributable to the exposure to the materials that each listener received in the two studies. In the Sperry et al study, each listener listened to each word four times (three conditions by five SNRs plus one quiet). In Experiment 3, each listener was only exposed to each word once. Some familiarity with the test materials is helpful, especially in difficult listening conditions as are encountered at the less favorable SNRs. Second, it is interesting that 55–56% mean performances on the FB and BB conditions observed in Experiment 3 at 4 dB S/N were close to the 59.1% mean performance that Sperry et al observed for their FB condition at 4 dB S/N. Again, the 3–4% difference between studies can be attributed to the familiarity issue just mentioned.

Delivered by Ingenta to: James H. Quillen VA Medical Center
IP : 152.130.8.8 On: Wed, 11 Jul 2012 20:15:06

Table 4. Percent Correct Recognition on the NU-6 Words Spoken by a Female Speaker in Multitalker Babble in Experiment 3 (2400 words/point) and in the Sperry et al (1997) Study (900 words/point)

	Backward Babble (BB)		Forward Babble (FB)		Difference
Condition/Study	Mean	SD	Mean	SD	(BB – FB)
4 dB S/N					
Experiment 3	55.9	7.0	55.3	6.8	0.6
Sperry et al	74.1	8.0	59.1	8.8	15.0
0 dB S/N					
Experiment 3	28.6	4.5	28.1	4.9	0.5
Sperry et al	56.1	10.8	40.3	11.2	15.8

More importantly, the relation between the results of the two studies at 4 dB S/N suggests that the different findings are attributable to the BB condition of the Sperry et al study. In Experiment 3, the FB and BB segments were obtained using the same procedures with one simply being the temporal reversal of the other. In the Sperry et al study, however, FB was a continuous 30 min segment, whereas BB was a 30 sec segment of FB that was digitally reversed (temporally) and looped continuously to produce the 30 min BB sample. The premise here is that the 30 sec segment of BB, in some unknown way, was not representative of a BB segment derived by reversing an intact, continuous 30 min segment of FB. In the Sperry et al study, the data for FB and BB are DC (direct current) shifted, which implies some linear process. In all probability, informational masking in the speech domain is not expected to be linear across SNRs because the more similar the target speech and speech masker are (in this case in presentation level) the more pronounced the effects of informational masking. The conclusion from the current data, especially in Experiment 3, is that with a word-recognition task, the six-talker babble contains insufficient cues like contextual and semantic content to elicit an informational masking component.

Finally, introspective reports of the listeners revealed no awareness that the babble was temporally reversed in half of the listening conditions. Cherry (1953) obtained similar introspective reports from listeners instructed to repeat the speech message presented to the right ear while ignoring the speech message presented temporally reversed to the left ear. When queried about the left-ear message, Cherry reported , "the reversed speech was identified as having 'something queer about it' by a few listeners, but was thought to be normal speech by others" (p. 978).

SUMMARY

Sperry et al (1997) using a speech-recognition task in multiple SNRs observed a 15% better performance when the competing multitalker babble was played backward (BB) than when the babble was played forward (FB), which can be interpreted as evidence of informational masking (Dirks and Bower, 1969). The three experiments of the current study were unable to find any appreciable evidence of informational masking in paradigms similar to the one used by Sperry et al. Experiment 1 used the FB and BB conditions to determine whether informational masking operated in the WIN paradigm, which coincidently uses the same speech and babble signals used by Sperry et al. The WIN, however, uses unique 4.3 sec segments of babble temporally fixed to each word as opposed to the continuous nonsegmented babble segments used by Sperry et al. Both listeners with normal hearing and listeners with hearing loss were examined. The only suggestion of informational masking was observed in Experiment 1 from the listeners with normal hearing at the 0 dB S/N. Overall, the conclusion was that informational masking was not evident in the WIN. Experiment 2 more likely replicated the Sperry et al study by using continuous segments of babble in the WIN paradigm. No significant differences were observed between the FB and BB conditions, again suggesting no evidence of informational masking. Experiment 3 focused on recognition performances using FB and BB at 0 and 4 dB S/Ns. At both SNRs, data from 2400 words for each condition indicated equal performances on the FB and BB conditions, which is interpreted as no indication of informational masking. The conclusion is that as measured in this study with FB and BB conditions, the six-talker multitalker babble does not induce an informational masking component for monosyllabic words presented through an earphone.

NOTES

1. To this observer, the differences in delivery of the target sentences and the competing message are such that it is difficult to recognize that the speaker of the two messages is the same.
2. Sperry et al (1997) included a speech-spectrum noise condition that is not pertinent to the current study.

REFERENCES

Agus TR, Akeroyd MA, Gatehouse S, Warden D. (2009) Informational masking in young and elderly listeners for speech masked by simultaneous speech and noise. *J Acoust Soc Am* 126(4):1926–1940.

American National Standards Institute (ANSI). (2004) *Specification for Audiometers (ANSI S3.6 2004)*. American National Standards Institute. New York.

Delivered by Ingenta to: James H. Quillen VA Medical Center
IP : 152.130.8.8 On: Wed, 11 Jul 2012 20:15:06

Arbogast TL, Mason CR, Kidd G, Jr. (2005) The effect of spatial separation on informational masking of speech in normal-hearing and hearing-impaired listeners. *J Acoust Soc Am* 117(4, Pt. 1):2169–2180.

Bolia RS, Nelson WT, Ericson MA, Simpson BD. (2000) A speech corpus for multitalker communications research. *J Acoust Soc Am* 107(2):1065–1066.

Bronkhorst AW, Plomp R. (1992) Effect of multiple speechlike maskers on binaural speech recognition in normal and impaired hearing. *J Acoust Soc Am* 92(6):3132–3139.

Brungart DS. (2001) Evaluation of speech intelligibility with the coordinate response measure. *J Acoust Soc Am* 109(5, Pt. 1): 2276–2279.

Brungart DS, Chang PS, Simpson BD, Wang D. (2009) Multitalker speech perception with ideal time-frequency segregation: effects of voice characteristics and number of talkers. *J Acoust Soc Am* 125 (6):4006–4022.

Carhart R, Tillman TW, Greetis ES. (1969) Perceptual masking in multiple sound backgrounds. *J Acoust Soc Am* 45(3):694–703.

Carhart R, Tillman TW, Johnson KR. (1968) Effects of interaural time delays on masking by two competing signals. *J Acoust Soc Am* 43(6):1223–1230.

Causey GD, Hermanson CL, Hood LJ, Bowling LS. (1983) A comparative evaluation of the Maryland NU 6 auditory test. *J Speech Hear Disord* 48(1):62–69.

Cherry EC. (1953) Some experiments on the recognition of speech, with one and with two ears. *J Acoust Soc Am* 25:975–979.

Department of Veterans Affairs. (2006) *Speech Recognition and Identification Materials. Disc 4.0*. Mountain Home, TN: VA Medical Center.

Dirks DD, Bower DR. (1969) Masking effects of speech competing messages. *J Speech Hear Res* 12(2):229–245.

Egan JP, Carterette EC, Thwing EJ. (1954) Some factors affecting multi-channel listening. *J Acoust Soc Am* 26:774–782.

Finney DJ. (1952) *Statistical Method in Biological Assay*. London: C. Griffen.

Garstecki DC, Mulac A. (1974) Effects of test material and competing message on speech discrimination. *J Aud Res* 14:171–178.

Hawkins JE, Stevens SS. (1950) The masking of pure tones and of speech by white noise. *J Acoust Soc Am* 22:6–13.

Hornsby BWY, Ricketts TA, Johnson EE. (2006) The effects of speech and speechlike maskers on unaided and aided speech recognition in persons with hearing loss. *J Am Acad Audiol* 17(6):432–447.

Kellogg EW. (1939) Reversed speech. *J Acoust Soc Am* 10:324–326.

Kidd G, Jr, Mason CR, Arbogast TL. (2002) Similarity, uncertainty, and masking in the identification of nonspeech auditory patterns. *J Acoust Soc Am* 111(3):1367–1376.

Lutfi RA. (1990) How much masking is informational masking? *J Acoust Soc Am* 88(6):2607–2610.

MacLeod A, Summerfield Q. (1990) A procedure for measuring auditory and audio-visual speech-reception thresholds for sentences in noise: rationale, evaluation, and recommendations for use. *Br J Audiol* 24(1):29–43.

Massaro DW. (1972) Preperceptual images, processing time, and perceptual units in auditory perception. *Psychol Rev* 79(2):124–145.

Meyer-Eppler W. (1950) Reversed speech and repetition systems as means of phonetic research. *J Acoust Soc Am* 22:804–806.

Miller GA. (1947) The masking of speech. *Psychol Bull* 44(2):105–129.

Nilsson M, Soli SD, Sullivan JA. (1994) Development of the Hearing in Noise Test for the measurement of speech reception thresholds in quiet and in noise. *J Acoust Soc Am* 95(2):1085–1099.

Pollack I. (1975) Auditory informational masking [Abstract]. *J Acoust Soc Am* 57(Suppl. 1):S5.

Pollack I, Pickett JM. (1958) Stereophonic listening and speech intelligibility against voice babble. *J Acoust Soc Am* 30:131–133.

Simpson SA, Cooke M. (2005) Consonant identification in *N*-talker babble is a nonmonotonic function of *N*. *J Acoust Soc Am* 118(5):2775–2778.

Speaks C, Jerger J. (1965) Method for measurement of speech identification. *J Speech Hear Res* 8:185–194.

Sperry JL, Wiley TL, Chial MR. (1997) Word recognition performance in various background competitors. *J Am Acad Audiol* 8(2):71–80.

Studebaker GA. (1985) A "rationalized" arcsine transform. *J Speech Hear Res* 28(3):455–462.

Summers V, Molis MR. (2004) Speech recognition in fluctuating and continuous maskers: effects of hearing loss and presentation level. *J Speech Lang Hear Res* 47(2):245–256.

Tillman TW, Carhart R. (1966) *An Expanded Test for Speech Discrimination Utilizing CNC Monosyllabic Words. Northwestern University Auditory Test No. 6*. USAF School of Aerospace Medicine Technical Report. Brooks Air Force Base, TX: USAF School of Aerospace Medicine.

Watson CS. (2005) Some comments on informational masking. *Acta Acustica united with Acustica* 91:502–512.

Watson CS, Kelly WJ, Wroton HW. (1976) Factors in the discrimination of tonal patterns. II. Selective attention and learning under various levels of stimulus uncertainty. *J Acoust Soc Am* 60(5):1176–1186.

Weber DL. (1986) Procedure-independent growth-of-masking functions. *J Acoust Soc Am* 79(6):2082–2084.

Webster JC, Thompson PO. (1954) Responding to both of two overlapping messages. *J Acoust Soc Am* 26:396–402.

Wilson RH. (2003) Development of a speech-in-multitalker-babble paradigm to assess word-recognition performance. *J Am Acad Audiol* 14(9):453–470.

Wilson RH, Burks CA. (2005) Use of 35 words for evaluation of hearing loss in signal-to-babble ratio: a clinic protocol. *J Rehabil Res Dev* 42(6):839–852.

Wilson RH, Carnell CS, Cleghorn AL. (2007) The Words-in-Noise (WIN) test with multitalker babble and speech-spectrum noise maskers. *J Am Acad Audiol* 18(6):522–529.

Wilson RH, McArdle R. (2007) Intra- and inter-session test, retest reliability of the Words-in-Noise (WIN) test. *J Am Acad Audiol* 18 (10):813–825.

Yost WA, Soderquist DR. (1981) Varying the masker or the signal level in forward masking: a procedural comparison. *Acoustics Letters* 4:219–223.

Delivered by Ingenta to: James H. Quillen VA Medical Center
IP : 152.130.8.8 On: Wed, 11 Jul 2012 20:15:06