A Comparative Study of Two Self-Adaptive Noise Filtering Techniques

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The study assessed the relative effectiveness of two commercially available self-adaptive noise filtering amplification systems: the Zeta Noise Blocker microchip (ZNB) and an automatic signal processing circuit (ASP). Word recognition (NU-6) performance in five competing signals (audiometer speech noise, cafeteria noise, multitalker babble, four-talker babble, and continuous discourse) was measured for 15 normal-hearing subjects aided with conventional, ZNB, and ASP hearing aids. Only a small proportion of subjects demonstrated significant performance improvements with ZNB or ASP aids when compared to performance with conventional aids. The two noise filtering systems performed similarly in four of the five competing signals used in the study.

A well known complaint of hearing aid users is limited hearing aid benefit in noisy listening situations. Historically, hearing aid designs have been unsatisfactory in selectively removing noise from speech, resulting in reduced speech discrimination, discomfort, and fatigue.

Several approaches, involving both hearing aid design and fitting procedures, have been utilized to improve the effectiveness of amplification systems in noise. Some success has been noted from frequency response shaping, earmold modifications, automatic gain control (AGC) circuitry, and directional microphones. A common and major drawback of all these systems, however, has been their inability to self-adjust to changing noise conditions. As Graupe, Gosspietsch, and Taylor (1986) explained, "They do not distinguish between

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noise and speech . . . and cannot adjust to specific noise frequency locations and intensities at a given time" (p. 29).

Recent technological advances have led to the commercial introduction of two self-adaptive noise filtering systems: the Zeta Noise Blocker microchip (ZNB) and automatic signal processing circuitry (ASP), both of which may be incorporated in commercially available hearing aids. These systems are designed, in unique ways, to detect the presence of background noise and adjust the hearing aid's response characteristics to improve the signal-to-noise ratio (S/N) at the listener's ear.

The ZNB employs a programmed microprocessor and a bank of adjustable filters to analyze and act upon its input (Graupe et al., 1986). The microprocessor discriminates speech from noise by analyzing the variation of the signal across time. The underlying rationale for this type of analysis is that noise is less fluctuating than is speech. After determining that noise is present, the microprocessor identifies its spectral properties. The filter's cut-off frequencies and attenuation levels are then automatically adjusted to approximate the composition of the noise input. The threshold of activation of the ZNB is reported as being "in the upper 50s to low 60s dB SPL, depending on frequency" (Grosspietsch, 1987, p. 20). Noise inputs of lesser intensities are monitored passively.

ASP is a term encompassing a variety of hearing aid circuits. We limit our discussion and study to ASP circuitry employing automatic passband adjustment or, more specifically, passband splitting techniques (Pollack, 1987). This type of system acts, in essence, as an automatic tone control (Kates, 1986; Pollack, 1987). Input is divided into a compressing low-frequency channel and a linear high-frequency channel. The cut-off frequency of the low-frequency channel can be adjusted to 800 Hz or 1600 Hz. In situations containing low-frequency noise, a low-frequency compression amplifier is activated, compressing the input in its band. The greater the intensity of low-frequency input, the greater the compression of this input. The response of the high-frequency channel remains linear during low-frequency compression, giving the hearing aid a high-frequency emphasis in these noise conditions. When noise levels are below the pre-set threshold of the compression amplifier, the low-frequency channel responds linearly, giving the hearing aid a more broadband response in quiet conditions. For more detailed and technical descriptions of ZNB and ASP circuitry, see Graupe et al. (1986), Kates (1986), and Pollack (1987).

Studies of the effectiveness of ZNB technology have reported varying findings. Stein and Dempesy-Hart (1984) and Wolinski (1986) measured aided word recognition scores in various competing signals with and without ZNB filtering. Stein and Dempesy-Hart tested normal-hearing and hearing-impaired subjects using a prototype bench model of the ZNB, while Wolinski tested moderate-to-severe hearing-impaired subjects using a first-generation commercial version of the ZNB. Both studies presented monosyllabic words in narrowband low-frequency and high-frequency noises, cafeteria noise, and six-talker babble. Stein and Dempesy-Hart also measured performance in white noise. In both studies, the ZNB provided the largest improvements in word recognition scores in low-frequency noise and cafeteria noise. The smallest performance improvements occurred under the more broadband competing noise conditions: six-talker babble and white noise. The proportion of subjects demonstrating significant improvements under each noise condition varied greatly between studies. For example, Stein and Dempesy-Hart reported significant word recognition improvements with ZNB filtering for 75% of subjects in cafeteria noise and 35% in six-talker babble. Wolinski found that only 39% and 6% of his subjects demonstrated significant improvements in these same respective noise conditions.

Van Tasell, Larsen, and Fabry (1988) measured aided speech reception thresholds for monosyllabic and spondaic words in low-frequency and broadband noise with and without ZNB filtering. A prototype ZNB employed within a master hearing aid system was used in the study. The effectiveness of the ZNB was found to vary as a function of speech material and noise type. The ZNB provided the largest threshold improvements when monosyllabic words were presented in low-frequency noise. No threshold improvements were seen when spondaic words were presented in broadband noise. The authors concluded that the ZNB was most effective when "noise is restricted in frequency content and when it does not occupy a region of important speech information" (p. 20).

Studies concerning the effectiveness of ASP circuitry are small in number and limited in scope. Stach, Speerschneider, and Jerger (1987) evaluated the performance of in-the-ear (ITE) and behind-the-ear (BTE) hearing aids employing ASP technology. Sentences from the Synthetic Sentence Identification (SSI) Test were presented in a continuous discourse competing noise condition. Aided SSI recognition scores were calculated with and without ASP filtering. Thirteen of 20 hearing-impaired subjects tested demonstrated performance improvements, ranging from 20% to 60%, with ASP filtering. Sigelman and Preves (1987) conducted field trials of an ITE ASP hearing aid. Data were gathered from several hearing aid dispensers who followed a recommended test procedure. The procedure included measurement of word recognition scores in broadband noise with and without ASP filtering. The specific type of broadband noise used by the dispensers was not reported by the investigators. Eighty-three percent of hearing-impaired subjects tested displayed nominal increases in word recognition scores. Mean improvements were 11% in "low-level noise" and 9% in "high-level noise." The proportion of subjects demonstrating statistically significant increases was not reported.

Although the above investigations provide useful information concerning the performance of self-adaptive noise filtering systems, current data are lacking in two major areas. First, the effectiveness of ZNB and ASP technology has not been systematically tested across a wide range of noise types. Competing noises utilized in ZNB studies by Stein and Dempesy-Hart (1984), Wolinski (1986), and Van Tasell et al. (1988) were primarily steady-state and nonspeech in nature, while ASP investigations by Sigelman and Preves (1987) and Stach et al. (1987) were limited to unspecified broadband noise and continuous discourse, respectively. Second, no study has directly compared the effectiveness of ZNB and ASP noise filtering techniques. Post-hoc comparison of available studies is limited due to the use of differing speech stimuli, noise types and levels, subject selection procedures, and hearing aid response parameters.

The purpose of this study was to expand our knowledge of self-adaptive noise filtering systems by comparing word recognition scores in noise for a group of subjects utilizing conventional, ZNB, and ASP amplification. Noise types were selected to allow an analysis of the relative merits of the two noise filtering techniques in a variety of broadband competing signals having different fluctuation characteristics, ranging from steady-state nonspeech noise to continuous discourse.

METHOD

Subjects

Factors such as degree and configuration of hearing loss, residual discrimination ability, previous hearing aid experience, noise levels, and hearing aid response parameters may differentially affect a listener's performance. To minimize the effect of these variables, we measured the word recognition performance of normal-hearing subjects listening to speech under adverse S/N conditions. The use of normal-hearing subjects allowed us to fix hearing aid response parameters and settings across subjects and listening conditions. Past investigations of both ZNB (Stein & Dempesy-Hart, 1984) and ASP (Preves & Sigelman, 1986) noise filtering techniques have reported similar performance trends for hearing-impaired subjects and normal-hearing subjects whose discrimination is degraded by noise. This similarity has been observed across competing signals having a variety of spectral characteristics.

Four male and 11 female adults served as subjects. Ages ranged from 21 to 30 years, with a mean age of 24.5 years. All subjects demonstrated normal hearing bilaterally by passing a hearing screening administered at 15 dB HTL for the octave frequencies 250-8000 Hz. No subject had previous experience with the test stimuli used in the experiment.

Conditions

Word recognition scores were obtained using a cassette tape recording of 200 monosyllabic words from Northwestern University Auditory Test No. 6 (NU-6) Lists 1A-4A. Testing was conducted under five listening conditions and five competing noise conditions.

Listening Conditions. The five listening conditions were unaided, aided with conventional amplification (CA), aided with ASP amplification (ASP), and two conditions using ZNB amplification (Z1 and Z2). Under the ASP condition, subjects were aided binaurally with Siemens 283 ASP BTE hearing aids. Under the two ZNB conditions, subjects were aided binaurally with Maico SP 137 BTE hearing aids (Z1) and Maico SP 345 BTE hearing aids (Z2). We tested two different ZNB aids to assess the consistency of the ZNB microchip when employed in different hearing aids. Under the conventional amplification condition, subjects were aided binaurally with the Z1 hearing aids set to the Zeta Off position. At this setting, the self-adaptive noise filter is deactivated and the aid operates in a non-adaptive, or conventional, manner (Graupe et al., 1986; Stein & Dempesy-Hart, 1984).

The same hearing aids were utilized across all subjects. Vented (.095 in.) shell earmolds were custom made for each subject prior to testing. Frequency responses of the six hearing aids were matched as closely as possible with their noise filtering circuits off and all settings (e.g., tone control and volume control) were fixed across subjects. A frequency response appropriate for hearing-impaired persons having mildly sloping audiometric configurations was chosen. Frequency responses used in the experiment are shown in Figure 1.

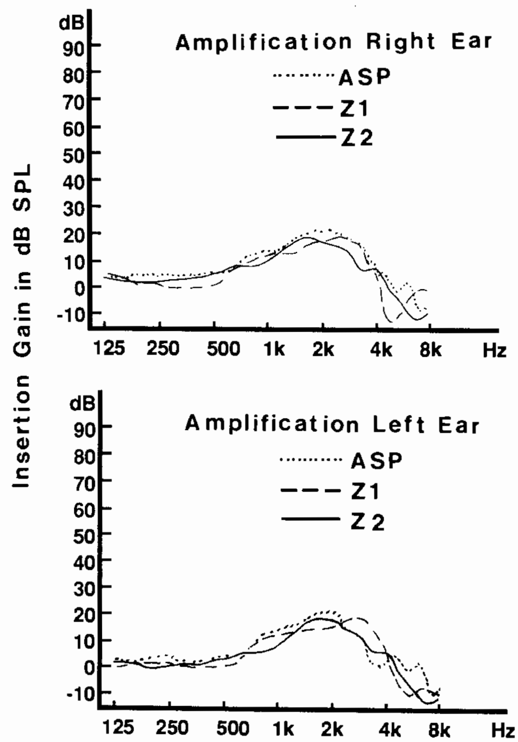

Figure 1. Frequency responses of the six hearing aids used in the study. ASP = Automatic Signal Processing hearing aid. Z1 and Z2 are hearing aids with a Zeta Noise Blocker circuit.

The response curves were obtained using a Rastronics CCI-10 Real Ear Analyzer with each hearing aid tested on a 25-year-old female subject. The hearing aids were set as follows: for the ASP, f = 8, G = -10, PC = 0, VC = 1, A = min.; for the Z1, SPL = max., Tone = N, VC = 3, Zeta Off; and for the Z2, SPL = min., Tone = H, VC = 2.5, Zeta Off. Under the ASP condition, the ASP function control was set to A = max. Under the Z1 and Z2 conditions, the hearing aids were set to the Zeta On position.

Noise Conditions. The five noise conditions were audiometer speech noise, cafeteria noise, multitalker babble (20 young adults simultaneously reading different passages), four-talker babble (three female talkers and one male talker), and continuous discourse (one male talker). The cafeteria noise, multitalker babble, four-talker babble, and continuous discourse were commercially available cassette tape recordings (Auditec of St. Louis, Inc.). A Beltone 200-C two-channel clinical audiometer was the source of the speech noise.

The above noise conditions were chosen to allow measurement of the effectiveness of the noise filtering hearing aids in a variety of broadband competing signals having different time-intensity characteristics. Audiometer speech noise is a steady-state noise with energy predominant in low- and mid-frequencies. Cafeteria noise and multitalker babble are quasi-steady in nature; both competing signals, while containing speech, have power spectra that fluctuate less than speech alone due to the averaging effects of the mixing procedure used during tape production. Four-talker babble is a more fluctuating signal because it is a mix of a small number of talkers. Continuous discourse, being the recording of a single talker, was the most fluctuating of the competing signals used in the experiment.

The NU-6 stimuli were delivered from a Sony TC-FX707R stereo cassette deck through channel one of the audiometer. The tape-recorded competing signals were routed from a TEAC V-45 stereo cassette deck through channel two of the audiometer. Speech and noise were mixed and presented to the subjects through an Electro-Voice SP 12C loudspeaker located in the test room of a sound-attenuating audiometric suite. Each subject was seated facing the loudspeaker at a distance of three feet.

Procedure

Prior to data collection, the presentation levels of the competing signals were determined via a transformed up-down adaptive procedure (Levitt, 1971). The procedure provided an estimate of the S/Ns which would be expected to reduce subjects' word recognition scores to 29.3%. This performance level was chosen to provide an adequate margin for possible word recognition increases under the aided listening conditions and to establish a baseline performance similar to that found in past ZNB and ASP investigations. The procedure consisted of presenting NU-6 stimuli at 68 dB SPL, measured at the listener's location, while adjusting the competing signal in 2-dB steps according to the rules of the adaptive transform; that is, the competing signal was increased after a correct response and decreased following two successive incorrect responses. The procedure was terminated after six reversals. The noise level required to produce an estimated 29.3% performance level was calculated by averaging the midpoints of the last four reversals. This procedure was conducted unaided for each subject in each noise condition. Results are shown in Table 1. Criterion performance was obtained at levels ranging from 65 dB SPL for speech noise to 78 dB SPL for continous discourse. There was more variability across subjects as the fluctuation characteristics of the competing signals increased. For example, criterion performance was obtained for all subjects at 65 dB SPL for steady-state speech noise, while the levels necessary for criterion performance in the most fluctuating competing signal, continuous discourse, differed by 5 dB (73-78 dB SPL) across subjects. This was probably due to the occurrence of NU-6 stimuli during pauses and/or drops in the power spectra of the more fluctuating competing signals.

Table 1

Presentation Levels in dB SPL Expected to Produce Word Recognition Scores of 29.3% in Five Competing Signals

Subject	Speech noise	Cafeteria noise	Multitalker babble	Four-Talker babble	Continuous discourse
1	65	67	66	67	78
2	65	67	66	67	76
3	65	67	66	67	76
4	65	68	67	67	78
5	65	67	66	66	77
6	65	68	67	67	75
7	65	68	67	68	75
8	65	67	67	67	76
9	65	68	65	65	73
10	65	68	68	68	76
11	65	68	66	67	76
12	65	68	67	67	76
13	65	67	68	65	73
14	65	67	67	67	76
15	65	68	68	68	73
M	65	67.5	66.7	66.9	75.6

The presentation level of the NU-6 stimuli was fixed at 68 dB SPL at the listener's location under all experimental conditions. The presentation levels of the competing signals established by the adaptive procedure for each subject in each noise condition were fixed across the subjects' unaided and four aided listening conditions. Twenty-five word recognition scores were obtained for each subject (5 listening conditions × 5 noise conditions). Each recognition score was obtained utilizing one of the four 50-word NU-6 lists. To avoid a learning effect, presentation of the NU-6 word lists was randomized within and across all experimental conditions. Subjects were informed that the test they were to take was designed to measure their ability to identify words under noisy listening conditions. They were told to ignore the noise and concentrate on repeating each word presented. It was further explained that the task would be difficult and, if they were not sure of the word presented, they were to guess. An oral response was used for efficient scoring. Subjects attended five one-hour sessions and received a five-minute rest period after every two or three word lists. The unaided condition was administered first, followed by the four aided conditions. The order of presentation of aids and competing signals was counter-balanced to minimize order effects. Battery voltages were checked before and after each run and batteries replaced as necessary. Prior to each condition, subjects were instructed to indicate whether the level of the competing signal was uncomfortable as the examiner adjusted the hearing aid gain controls to their test positions. None of the subjects indicated discomfort in any listening condition.

RESULTS

The relative effectiveness of the noise filtering hearing aids was assessed by comparing scores in the CA condition to those found in the Z1, Z2, and ASP conditions. Scores were analyzed using the computer-generated critical difference tables of Thornton and Raffin (1978). Subjects who performed significantly better with each noise filtering hearing aid compared to CA are listed in Table 2. A limited number of subjects, ranging from 1 to 3 of the 15 tested, showed significantly higher word recognition scores ($p < .05$) under four noise conditions with ZNB hearing aids and under three noise conditions with ASP amplification. No subject displayed significant differences in scores in continuous discourse under either ZNB listening condition compared to CA. No significant differences were found in continuous discourse or speech noise with the ASP hearing aids compared to CA. It should be noted that none of the subjects showed a significant performance decrease in any competing signal with either the ZNB or ASP hearing aids compared to CA.

The number of listeners who obtained higher scores was similar between the two ZNB hearing aids and between the ZNB and ASP systems. The only notable difference occurred in speech noise, where 3 subjects demonstrated significantly higher scores with both ZNB hearing aids, but no subject obtained a significantly improved score with ASP amplification. In most instances, significant performance differences were obtained by the same subjects across hearing aids in a given competing signal. The one exception occurred in four-talker babble where subjects 7 and 8 demonstrated individual performance increases under ASP and Z1 listening conditions, respectively. Only two subjects, 2 and 10, achieved significant increases with noise filtering hearing aids in more than one competing signal. Individual word recognition scores obtained under the various listening conditions in each competing signal are shown in the Appendix.

Table 2

Percent Correct Recognition Scores for Subjects Demonstrating Significant ($p < .05$) Recognition Improvement over Conventional Amplification (CA) when Aided with ASP, Z1, and Z2 Amplification

	Aided condition			
Competing signal	**CA**	**ASP**	**Z1**	**Z2**
Speech noise				
Subject 2	24		50	44
Subject 5	28		54	50
Subject 10	28		48	54
Cafeteria noise				
Subject 9	14	38	40	36
Subject 10	18	36		40
Subject 13	24	54	60	54
Multitalker babble				
Subject 4	16	50	36	36
Subject 6	20	42	40	48
Subject 15	8	36	26	26
Four-talker babble				
Subject 2	18	40	36	44
Subject 7	16	34		
Subject 8	26		46	

Note. ASP = Automatic Signal Processing hearing aid. Z1 and Z2 are hearing aids with a Zeta Noise Blocker circuit. Empty cells indicate no significant improvement for that subject in that condition. No significant improvements occurred in continuous discourse.

DISCUSSION

Although the ZNB and ASP hearing aids utilized different noise filtering techniques, their effectiveness was similar in the competing signals used in this study. Only a small proportion of subjects demonstrated statistically significant word recognition increases over conventional amplification with either noise filtering system. The majority of performance differences occurred with both systems in steady-state or quasi-steady competing signals. No increases were observed with either system in continuous discourse. A difference in the effectiveness of the ZNB and ASP hearing aids was seen in speech noise only.

A comparison of the results of this study with past investigations of ZNB and ASP technology is limited, due primarily to differences in the types of systems tested (e.g., prototype versus commercial versions) and the types of primary and competing signals used. Where commonalities exist, similarities in results are evident. The only existing study of the ZNB microchip employed in a commercially available hearing aid is that of Wolinski (1986). Wolinski found that 39% and 6% of subjects tested demonstrated significant word recognition increases in cafeteria noise and six-talker babble, respectively, when aided with Maico SP 345 hearing aids. In our study, significant increases were achieved by 20% of subjects in cafeteria noise and about 7% of subjects in four-talker babble when aided with the same hearing aid. Data concerning monosyllabic word recognition performance with ASP amplification are limited to those reported by Sigelman and Preves (1987). The authors reported mean nominal recognition increases of 9-11% in broadband noise. However, the number of subjects demonstrating statistically significant increases was not reported, preventing a comparison of their results with those of the present study.

The limited improvement provided by the ZNB and ASP hearing aids may be explained by considering the respective techniques used to improve S/N conditions. The competing signals used in this study, while having different fluctuation characteristics, were all broadband in nature. Use of broadband competing signals allowed a practical assessment of the effectiveness of the ZNB and ASP systems as listeners are most often exposed to broadband background signals in natural listening situations. It would appear, however, that the designs of both noise filtering systems may limit their effectiveness in this type of competing signal. The compression effect of the ASP technique is limited to low-frequency input. The high-frequency channel responds linearly and is incapable of reducing the higher frequency spectral components of broadband competing signals which may interfere with perception of speech. The ZNB technique overcomes this limitation by employing a band of adjustable filters capable of attenuating noise inputs across a wide frequency range. Unfortunately, broadband filtering of competing signals by the ZNB is likely to remove components of the primary speech signal as well. Past studies have shown that the ZNB is most effective when competing signals are narrowband in nature. Both Stein and Dempesy-Hart (1984) and Wolinski (1986) found that ZNB filtering was more effective in low-frequency narrowband noise than in broadband competing signals such as white noise and six-talker babble. Van Tasell et al. (1988) reported best performance with the ZNB when primary and competing signals were separated in frequency. There are no studies comparing the effectiveness of ASP systems in broadband and narrowband noise.

The noise filtering technique used by the ZNB hearing aids may also have limited their ability to act upon competing signals having fluctuation characteristics similar to speech. Recall that the ZNB identifies the presence of noise by analyzing the time characteristics of the incoming signal. It follows that the ZNB would be less effective in identifying and attenuating noise inputs as their fluctuation characteristics approach those of a single-talker speech sample. This may explain why significant differences in word recognition were not observed with ZNB amplification in continuous discourse.

Although the proportion of subjects who achieved significant improvements with the noise filtering hearing aids was small, some subjects did achieve higher word recognition scores with these systems. Further, in a given competing signal, subjects who showed improvements with one noise filtering aid tended to also show improvements with one or more of the others. These results suggest that, rather than expecting uniform differences across subject groups, researchers should concentrate on the nature of, and reasons for, individual responses to this circuitry. It may be that individual listener characteristics, such as selective attention or processing strategy, determine individual effectiveness. This question has not been addressed in previous investigations of ZNB and ASP hearing aids.

The different responses to these systems across subjects has clinical implications as well. Given our current inability to predict individual effectiveness, it would appear that trial use of these systems should be employed in the fitting process. Specifically, performance with and reaction to these hearing aids, with noise filtering circuits engaged and disengaged, should be monitored on an individual basis.

Our investigation tested the performance of ZNB and ASP technology in a limited number of representative hearing aids. During and since our study, additional manufacturers have introduced hearing aids employing a second generation ZNB microchip or versions of the automatic passband adjustment technique. Additionally, the effectiveness of the ZNB and ASP systems may be related to frequency response or other control settings. As previously mentioned, we utilized a frequency response appropriate for hearing-impaired persons having mildly-sloping audiometric configurations. Further research is needed to determine the relative effectiveness of ZNB and ASP systems for hearing-impaired subjects having varying degrees and configurations of hearing loss.

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APPENDIX

Table A-1

Percent Correct Word Recognition Scores
Obtained under Five Listening Conditions in Speech Noise

Subject	Unaided	CA	ASP	Z1	Z2
1	34	34	36	46	32
2	22	24	36	[50]	[44]
3	30	36	30	42	46
4	32	32	44	44	40
5	26	28	46	[54]	[50]
6	30	30	36	46	32
7	42	36	38	44	46
8	36	34	32	50	50
9	40	30	34	44	42
10	30	28	38	[48]	[54]
11	34	36	48	54	42
12	30	40	46	42	46
13	32	28	42	32	38
14	44	28	42	30	40
15	32	44	44	50	34

Note. CA = Conventional amplification. ASP = Automatic Signal Processing hearing aid. Z1 and Z2 are hearing aids with a Zeta Noise Blocker circuit. Scores within brackets differ significantly from CA scores at $p < .05$.

Table A-2

Percent Correct Word Recognition Scores
Obtained under Five Listening Conditions in Cafeteria Noise

Subject	Unaided	CA	ASP	Z1	Z2
1	28	40	26	46	46
2	32	26	42	36	40
3	36	34	26	46	42
4	34	28	38	38	40
5	44	34	48	50	34
6	28	30	42	44	38
7	28	30	26	42	44
8	38	40	44	40	50
9	22	14	[38]	[40]	[36]
10	34	18	[36]	28	[40]
11	28	28	38	32	42
12	22	26	42	42	44
13	22	24	[54]	[60]	[54]
14	38	36	54	44	46
15	30	22	34	30	30

Note. For explanation of abbreviations and brackets, see note to Table A-1.

Table A-3

Percent Correct Word Recognition Scores
Obtained under Five Listening Conditions in Multitalker Babble

Subject	Unaided	CA	ASP	Z1	Z2
1	40	36	30	30	30
2	38	38	40	30	38
3	48	42	34	30	38
4	28	16	[50]	[36]	[36]
5	42	38	40	40	40
6	34	20	[42]	[40]	[48]
7	26	26	32	36	34
8	34	32	34	36	30
9	34	32	36	48	42
10	30	32	36	42	26
11	36	36	24	48	54
12	40	26	38	34	38
13	26	16	32	20	24
14	24	36	46	30	30
15	22	8	[36]	[26]	[26]

Note. For explanation of abbreviations and brackets, see note to Table A-1.

Table A-4

Percent Correct Word Recognition Scores
Obtained under Five Listening Conditions in Four-Talker Babble

Subject	Unaided	CA	ASP	Z1	Z2
1	48	34	30	40	38
2	28	18	[40]	[36]	[44]
3	26	44	38	36	42
4	48	32	42	38	40
5	34	38	44	38	36
6	26	20	26	26	30
7	26	16	[34]	24	28
8	24	26	44	[46]	34
9	38	30	46	42	42
10	24	22	38	24	26
11	28	36	42	32	36
12	34	32	40	38	38
13	34	40	48	38	48
14	36	34	48	34	44
15	24	32	44	28	24

Note. For explanation of abbreviations and brackets, see note to Table A-1.

Table A-5

Percent Correct Word Recognition Scores
Obtained under Five Listening Conditions in Continuous Discourse

Subject	Unaided	CA	ASP	Z1	Z2
1	46	44	40	46	30
2	48	46	44	46	48
3	30	40	38	36	46
4	32	36	50	44	52
5	48	36	50	46	46
6	38	56	44	46	46
7	32	44	36	46	46
8	44	46	60	38	50
9	38	46	46	42	50
10	26	42	58	44	44
11	36	54	54	66	46
12	36	50	52	54	54
13	40	52	54	54	52
14	42	56	60	62	46
15	42	58	50	44	48

Note. For explanations of abbreviations, see note to Table A-1.