An Evaluation of the Speech Perception in Noise Test

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ABSTRACT

The effects of presentation level and signal-to-babble ratio (S/B) on SPIN performance were investigated for eighty normal hearing listeners. Both intensity and S/B had a significant effect on scores. Performance improved at the more favourable S/B regardless of presentation level, and scores were better at the lower presentation level regardless of S/B. Possible clinical applications of the SPIN test are discussed.

OPSOMMING

Die uitwerking van aanbiedingsvlak en sein-tot-babbel-verhouding (S/B) op SPIN-toets-diskriminasietellings is ondersoek by tagtig normaalhorende luisteraars. Beide aanbiedingsvlak en S/B het 'n beduidende uitwerking op diskriminasietellings. 'n Hoër persentasie korrekte diskriminasie is by die meer gunstige S/B verkry, ongeag die aanbiedingsvlak, en beter diskriminasietellings is by die laer aanbiedingsvlak verkry, ongeag die S/B. Kliniese toepassings van die SPIN-toets is bespreek.

The routine procedure in clinical speech audiometry over the past few decades has been to obtain a speech reception threshold for spondaic words and an estimation of monosyllabic discrimination ability. These measures are generally obtained in quiet conditions. In spite of the seeming popularity of this approach, much criticism has been directed against it (Dirks, Morgan and Dubno, 1982). Discrimination tests using monosyllabic words have been criticized for a number of reasons, but most frequently because test stimuli and conditions do not represent typical listening environments, and because test forms are not equivalent (Dirks and Dubno, 1984). With this in mind Kalikow, Stevens and Elliott (1977) developed the Speech Perception in Noise (SPIN) test in order to assess the understanding of speech in noise. They recognised that in speech communication adults utilize acoustic-phonetic and linguistic-contextual information for perception. Consequently the SPIN test comprises eight lists of 50 sentences each, where the predictability of the final target or key word of each sentence is controlled. In each list 25 items are designed to be primarily identified by the acoustic-phonetic information (low predictability (LP)) and the other 25 sentences include linguistic-contextual information which could aid identification (high predictability (HP)). The following are examples of each, "I had not thought about the growl" (LP) and "The watchdog gave a warning growl" (HP). Since everyday speech communication commonly occurs in the presence of noise, the sentences are presented in a 12-voice background babble. The sentences and babble are recorded on separate channels of audio tape, thus permitting variation of the signal-to-babble (S/B) ratio.

In constructing the test Kalikow et al. (1977) chose 250 target words from an original pool of words, with each test word presented in both an HP and an LP context in complementary lists. Form equivalence for these ten lists was investigated for a group of normal listeners at 80 dB SPL and at a 0 dB S/B. Two lists were discarded, and on the basis of an analysis of variance the remaining eight were considered to be equivalent for the difference score (i.e. HP - LP). While the analysis did not show similar equivalence for HP and LP scores, Kalikow et al. (1977) did no feel that this was a serious problem.

Morgan, Kamm and Velde (1981) and Bilger, Nuetzel, Rabinowitz and Rzeczkowski (1984) who also examined list equivalence did not agree with the results of Kalikow et al. (1977) and concluded that only seven of the original ten lists were equivalent. However, the experimental design of all three studies differed with respect to presentation level and S/B, subjects (normal hearing or hearing impaired) and statistical method of analysis. Thus the results of these later studies do not necessarily contradict those of Kalikow et al. (1977).

The effects of variations in presentation level, S/B, age and hearing impairment on SPIN performance have also been investigated. A consistent finding is the expected separation between the HP and LP scores, both of which improve with improved S/B ratios (Kalikow et al., 1977; Hutcherson, Dirks and Morgan, 1979; Elliott, 1979; Owen, 1981). Kalikow et al. (1977) found a slightly smaller difference score for an elderly group as compared to young subjects and Elliott (1979) found poorer HP sentence scores for 11 and 13 year old children compared to 15 and 17 year olds, which was not apparent when the sentences were presented in quiet. This finding may lend support to Owen's (1981) conclusion that differences found in difference scores are related to the audibility of the sentences rather than to the listener's use of context.

From these studies no clear pattern of results or administrative protocol emerges that might make the SPIN test clinically useful. With these issues in mind the present study was designed to examine the performance of a group of audiologically normal subjects using a locally produced recording of the test material. The object was to collect data that might provide a basis for comparison with the SPIN results of hearing impaired individuals and to identify aspects of the test that might most usefully and reliably be used in a clinical context.

METHODOLOGY

AIM

To investigate the performance of a group of normal hearing subjects on the SPIN test, and to examine the effect on performance of presentation level and signal-to-babble ratio.

SUBJECTS

Eighty young adults aged between 18 and 29 years with normal hearing sensitivity (<15 dB re: ANSI 1979) at octave frequencies from 250 to 8000 Hz bilaterally, served as subjects. English was the native language of all subjects, and no subject had had any previous test experience with the SPIN materials.

INSTRUMENTATION

The eight lists of the SPIN test were recorded by an English-speaking South African male. The babble was generated by recording each of six adults (3 males and 3 females) reading the same passage from a children's story book in an anechoic chamber, mixing these six recordings and combining two repetitions of the six-voice babble to produce the final 12-voice babble. Both the sentence and babble tracks were preceded by 1000 Hz calibration signals.

During the test sessions the lists were played on a two-channel (Pioneer Stereo Cassette Tape Deck - CT-F650) tape recorder. The signal and babble outputs from the tape recorder were routed to a speech audiometer (Grason-Stadler, GSI 10) where the intensity of each was determined separately before being mixed. The mixed output was delivered to the subject via a TDH-39 earphone mounted in a supra-aural cushion (MX 41/AR). The audiometers were calibrated according to ANSI 1979 standards, and prior to each test session the VU meters of each channel were adjusted according to the 1000 Hz calibration signal.

All testing was conducted in dual chamber sound treated test suites.

PROCEDURE

Lists were presented at two intensity levels (60 and 40 dB HL) and two S/B ratios (0 and +5 dB). The 60 dB HL 0 S/B condition was chosen to allow comparison to the Kalikow et al. (1977) study. The 40 dB HL level was chosen because normal to loud conversational speech falls within the 40 to 60 dB HL range, and because at a 40 dB sensation level (re: SRT) testing would be possible for a larger percentage of hearing impaired individuals than at higher levels. The +5 dB S/B ratio was chosen because it is a more favourable condition as research (Pearsons, Bennett and Fidell, 1976 as cited by Dirks et al. 1982) has shown that this ratio is usually maintained for conversations in background noise.

Subjects were divided into two groups. Forty subjects were tested with the odd numbered lists, and forty subjects with the four even numbered lists, thus ensuring that complementary lists were not heard by the same person. The stimuli (signal and babble) were presented to the subject's preferred ear under four listening conditions:

60 dB HL with a S/B of +5 dB,
60 dB HL with a S/B of 0 dB,
40 dB HL with a S/B of +5 dB, and
40 dB HL with a S/B of 0 dB.

The order of presentation remained constant, but the order of presenting the lists was varied so that each list was presented under each listening condition the same number of times. Subjects were instructed to write down the last word of each sentence.

ANALYSIS OF RESULTS

A strict scoring protocol was adopted. (Singular/plural conversions were not acceptable). Total, HP, LP and difference scores were converted into percentages. Summary statistics (means and standard deviations) were used to describe central tendencies for each of the listening conditions. Data were subjected to a two factor analysis of variance with repeated measures of both factors (Treatments-by-Treatments-by-Subjects AOV) to assess the effects of presentation level and S/B ratio.

RESULTS AND DISCUSSION

Table 1 summarizes the mean scores and standard deviations found for all the lists under the different listening conditions.

Table 1: Means and standard deviations of scores obtained under four listening conditions.

		Listening Conditions			
		60 dB		40 dB	
Total Score	$\overline{X}$	80,34	52,53	85,48	59,73
(HP+LP)	SD	8,89	11,77	6,42	13,04
HP Score	$\overline{X}$	96,15	73,00	98,10	78,50
	SD	5,30	13,07	3,49	13,94
LP Score	$\overline{X}$	64,30	32,05	72,20	40,95
	SD	14,66	13,51	11,04	14,86
Difference Score	$\overline{X}$	31,90	40,95	25,90	37,50
(HP-LP)	SD	13,44	12,36	10,83	11.99

The results obtained at 60 dB 0 S/B in the present study are slightly lower than those reported by Kalikow et al. (1977), who reported the following mean values: HP = 87,8 LP = 40,3, and Difference = 47,4. Means for the other conditions have not been reported in the literature. There is a difference for scores obtained at the two S/B ratios for each intensity as well as at the two presentation levels for each S/B ratio.

Four 2-way analyses of variance with repeated measures on both factors were performed to determine whether scores (total, HP, LP and difference) obtained under four listening conditions (60 dB, +5 S/B, 60 dB, 0 S/B, 40 dB, +5 S/B and 40 dB, 0 S/B) differed significantly. The results of these ANOVA's showed no significant interaction between intensity level and S/B ratio. Both main effects (intensity level and S/B ratio) were significant ($p<0.01$), mean scores being better at the more favourable S/B ratio regardless of S/B ratio. The F values obtained are summarised in Table 2. (In each case the degrees of freedom were 1,79.)

Table 2: F-values obtained in four ANOVA's to test the difference between four scores (total HP, LP and Difference) obtained under four listening conditions.

	Total	HP	LP	Difference
Source				
Intensity	74,69*	14,43*	78,69*	13,40*
S/B	888,17*	435,08*	689,27*	54,07*
Intensity x x S/B	0,94	2,86	0,13	1,06

* p 0.01

The finding that all scores improve at the more favourable S/B ratio regardless of presentation level was to be expected and confirms results from previous studies (Hutcherson et al., 1979; Owen, 1981). An unexpected finding was that scores were better at the lower presentation level for both S/B conditions. This finding is contradictory to that of Hutcherson et al. (1979) who found little difference in scores at 50 dB and 80 dB SPL, and a definite improvement from 30 to 50 dB SPL. Since the order of testing under the four listening conditions was held constant it may be postulated that a learning effect produced this result. However, in such a case less of a difference would be expected between the 60/40 dB 0 S/B conditions than the +5 S/B conditions, but examination of the results indicates that the difference is of equal magnitude. A similar intensity effect appears to be present in data reported for thee normal hearing subjects for words from NU #6 lists presented in SPIN background babble (Dirks et al., 1982).

Taken together these results may suggest that there is an optimal presentation level for discrimination of speech in noise, and that an increase or decrease in this level will result in a deterioration of performance. This level may correspond to that of conversational speech (40 dB HL). The effect should be more thoroughly explored — for both the normal hearing population and those with sensorineural hearing losses. It would be interesting to determine how, for example, individuals with cochlear losses and concomitant intolerance for loud sounds would perform.

The immediate clinical implication of these results is that the SPIN test should not be administered under listening conditions for which normative data is unavailable. Regardless of the measure used, both intensity and S/B affect performance. Consequently no generalizations about scores can be made. The present findings provide a means for comparing the performance of hearing impaired individuals with that of normal listeners. For such a purpose it is suggested that the 40 dB +5 S/B protocol is adopted. At the 40 dB SL re SRT presentation level testing is likely to be possible for the majority of hearing impaired listeners, and the +5 dB S/B provides the most well defined normal performance. The good HP scores and the relatively high LP scores would allow measurement of the poorer performance by the hearing-impaired individual over a wider range than would be possible under the other three conditions. The HP and LP scores provide two sources of information. They provide an indication of performance that can be compared with normal performance. In addition the relationship between the HP and LP scores for an individual provide an indication of the extent to which he is taking advantage of sentence context, and this has important therapeutic implications. However, this relationship is only meaningful in the context of the normal HP and LP scores.

Considering that noise has a differential effect on individuals even with similar audiometric configurations and degree of loss (Plomp and Mimpen, 1979), determination of performance functions for various S/B ratios and intensity levels would give the best estimate of ability to understand speech at suprathreshold levels. However, in its present form the SPIN test would not be a cost effective or practical method for this purpose, being too time-consuming and fatiguing.

In conclusion it is suggested that the SPIN test be administered at the 40 dB +5 S/B level in order to obtain comparative and rehabilitative information. Any diagnostic application of the SPIN test among hearing-impaired individuals requires further research.

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