Performance of Normal-Hearing Young Adults on the SSW Test: Effects of Intensity

Philip C. Doyle
School of Human Communication Disorders
Dalhousie University

Dennis J. Arnst
Hearing Services and Consultants, Fresno, California

Jeffrey L. Danhauer and Sanford E. Gerber
Department of Speech and Hearing Sciences
University of California, Santa Barbara

Abstract

This study investigated the effects of intensity on the intelligibility of Staggered Spondaic Word Test (SSW) stimuli. Thirty young adult listeners with normal-hearing were presented SSW test stimuli at ascending sensation levels (SLs) of 0, 10, 20, and 30 dB. Listeners' data were scored with standard procedures and then used to generate a performance intensity function. Results revealed that the overall intelligibility of SSW test stimuli is good at SLs as low as 10 dB, regardless of scoring method. The possible clinical use of lower than standard presentation levels is discussed.

Introduction

The Staggered Spondaic Word Test (SSW) (Katz, 1962) is a clinical tool for assessing the central auditory nervous system. The test is used as part of a comprehensive audiologic test battery when central auditory dysfunction is suspected. Test design requires the listener to identify two dichotically presented spondaic words that are partially overlapped in time, this overlap occurring between the second syllable of the first spondee presented and the first syllable of the second spondee presented (Arnst, 1982). Thus, both noncompeting and competing listening conditions for either the right or the left ear can be evaluated with presentation of each test item. The test is comprised of 40 spondaic word pairs. Two spondaic words (e.g., "upstairs" and "downtown") would comprise an entire test item, with each individual test item consisting of four elements or constituent monosyllables (e.g., "up" "stairs" "down" "town").

Standard clinical procedure requires that the test be presented at a 50 dB sensation level (SL) re the pure tone average (PTA) of 500, 1000, and 2000 Hz for the respective ear. Several studies have indicated that normal-hearing listeners exhibit little difficulty and make few errors on the test at this level (Arnst, 1981; Goldman & Katz, 1966; Katz, Basil, & Smith, 1963; and Lukas & Genchur-Lukas, 1985).

The rationale for the use of spondaic words was based on data showing these stimuli to be relatively familiar to most listeners and intelligible over a wide range of intensities (Katz, 1962). In addition, intelligibility of spondaic stimuli has been shown to increase rapidly with minor increases in intensity (Hudgins, Hawkins, Karlin, & Stevens, 1947). Katz (1962) also believed that perceptual errors resulting from peripheral hearing loss could be accounted for and corrected, thereby providing a more sensitive measure of central auditory function. Arnst and Doyle (1983) provided preliminary validation for this rationale in adults with cochlear hearing loss. However, questions pertaining to the identification of spondaic words presented in a dichotic manner at intensity levels at less than 50 dB SL may be raised. Specifically, in addition to the steep intelligibility increase demonstrated for spondees (Hudgins et al., 1947), binaural summation may account for a 3-6 dB increase in loudness at suprathreshold levels (Keys, 1947; Hirsh & Pollack, 1948). This should influence the SSW stimuli presented in the "competing" condition.

Balas and Simon (1965) presented SSW stimuli to 72 normal-hearing listeners from 17 to 30 (mean: 21) years of age. Listeners were randomly placed into one of six SL presentation groups to determine the point of maximum performance (intelligibility) for the spondaic word stimuli. Each listener was presented the entire 40-item test list at one of six SLs (0, 10, 20, 30, 40, or 50 dB). Any substitution, omission, or distortion error on any part of a single test item resulted in the entire item (spondaic word pair) being scored as incorrect. Table 1 shows that the group mean percent correct intelligibility scores across the six SLs were approximately 0.4% at 0, 42% at 10, 77% at 20, 89% at 30, 95% at 40, and 99% at 50 dB. Thus, poor intelligibility was observed at a 0 dB SL, with scores improving at 10 and 20 dB and with good performance observed at 30 dB and above. Maximum intelligibility scores were found at 50 dB, but no asymptote was evident in their overall performance intensity (PI) function. Unfortunately, the clinical applicability of Balas and Simon's (1965) results may have been limited because the spondaic word list they assessed was not the standard SSW test (List EC).

Doyle (1982) evaluated normal-hearing listeners' PI functions using the standard SSW test stimuli and scoring procedure, which demonstrated their performance at several suprathreshold SLs. Doyle's listeners were 60 normal-hearing young adults (mean age: 24 years) who were each randomly assigned to one of the same six presentation level groups used by Balas and Simon (1965). PI functions for 10 listeners at each SL were then plotted. Table 1 shows that Doyle's listeners' mean intelligibility scores were approximately 44% at 0, 84%

at 10, 97% at 20, 98% at 30, 98% at 40, and 98% at 50 dB SL using Balas and Simon's "all-or-none" scoring method. Doyle's results were considerably better than Balas and Simon's, with listeners demonstrating high intelligibility at 10 dB SL and above. In fact, the greatest standard deviation observed at any SL at 10 dB or above was only 2.4. Listeners' intelligibility scores improved even more when the standard SSW test scoring method was used (i.e., each constituent monosyllable within each stimulus word pair, such as "up" "stairs" "down" "town," was scored individually).

Table 1. Normal-hearing listeners' mean percent correct SSW test scores and standard deviations (SDs) for List EC presented at six sensation levels using the 40-item and 160-item scoring methods.

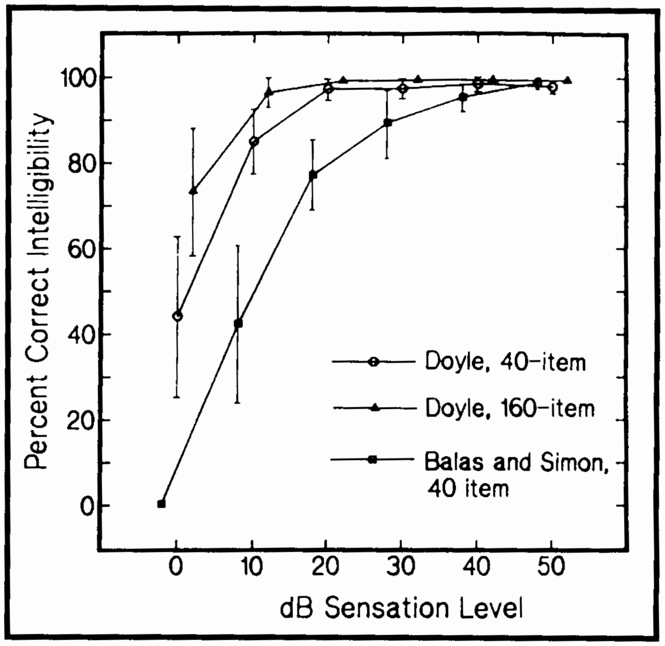
Scoring Method	Sensation Level (SL) dB 0	10	20	30	40	50
Doyle (1982) 40-item						
Mean	43.5*‡	84.0*	97.2*	97.5	98.0	97.7
SD	18.9	7.8	2.4	2.3	1.9	1.8
Doyle (1982) 160-item						
Mean	70.7‡+	95.0+	99.2+	99.3+	99.4	99.3
SD	15.3	3.1	0.8	0.6	0.5	0.5
Balas and Simon (1965) 40-item						
Mean	0.4	42.5	77.3	89.3	95.4	98.9
SD	0.9	18.3	8.2	8.0	3.1	1.2

*Significantly different from Balas and Simon at $p<0.01$.
+Significantly different from the 40-item method at $p<0.01$.
‡Significantly different from the other SLs at $p<0.01$.

Using the standard scoring method, 160 constituent monosyllables (40 test items x four constituent monosyllables) were scored, and the mean intelligibility scores were about 71% at 0, 95% at 10, 99% at 30, 99% at 40, and 99% at 50 dB SL. Balas and Simon's PI function was compared with Doyle's results using both the 40- and the 160-item scoring methods. This comparison is shown in Figure 1 and reveals that the nonstandard scoring method and word list used by Balas and Simon resulted in what appears to be poorer listener performance.

The results of these two studies provide preliminary information about normal-hearing listeners' performance on SSW test stimuli presented at a single SL. However, these data do not provide information regarding the PI function for SSW test stimuli presented to the same subject across SLs. Therefore, the present study evaluated SSW test performance by normal-hearing listeners who were administered the standard SSW test (List EC) stimuli at multiple SLs.

Figure 1. SSW test performance intensity (PI) functions obtained for normal-hearing listeners by Doyle (1982) using List EC and the 40 item and 160 item scoring methods and Balas & Simon's (1965) data for their list using the 40 item scoring method.



Method

Listeners

Thirty listeners (15 women and 15 men) between 18 and 30 years of age (mean: 24) volunteered for the study. Each listener had normal-hearing as evidenced by pure tone air-conduction (AC) thresholds of 20 dB hearing threshold level (HTL) or less for octave frequencies between 250 and 8000 Hz; bone conduction (BC) thresholds of less than or equal to 5 dB of the AC thresholds between 250 and 4000 Hz; speech reception thresholds (SRTs) within 5 dB of the three-frequency pure tone average (PTA) in each ear, and bilateral word discrimination scores (WDS) of 96% or greater for 50-item W-22 word lists. None of the listeners reported a history of hearing loss, ear disease, neurologic impairment, persistent headaches, or dizziness. All were native English speakers and none had any previous experience with, or exposure to, the SSW test.

Procedure

Following preliminary audiometric testing, each listener was presented the SSW test at four ascending SLs (0, 10, 20, and 30 dB re the PTA). SSW test items (stimulus word pairs) 1 to 10 were presented at 0 dB, items 11 to 20 at 10 dB, items 21 to 30 at 20 dB, and items 31 to 40 at 30 dB SL. This procedure was used to plot a PI function (Jerger, Speaks, & Trammell, 1968). The maximum SL of 30 dB was based on previous data (Doyle, 1982), which showed little change in group performance at SLs of 20 dB and above.

Instrumentation and Stimuli

All preliminary testing and experimental procedures were conducted in a sound treated audiometric suite (Tracoustics Model RS253BO) that met ANSI standards. A two-channel clinical audiometer (Grason-Stadler 1701) and earphones

(TDH-39) enclosed in supra-aural cushions (MX 41/AR) were used in all phases of the study. The BC thresholds were obtained with a standard oscillator (Radioear B-70) and steel headband. Auditec of St. Louis recordings of all speech materials (CID W-1s for SRTs, CID W-22s for WDSs, and SSW List EC for the experimental stimuli) were routed to the audiometer and earphones from a reel-to-reel tape recorder/player (Sony TC-377).

Data Analysis

All listeners' responses to each of the four monosyllabic components in each word pair were scored so that each SL provided 40 scorable elements (10 spondaic word pairs per SL x four constituent monosyllables) with omission, substitution, and distortion errors being of equal value (Lukas & Genchur-Lukas, 1985). The subjects' pooled mean percent correct scores were used to generate a composite PI function. Data also were submitted to a one-way analysis of variance (ANOVA) to determine differential main effects across SLs.

Table 2. Normal-hearing listeners' mean percent correct SSW test performance and standard deviations across the four SLs using List EC (10 items were presented at each level and all four monosyllabic components were scored for each item.)

	Sensation Level (SL) dB			
	0	**10**	**20**	**30**
Mean	50.2*	87.7	97.3	98.3
SD	18.5	6.8	3.7	3.2

*Significantly different from other SLs at $p<0.01$.

Table 3. Values for Scheffe's post-hoc test for overall intelligibility of SSW List EC.

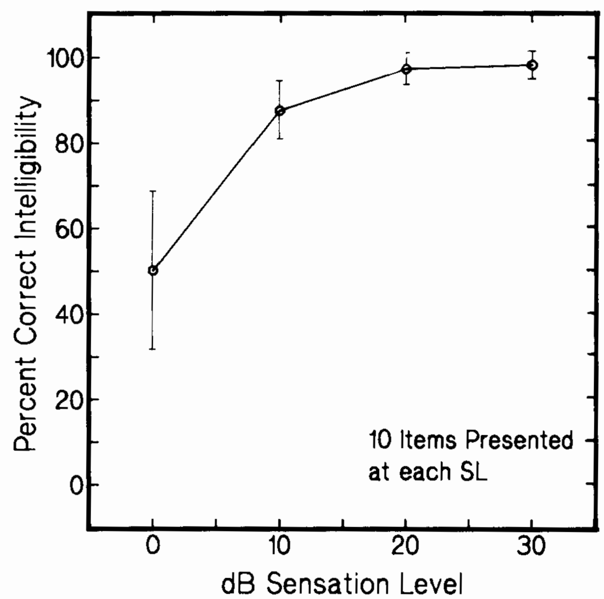
Sensation Level (SL) Comparisons, dB		
0-10 5.04*	**0-20** 6.34*	**0-30** 8.40*
	10-20 1.74	**10-30** 1.63
		20-30 0.44

*Significant at the 0.01 level of confidence.

All values based on 3,116 degrees of freedom; critical difference = 4.34.

Figure 2. SSW test PI function obtained for normal-hearing listeners in the present study using List EC; 10 items were presented at each sensation level and all four constitute monosyllables of each item were scored.

* Significant at the 0.01 level of confidence.



Results

The means and standard deviations displayed in Table 2 show that intelligibility scores improved rapidly from about 50% at a 0 dB SL to 98% at a 30 dB SL. The ANOVA revealed a significant main effect for SL ($F = 64.04$; $df = 3, 116$; $p<0.01$). A post-hoc Scheffe's test was then used to determine and specify significant differences in the performance between each SL. Post-hoc analyses revealed that this significance resulted because the score at a 0 dB SL was different from scores for the other three SLs. Values for these post-hoc comparisons are presented in Table 3. Figure 2 shows the PI function plotted from the mean scores and their standard deviations.

Discussion

Results from this study indicate that SSW test List EC is highly intelligible to normal-hearing listeners even at SLs as low as 10 dB. This was evidenced by our failure to find significant differences among listeners' performance at SLs of 10, 20, and 30 dB. Our findings at these three SLs are similar to those of Balas and Simon (1965) at SLs of 40 and 50 dB. Further, our results at 10 dB SL are quite similar (less than a 2% difference) to Balas and Simon's findings at 30 dB SL. Our listeners' better scores at the lower SLs may result from the standard SSW List EC being more intelligible at lower levels than the list Balas and Simon used. Although Balas and Simon's results are frequently cited in the literature, our results suggest that their PI function may not be indicative of normal-hearing listeners' performance on the standard list that is currently in clinical use. Indeed, the results obtained here correspond to those demonstrated for spondaic word stimuli (Hudgins et al., 1947). The differences noted here were sustained regardless of the scoring method used. That is, the value of each error observed would have been of an equal percentage value (2.5%) in the Balas and Simon study and our study (i.e., 40 total scorable elements per SL). Further, our findings are consistent with those reported by Doyle (1982) using the standard procedure for scoring the SSW test (i.e., 160 total scorable elements).

The PI function generated by Doyle and that reported here are very similar, especially at SLs of 10 dB or higher, regardless of the number of stimuli scored at each SL. Though there is little question that the scoring of individual constituent monosyllables more accurately reflects the listeners' performance at SLs of 20 dB or lower, our data show that normal-hearing listeners do well at SLs of 20 dB or higher.

Our use of of Jerger et al.'s (1968) procedure in plotting PI functions using only 10 stimuli per level yielded sufficient information to describe these listeners' SSW test results as indicated from the close agreement with Doyle's previous data with List EC. The results suggest that, at least for normal-hearing listeners, the test may be presented at SLs of less than 50 dB and in shorter time. This could be useful with other populations such as persons with sensorineural hearing-impairment who have reduced dynamic ranges, but data must be gathered on them before this procedure can be advocated for routine clinical use.

We note that it is possible that the listeners' poorer performance at the 0 and 10 dB SLs could have resulted from our particular procedure. That is, we presented the SSW test stimuli serially in blocks of 10 items at each SL in an ascending order. If by chance the first 10 or 20 stimuli in the test are more difficult, the scores at the lower SLs could suffer. However, there is no empirical data to support this concern. In addition, we feel that it is not likely that this interfered with our results, considering the poor performance of listeners in Doyle's study at the lower SLs where all 40 test items were presented at each SL to separate listener groups.

In conclusion, our results are substantially better than those of Balas and Simon (1965). The strong agreement between the present PI functions generated through the use of partial lists and those reported by Doyle (1982) using full list presentations support the idea that the spondaic word stimuli used in this test are extremely intelligible. This may result from the inherent intelligibility of spondaic stimuli (Goldman & Katz, 1966), effects of binaural summation (Keys, 1947; Hirsh & Pollock, 1948) or a combination of the two. Our data indicate that the SSW test items may be presented at levels below the standard 50 dB for normal-hearing listeners, but rigorous standardization for nonnormal-hearing listeners must be accomplished prior to clinical implementation.

Address all correspondence to:
Philip C. Doyle, PhD
School of Human Communication Disorders
Dalhousie University
Halifax, NS
B3L 1R2

References

Arnst, D. J. (1981). Errors on the staggered spondaic word (SSW) test in a group of adult listeners. *Ear and Hearing, 2*, 112-116.

Arnst, D. J. (1982). Overview of the staggered spondaic word test and the competing environmental sounds test. In D. J. Arnst & J. Katz (Eds.), *Central auditory assessment: The SSW test development and clinical use.* San Diego: College-Hill Press.

Arnst, D. J., & Doyle, P. C. (1983). Verification of the corrected staggered spondaic word (SSW) score in adults with cochlear hearing loss. *Ear and Hearing, 4*, 243-246.

Balas, R., & Simon, G. (1965). The articulation function of a staggered spondaic word list for a normal-hearing population. *Journal of Auditory Research, 5*, 285-289.

Doyle, P. C. (1982). Performance-intensity functions for a normal-hearing population on the Staggered Spondaic Word (SSW) Test. In D. J. Arnst, & J. Katz (Eds.), *Central auditory assessment: The SSW test development and clinical use.* San Diego: College-Hill Press.

Goldman, S., & Katz, J. (1966). *A comparison of the performance of normal-hearing subjects on the staggered spondaic word test given under four conditions - dichotic, diotic, monaural (dominant ear) and monaural (non-dominant ear).* Paper presented at the American Speech and Hearing Association Convention, Chicago, Illinois.

Hirsh, I. J., & Pollack, I. (1948). Role of interaural phase in loudness. *Journal of the Acoustical Society of America, 20*, 761-766.

Hudgins, C. V., Hawkins, J. E., Karlin, J. E., & Stevens, S. S. (1947). The development of recorded auditory tests for measuring hearing loss for speech. *Laryngoscope, 57*, 57-89.

Jerger, J., Speaks, C., & Trammell, J. (1968). A new approach to speech audiometry. *Journal of Speech and Hearing Disorders, 33*, 318-328.

Katz, J. (1962). The use of staggered spondaic words for assessing the integrity of the central auditory nervous system. *Journal of Auditory Research, 2*, 327-337.

Katz, J., Basil, R., & Smith, J. (1963). The staggered spondaic word test for determining central auditory lesions. *Annals of Otology, Rhinology, and Laryngology, 72*, 908-917.

Keys, J. W. (1947). Binaural versus monaural hearing. *Journal of the Acoustical Society of America, 19*, 629-631.

Lukas, R. A., & Genchur-Lukas, J. (1985). Spondaic word tests. In J. Katz (Ed.) *Handbook of clinical audiology* (3rd ed., pp. 383-403). Baltimore: Williams & Wilkins.