STANDARDIZED HEARING TEST PREDICTABILITY FOR HEARING AID SUCCESS

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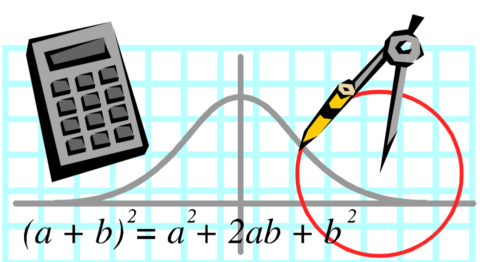
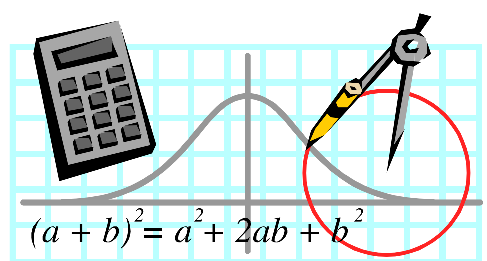




INTRODUCTION

Hearing loss is an issue affecting not only the elderly. Hearing loss affects approximately 28 million people in the United States. Noise-induced hearing loss affects approximately 10 million of these individuals[1]. Whether it is through occupational settings such as construction or loud music, the healthcare industry is witnessing more and more individuals with impaired hearing.

To diagnose this problem, hearing loss is measured by determining auditory thresholds (sensitivity) at various frequencies. For comprehensive assessment, measurements of speech understanding and middle ear status should also be examined. Loss of sensitivity in the higher frequencies from 3,000 through 6,000 Hertz (Hz) is one of the first audiometric signs of hearing loss. With additional loss from noise or aging, the threshold at 8,000 Hz may worsen.

One important consequence for individuals experiencing loss in hearing is difficulty in understanding speech. The majority of speech is contained within lower frequencies, much of our ability to differentiate one speech sound from another is contained within the higher frequencies. Therefore, because of this loss much of the information obtained from speech is inaudible or unusable. Other sounds; e.g., background noise, other voices, acoustics, may further reduce a hearing-impaired person's ability to understand normal speech patterns.

Hearing aids are often a solution for individuals experiencing hearing loss. These devices amplify sounds without the ability to filter background noises. Hearing aids are also calibrated for each person, individualizing them to the specifics of the magnitude of hearing loss.

In order to test the success of the hearing aid, audiologists utilize a testing wherein a list of 50 words of equal complexity is read to determine if the patient understands them. Audiologists regularly test the difficulty of understanding of these lists with clinically normal hearing subjects. Tests have been done in ideal conditions as well as in the presence of background noise to determine whether they can be understood easily or not.

The purpose of the current study done by the University of Iowa was to employ random lists of 50-words each to determine the difficulty of understanding in the presence of background noise. Given that there are multiple lists available to audiologists for use,[2] our hypothesis was that each test would give similar results.

METHODS

Two lists of 50-words were selected at random. These lists are Standard 50-word tests used by audiologists as standard procedure for hearing tests. The words are selected based on their difficulty level in understanding when spoken clearly. The lists were recorded and played to the patients at a low volume with a noisy background. Participants were asked to repeat the words and were scored correct or incorrect in their perception of the words.

Initially, ten patients were asked to participate in the study. These patients met our criteria of having clinically diagnosed normal hearing. They were tested with both lists in the presence of background noise to determine the understandability of the words. The results of the test can be seen in Figure 1. Based on the results from this, we decided to obtain a larger population to study. A total of 48 patients participated in this study, the results of the larger sample can be seen in Figure 2.

Data was analyzed using Minitab statistical software as well as Texas-Instrument 89 calculator. Because of the larger population, we assumed this to be a normally distributed population and calculated our statistics accordingly. Confidence intervals of means and variances for each set as well as the differences in sets were computed at 90, 95, and 99 percent. NOTE: Set 1 is the larger set (n=48) and Set 3 is the initial group of patients for that set (n=10). Conversely, Set 2 is the larger set for the initial result of Set 4.

Figure 1: Hearing Results of Original Sample Set (n=10)

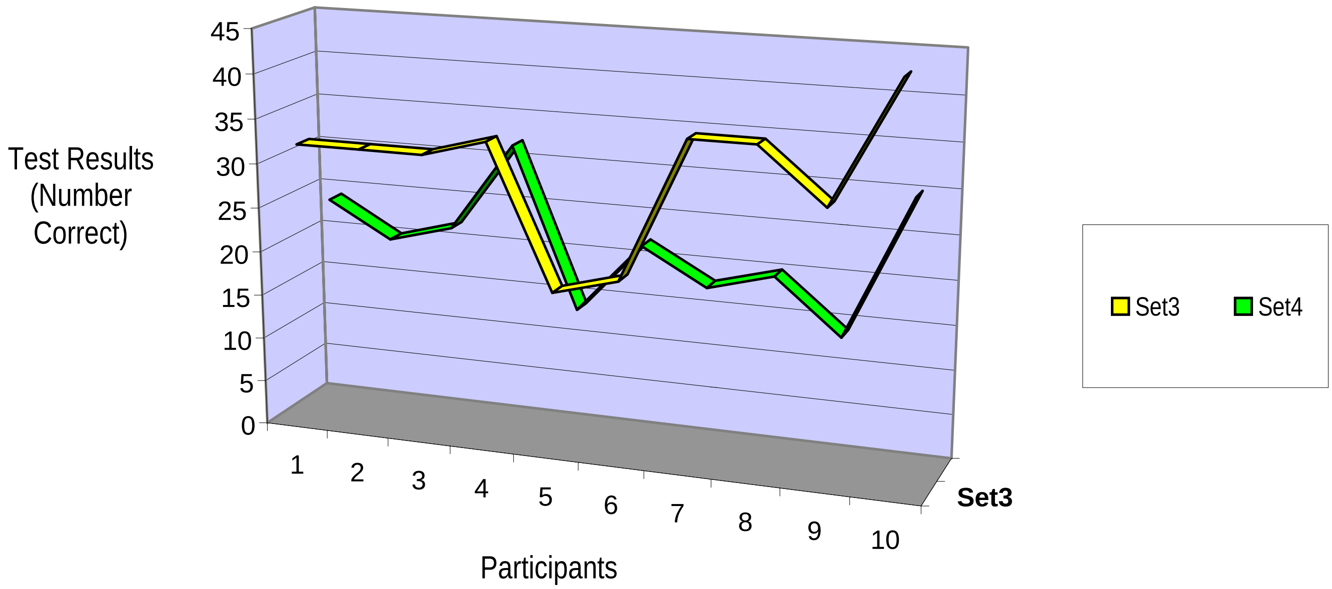
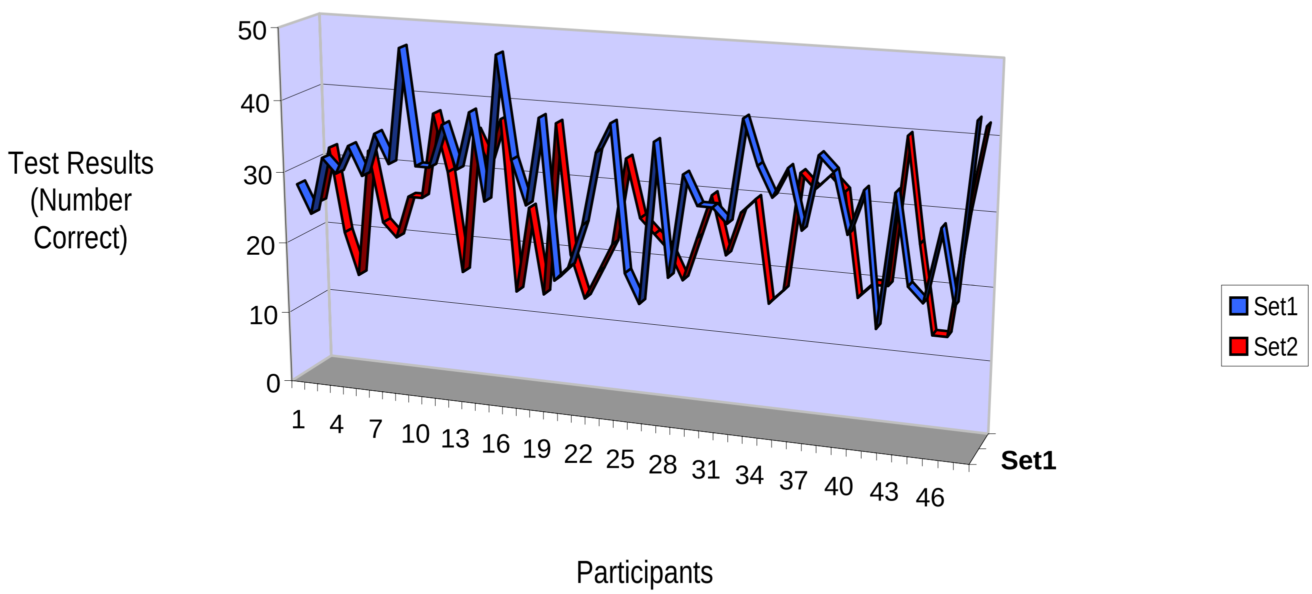


Figure 2: Hearing Results of Larger Population (n=48)

Set 1 (and Set 3 from Fig. 1) represents the first 50-word list and Set 2 (and Set 4 from Fig. 1) the other list.



RESULTS

Initial testing gave interesting results. In looking at the results of the histograms for each group of words in the larger samples, the first set (Figure 3) more closely represents a normally distributed result than does the second group (Figure 4). If one were to combine results from both sets (See Figure 5), it is evident that the results are reflective of a normal distribution and leads us to believe that if more subjects were studied you would see these tests balance into a normal distribution.

Figure 3: Histogram of Test Results with Normal Curve for Set 1 (n=48)

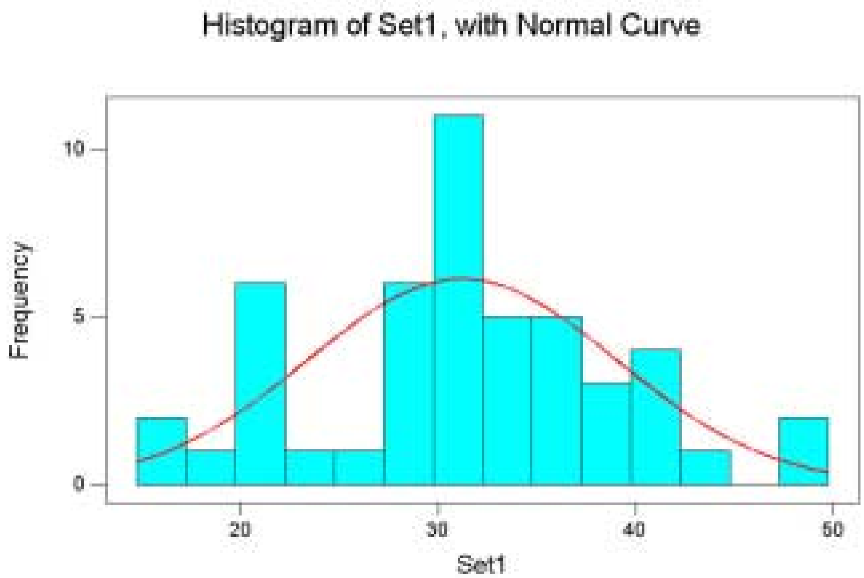


Figure 4: Histogram of Test Results with Normal Curve for Set 2 (n=48)

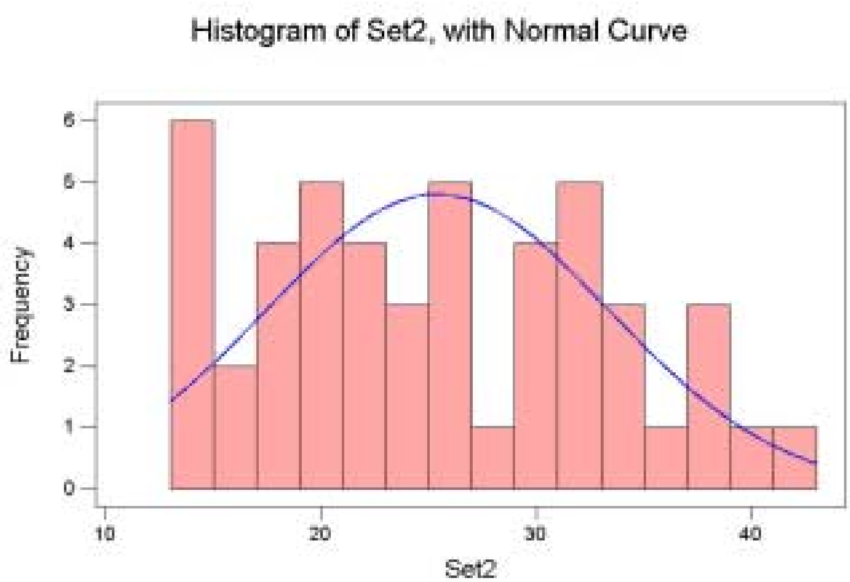
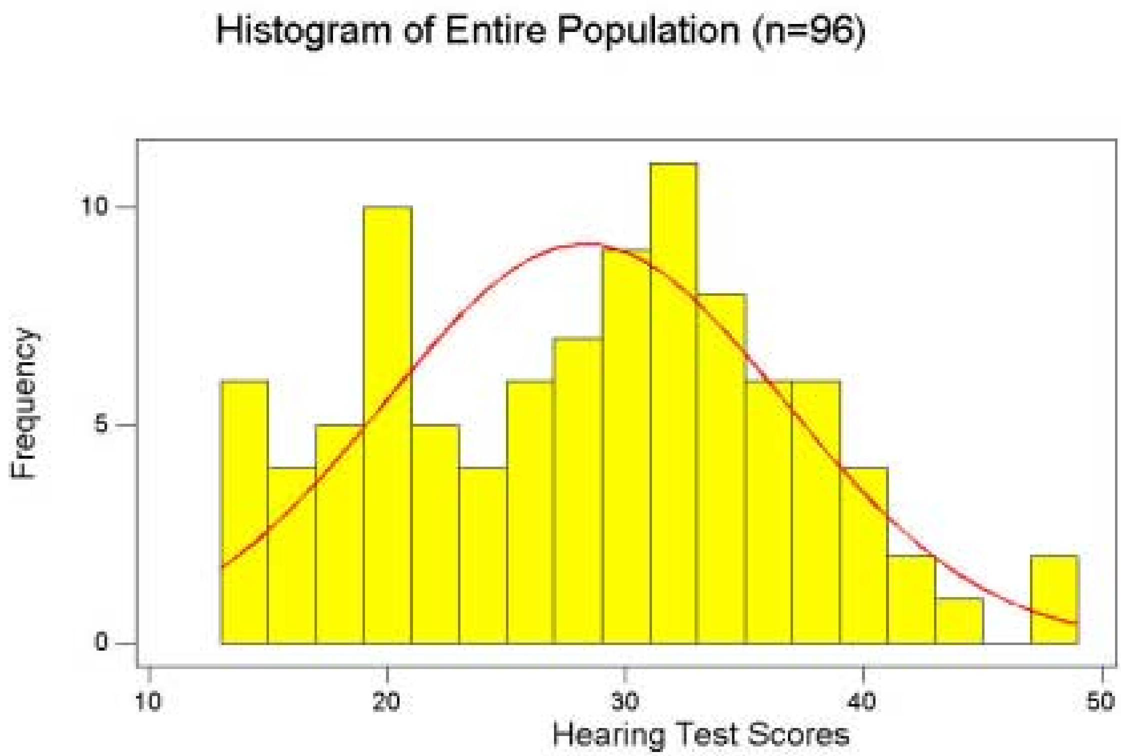


Figure 5: Histogram of Two Groups Combined (n=96)



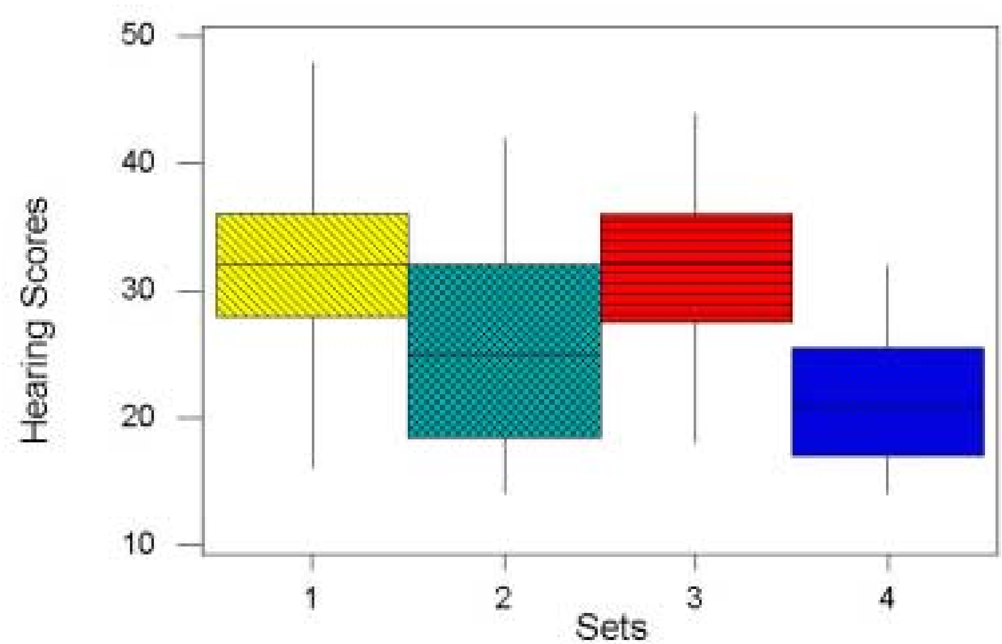
For the initial sample set (Sets 3 and 4, n=10), descriptive statistics (See Table 1) and corresponding graphical display indicated a difference in the understandability of the two lists. As a result, more participants were studied which gave similar results. The larger population is labeled as Sets 1 and 2. As you can see from the box plots (Figure 6), the average score is higher for the first list of words than the second.

Table 1: Descriptive Statistics: Set 1, Set 2, Set 3, Set 4

Variable	N	Mean	Median	TrMean	StDev	SE Mean
Set 1	48	31.21	32.00	31.14	7.81	1.13
Set 2	48	25.42	25.00	25.23	7.97	1.15
Set 3	10	31.40	32.00	31.50	7.60	2.40
Set 4	10	21.60	21.00	21.25	5.95	1.88

Figure 6: Box Plot Representation of Data.

Set 1 (n=48) is the larger population of the same list as Set 3 (n=10) and Set 2 (n=48) is the larger population of the same list as Set 4 (n=10)



To estimate the population parameters, we took point estimates for the larger population groups (n=48). Given the population size, we assumed a normal distribution. Because of this, the population mean and population variance are the point estimates (Set 1 μ=31.21, s^2=60.996; Set 2 μ=25.42, s^2=63.5209).

Confidence intervals were calculated on the sample means as well as variances. As a matter of curiosity, we grouped all of the results into one group called Set' for the sake of curiosity. We also looked at the differences between like sets for both mean and variance. See Table 2 for the results.

Table 2: Confidence Intervals for Means, Variances and Differences of Each

Means				
Set	**Descriptive Statistics**	**90%**	**95%**	**99%**
Set'★	n=96, μ=28.313, s=8.372	26.8936, 29.7324	26.6166, 30.0094	26.0670, 30.5590
Set 1★	n=48, μ=31.21, s=7.81	29.3185, 33.1015	28.9423, 33.4777	28.1837, 34.2363
Set 2★	n=48, μ=25.42, s=7.97	23.1058, 27.3502	23.1058, 27.7342	22.3317, 28.5083
Set 3❖	n=10, μ=31.40, s=7.604	26.9921, 35.8079	25.9603, 36.8397	23.5855, 39.2145
Set 4❖	n=10, μ=21.60, s=5.948	18.1521, 25.0479	17.345, 25.855	15.4874, 27.1726

★Sample mean-$z_{\alpha/2}(\sigma/\sqrt{n})<\mu<$ Sample mean+$z_{\alpha/2}(\sigma/\sqrt{n})$ is a $(1-\alpha)100\%$ confidence interval for the mean population. [3]

❖Sample mean-$t_{\alpha/2,n-1}(s/\sqrt{n})<\mu<$ Sample mean+$t_{\alpha/2,n-1}(s/\sqrt{n})$ is a $(1-\alpha)100\%$ confidence interval for the mean population.

Differences in Means			
Set	**90%**	**95%**	**99%**
Set 1 vs. Set 2*	3.1144, 8.4656	2.5921, 8.9879	1.5556, 10.0245
Set 3 vs. Set 4*	4.5060, 15.094	3.3862, 16.2136	1.0127, 18.5873

*(Sample mean 1-Sample mean 2)-$t_{\alpha/2,n1+n2-2}$ (s_p) $(\sqrt{(1/n1 + 1/n2)})<\mu1-\mu2<$ (Sample mean 1-Sample mean 2)-$t_{\alpha/2,n1+n2-2}$ (s_p) $(\sqrt{(1/n1 + 1/n2)})$ is a $(1-\alpha)100\%$ confidence interval for the difference between the two population means.

Variances				
Set	**Descriptive Statistics**	**90%**	**95%**	**99%**
Set'	n=96, μ=28.313, s=8.372	55.0344, 88.4487	52.7867, 95.2250	48.7385, 102.6330
Set 1	n=48, μ=31.21, s=7.81	44.7932, 88.8451	42.2706, 95.7003	37.8688, 111.2270
Set 2	n=48, μ=25.42, s=7.97	46.6474, 92.9226	44.0203, 99.6616	39.4363, 115.8310
Set 3	n=10, μ=31.40, s=7.604	30.7578, 156.5030	27.3561, 192.7150	22.0603, 299.9520
Set 4	n=10, μ=21.60, s=5.948	18.8197, 95.7590	16.7383, 117.916	13.498, 183.531

$[(n-1)s^2]/\chi^2_{\alpha/2,n-1}<\sigma^2<[(n-1)s^2]/\chi^2_{1-\alpha/2,n-1}$ is a$(1-\alpha)100\%$ confidence interval for σ^2.

Ratio of Variances			
Set	**90%**	**95%**	**99%**
Set 1 vs. Set 2	0.59139, 1.5592	0.5383, 1.7129	0.4471, 2.0623
Set 3 vs. Set 4	0.5139, 5.1972	0.4061, 6.5781	0.2499, 10.6902

$(s_1^2/s_2^2)(1/f_{\alpha/2,n1-1,n2-1}<\sigma_1^2/\sigma_2^2<(s_1^2/s_2^2)(\ f_{\alpha/2,n2-1,n1-1)}$ is a $(1-\alpha)100\%$ confidence interval for σ_1^2/σ_2^2.

CONCLUSIONS

Based on the results of the confidence intervals of the means, we would be inclined to go with the largest sample (Set`) when estimating the true population parameters. However, it is clear that since Set' is merely hypothetical, Sets1&2 or 3&4 indicate that a much wider range would be estimated. At a 90% confidence interval Set` gives a range of 26.8936 to 29.73.24. Set 4 gives and interval of 18.521 to 25.0479. Combining these two (high and low quality) sample observations we would estimate that the true mean is 90% likely to be at least 18 and less than 30.

Since Set 3's parent population is Set 1 and Set 4's parent population is Set 2 it is not at all surprising to note that the mean intervals found for Set 3 versus Set 4 for the most part encompass the intervals for Set 1 versus Set 2. (The only exception is the lower end of the 90% interval. Curious.)

Again, when analyzing the confidence intervals for sample variances, we would be inclined to go with the largest sample (Set`) when estimating the true population parameters. However it is clear that if a person only had Sets1 & 2 or 3 & 4 that a much wider range would be estimated. At a 90% confidence interval Set` gives a range of 55.0344 to 88.4487. Set 4 gives and interval of 18.8197 to 95.7590. Combining these two (high and low quality) sample observations I would estimate that the true variance is 90% likely to be at least 18 and less than 96.

Again, when analyzing the ratio of variances, it is no surprise that the smaller samples produce a larger range for each level of confidence. Bigger samples are always better!

Given that Sets 1 and 2 are randomly selected word lists and the discrepancies in responses, we can conclude that the randomly selected words from Set 1 are easier to understand in the presence of background noise than are the words from Set 2.

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[1] Noise and Hearing Loss. National Institutes of Health Consensus Development Conference Statement, January 22-24, 1990.
[2] Mackersie CL, Boothroyd A, Prida T. Use of a Simultaneous Sentence Perception Test to Enhance Sensitivity to Ease of Listening; J Speech Lang Hear Res 2000; 43:675-682.
[3] John E. Freund's Mathematical Statistics, Sixth Edition. Miller I, Miller M (Eds.), Prentice Hall, Upper Saddle River, NJ, 1999, pp. 360-383.