TECHNICAL NOTE

Rodney G. Gullberg,[1] *M.P.A.*

Statistical Evaluation of Truncated Breath-Alcohol Test Measurements

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ABSTRACT: The reporting of breath-alcohol measurements truncated to two decimal places is a form of computational error. The magnitude of the error can range from 0.000 to 0.009 g/210 L. The truncation error will follow a uniform distribution. A total of 500 breath-alcohol test measurements were evaluated to determine the distribution of the third digit. There are 10 possible discrete values for the third digit. The frequency of each third digit was found to range from 44 for the lowest to 57 for the highest. The data closely approximated the uniform distribution. To conform exactly with the uniform distribution, there would have to be 50 of each decimal value. Given that the third digit approximates the uniform distribution, one cannot attach a greater probability to a particular third-digit value as opposed to another.

KEYWORDS: criminalistics, breath-alcohol testing devices, statistical analysis

All analytical measurements consist of two components: the true value of the measured characteristic and the measurement error [*1*]. The measurement error consists of both systematic and random error. Good analytical procedures will eliminate, if at all possible, systematic error and minimize random error. Random error is typically small as a result of limitations in the instrumentation. The random error should be normally distributed with a mean of zero [*2*].

Errors in measurements can be of several types, each requiring different methods of evaluation [*3*]. Generally, these types include inherent error, analytical error, and computational error. The type of error which this paper will focus on is the computational error as a result of truncation in the reported result.

Microprocessor based breath-alcohol test instruments compute results based on an algorithm in the software program. The computational errors that can result are either round off or truncation errors which produce "noise" (variability) in the data [*4*]. Since most eight-bit microprocessors will compute approximately nine-digit floating point results, the round-off error will be small compared to the truncation error when truncation occurs to two decimal places.

The nine computed digits are certainly not all significant. Breath-alcohol test instruments

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[1]Sergeant—breath test section supervisor, Washington State Patrol Crime Laboratory, Seattle, WA.

are typically capable of producing only three significant figures, since three digits reflect the level of measured precision [5]. The third digit is therefore necessary to express instrumental precision. Therefore, an error results when truncating to two decimal places. The truncation error considered here is the result of reporting the measurement to two decimal places and has nothing to do with the accuracy of the third or subsequent digits. Truncating a reported result to two decimal places can yield an error of up to 0.005 g/210 L. Note, however, that the truncated result will always be biased in favor of an individual submitting to a breath test. Rounding the result, on the other hand, could yield a result that is 0.009 g/210 L higher.

Breath-alcohol test results are reported as a measurement truncated to two decimal places [6]. This results in an error caused by truncation—although the error will not be adverse to the tested individual providing the breath sample. The error may be small approaching zero—or large—approaching 0.009 g/210 L. This will result in an error distribution, which will approximate the uniform distribution [7]. Since the error caused by truncation follows the uniform distribution, there will be equal probability that the error is small—approaching zero—as that the error is larger approaching 0.009 g/210 L.

Procedure

The state of Washington has recently implemented a new breath-alcohol testing program using the BAC Verifier DataMaster which is manufactured by National Patent Analytical Systems Inc. (Eastern Electronics), East Hartford, Connecticut. The instrument is microprocessor based and applies appropriate algorithms in its software to arrive at a breath-alcohol measurement in grams per 210 L of breath. The computational algorithms work with nine-digit floating point values (five bytes for the mantissa with single precision). Rounding errors would occur in the ninth decimal place, and therefore, would not affect the second or third decimal place.

The instrument has the capability of displaying the results truncated to the third decimal place. Procedurally, the instrument is set to truncate to two decimal places for visual display and for printout evidence purposes.

The instrument has internal memory storage of breath-alcohol test results which are transmitted to a host computer. The memory preserves the breath-alcohol measurements to the three-decimal-place truncated result. Reviewing the database records at the host computer allows one to evaluate the magnitude of error as a result of truncating results to two decimal places.

A total of 500 breath-alcohol test measurements reported to 3 decimal places were evaluated to determine the error resulting when truncation to 2 decimal places occurred. The number of each of the 10 possible third-digit values were evaluated and the distribution determined. The breath-alcohol test values ranged from 0.085 to 0.201 g/210 L.

Results

Table 1 shows the tabulation of the truncation errors for the 500 breath-alcohol test measurements. The data were combined from several different BAC Verifier DataMaster instruments. The number of measurements represents the number of tests that recorded a particular third-digit value. Truncating the third digit resulted in a specific truncation error of that same magnitude. The number of measurements ranged from 44 to 57.

The magnitude of error as seen in Table 1 is a discrete random variable. The distribution is discrete since there are ten equally spaced increments of 0.001 g/210 L. A discrete variable can only take on particular values. The variable range is from 0.000 to 0.009 g/210 L.

Figure 1 shows the distribution of truncation errors. Although the distribution of errors in Fig. 1 is discrete, it is clear that it closely approximates the uniform distribution. The expected number of errors, if they were truly uniformly distributed, would be $n/10$ or 50.

TABLE 1—*Distribution of truncation errors.*

Magnitude of Error, g/210 L	Number of Measurements
0.000	44
0.001	57
0.002	49
0.003	52
0.004	53
0.005	48
0.006	46
0.007	55
0.008	45
0.009	51

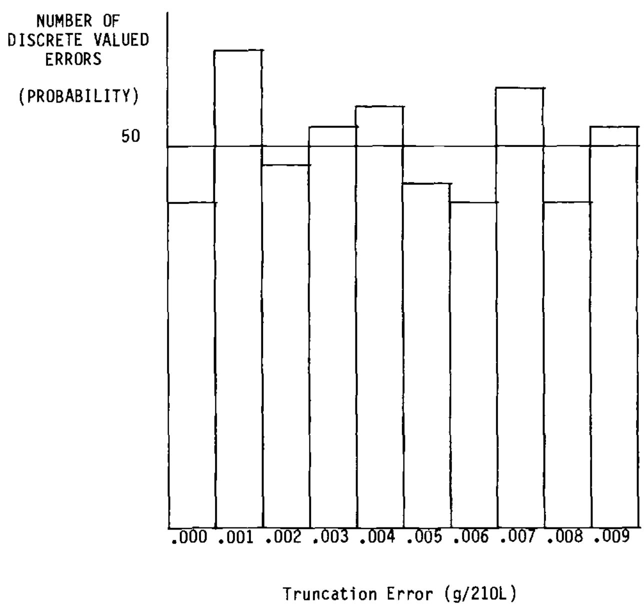

FIG. 1—*Distribution of errors as a result of truncation.*

Discussion

The third decimal place in breath-alcohol test measurements is significant. It is therefore of interest to know what the distribution of third-digit values, and thus the truncation error, appears like. Since the distribution appears to conform to the uniform distribution, it would be random in nature. A good random number generator on a computer would generate a uniform distribution of integer values. The random nature of the third decimal place does not mean it is less significant on an individual test. The random nature only refers to its distribution of values when considering a large number of measurements.

Since the reporting error as a result of truncation in breath-alcohol test measurements follows a uniform distribution, there will be equal probability for any particular magnitude of error. The probability that the reported error was 0.001 g/210 L is equal to the probability that the error was 0.009 g/210 L. This is a unique property of the uniform distribution.

Therefore, when one is considering a two-digit breath-alcohol test result, there is an equal probability that the third unobserved digit is a nine or a one. The defense could not logically suggest there is a greater probability that the third digit is a zero. Likewise, the prosecution could not logically suggest a greater probability that the third digit is a nine. There would be equal probabilities assigned to the outcome of the third unobserved digit. Regardless of the magnitude of the truncation error, it will always be in the individual's favor.

Conclusion

Reporting breath-alcohol test results truncated to two decimal places yields an accurate result to two decimal place precision. However, it is important that experts reporting on the meaning of breath-alcohol test measurements know of all sources of error. One of those sources is due to truncation of the final reported measurement to two decimal places. The magnitude of error conforms closely to the uniform distribution. This suggests an equal probability for each of the discrete error values. Although truncation to two decimal places will not falsely elevate the results to an individual's detriment, it is none the less a source of computational error. This same computational error as a result of truncation applies to all breath-alcohol test instruments capable of computing to three decimal places.

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Address requests for reprints or additional information to
Rodney G. Gullberg
Washington State Patrol Crime Laboratory
Public Safety Bldg., 2nd floor
Seattle, WA 98104-1820