Rounding Error Changes World Record

Rounding errors can often have disastrous results. Justin Gatlin was elated when he set the world record as the person to run 100 meters in the fastest time of 9.76 seconds. His record time lasted only 5 days, when it was revised to 9.77 seconds, so Gatlin then tied the world record instead of breaking it. His actual time was 9.766 seconds, and it should have been rounded up to 9.77 seconds, but the person doing the timing didn't know that a button had to be pressed for proper rounding. Gatlin's agent said that he (Gatlin) was very distraught and that the incident is "a total embarrassment to the IAAF (International Association of Athletics Federations) and our sport."

- The value of the standard deviation s is usually positive. It is zero only when all of the data values are the same number. (It is never negative.) Also, larger values of s indicate greater amounts of variation.
- The value of the standard deviation s can increase dramatically with the inclusion of one or more outliers (data values that are very far away from all of the others).
- The units of the standard deviation s (such as minutes, feet, pounds, and so on) are the same as the units of the original data values.
- The sample standard deviation s is a **biased estimator** of the population standard deviation σ, as described in Part 2 of this section.

If our goal was to develop skills for manually calculating values of standard deviations, we would focus on Formula 3-5, which simplifies the calculations. However, we prefer to show a calculation using Formula 3-4, because that formula better illustrates that the standard deviation is based on deviations of sample values away from the mean.

Example 2 Calculating Standard Deviation with Formula 3-4

Use Formula 3-4 to find the standard deviation of these numbers of chocolate chips: 22, 22, 26, 24. (These are the first four chip counts for the Chips Ahoy cookies. Here we use only four values so that we can illustrate calculations with a relatively simple example.)

Solution

The left column of Table 3-2 summarizes the general procedure for finding the standard deviation using Formula 3-4, and the right column illustrates that procedure for the sample values 22, 22, 26, and 24. The result shown in Table 3-2 is 1.9 chips, which is rounded to one more decimal place than is present in the original list of sample values (22, 22, 26, 24). Also, the units for the standard deviation are the same as the units of the original data. Because the original data are actually 22 chips, 22 chips, 26 chips, and 24 chips, the standard deviation is 1.9 chips.

Table 3-2

General Procedure for Finding Standard Deviation with Formula 3-4	Specific Example Using These Sample Values: 22, 22, 26, 24
Step 1: Compute the mean $\overline{x}$.	The sum of 22, 22, 26, and 24 is 94, so $\overline{x} = \frac{\Sigma x}{n} = \frac{22 + 22 + 26 + 24}{4} = \frac{94}{4} = 23.5$
Step 2: Subtract the mean from each individual sample value. (The result is a list of deviations of the form $(x - \overline{x})$.)	Subtract the mean of 23.5 from each sample value to get these deviations away from the mean: −1.5, −1.5, 2.5, 0.5.
Step 3: Square each of the deviations obtained from Step 2. (This produces numbers of the form $(x - \overline{x})^2$.)	The squares of the deviations from Step 2 are: 2.25, 2.25, 6.25, 0.25.
Step 4: Add all of the squares obtained from Step 3. The result is $\Sigma(x - \overline{x})^2$.	The sum of the squares from Step 3 is $2.25 + 2.25 + 6.25 + 0.25 = 11$.
Step 5: Divide the total from Step 4 by the number $n - 1$, which is 1 less than the total number of sample values present.	With $n = 4$ data values, $n - 1 = 3$, so we divide 11 by 3 to get this result: $\frac{11}{3} = 3.6667$
Step 6: Find the square root of the result of Step 5. The result is the standard deviation, denoted by s.	The standard deviation is $\sqrt{3.6667} = 1.9149$. Rounding the result, we get $s = 1.9$ chips.