Cutting Wood and Missing Putts

How are constant error, variable error, and absolute error useful for understanding motor control?

Two things I like to do—cutting wood and golfing—remind me often of the importance of measures of central tendency and variability in motor control performance. For example, I use my chainsaw to cut up fallen trees to burn in the woodstove. Cutting logs into burnable lengths is not an exact science. In the middle of a Canadian winter, when the temperature is cold and plenty of snow blankets the ground, it is generally considered a good idea to keep moving. I do not take time to measure the lengths of the logs I saw; rather, I make a quick visual estimate and then start to make my cut. But, in doing so, I must remember two important things related to the mean and the standard deviation of the logs I cut. First, because our woodstove is only large enough to hold pieces of wood that are 50 centimeters (20 in.) or shorter, any pieces that are longer than that are useless. And second, wood is easier to stack when the pieces are all roughly of the same length. Essentially, these features remind me that the mean and standard deviation are both important; I must have a mean that is less than 50 centimeters and a standard deviation that is as small as possible.

When considering data in terms of a specific goal or standard, it is often better to express the mean and standard deviation in terms of error measures—in my case, relative to a goal wood length of 50 centimeters. For example, wood lengths of 45, 42, 48, 47, and 52 centimeters would be expressed as lengths that are –5, –8, –2, –3, and +2 centimeters, respectively, relative to my goal wood length of 50 centimeters. If we calculated the mean of these lengths of wood, then we could express the stack of wood as having either an average length of 46.8 centimeters, or the error scores as having a mean constant error of –3.2 centimeters. Having a negative constant error is good in this case, because the average piece of wood that I have cut will easily fit in the woodstove (i.e., the mean is less than 50 centimeters).

The careful reader will have noted, however, that even though my mean constant error is negative, there is still one block of wood that will not fit (the 52 cm log). Thus, by itself, the mean constant error score (–3.2 cm) is misleading, because it does not provide any indication of how many logs might not actually fit in the woodstove. Our measure of variability, the standard deviation, gives us some indication of this information. The measure of variability of these error scores (called the variable error) represents the deviation of the error score for each log relative to the mean constant error and is calculated in the same way as is a standard deviation. In this case, the variable error is 3.3 centimeters. In general, when I am cutting wood, I want to achieve a negative mean constant error with a variable error that is as small as possible.

Although constant error provides a useful heuristic measure of average performance in cutting wood with a chainsaw, it is a quite misleading measure of central tendency in another activity I like to do. Let's say that I have struck 10 golf putts—5 of these putts go past the hole by 5, 10, 15, 20, and 25 centimeters, respectively, and the other five putts come up short of the hole by equal amounts (–5, –10, –15, –20 and –25 cm). On average, by how much have I missed the hole with these putts? If you were to calculate the average as in the previous wood-cutting example (the sum of the 10 individual error scores, divided by 10) the answer would be a mean constant error of 0. In other words, my "average" putt ended up in the hole. However, we know that this answer surely must be wrong because none of the individual putts actually went in the hole. So, we must use a different way to express these error scores to avoid an answer that makes no sense.

The problem that we sometimes run into with constant error is that it provides a measure of average bias, the tendency to err in a specific way (e.g., by too much or too little; too far left versus too far right). In some cases a specific bias is desirable, such as the tendency to undercut a wood length of 50 centimeters so that all of my wood pieces fit in the woodstove. In the case of my putts that have no consistent bias, we are much better off using a measure of central tendency that removes the bias from each score prior to calculating the mean. Such a procedure is called using the absolute (unsigned) scores. Hence, this measure of central tendency is called the mean absolute error. Here, our measure of central tendency is the mean of the unsigned scores (5, 5, 10, 10, 15, 15, 20, 20, 25, 25), which is 15 centimeters. That is, the golf putts tended to miss the hole by an average of 15 centimeters. In this particular case, the mean absolute error score (15 cm from the hole) represents a more accurate picture of the entire set of individual scores than what is represented in the mean constant error (in the hole).

Averages are convenient ways to express how we tend to perform. But, numbers that represent central tendencies can be misleading if the tendency itself is not a strong one. Measures of variability are one way to identify the strength of a tendency. Depending on the context, different methods of calculating central tendencies may characterize the data in more representative ways.

SELF-DIRECTED LEARNING ACTIVITIES

1. Define *constant error*, *absolute error*, and *variable error* in your own words.

2. What do the terms *algebraic error* and *total error* (or Henry's E) refer to? How are they calculated, and how are they similar to the terms *constant error* and *absolute error*, respectively?
3. Look up and briefly describe a research investigation that uses at least two error measures. Why do you think the researchers used these measures in particular?
4. Conduct a brief study on yourself. Close your eyes and, using a pencil, draw five lines as close to 4 inches (10 cm) as possible, one below the previous one, without opening your eyes until you have drawn the fifth line. Measure and record the length of each line you drew; then calculate all of the error measures that have been discussed.

Notes

- Here is a web-based standard deviation calculator:
  www.tinyurl.com/standarddeviationcalculator

Suggested Readings

Chapanis, A. (1951). Theory and methods for analyzing errors in man–machine systems. *Annals of the New York Academy of Sciences, 51,* 1179-1203.

Schmidt, R.A., & Lee, T.D. (2011). Methodology for studying motor performance. In *Motor control and learning: A behavioral emphasis* (5th ed., pp. 21-56). Champaign, IL: Human Kinetics.