Pouring Coffee

How does the information-processing rate create a speed–accuracy trade-off?

The next time you visit your mom or favorite aunt, ask her to take part in a little experiment. Set a coffee cup in the bottom of the kitchen sink and ask her to fill the cup right to the very top with strong, dark coffee. Ask her to do it as fast as possible, and, using your watch or phone, record the time it takes for her to pour the coffee. Then, ask her to spread out her finest white linen cloth on the table, and place the coffee cup on the linen. Again ask her to fill the cup to the very top with coffee as fast as possible and measure her time again. I can predict with great confidence that the time it takes to pour coffee into the cup when placed on the linen will be much longer than the time it takes to pour the coffee when the cup is in the sink. However, the likelihood that some coffee might have been spilled in the process is much greater in the sink than on the linen.

The coffee example is another demonstration of the speed–accuracy trade-off, which is a rather universal principle of not only motor control but also human behavior in general. The trade-off is that you run the risk of making more errors as you go faster, such as when I type too fast. To avoid making errors, I have to slow down. The trade-offs are that you can sacrifice speed for better accuracy, or sacrifice accuracy for faster speed.

Our ability to think and function requires that we perceive, process, and act on incoming sensations. The time it takes to process those sensations is the primary, rate-limiting factor in making decisions, be they movement-related decisions or otherwise. To avoid spilling coffee in our example, we need to be aware of a number of situations simultaneously, such as the current level of coffee in the cup, where the top edge of the cup is, and the rate at which we are pouring the coffee. These are sources of information that need to be processed—that is, detected and acted on. Assuming that we process information at a constant rate, it will take longer to process a greater amount of information than a lesser amount of information. The reason there is more information to be processed when pouring coffee into the cup quickly is that the level of the coffee is changing at a faster rate than when it is poured slowly.

Here is another example. Suppose someone were to offer you $100 to thread a needle, but stipulated that you had only one chance to pass the thread through the eye to win the money. How deliberate would you be in making that one attempt? The answer would probably depend on how badly you wanted the $100, but also on the size of the eye of the needle. Threading a needle requires that you continuously process the position of the leading edge of the thread relative to the tolerance for error, as defined by the size of the needle's eye. The smaller the tolerance for error is, the more information exists that needs to be processed. A large eye would require very little time to achieve success because the size of the thread compared to the size of the needle's eye creates a relatively large tolerance for error. Relatively little information needs to be processed, so we should be able to process it quickly without making an error. For a small eye, however, to thread the needle correctly on the first try, we need to move more slowly because the size of the thread compared to the needle's eye leaves little tolerance for error. Every millimeter or so that we move the thread closer to the needle eye requires that we update the relative position of the two, determine a measure of accuracy, and make changes to the thread's trajectory, if necessary. In other words, there is more information to be processed.

Fitts' law (see "The Calculator") was based on information theory and represents a specific type of speed–accuracy trade-off for movements to targets at varying distances and sizes. In one of the tasks that Fitts used for his research, he reasoned that the amount of information increased by one bit (or binary digit) whenever the distance of the target doubled or the size of the target was cut in half. Given a constant rate of human information processing, Fitts correctly predicted that movement time would increase by a constant amount for each increased *bit* of task difficulty. It is important to note, however, that Fitts required that errors be kept to a minimum. So, here is a specific type of the speed–accuracy trade-off in which movement speed must be slowed to maintain a constant error rate.

Hick's law, which I will discuss a little later (see "Red Light, Green Light" in chapter 5), is also grounded in information theory and explains the speed–accuracy trade-off in situations in which we must react as fast as possible to differing amounts of information. For Hick, the amount of information to be processed was defined in terms of the number of stimulus and response alternatives from which to choose. Reaction time increased by a constant amount whenever the number of alternative choices doubled. Like the trade-off in Fitts' law, the task was to make the correct response and avoid errors, so the subject had to slow down to respond correctly when more choices were available.

Schmidt's law (see "The Gimme Putt") addresses the speed–accuracy trade-off in a different way. For this work, Schmidt and his colleagues created targets of constant size and asked subjects to move varying distances at prescribed movement times, thereby creating different movement speeds. His finding that the spread of errors around the target increased by a constant amount relative to the speed of movement represented a variation of the same speed–accuracy relationship that Fitts had discovered, even though the type of trade-off was different—Schmidt varied movement speed and recorded the errors that resulted.

Researchers have examined many more types of trade-offs over the years, providing a fascinating basis for studying common elements of behavior in human decision making. Deciding whether to trade speed for accuracy, or vice versa, represents choices that we make hundreds of times every day; these decisions reflect the struggle over the goals we wish to achieve and the consequences we risk in striving to achieve those goals. I have a pretty good idea of what your mom would do when pouring coffee above her finest white linen.

Self-Directed Learning Activities

1. Describe the speed–accuracy trade-off in your own words.
2. Describe how Fitts' law and Schmidt's law differ in terms of the speed–accuracy trade-off.
3. From the research literature, find what is meant by the temporal speed–accuracy trade-off. How does it differ from the speed–accuracy trade-off as described by Fitts' law and Schmidt's law?
4. In this story I asked you to conduct a little experiment involving coffee and your mother's best white linen. If your mother is like mine, that experiment would never actually happen. So, design another experiment that creates a similar trade-off as the coffee example does.

Notes

- Fitts also used tasks in which people put pins into wells and put washers onto pegs, all of which could vary in size. The information to be processed in these tasks was related directly to the tolerance for correctness.
- The term *bit* stands for "binary digit," a measure of information that is directly proportional to the uncertainty in a task. Task information increases by one bit whenever uncertainty is doubled.
- In *Human Performance*, Fitts and Posner provide an amusing example of a speed–accuracy trade-off: the politician who tries to impress an audience by providing quick answers sometimes would be better off reflecting before answering.
- Apparently the speed–accuracy trade-off is not limited to humans; foraging behavior in bumblebees also reveals a strong speed–accuracy relation:

  Chittka, L., Dyer, A.G., Bock, F., & Dornhaus, A. (2003). Bees trade off foraging speed for accuracy. *Nature, 424,* 388.

From T.D. Lee, 2011, *Motor control in everyday actions* (Champaign, IL: Human Kinetics).

Suggested Readings

Fitts, P.M., & Posner, M.I. (1967). *Human performance.* Belmont, CA: Brooks/Cole.

Schmidt, R.A., & Lee, T.D. (2011). Human information processing. In *Motor control and learning: A behavioral emphasis* (5th ed., pp. 57-96) Champaign, IL: Human Kinetics.