FORENSIC MOTOR CONTROL

What are generalized motor programs, and what do keystroke dynamics reveal about them?

Most of what I know about forensic identification comes from crime shows that I've seen on TV. The suspect is caught because a fingerprint was left on the murder weapon. The evidence is used to convict the suspect because no two fingerprints have ever been found to be identical. Crime shows tell us that other forensic methods can be used as well, such as DNA and eye retina data, but the fingerprint is the oldest biometric tool used for identification. However, another method that reveals a great deal about your identity is how you write or even type your name. For example, the password that you type to log on to your e-mail account may be just as identifiable as your fingerprint.

Try the following task as an example: go into any word processing program and type your name 10 times, once on each line, as I have done here:

Tim Lee
Tim Lee
Tim Lee
Tim Lee
Tim Lee
Tim Lee
Tim Lee
Tim Lee
Tim Lee
Tim Lee

I am not a skilled typist. I use my right middle finger to hold down the shift key and press the letter *T* with my left middle finger, then use my right middle finger to press *i* and my right index finger to press *m*, and then my right thumb to press the space bar. It is not very efficient, but I do it the same way every time I type my name. Regardless of how skilled a typist you are, you most likely repeat much the same process each of the 10 times you type your name.

Now, let's try to unravel the temporal "fingerprint" that you left behind when you typed your name. Suppose we conducted a simple analysis of the keystrokes and the time between each of the keystrokes that you made. The total time taken to type your name once is simply the time from the

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

first keystroke to the last keystroke. At a more fine-grained level of analysis, the total time constitutes the time each key is held down (the dwell time) plus the time between the release of one key and the depression of the next (the transition time). All of the individual dwell times plus all of the transition times will sum to the total time.

In figure 7.5, I have plotted a hypothetical example of the 10 trials to type my name. The light gray bands denote the dwell times, and the darker gray bands indicate the transition times. I have ordered the lines of bands that represent the 10 trials from the fastest (least total time) at the top to the slowest trial at the bottom (most total time).

If you were to analyze each of the 10 repetitions of your name, you would probably find that all of the total times would be similar, but probably never *exactly* the same each time, just as in figure 7.5. The "noise" in our central nervous systems, plus other factors, causes the results to vary a little bit each time, resulting in some repetitions to be slower, and others faster, than the average total time.

But, take a closer look at each individual band in figure 7.5 as it changes over the 10 trials. What you will notice is that as the total time increases, each band gets proportionally longer too. We could express these numbers another way by dividing the time for each individual band by the total time for that trial to obtain a relative proportion of time represented by each band. Given the hypothetical evidence in figure 7.5, what we would discover is that the relative time for each band, expressed as a percentage, would stay roughly the same across all of the repetitions. Applying temporal and other methods to deconstruct how we type (e.g., key press forces) is called the study of keystroke dynamics.

According to generalized motor program theory, relative time is one of the key features of movement that is controlled by the central nervous system,

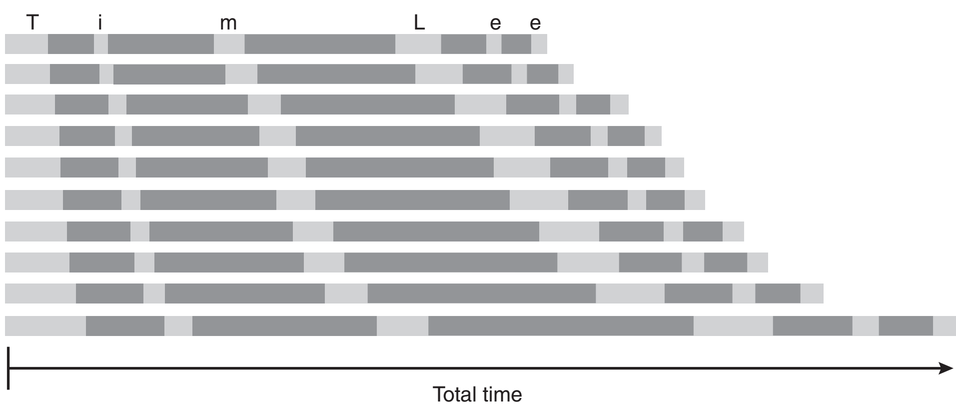

Figure 7.5 Ten hypothetical trials for typing my name. Each trial is represented as a single horizontal line, with the fastest trial (shortest total time) at the top and the slowest trial (longest total time) at the bottom.

especially for brief, rapid actions. Relative time is an expression of our motor control fingerprint. For well-learned tasks such as typing and handwriting, our central nervous system regulates the relative timing of impulses that are sent to the muscles that carry out these tasks. Various factors influence the real time on any particular instance. For example, using a keyboard that requires more force to depress the keys might result in overall slower times than would result using a keyboard that has a light touch, but the relative timing would likely remain the same.

Research in keystroke dynamics may result in the ability to identify people who carry out Internet fraud. In many ways it is similar to the use of handwriting dynamics to analyze the timing of the cursive expressions of a signature. It is fairly easy to forge the spatial representation of someone's signature, but very difficult to forge the temporal dynamics that result in that signature. These expressions of timing behavior represent our motor control fingerprints.

Self-Directed Learning Activities

1. Define the term *generalized motor program* in your own words.
2. How does the concept of a generalized motor program differ from the concept of a motor program as it was used in stories such as "Antilock Brakes" (in chapter 5) and "Point of No Return" (earlier in this chapter)?
3. Suggest a method by which the handwriting dynamics of signatures could be used to detect fraud.
4. Some people contend that there is one generalized motor program for the full swing in golf, regardless of which club is used. How could a temporal dynamics analysis be used to assess this contention?

Notes

- An excellent review of fingerprint analysis by David Ashbaugh of the Royal Canadian Mounted Police is available here:

  www.onin.com/fp/ridgeology.pdf

- A lot of controversy remains about invariances in motor performance; how they are measured; and what invariance, or lack of invariance, means in terms of motor programs. The following articles provide good arguments for the debate:

Gentner, D.R. (1987). Timing of skilled motor performance: Tests of the proportional duration model. *Psychological Review, 94,* 255-276.

Heuer, H. (1988). Testing the invariance of relative timing: Comment on Gentner (1987). *Psychological Review, 95,* 552-557.

Suggested Readings

Schmidt, R.A. (1975). A schema theory of discrete motor skill learning. *Psychological Review, 82,* 225-260.

Schmidt, R.A. (1985). The search for invariance in skilled movement behavior. *Research Quarterly for Exercise and Sport, 56,* 188-200.

Schmidt, R.A., & Lee, T.D. (2011). Central contributions to motor control. In *Motor control and learning: A behavioral emphasis* (5th ed., pp. 177-222) Champaign, IL: Human Kinetics.