Antilock Brakes

How does the complexity of a motor program influence reaction time?

Those of us who live in northern climates have to deal with icy road conditions for several months of the year. When first learning to drive, I was taught to respond to a skid on icy roads by pumping the brakes very rapidly instead of slamming and holding down the brake pedal. This is called cadence braking and takes both rapid foot movements and a keen presence of mind to be effective (not something that is easy to do when panicked by a car skidding on an icy road). Cadence braking is an effective method for cars with older styles of brakes, called drum, or disk, brakes—the kind of brakes that were installed on cars when I was learning to drive. Most cars now come equipped with an antilock braking system (ABS), which was developed to provide the pumping action automatically when the brake pedal is pressed hard. The ABS system was an advance in automotive technology that was created for a number of reasons, including one that the manufacturers never even considered.

Reaction time in braking, as we have discussed before, is the time that elapses between the appearance of an emergency signal and the initiation of the action to push the brake (see "Jumping the Gun"). The duration of a reaction time is affected by a number of factors, including one that is a little counterintuitive, discovered years ago by Franklin Henry. The participants in Henry's research responded to an auditory stimulus by making one of three types of actions that differed in complexity. In one portion of the experiment, the trials required that participants make only a simple hand withdrawal as soon as possible after the tone sounded. In another set of trials, participants had to complete two rapid movements as soon as possible after the hand withdrawal. Trials in the third portion of the experiment required four quick movements in immediate succession after the initial hand withdrawal response to the tone. Henry found that the reaction time for each of the successively more complex movements was a little bit longer: the second action resulted in a reaction time that was 23 percent longer than the reaction time in the simple hand withdrawal response trials, and the third action was 31 percent longer than the hand withdrawal response.

Some might think that these results are not surprising because it should take more time to complete a more complicated response. However, remember that reaction time is measured only as the time it takes to initiate the response. Because all three actions required the same hand withdrawal

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

at the start, the measurement of the reaction time period was complete before any other movements were required. Therefore, the differences in the observed reaction times must have reflected differences in the latency period to get the response started, with more complex actions producing longer reaction time latencies.

It is interesting to note that Henry's work was conducted back in the late 1950s and early 1960s, when the idea of using computers as analogies to explain human cognition (i.e., the information processing model) was still in its infancy. His explanation for these effects relied on the analogy of a computer program; Henry called it a motor program. The idea was that learned, rapid movements are stored as a program in memory, which takes time to load when retrieved from memory. Henry's argument was that the latency to retrieve the program, here measured as reaction time, corresponded directly with the complexity of the response: the more complicated the required movement was, the longer the latency to load and initiate its motor program.

Henry's research has since been replicated many times by researchers working in different laboratories and using different types of actions with various response complexities. One of the experiments that more directly approximates the task of pumping the brakes of a car was reported by Sternberg and his colleagues. Participants in this experiment were asked to speak simple phrases as soon as possible after a signal was provided, such as *two-three-four-five-six*. As with Henry's research, the participants were well aware of the phrase they were to speak, so response uncertainty was not a factor in any of the results (see "Jumping the Gun"). Sternberg found that the time it took to begin to say *two-three-four-five-six* was almost 20 percent longer than the time it took to begin to say *two*. In the case of the participants in the Sternberg study, each word added to the phrase increased the complexity of the response and contributed about another 4 percent to the reaction time latency.

So, let's consider these findings in the context of braking a car on a slippery road. For cars equipped with the kind of brakes used when I learned to drive, the appropriate response is a preprogrammed rapid pumping on the pedal—say, as many as 10 rapid bursts of force on the brake pedal. For cars now equipped with ABS brakes, the response is simply a single, forceful depressing of the pedal. It stands as a clear prediction from the research of Franklin Henry, Sternberg and his colleagues, and many others that the time to initiate a single braking action using ABS brakes should be shorter than the time to initiate a cadence braking response using a drum, or disk, brake system. The unexpected advantage in ABS technology in automobiles was not just a more effective braking system but also one that is likely initiated faster in an emergency situation than the older system.

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SELF-DIRECTED LEARNING ACTIVITIES

1. Define the term *motor program* in your own words.
2. Research what other factors specifically related to the action required have been found to influence reaction time.
3. Given what you found in question 2, suggest two other differences between a cadence braking action and an ABS braking action that might also influence the reaction time latency.
4. Create a methodology for an experiment in which you compare the reaction time to initiate a cadence brake response to that to initiate an ABS brake response.

NOTES

- Young and Stanton provide a good summary of other factors that affect brake reaction time:

  Young, M.S., & Stanton, N.A. (2007). Back to the future: Brake reaction times for manual and automated vehicles. *Ergonomics, 50,* 46-58.

SUGGESTED READINGS

Christina, R.W. (1992). Unraveling the mystery of the response complexity effect in skilled movements. *Research Quarterly for Exercise and Sport, 63,* 218-230.

Henry, F.M., & Rogers, D.E. (1960). Increased response latency for complicated movements and a “memory drum” theory of neuromotor reaction. *Research Quarterly, 31,* 448-458.

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.

Sternberg, S., Monsell, S., Knoll, R.L., & Wright, C.E. (1978). The latency and duration of rapid movement sequences: Comparisons of speech and typewriting. In G.E. Stelmach (Ed.), *Information processing in motor control and learning* (pp. 117-152). New York: Academic Press.

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