Like Riding a Bicycle

How are motor skills stored in memory?

Why is it that some actions are remembered well for long periods without being performed, whereas others are forgotten quickly? Riding a bicycle is the classic example of a skill that seems to be retained forever once it has been learned. I can get on a bicycle after many years of not riding one, and my ability to stay upright and get to where I want to go is seemingly unimpaired. And yet, the key presses that I used to make a phone call just a few moments ago are almost completely forgotten if I want to call the same person again. What is it about how we store and retain memories that makes it easy or difficult to remember motor skills?

Perhaps one of the first things to consider in answering this question is the not-so-obvious one: Which motor skills do we really *want* to remember? For skills such as riding a bicycle, fly casting, operating a lathe, performing surgery, and driving a car, it is obvious that we would want to have good retention. This would be a positive attribute of memory. On the other hand, remembering the exact sequence of keys that I just typed moments ago would appear to be a frivolous attribute of memory, and perhaps detrimental too. Clearly, it is important that I remember the skill of typing. But, potentially, a good memory could interfere with performance in the future if I retained a strong recollection of my immediate typing experiences.

The stories “The Keypad” (in chapter 10) and “H.M.” (later in this chapter) address the memory attributes of two patients who had suffered different brain impairments. In ”The Keypad” I discussed an amnesic patient who played some rounds of golf with neuropsychologist Dan Schacter. The patient had a good memory for the golf swing, and he continued to play as well after becoming amnesic as he had before. On the other hand, the patient had severe difficulty remembering some of the things that average golfers take for granted, such as where he had hit his golf shot and even whether or not he had hit his shot.

Remembering where you hit your golf shot is really only important for a short period of time. After you hit your next shot, the memory of the previous location of your ball is irrelevant. It is similar to remembering where you parked your car. I don’t want to remember where I parked my car yesterday; I want to remember where I parked it this morning. In fact, it might be easier to remember where you parked your car this morning if you forgot where you parked it yesterday, because the older memory might interfere with the retrieval of the newer memory.

The same can be said for the retention and performance of some motor skills. A simple experiment performed by David Rosenbaum and colleagues some years ago provides a wonderful demonstration of the concept that retention can, at times, either enhance or degrade performance. Rosenbaum's subjects were asked to simply say out loud a short string of letters of the alphabet (e.g., ABCD), and then to keep repeating that string as fast as possible for a period of time (e.g., ABCDABCDABCD). The twist here was that the subjects were asked to alternate between shouting and whispering the letters. You can demonstrate the task easily: start by shouting A, then whispering B, shouting C, and whispering D. Then repeat the string by continuing to alternate shouting and whispering. Notice that for a string of even-numbered letters (4 = AbCd, 6 = AbCdEf, 8 = AbCdEfGh, where a capitalized letter is shouted and a lowercase letter is whispered), the same letters are always vocalized in the same way (i.e., the same letters are either shouted or whispered). Rosenbaum's subjects found this easy to do and could vocalize many letters in a short period of time. Rosenbaum then asked his subjects to produce odd-numbered strings (e.g., 3 = AbC, 5 = AbCdE, 7 = AbCdEfG). Try this yourself, alternately shouting and whispering each subsequent letter for a three-letter string (e.g., AbCaBcAbCaBc). You will find very quickly that this task is much more difficult because once you finish a string of letters and start over again, the letters that were previously shouted loudly now must be whispered, and vice versa.

The conclusion from the Rosenbaum experiment is that the memory for how you previously spoke the letter could either facilitate performance (i.e., for even-numbered letter strings) or hinder performance (i.e., for odd-numbered letter strings). But that is not the whole story. Try the task again, but now cycle through several repetitions of a very long even-numbered string (i.e., the entire alphabet: AbCd . . . WxYzAbCd . . .), again alternating shouts and whispers, and compare your performance with that of repeating a very long odd-numbered string (i.e., the entire alphabet minus the letter Z: AbCd . . . WxYaBcD . . .). What you will probably find is that speed of vocalizations is about the same, regardless of whether the string was odd or even. For long strings, the retention of how you previously spoke the letter A has vanished, and so too has the positive and negative effects on performance.

Because the memory for the short string had a strong influence on performance, a logical conclusion is that the memory facilitated performance when the remembered vocalization was used again as before, but degraded performance when it interfered with the required (opposite) vocal stress. However, because the memory for the long string had deteriorated by the time the end of the string was reached, there was no longer a facilitation effect, but neither was there an interference effect. It seems as though the specific motor command for shouting a letter is remembered only for a brief period of time, during which the memory can have either a positive or negative effect on subsequent performance.

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

So, what does all this say about why some skills are retained only for brief periods of time, whereas others are retained for quite long periods of time? For this question, let's consider another experiment, this one by neuroscientist Stephan Swinnen. Subjects in this research practiced a relatively simple task: rapidly flexing, extending, and flexing the elbow, the start and finish of this three-component movement was to be completed in exactly 650 milliseconds. After learning this task, his subjects performed retention tests after delays of several minutes up to five months. The results were intriguing. The subjects lost all capability to perform the task in the exact goal time (650 msec). However, the rhythm (or relative timing) with which they had learned to flex, extend, and then flex the elbow was retained very well. There appeared to be dissociated effects for the memory of the timing aspects of this task: the rhythm was retained well, but the specific goal time was not.

These and other research findings have led researchers to speculate that motor skills are not learned and stored as a single representation in memory. Different attributes of a motor skill may be stored as separate memory representations. Further, we can speculate that each of these representations has unique retention characteristics; some attributes are retained well for a very long time, and others are retained for only very brief periods of time. When the performance of a particular motor skill is required, it is likely that a person draws on multiple memories to regulate movement control. What one observes in a performance reflects the combined strengths of all the memories.

In the case of riding a bicycle, the characteristics of memory that permit us to stay upright and move forward are the most important and likely remembered very well. This is why it appears that we retain the skill of bike riding forever. However, other features, perhaps less noticeable and not important for staying upright and moving forward, may be retained much less well, such as the efficiency of effort or power. The loss of these memory features may reduce your efficiency but won't make you fall over.

Self-Directed Learning Activities

1. Define the term *forgetting* in your own words.
2. Pick a sport task and describe the types of skills required for it that are typically either forgotten rapidly or retained very well.
3. Ask a friend to perform Rosenbaum's letter-vocalizing memory experiment, described in the story, using strings of 4, 5, 6, 7, 25, and 26 letters. What do your results suggest about the effect of memory on performance?
4. Create an adaptation of Rosenbaum's memory experiment using a task not mentioned in the story. For example, one task would be to have subjects alternate playing notes softly and loudly on a piano. Be creative.

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

Suggested Readings

Rosenbaum, D.A., Weber, R.J., Hazelett, W.M., & Hindorff, V. (1986). The parameter remapping effect in human performance: Evidence from tongue twisters and finger fumblers. *Journal of Memory and Language, 25,* 710-725.

Schmidt, R.A., & Lee, T.D. (2011). Retention and transfer. In *Motor control and learning: A behavioral emphasis* (5th ed., pp. 461-490). Champaign, IL: Human Kinetics.

Swinnen, S.P. (1988). *Learning and long-term retention of absolute and relative time.* Unpublished manuscript, Catholic University of Leuven, Belgium.

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