Optimal Practice Processes for Performance

Throughout their lifetime, in both their leisure and work time, people engage in many activities to learn new skills or develop their abilities such as training for marathons, learning a new language, learning how to code, learning a new process (e.g., six sigma certification), or preparing for emergencies (e.g., drills).

Although these learning activities have each their own idiosyncrasies, they share in common that they can be treated as practice processes, with often a specific horizon for performance.

Consistent with the saying that “practice makes better,” the “law of practice” predicts that performance improves with practice. However, just the sheer amount of practice is often not enough to improve performance: its type and timing also matter. For instance, practical evidence suggests that distributing practice over multiple sessions is often more conducive to long-term retention. Yet, there exist few guidelines to optimize such processes.

Building upon research in endurance sports training and learning and on modeling techniques from behavioral operations management, this paper proposes an analytical model of behavioral response to practice and then optimizes the resulting practice process to maximize performance on a predefined date.

We consider a setting where the amount and profile of practice are unconstrained decision variables and learning individuals are captive. We focus on optimizing the distribution of practice and ignore other on-task practice considerations (e.g., variability in the content of practice, guidance) and off-task practice considerations (e.g., motivation, verbal instructions).

We model each practice session as having both a positive impact on performance (by contributing to a stock of “fitness”) and a negative impact on performance (by contributing to a
stock of “fatigue”). Between practice sessions, these two stocks decay exponentially, albeit at different rates. We consider two models of performance, one in which the effect of practice on performance is additive, which fits better the phase of skill acquisition, and one in which the effect is multiplicative, which fits better the phase of skill retention.

Moreover, and consistent with behavioral models in operations management (e.g., Nasiry and Popescu 2011, Das Gupta et al. 2015), we assume that the effect of practice on fitness and fatigue is moderated by a reference point, which adapts over time to past practice. In particular, we define effort the amount of practice relative to that reference point. We consider two mechanisms of adaptation, depending on whether the reference points adapt as the geometric mean or as the maximum of the past reference point and current practice. Under maximum adaptation, the reference point decays slowly, as is the case with continuous motor skills (e.g., riding a bike, skiing); whereas under geometric adaptation, the reference point decays fast, as is the case with cognitive skills.

We characterize the optimal practice processes for both the acquisition and the retention of skills, under slow and fast adaptation, when the last-period practice (e.g., final test) has a low or high minimum intensity requirement.

We find that, for skill acquisition, the optimal efforts are in general U-shaped, as a result of a sequence of U and inverted-U shapes of practice, or the other way around. Thus, we find that the optimal practice process for skill acquisition consists of phases of increase in practice and phases of decrease in practice, consistent with the principle of spacing out practices to enhance learning. The transition in practice intensities are in general smooth, unless the last-period practice has a high-intensity requirement and the reference point adapts quickly to high-intensity practices and
slowly to low-intensity practices (as is typically the case for continuous motor tasks), in which case they may be rugged.

In contrast, for skill retention, we find that one should aim for constant efforts if the last-period practice has no intensity requirement or if the reference point adapts quickly to low-intensity practices but slowly to high-intensity practices (as is typically the case for cognitive skills). To maintain constant efforts, the optimal practice process must be monotone (increasing or decreasing). However, if the last-period practice has a high-intensity requirement and the reference point adapts quickly to high-intensity practices but slowly to low-intensity practices (as is typically the case for cognitive motor skills), a pulsed pattern may be optimal, consistent with the principle of periodization in endurance sports training.

Irrespective of the model variant, we find that skipping practice is never optimal, demonstrating the power of habits. Although distributed practice has been found to dominate massed practice, our model thus suggests that multi-period breaks are seldom optimal. We also find that the optimal practice intensities are rarely constant. Given the duration of practice sessions is often fixed due to scheduling constraints, one may thus need to vary their intensity. Given its parametric form, the proposed model can be tailored to fit individual characteristics.

Bibliography
