YOU ARE A QUITTER

SAMUELE MARCORA'S RADICAL NEW PSYCHOBIOLOGICAL MODEL OF ENDURANCE PERFORMANCE WILL BLOW YOUR MIND—AND THEN EMPOWER IT LIKE NEVER BEFORE.

By Matt Fitzgerald

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One of the most spectacular bonks in triathlon history occurred at the 1995 Hawaii Ironman. Paula Newby-Fraser, having already won the race seven times, built a seemingly insurmountable 11-minute lead on the bike. But Karen Smyers came after her hard on the run, chipping away at the gap at more than 20 seconds per mile, mile after mile. With 10K to go, Newby-Fraser still had three minutes in hand, but seeing how close Smyers had drawn she panicked and began skipping aid stations. In the closing miles of the race her stride slowly tightened up, and then it fell apart. As she descended the famous hill on Palani Road with scarcely two kilometers left to cover, the 33-year-old Zimbabwean multisport legend started weaving like a drunk driver. She told the rest in an interview with *Outside* magazine after the race:

I stopped at one point and said: "I can't finish." I was starting to lose consciousness. It is just one of those things that happened. I know it kind of looked like something out of a movie. I can't believe it. Even now, as I look back on it, I think: "Why couldn't I have kept going another 200 yards?" But there was no way. I actually thought that I had given my life to this race and I was going to die. I felt like I was going into seizure. When I sat down on the road, there was no way I could move. I said, "Just take another step," and there was no way I could do it.

Moments after Smyers passed a stationary Newby-Fraser on the homestretch, the utterly defeated seven-time champion collapsed. She stayed on the ground for nearly 20 minutes before she had recovered enough to stand and walk across the finish line, now in fourth place.

Newby-Fraser posed an interesting question: Why couldn't she have just kept going another 200 yards (actually it was closer to 500) to the finish line? One might speculate that skipping those last few aid stations caused her muscle energy stores to run dry and her muscles themselves to shut down; or that feeling the pressure of the chasing Smyers had caused her to overreach and overheat; or that 10 straight years of triathlon racing had taken a toll on her body, which could no longer go quite as long and hard as it used to.

If asked for his opinion, Samuele Marcora, 41, an exercise physiologist at Bangor University in Wales, would offer a rather different explanation of Newby-Fraser's dramatic implosion within sight of the finish line of the 1995 Ironman World Championship. He would say she just plain quit. Her muscles were still perfectly capable of getting her to the finish line ahead of Smyers. The feeling that she was physically incapable of taking another step was an illusion. She just couldn't take the suffering any longer. It had become too hard. So, she voluntarily stopped and sat down.

It's not that Marcora, who was born and raised in Italy, thinks Newby-Fraser is mentally weak or was unmotivated. He simply believes that all endurance athletes are quitters. Or, to make the point only slightly less provocatively, he believes that endurance fatigue is a volitional psychological phenomenon. There is a limit to how much each of us is willing to suffer during a race or workout. When that limit is reached, we stop. And that limit is always reached before we physically have to stop. We never run out of gas. We quit.

"What we call exhaustion is not the inability to continue," Marcora explained in a recent interview. "My idea is that perception of effort is basically a safety mechanism like many other sensations. Think about thirst or hunger or pain. All these sensations are there to make us do something that is beneficial for our survival, and I think perception of effort does the same."

"Bullshit," you say. "Maybe other people quit, but not me. I can't speak for anyone else, but when I bonk, it's because my body truly cannot continue. I can *feel* it."

I gladly pardon your French. It's galling to suggest that we endurance athletes, who pride ourselves on our mental toughness, are limited not by physical barriers but instead by the perception of effort. And it certainly does contradict our experience. It sure *feels* as if we cannot go on in those miserable moments when we don't go on. But feelings can be deceptive, and Marcora has something much stronger than feelings standing behind his argument—he has actual proof.

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In a study recently published in the *European Journal of Applied Physiology*, Marcora asked 10 members of the Bangor University rugby team to each perform a maximal voluntary cycling power (MVCP) test, which consisted of an all-out five-second effort on a stationary bike. After a period of rest, the subjects were then required to pedal the same bikes as long as possible at a fixed wattage that corresponded to 90 percent of their individual VO_2 max values. On average, the subjects were able to continue for roughly 12 minutes at 242 watts before giving in to exhaustion. Immediately after bonking in this high-intensity endurance ride, the subjects repeated the five-second MVCP test.

As you might expect, the subjects were not able to produce as much power in the second test as in the first. In fact, their power dropped by about 30 percent, from an average of 1,075 watts in the first test to 731 watts in the second. Yet they still produced 731 watts for five seconds immediately after bonking in the endurance ride at 242 watts.

The fact that the rugby players were able to briefly triple their power output in the second MVCP test relative to the ride to exhaustion cannot be explained by the conventional model of endurance fatigue, which proposes that the involuntarily decline in performance that defines bonking occurs when some physiological limit is encountered—for example, lactic acid buildup in the muscles causes the muscles to essentially stop functioning. According to this conventional model, athletes cycling to the point of failure at 242 watts could not possibly go on to produce 731 watts for five seconds immediately afterward.

The only reasonable explanation for this finding is that the subjects terminated the submaximal ride to exhaustion by choice. An additional finding, that ratings of perceived effort (RPE) were maximal at the point of failure—on average, their RPE was 19.6 on a scale of 6 to 20—indicates that perception of effort was the factor that triggered the choice to quit. The rugby players certainly didn't feel as if they quit voluntarily, but the evidence suggests they did.

The general body of research on endurance fatigue, which has never found a single physiological limit that strictly determines endurance fatigue, supports the conclusion that Marcora drew from this study. There is no specific core body temperature, no blood lactate level, no muscle glycogen depletion level, no muscle damage threshold, no degree of muscle cell depolarization, nor any other such parameter that is always correlated with fatigue. The only measurement in all of exercise science that accurately predicts fatigue in every circumstance in motivated subjects is perceived effort. When we feel we can't go on, we can't.

Marcora believes that this feeling is causal: We can't go on because we feel we can't. This belief is part of a radical new theory that he calls a psychobiological model of endurance performance. "My proposal," he says, "is that endurance performance is directly determined exclusively by psychological factors. The two most important ones are perception of effort and motivation. Physiological factors, including the most important one, which is training, have only an indirect effect on performance, which is to say they affect performance only by having an effect on perception of effort or motivation."

At first blush, the notion that physiological factors such as training affect endurance performance only indirectly might seem crazy. Marcora's model proposes nothing more than that exercise always begins, ends and is paced by conscious choice. Is that really so radical? We know that we always start exercise by making a conscious choice to start moving. We know that throughout exercise we are aware of our effort level and use this perception for pacing purposes. We know that the higher our perceived effort level is, the closer we are to the point of exhaustion. We know that in most circumstances we clearly terminate exercise by conscious choice, such as when we cross a race finish line. Marcora's psychobiological model goes only one step beyond what we all know from experience in proposing that exercise is *always* terminated by choice, even when that choice is counterbalanced by a competitive desire to keep going.

When Newby-Fraser sat down on the curb a quarter-mile from the finish line of the 1995 Hawaii Ironman, she was quickly joined by her boyfriend (now husband), Paul Huddle, who, after ascertaining that she was not suffering a medical emergency, tried to lighten the mood by joking, "How many times have you dreamed of just pulling over and sitting down?"

That's just it. Every triathlete can relate to this inner battle between motivation (the angel on our right shoulder urging us to continue) and perception of effort (the devil on our left shoulder tempting us to quit).

"In Italian, we call endurance *resistenze*, which means 'to resist,'" says Marcora, who has always been active in sports (including American football—in Italy) but was never a seriously competitive endurance athlete. "The quintessential cognitive ability of endurance athletes is to exert control over themselves—over their natural disposition not to exert effort. Your body is telling you it's time to quit. You have to exert cognitive control to say, 'No, I don't want to quit!'"

Despite supporting evidence in laboratory research and in the real-world experience of endurance athletes, Marcora's psychobiological model of endurance performance has won few converts in the exercise science community. Even among the minority of exercise physiologists who have come to recognize that the brain has some role in exercise performance since the influential South African sports scientist Tim Noakes developed his "central governor" theory in the early 1990s, few are willing to believe that "mere" conscious perceptions are powerful enough to force an athlete like Newby-Fraser to bonk when her body is still able and her mind remains strongly motivated to continue. Marcora dismisses such resistance as symptomatic of an age-old dualism that separates mind and body and sees the intangible contents of the mind as lacking the requisite force to control the material body. Tell the crack cocaine addict who will do just about anything for the next fix that perceptions are not powerful enough to completely control a person's behavior, he might say.

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What is perceived effort, though? All perceptions are the products of specific patterns of brain activity. While perceptions such as pain and hunger have been intensively studied and are consequently fairly well understood, no one in psychology or exercise physiology had seriously studied perceived effort before Marcora became interested in the phenomenon several years ago. So he gave himself the education in neurophysiology that his master's studies in exercise physiology at the University of Wisconsin-La Crosse and his doctoral studies in the same at Bangor University had not provided, even taking a six-month sabbatical from teaching to take classes in his institution's psychology department. Today Marcora is still unable to fully explain perceived effort, but he has been able to define its general nature.

"The main stimulus for perception of effort is how much we are recruiting our muscles—leg muscles and inspiratory muscles in the case of cycling or running," he says. More exactly, perception of effort is tied to the amount of activity in the brain's motor centers, which generate the electrical signals that make the muscles contract. The stronger those signals are, the harder the muscles work and the more effort is consciously perceived.

But that's not the whole story. The brain's motor centers will not send movement commands to the muscles in the first place unless another part of the brain, called the anterior cingulate cortex (ACC), commands the motor centers to command the muscles to move. The ACC is a part of the brain that becomes active when you make a conscious decision to jump in the pool and start swimming. It is also the part of your brain that orders the motor centers to keep swimming when you are halfway through a brutal interval set and suffering heroically. The ACC plays a crucial role in all kinds of task focus, from exercise to standardized test taking, and is known to be underactive in those with attention deficit disorder. Marcora believes that perception of effort is linked not just to the intensity of activity in the motor centers but also to the intensity and duration of activity of the ACC.

Notice there is no reference to the heart and skeletal muscles in this explanation of perception of effort. Does Marcora see no role for actual muscle fatigue in perception of effort? He does, but again, its influence is indirect. As Marcora's study with rugby players showed, a certain amount of muscle fatigue does occur in an exhaustive endurance test, but not enough to account for declining performance. But what happens is that, as the muscles gradually lose contractility during prolonged exercise, the brain has to drive the muscles harder and harder to maintain the same level of work output, and this, rather than the muscle fatigue itself, causes perception of effort to increase.

Marcora's idea that physiology below the neck has no direct effect on perception of effort contradicts Noakes' central governor theory, which was the first and, until Marcora came around, only model of endurance exercise performance that placed the brain at its center. Noakes proposed that feedback signals sent to the brain from the muscles and other organs during exercise are responsible for perception of effort. However, Marcora is able to adduce strong evidence that this is not the case. For example, researchers at the University of Zurich measured the effect of injections that interrupted the transmission of somatosensory signals from the legs to the brains of cyclists engaging in a simulated 5K time trial. In short, the subjects could not feel their legs while they pedaled. If the brain depended on this type of feedback to perceive effort, then the injections should have sharply reduced their ratings of perceived effort compared to a control trial. They did not. In fact, the leg numbing caused RPE to increase slightly, as it produced a slight muscle weakening that the brain had to compensate for by increasing central drive to the muscles.

Another key difference between Marcora's psychobiological model of endurance performance and Noakes' central governor theory is that in the latter, the brain is understood to regulate pace largely on a subconscious level, whereas in Marcora's model the pacing mechanism is entirely conscious. Thus, Noakes might speculate that Newby-Fraser's bonk occurred because her brain received signals from her body indicating that something bad might happen—for example, heat stroke—if she continued much longer. These signals were processed on a subconscious level and caused the motor centers of her brain to reduce output to the muscles, the final result being that Newby–Fraser stopped moving involuntarily. Her consciously perceived misery reinforced this reaction but was not the actual cause of the implosion.

Marcora concedes that the decline in performance seen in short, maximum-intensity efforts is caused by such a subconscious process, but he believes that fatigue occurring in any effort lasting longer than roughly 30 seconds is truly voluntary. He ridicules the central governor model as being a fundamentally unfounded pseudo-explanation. “It’s the latest version of the homunculus problem,” he says. “It’s a common mistake to explain how our minds control our behavior by inventing a little human being who lives inside your head. That’s not solving the problem. It’s just transporting the problem to another entity. … He’s there inside your mind doing everything a human being can do and controlling the recruitment of your muscles. It seems like a very attractive solution, but it doesn’t solve anything. Because then I ask, ‘OK, what is inside the central governor that allows it to do all these things?’ Then I could ask, ‘What is inside the mini central governor inside the central governor?’ It’s logically absurd.”

Defenders of the central governor model counter that, first of all, it allows for both subconscious and conscious precipitants of exhaustion and does not characterize endurance fatigue as entirely subconscious, as Marcora claims. And secondly, they seize on Marcora’s concession that fatigue in short efforts happens involuntarily as a weakness of his model. “When we looked at his model in detail, it was quite clear that he was also allowing for changes to happen without the athlete having to decide to slow down,” says Ross Tucker, who earned his doctorate in exercise physiology under Noakes at the University of Cape Town, South Africa. “So his own argument contradicted the model, which is why I felt—and others felt the same—that he was really just renaming the same thing, changing one or two things slightly, but not really coming up with anything new.”

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Tucker points to a recent study in which he had Olympic canoeists perform 200-meter sprints. He found that although their speed at the end of the effort was 30 percent slower than their speed at the beginning, they were not aware of any loss of speed. Obviously, fatigue-induced slowing cannot be characterized as a conscious choice if one is not even aware that it has happened. Again, Marcora gladly grants that perception of effort is not active as a fatigue-imposing protective mechanism in such short efforts. Tucker and others deem highly dubious the notion that this mechanism functions like a switch that stays off in sprints and turns on in endurance efforts. Exactly when does it turn on—29 seconds? 30? 31?—and why?

The part of Marcora’s model that some people might have trouble getting their heads around is his neat distinction between conscious and unconscious. Neuroscientists understand consciousness to be only the thinnest of veneers coating a vast universe of subconscious process that governs most of our behavior. Responses to perceptual stimuli are no exception. Science is a long way from determining precisely where consciousness and unconsciousness begin and end, but based on what we do know, it’s hard to believe that endurance fatigue is always 100 percent consciously imposed, as Marcora proposes.

Nevertheless, even if perception of effort is ultimately proved to be only *mainly* responsible for causing endurance fatigue, then Marcora will have revolutionized our understanding of endurance performance, as most graduate programs in exercise physiology today teach that perception of effort has no causal relationship to fatigue whatsoever.

Marcora’s most famous study (covered-in-the-*New-York-Times* famous) demonstrates how great a game-changer his model could ultimately be. Marcora recruited 16 subjects to pedal stationary bikes to exhaustion at 80 percent of VO_2max on two occasions: once after performing cognitively demanding mental tasks on a computer for 90 minutes and once after watching “emotionally neutral” documentaries for 90 minutes. The mental task reduced performance in the subsequent ride to exhaustion by 15 percent compared to the control condition. On average, the subjects lasted for 12 minutes, 33 seconds on the bike after watching documentaries. After playing cognitively demanding video games, they gave up after only 10 minutes, 39 seconds.

Physical fatigue was not a factor. The mental task imposed only brain-centered fatigue, and particularly fatigue in the ACC, the same brain region that Marcora believes endurance athletes rely on to resist their evolutionarily hardwired desire to cease endurance exercise.

“It proves that endurance performance is cognitively demanding because if it weren’t, then cognitive fatigue shouldn’t have had an effect,” Marcora says of his study. More particularly, the results suggest that the brain’s capacity to exert cognitive control with respect to perceived effort is a primary limiter of endurance performance. If this is true, then strengthening cognitive control must be among the most effective ways to enhance endurance performance.

“I actually think that the effects of training on muscle fatigue [are] the least important mechanism for improved performance,” Marcora says. “I think the most important mechanism is adaptations in your brain induced by your exercise training that make you perceive less effort. It’s speculation, but I’m designing experiments to prove it.”

Already there is evidence from outside of Marcora’s research that indicates he’s on the right track. For example, studies have shown that aerobic exercise increases cognitive control in elderly persons. It does not enhance brain function generally; it enhances cognitive control specifically, and it even causes the ACC to measurably grow.

Marcora’s psychobiological model of endurance performance promises to usher in a whole new set of techniques to enhance endurance performance. Showing the courage of his convictions, Marcora is undertaking a study in which he aims to prove that regular training in cognitively demanding computer tasks enhances endurance performance in subjects who engage in no physical exercise.

“Basically it’s just playing in front of the computer, but the tasks are specific,” Marcora explains. “You cannot play Madden football for two hours and train your brain. You need to use certain specific tasks. … It’s very boring and repetitive. That’s an important characteristic, but it’s not just that. You can do a lot of tasks that are repetitive. You need to have certain characteristics of the cognitive task that activate these areas of the brain. We do 45 to 90 minutes five times a week. I am very confident that we will improve endurance performance.”

Let that sink in for a minute. The man proposes and expects to improve endurance exercise performance by playing cognitively demanding video games.

The next step will be to incorporate "brain training" into the physical training programs of endurance athletes and see if that enhances performance. "So the idea is to use it when you are injured or when you have reached the maximal skeletal limit, if you like, of your training load," Marcora says.

Marcora has identified five other specific, practical applications of the psychobiological model, ranging from the simple and immediate to the far off and far out:

Perception-based training. Today, objective metrics such as yardage, pace, time, heart rate and wattage are used to quantify training loads. Marcora proposes that endurance athletes make room for ratings of perceived effort in training load monitoring. He notes that Carl Foster at the University of Wisconsin-La Crosse has already developed a metric called session RPE—which is simply the athlete's self-rated average effort level for the workout multiplied by the workout duration—which Marcora has validated in soccer players.

Shifting from an emphasis on objective measures of training load to perception-based metrics is more than semantic and has the potential to steer an individual athlete's training in a very different direction. How an athlete feels during training is the best indicator of his or her overall physiological response to training.

A new sports psychology. If the brain's cognitive control capacity is the most important variable in endurance performance, then sports psychology is more important than we ever knew. However, it will not be sufficient for sports psychologists to gain more widespread influence over endurance athletes' training and racing. Their methods will have to evolve, as the conventional model of sports psychology is ignorant of how the brain really works in relation to endurance performance.

For example, sports psychologists commonly encourage athletes to visualize themselves performing exceptionally well and feeling exceptionally good during an upcoming race. However, research by Foster has shown that perception of effort during exercise is influenced by expectations in such a way that, when an athlete feels worse than expected at any given point in a race, this itself makes him feel even worse and thus perform worse. Therefore, the athlete is better off expecting to feel miserable in every race, as bracing himself for suffering in this manner will minimize the risk that the athlete's performance will be compromised by higher-than-expected perceptions of effort.

Samuele Marcora's psychobiological theory about endurance fatigue contends that Paula Newby-Fraser's famous bonk within sight of the finish line at the 1995 Ironman World Championships was entirely voluntary.

Drugs. A widely used drug has been proven to enhance performance by acting on the brain to reduce perception of effort: caffeine. But there are others, not legal for use in sport, such as Modafinil, and Marcora sees rich potential for the development of new drugs that will make hard exercise feel absurdly easy, thus enabling athletes to work even harder. "Of course it will immediately become doping," says Marcora. "That's just the way it is. But it's a goal of mine for clinical use."

Marcora has conducted a great deal of research on kidney diseases (one of which his mother suffers from), cancers and other diseases that cause brain-based muscle fatigue, and he hopes to aid in the development of drugs that improve the quality of life for patients afflicted by such diseases.

Neurofeedback. Imagine periodically checking your sports watch for readings of the intensity of activity in your ACC while you run. Marcora believes it could happen. "The principle is the same as biofeedback," he says. "You can use EEG [electroencephalography] or near infrared spectroscopy to measure physiological responses in the brain to improve the ability to control your brain activity."

Direct brain stimulation. Remember electroshock therapy? That crude procedure was used in past decades to treat psychiatric disorders with unpredictable success and often disastrous side effects. More advanced means of artificially stimulating the brain now exist and are being used in the treatment of depression, but Marcora believes that even more refined versions of these technologies could one day be used to train the brain for better endurance performance.

"I'm talking about things like transcranial magnetic stimulation, which is safe," he says. "You stimulate brain areas to induce adaptations that are beneficial for endurance performance. There may be technical difficulties or side effects, so who knows? It may never happen. But let's be wild with speculation!"

Matt Fitzgerald is the author of RUN: The Mind-Body Method of Running by Feel *(VeloPress, 2010, Velopress.com).*