PERFECT CONTROL

A Driver’s STEP-BY-STEP GUIDE to Advanced CAR CONTROL Through the PHYSICS OF RACING

THE SCIENCE OF SPEED SERIES
PERFECT CONTROL
PERFECT
CONTROL

A Driver’s
STEP-BY-STEP GUIDE
to Advanced
CAR CONTROL
Through the
PHYSICS OF RACING

The Science of Speed Series
created by PARADIGM SHIFT DRIVER DEVELOPMENT
written by ADAM BROUILLARD

www.paradigmshifttracing.com
CONTENTS

HOW THE LIMIT REQUIRES UNDERSTEER & OVERSTEER 11
ARE YOU A PREDICTIVE OR REACTIVE DRIVER? 14

PART 1: CAR CONTROL CUES

AUDITORY CUES (USING TIRES NOISES & ENGINE RPM CUES) 22
STEERING WHEEL CUES (FINDING MINIMUM AND MAXIMUM GRIP) 24
HOW G-FORCE & VISUAL CUES OFFER PRECISION CONTROL 32
ROTATION EXPLAINED (FINDING THE EDGE OF UNDER & OVERSTEER) 34
THE UNIVERSAL CUE (OPTIMIZING OVERALL VEHICLE MOVEMENT) 40

PART 2: DRIVER INPUTS

BEYOND SMOOTH (IMPROVING YOUR REACTIVE CAR CONTROL) 48
TIRE FORCES SIMPLIFIED (VISUALIZING STEERING, THROTTLE, & BRAKES) 58

PART 3: CORNER ENTRY CONTROL

HOW THE GREATS ENTER A CORNER & THE SKILLS NEEDED TO DO IT 73
USING BASIC & ADVANCED BRAKING TO CONTROL BALANCE 88
WHEN, WHY, AND HOW TO TRANSITION TO ACCELERATION 94
DRIVER PREDICTIONS & HOW TO FIX A THOUSAND MISTAKES PER LAP 98

PART 4: CORNER EXIT CONTROL

MAXIMIZING GRIP & MINIMIZING DRAG WHEN UNDERSTEERING 101
HOW FRONT-WHEEL DRIVE TEACHES CORNER EXIT OPTIMIZATION 112
TRADING STEERING FOR THROTTLE WHEN OVERSTEERING 125
“It ain’t what you don’t know that gets you into trouble.
It’s what you know for sure that just ain’t so.”
- Mark Twain
THE LIMITS OF CONTROL

When a novice first tries high-performance driving, they will often drive the same way on a racetrack that they do in every-day driving, only faster. This causes all kinds of issues when they get to the limit, because the car control cues and driver inputs they are used to completely change. This can be a problem, because if your goal is ultimate speed, the limit is where you need to be.

Let’s imagine you need to pull into a parking spot at your local store. As you drive down the row, you eye your spot and then maneuver your car to the far side so you can get a wider entry. As you approach, you begin turning the wheel and maybe using a little brakes or throttle to change your speed, all the while focusing on the spot and predicting the path you need to take to arrive there correctly. You may make small alterations in your steering or other driver inputs to keep you on the ideal path into your spot. A key point here is that you most likely aren’t even thinking about the steering, throttle, or brakes. All your attention is on the parking spot and the path you need to take to get there. The car control needed is basically automatic.

But what would the average driver do if turning the steering wheel sometimes made the car steer more and sometimes didn’t? What if the car suddenly starting turning faster even if you didn’t turn the steering wheel more? What if the brakes sometimes slowed you down and sometimes didn’t, or the throttle seemed to sometimes just make you spin in place? Basically, everything the driver thought they knew about how the car should react seemed to change randomly. They would probably start walking to the store.

Before you can fully utilize Line Theory rules, you must get to an almost automatic level of car control.
But these are exactly the types of responses a racing driver will have to learn to contend with and many become so overwhelmed that the majority of their attention shifts to controlling the car and not on where they need to go. Their car control is no longer automatic like that average driver in the parking lot.

Introduced in our book *The Perfect Corner*, Line Theory is the term we use for the physics-based set of rules a driver can use to optimize their line. While drivers of any skill level can begin to apply Line Theory rules, to fully exploit them you must reach an almost automatic level of car control. To achieve this, you will need to first learn the correct car control cues and driver inputs needed for driving at the limit.

Car control, in essence, is about managing inputs and outputs. The outputs are your controls over the vehicle. Primarily brakes, throttle, and steering. The inputs would be all the information you are getting from the car and your surroundings. Primarily visual, auditory, and tactile. We call these inputs cues. How to optimally use these driver inputs and cues together is what this book is all about.
**A TIGHTROPE ACT**

Can you walk a tightrope? The vast majority of people would probably answer no. We know it is possible, because we have all seen it done, but what if you lived in a world where no one had ever done it and someone asked you to try. You would probably think it impossible and a quick try would reaffirm that thought.

So how does this relate to motor racing? While a tightrope is basically pass/fail, as you either fall off or stay on, driving a car is only as hard as a driver makes it. But to the average viewer, sometimes the difference is almost imperceptible. Watch a pretty fast local driver and to the untrained eye, they look like they are doing virtually the same thing as a world-class driver. Even an average racer in a relatively easy-to-drive car could probably get within a second or two of a world-class driver given specific instructions and a few weeks of practice. Only the stopwatch tells the ultimate difference, and the average racer most likely doesn’t even know why they are slower. They might just chalk it up to having less talent or think maybe the world-class driver has figured out some sort of better line.

In reality though, the world-class driver is doing something just as hard as what a tightrope walker does and it takes more than a few weeks to learn this. To an average racer, what the world-class driver is doing would feel almost impossible. Just like a tightrope walker, they make a finally tuned balancing act at the limit of control look easy.

Pushing yourself to where you need to be might feel impossible at first, just like tightrope walking. But with practice, the impossible will become hard, and then manageable, and then eventually, second nature.
What this average racer doesn’t realize is that they have essentially been walking around on a 6-inch wide board as they drive. They might every once in a while step up on the tightrope and fall off and then remind themselves to stay on the board, but unfortunately, walking around on a board will teach you very little about tightrope walking.

The first step to reaching a world-class level of car control is to realize you’ll need to step onto that tightrope before you can start learning how to balance on it. This book will give you the tools needed to do that, but understand this is hard, very hard. It will take years to master. There is a reason most world-class drivers started as children. Pushing yourself to where you need to be might feel impossible at first, just like tightrope walking. But with practice, the impossible will become hard, and then manageable, and then eventually, second nature.

Is this car at the limit and oversteering or understeering?

To find out, a driver must test - change a driver input and check the car’s response.
THE LIMIT DEFINED

So what is the limit? Ask 10 drivers and you might get 10 different answers. We define the limit as when no change in driver input can cause an increase in force. This sounds a little technical, but a simple example would be a driver traveling at a constant speed and then slowly tightening the steering. There would be a certain point where turning the steering wheel more would not make the car turn any tighter. The tires have reached their limit. In this example, it would be the front tires that reached their limit and many drivers understand this is called understeer. If the rear tires are what is limiting how much a car can turn, then you have oversteer.

The key takeaway here is that anytime you are at the limit, you will either be understeering or oversteering. This also means that for ultimate speed, you will always either be understeering and/or oversteering the entire way through a corner. While theoretically it’s ideal to use all four tires equally, it’s not technically possible to be perfectly neutral and keep both front and rear tires at the limit at the same time. This would be a transient state at best, and as you’ll see, it’s actually impossible to know if you truly are at the limit of both at the same time. If you ever think you have achieved perfect neutral balance, it just means you haven’t developed the sensitivity yet to detect whether you are actually understeering or oversteering.

For ultimate speed, you will always either be understeering and/or oversteering the entire way through a corner.
So if we know we want to always be at the limit of understeer or oversteer in a corner, how can we ensure we are actually accomplishing that? Imagine you are driving through a corner and you think you are probably at the limit of understeer. How can you be sure? What cues do we have to guide us? It turns out the answer is actually quite simple, although often not very intuitive.

The only way to truly know if you are at the limit is to change a driver input and see what happens. Try turning the steering wheel more. Did the car tighten its turn? Then you weren’t at the limit. Did the car not turn any faster? Then you were either at the limit or over it, possibly way over it. Being over the limit is typically bad, but the only way to find out how far over the limit you are is to unwind the steering until the car lessens its rate of turning a little. You have to make a change and see what happens.

The only way to know if you are at the limit is to change your driver input and check the vehicle’s response. We call this process testing.

We’re actually getting a little ahead of ourselves here, as we aren’t quite ready to get into the specific cues and driver inputs yet. But we did want to bring up this example to point out that the only way to know if you are truly at the limit or not is to change a driver input and see what happens. We call this process testing. To drive at the limit, you have to constantly be testing to see if you can generate any more force from the tires. This is why you often see top drivers making constant, small motions with the steering wheel during a corner. Testing can also be done with the throttle or brakes as well though.
During corner exit for example, you can test for the limit with the steering wheel or throttle, or a little of both. Ayrton Senna was known for testing the limit more with the throttle and less with steering. Some drivers will use the steering wheel more. Ideally, you will be trying to find the limit with both at the same time by making small modulations and checking the car’s reaction. Understand though, that this is not going to be “Hmm, let me test now.” It must be trained to the point that it is automatic and the driver will naturally try to stay at the limit by modulating their inputs. The more sensitive a driver is, the smaller these inputs can be, but they must always be there if the driver wants to know they are at the limit and getting the most out of the car.

The reason this is the only way to know for sure is that tire grip is an ever-changing target. No cue exists that can accurately tell you if you are currently at the exact peak of grip. The only way to know is to change an input and see if this increased or decreased the force acting on the car. Even a highly accurate tire-testing machine that was programmed to keep a tire as close to the peak of grip as possible would need at least some movement back and forth across the peak to do this. We’ll talk much more about this as we continue, but just remember, if you aren’t making some sort of driver input change and checking how the car reacts, you can’t really know for sure if you are at the limit.

Ayrton Senna was known for a unique throttle stabbing technique to test for the limit.
PREDICTIVE VS REACTIVE DRIVING

A big difference between a driver and a basic tire-testing machine however, is that a driver has a memory and can learn. A driver will be able to adapt to a car and circuit and start predicting how much grip the car has in different situations. They will always have to test this limit with changes in driver inputs, but their predictions will allow them to stay closer to that grip peak more easily.

We call this need for constant testing reactive driving, and the learned adaptations a driver makes to a certain car and track we call predictive driving. When a driver does a practice session and their lap times are better at the end, that is an improvement in their predictive driving. The steady improvement in a driver’s skills over the years if they train properly is an improvement in their reactive driving. Reactive driving represents a driver’s core car control abilities.

Unfortunately, many drivers don’t recognize the difference and think the only way to get better is by simply improving their predictive driving. Doing countless laps in a certain car/track combo and learning every nuance of the circuit and car. We’ve found this can actually hinder one’s ability to improve, as you are not pushing your core car control abilities to the limit and can end up driving too much by memory. Only focusing on improving predictions will cause a driver to lose a lot of time if they switch cars and it takes them a long time to learn new tracks. Although they can sometimes get to the front of the field with enough practice, they will rarely reach their ultimate potential.
On the other hand, the fastest drivers are the ones with amazing reactive driving abilities. In other words, they have great car control. They can adapt quickly to different tracks and cars. They are great in the wet because of their ability to control the car in a new situation quickly. But also importantly, if you have great reactive driving ability, you will be able to improve your predictive driving much faster and get up to speed on a new track or in a new car much quicker. Your practice time will be much more efficiently used. Some drivers think you are either born with this talent or not, but the good news is that reactive driving is something you can learn to improve. While there is certainly a genetic component that will allow some drivers to improve car control faster than others, most drivers are probably far from their ultimate potential because many don’t know the proper cues and driver inputs to focus on and train.

Imagine you’ve started a team in the brand new World Championships of Braking. It’s a competition to see who can stop a car from 100 mph in the shortest distance. This sounds like a silly competition, but we’re using braking because it’s relatively simple to understand the cues and driver inputs involved. On your team, you have two drivers starting with equal skill. They will train the exact same amount of time each day, but the first driver gets to always use the competition car, and the second driver must change cars every single time they practice and never gets to practice in the competition car except for a few minutes before their competition run. The first event is in a week.

Because braking is relatively straightforward, the first driver will probably get within a few feet of what would be optimum within a few days at most. Most likely, they would probably initially listen for tire squealing and start predicting how hard they need to push the brake pedal to reduce their stopping distance. There would be some trial and error where they try different pedal pressures and then check their distance. Eventually they would settle on a good solution where they have basically memorized how hard to push the pedal and their braking distance is usually within a few feet of optimal.
The second driver however, is being forced to use a different car every time and so this trial and error doesn’t work. They are unable to improve their predictive driving and can only work on their reactive driving. They try basing their braking on listening for tire squealing, which is working okay, but they get pretty big variations in their stopping distance.

The first competition arrives and the first driver handily defeats the second driver, but is beaten by a few former F1 drivers who have gotten to practice in the competition car all week. This trend continues into the season with the first driver not really improving and always being beaten by the F1 drivers, but always beating the second driver. The first driver is happy with their results and thinks the F1 drivers are just more naturally talented.

Tired of always losing, the second driver has started to do some research because the tire squealing thing isn’t really giving them very consistent performance. They need a more precise cue and so they start to pay attention to how fast they decelerate with different pedal pressures. This is primarily with their eyes, but also feeling the g-forces. Initially it’s pretty frustrating and they feel like giving up, but they push through and with lots of work, they slowly start to improve their reactive driving ability based on this more precise cue. Introduced in *The Perfect Corner*, the second driver is now training himself to react to the Universal Cue. We’ll talk much more about this later in the book.

The first season ends with the second driver finally running almost neck and neck with the first driver and the F1 drivers are now getting so good with the car that first and second is now often mere inches apart. The competition promoters feel like it’s getting boring though and want to shake things up, so they’ve announced that for the next season the competition car won’t be revealed until right before the event and everyone only gets a few minutes of practice.
On the day of the next season’s first event, the first driver does their run and almost spins out, coming in near the bottom of the results. They just blame it on the car not fitting their driving style and maybe next time the car will be a better match for them. But the second driver feels totally at home, as they have been constantly driving new cars for over a year now. They come in third right behind the F1 drivers, and the top three are all within a few feet of each other. There is a much bigger spread in the overall results and it’s clear which drivers have great reactive driving abilities and which don’t. Given a few weeks of practice with the new car, the F1 drivers and now the second driver would probably all be within a few inches of each other again. The first driver just doesn’t understand where the second driver’s sudden talent came from.

Hopefully this little story gave you a good idea of the difference between predictive and reactive driving. Of course, learning all the skills needed to drive a car on a road course is a good bit harder than just braking. It would certainly take longer than a year to compete with F1 drivers, but the principles are the same. Also, don’t think we are saying that predictive driving is not important and you should not practice a car/track combo. If you have a race coming up soon, you’ll want to spend the majority of your practice time on that. The better your reactive driving skills are though, the faster you will be able to get up to speed and your practice time will be more efficiently used.

The better your reactive driving skills are, the faster you will be able to get up to speed and your practice time will be more efficiently used.
In this last story, what would happen if the surprise car in the beginning of the second season had no normal brakes and only the handbrake worked? The second driver’s reactive training wouldn’t transfer nearly as well would it? The driver input needed would now be completely different to what they had trained and the tight connection they had developed between the Universal Cue and their braking foot would be useless.

While that would certainly be a problem, the good news is that the vast majority of cars have essentially the exact same control systems and improving your reactive driving ability will allow you drive them all more effectively. There are a few exceptions, but for the most part, we are talking about a rear-wheel drive car with a steering wheel, throttle, and brake pedal. Even common variations such as front-wheel drive, 4-wheel drive, and rear-brake only karts change things very little and you can basically use the same techniques on all of them.

So if that’s the case, then why do you sometimes hear how you need to drive a certain car a certain way, you shouldn’t trail brake that car, etc…? Basically, that different cars require different driving techniques. The reason is that some people make the same mistake that the first driver in our last story was making. They only learn to drive a car predictively, so when they switch to cars that require a different pedal pressure, optimal line, steering ratio, etc... all their memorized inputs don’t work. Just like our first driver, many do this because they don’t realize there is an alternative that allows them to improve their abilities in practically any vehicle. They never learn what they should ideally focus on and train. Although focusing on improving your reactive driving can initially be more difficult, the rewards are much greater as you will be improving your core driving ability. You will be able to adapt to virtually any car and track very quickly. You not only lower your potential best lap time, but also make much better use of your practice time.
PART 1 - CAR CONTROL CUES

The first part of the car control equation is the cues. A cue can be anything that gives you information about what the car is doing. These are not only things within the car; they can be external things such as where it currently is on track as well as the direction and speed it’s moving. There are so many different things a driver can pay attention to that it’s no wonder many can feel confused from hearing so many different pieces of advice from so many sources.

Another problem is that the best cues, although we’ll see how they are actually quite simple, may not be very intuitive. Drivers that get into motorsport as adults often have the biggest problems. A more grown up, analytical mindset can often lead you off on tangents whereas the actual answer was in front of you the whole time. Naturally talented children that start racing early can have an easier time, as they tend to be less analytical and just try to “go fast,” which as we’ll see is actually just a simplified way of explaining the Universal Cue. By the time they are older and become more analytical, they already have this ability so well trained and ingrained in their reflexes that they often can’t really articulate what they are doing. Not everyone is fortunate enough to start young though, so we’ll work through this the other way around to achieve what a gifted child might do naturally.

End of Sample
Do you understand the true meaning of driving at the limit?

Learn how to identify and prioritize the different visual, auditory, and tactile car control cues, plus the optimal driver inputs needed to extract 100% from practically any vehicle.

We will also look in-depth at the Universal Cue. The driving cue that directly represents the physics of racing and provides the final layer of car control precision. Learn how world-class drivers use it to self-evaluate and perfect their on track performance.

Please visit us at www.paradigmshiftracing.com

©2016 PARADIGM SHIFT MOTORSPORT BOOKS

$21.95