

THE DRIVER:

EVALUATING PERFORMANCE

Drivers apply throttle and brakes, shift gears, and turn the steering wheel. Sounds easy, doesn't it?

Race car driving, of course, is *anything but easy* to do well. However, capturing driver input with a six-channel data system is simple. Throttle and steering are recorded directly. The calculated gear graph shows shifting. Longitudinal G's show the effects of braking on the chassis. The consequences of driver actions also show in the MPH and lateral G graphs.

Since it divulges both cause and effect, a data acquisition system is an especially effective tool for evaluating driver performance.

Caution!

Driver evaluation is serious business. Let's face it—drivers don't always accept criticism gracefully, even thoughtful, well-intended, and tactfully presented suggestions. Driver support for the data system is important. Any ill will can compromise potential benefits from either driver or car analysis.

A driver can be overwhelmed with a barrage of suggestions. Worse yet, it's possible to unintentionally undermine the self-confidence of a driver.

To complicate matters, driver input and car behavior often produce similar or even identical graphs. Distinguishing them can be difficult and a little subjective. Use care evaluating this ambiguous data.

The lessons are clear—investigate thoroughly and don't jump to conclusions. Solicit the driver's insight and reach decisions jointly. Above all, be tactful.

Categories

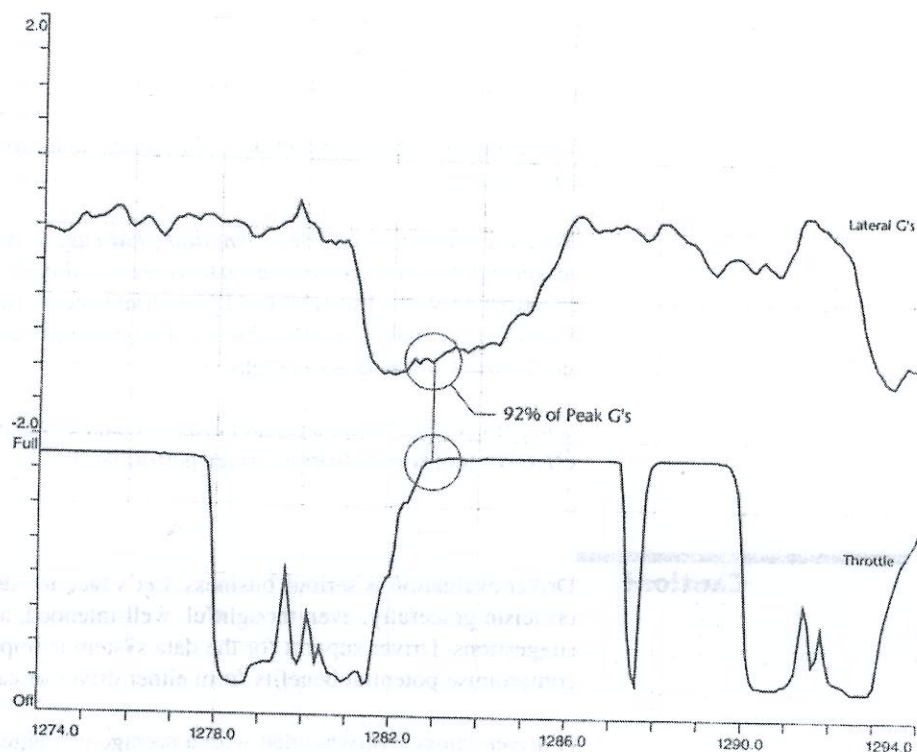
For ease of discussion as well as later use as a reference, driver performance topics are split into these four broad categories:

- Throttle Application
- Braking
- Cornering Technique
- Shifting

THROTTLE APPLICATION

The driver can use too much, not enough, or just the right amount of throttle. Here's how to find out which.

Figure 8.01
Throttle Application—Low to Medium Speed Corners
Full throttle at 92% of peak cornering G's for this 75 MPH second gear turn shows energetic driving and a balanced chassis.



Low to Medium Speed Corners

The driver should apply full throttle shortly after the G peak in low-to-medium speed corners. Chapter 7 explains how to find the target G level for full throttle.

The driver of the car in Figure 8.01 uses his throttle well in this 75 MPH turn. After the 1.38 G cornering peak, he reaches full throttle at 1.27 G's, or 92% of peak. The target for this car is 90% of the G peak.

Notice the brisk throttle application—he didn't slam it on, but he wasn't shy about it either. In a less powerful car, throttle application should be quicker.

When cornering G's at full throttle are less than the target G level and the graphs don't reveal wheelspin, balance, or forward traction problems, the driver is probably tentative with the gas. As usual, more fact-finding leads to the answer.

Start by examining graphs of corners and talking to the driver. Check an easy, low risk corner. If the throttle graph shows good throttle application there, but not at the more difficult corners, the driver may be a little tentative. Another good clue is the amount of time spent at intermediate throttle levels.

Figure 8.02
Throttle Application—
High Speed Corner
 Full throttle arrives before
 peak cornering G's on this
 high speed (95 MPH)
 corner, the product of an
 assertive driver and a
 balanced chassis.

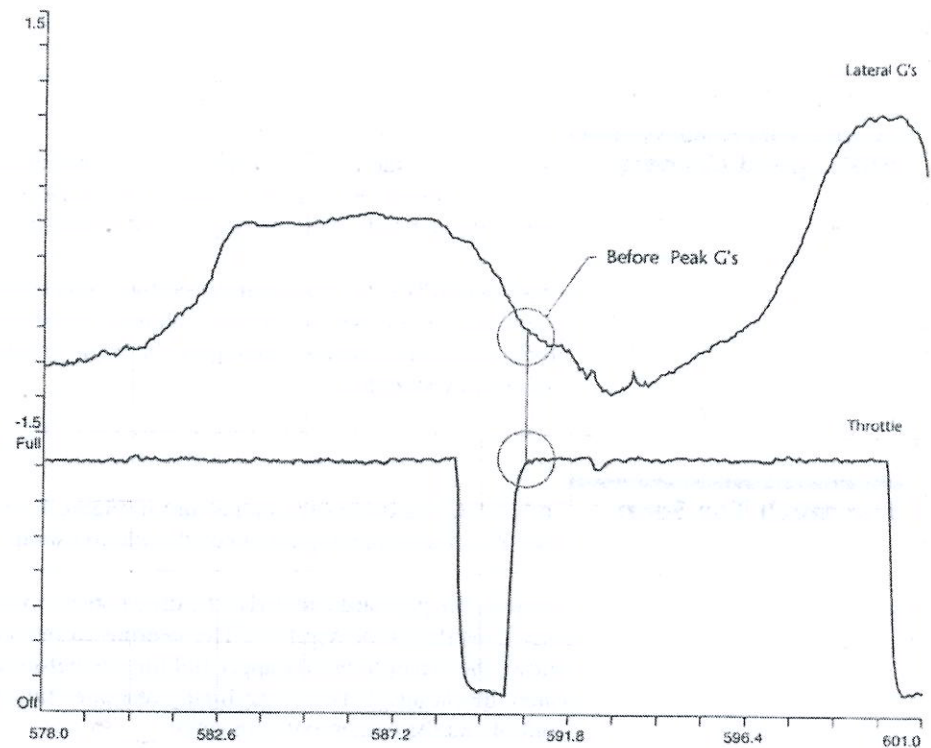
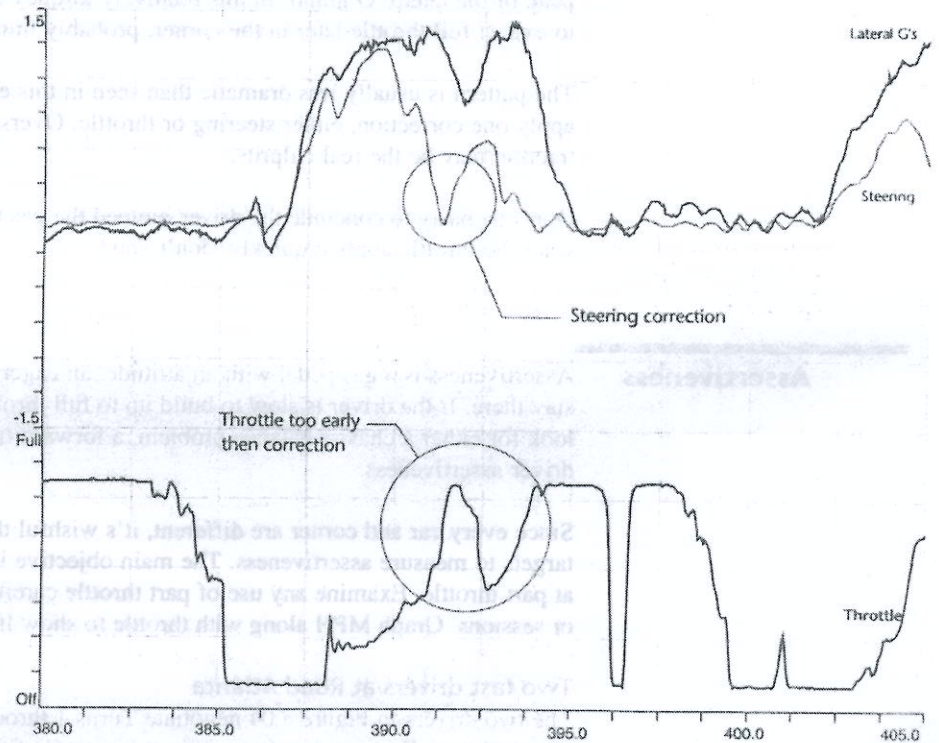


Figure 8.03
Throttle Too Early
 Throttle and steering
 corrections unwreak the
 havoc caused by jumping
 the gas early in this
 decreasing radius corner.



High Speed Corners

Full throttle on the way into a high speed corner often helps the car take a set and balances it. Figure 8.02 shows Road Atlanta's Turn 1. The driver reaches full throttle immediately after turning in, well before the G peak.

About 90 MPH is the minimum speed for corners where this technique should be expected. Don't expect to see this technique on decreasing radius corners, for the obvious reasons related to staying on the track! It usually appears at corners followed by straights.

Too Much Too Soon

The 180 degree decreasing radius turn in Figure 8.03 is a classic and exaggerated case of a driver applying too much throttle too soon.

Jumping the gas hard and early, the driver steers to catch the car's tail when engine torque overloads the rear tires. The steering correction reduces cornering G's and allows the driver to briefly apply full throttle before backing off the throttle to catch the car again. The driver finally reapplies full throttle when the car is under control and the corner exit is in sight.

The corner's decreasing radius is evident in the upward sloping "plateau" at the peak of the lateral G graph. In this relatively torquey car, it would be more normal to expect full throttle later in the corner, probably immediately after the G peak.

The pattern is usually less dramatic than seen in this example. The driver may only apply one correction, either steering or throttle. Oversteer or inadequate forward traction may be the real culprits.

Don't be hasty to conclude the driver jumped the gas too soon. After all, you do want the throttle applied quickly, don't you?

Assertiveness

Assertiveness is a gas pedal with an attitude, an eagerness to get to full throttle and stay there. If the driver is slow to build up to full throttle, or backs off anytime, look for either a chassis balance problem, a forward traction problem, or a lack of driver assertiveness.

Since every car and corner are different, it's wishful thinking to hope for specific targets to measure assertiveness. The main objective is minimizing the time spent at part throttle. Examine any use of part throttle carefully. Compare between laps or sessions. Graph MPH along with throttle to show if changes in technique work.

Two fast drivers at Road Atlanta

The two drivers in Figure 8.04 negotiate Turns 1 through 5 at Road Atlanta in identical cars. Both are lapping within 0.5 second of the track record in their class. Both cars are well balanced.

The driver in the upper graph downshifts in the entry to Turn 1, generating the short blip in the off-throttle braking zone, while the driver in the lower graph doesn't downshift. Both drivers spend about the same time with the throttle closed, but the driver in the top graph clearly returns to full throttle quicker.

Figure 8.04
Throttle—Two Drivers
at Road Atlanta
 Two gas pedals with a magnetic affinity for the floor. Average throttle for the full lap was 85.58% for the top driver, 85.87% for the bottom—he was 0.3 second quicker.

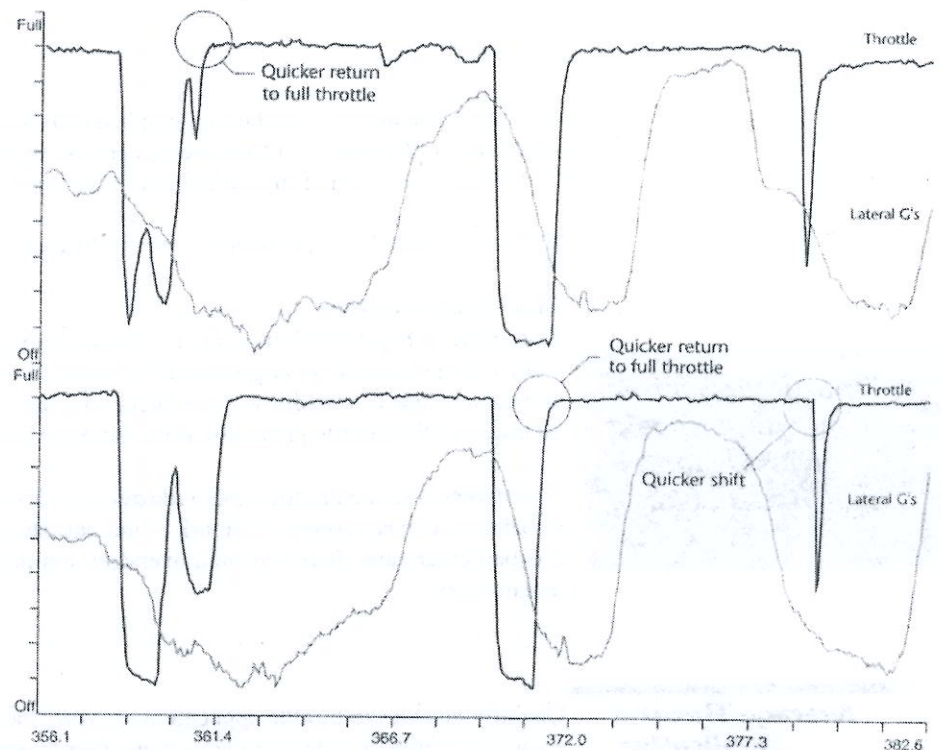
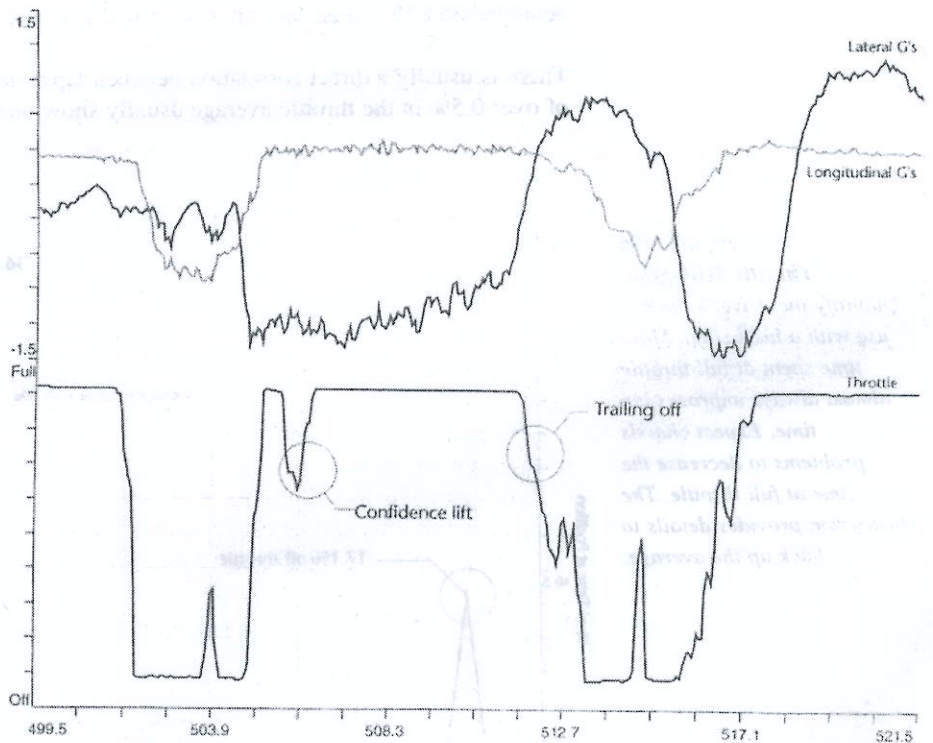


Figure 8.05
Throttle Assertiveness
Needed
 Almost brave! Spirited initial throttle application is partially blunted by lifts.



At Turn 3, the driver in the bottom graph spends less time off the throttle in the corner entry. The driver in the lower graph also upshifts more quickly, witnessed by the narrower width of the abrupt dip in the graph at the shift.

The conclusion? Both are assertive, but in different places.

More hustle needed

The driver in Figure 8.05 provides a contrasting example in the same turns. In Turn 1, he gets on the gas aggressively, but follows with a little "confidence lift" despite no signs of instability in the lateral G graph. At the braking zone for Turn 3, he trails off the throttle gradually. Both incidents reduced his full throttle time.

Tentativeness in the throttle should *always* lead first to a check for signs of chassis imbalance in every corner. Then ask—find out why the driver is taking it easy. In this particular case, there was mild oversteer, but not enough to justify the driver's tentativeness.

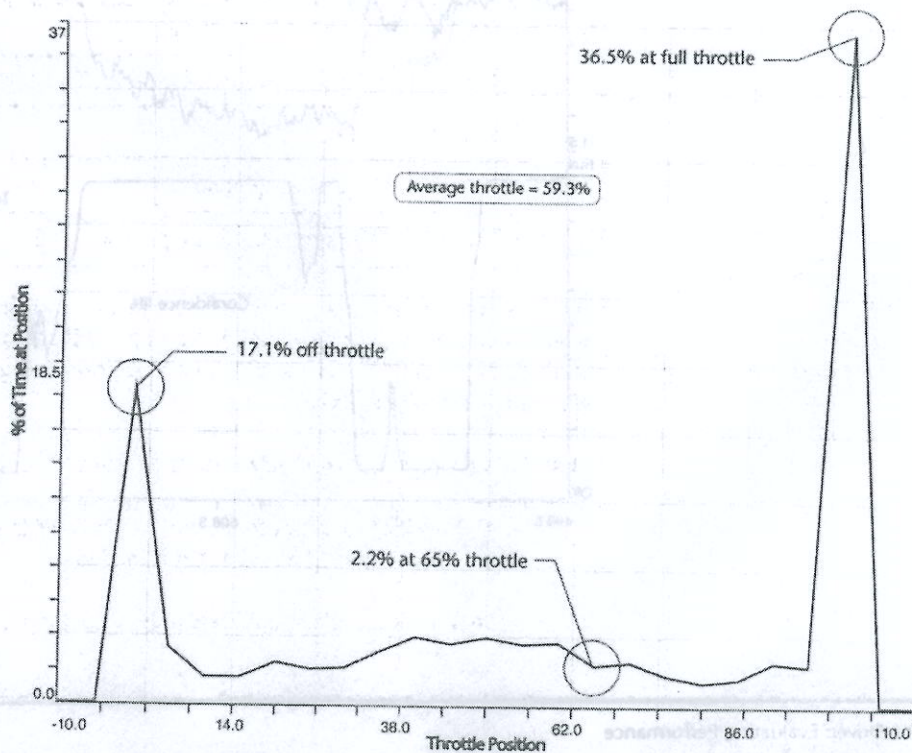
Tentativeness in the throttle should always lead to a chassis balance check.

Average Throttle Application

Quantify changes in throttle application by using the data system software or an external program to calculate the average throttle application over a lap or the portion of the lap being examined. For example, in Figure 8.04, the average throttle for the driver in the upper graph was 85.58%, while the driver in the lower graph achieved 85.87%. Their lap times were within 0.3 second.

There is usually a direct correlation between lap time and average throttle. Changes of over 0.5% in the throttle average usually show on the stopwatch.

Figure 8.06
Throttle Histogram
Quantify the driver's throttle use with a histogram. More time spent at full throttle almost always improves lap time. Expect chassis problems to decrease the time at full throttle. The histogram provides details to back up the average.



Throttle Histogram

A histogram quantifies the driver's throttle use. With rare exception, more time at full throttle is better. Figure 8.06 illustrates.

Expect considerably more time at full throttle than at any other position, with the next largest percentage at closed throttle. Percentages at part throttle positions should be small by comparison.

Any change in driving style that increases the time spent at full throttle usually lowers lap times, for the obvious reasons. Don't forget that the full throttle percentage is also dependent on chassis balance. *Look for balance problems first* when the full throttle percentage is lower than expected.

BRAKING

The driver's job, in scientific terms, is mashing the brake pedal. There are four common problems: mashing too early, not mashing hard enough, not mashing quickly enough, and mashing too late. A fifth, mashing too hard, locks the brakes and is usually not repeated by the driver.

Here's how to evaluate driver performance in braking.

Using Full Braking Power

Ideally, the driver should use the car's maximum braking potential in every braking zone, maintaining the car's straightline speed as long as possible. The real world usually intervenes, complicating both the driver's task and ours. Circumstances can change the peak braking G's at any particular corner.

BRAKING SITUATION	EFFECT
Braking uphill or at hill bottom	More G's
Braking downhill or over hill top	Less G's
Braking while turning	Less G's
Rough or slick braking zone	Less G's
Short braking zone, only losing a few MPH	Less G's

Most external influences reduce braking, just as a driver performance problem would. Once again, the challenge is finding out if the braking G's are the maximum reasonably possible under the circumstances, or if a legitimate car or driver performance problem exists.

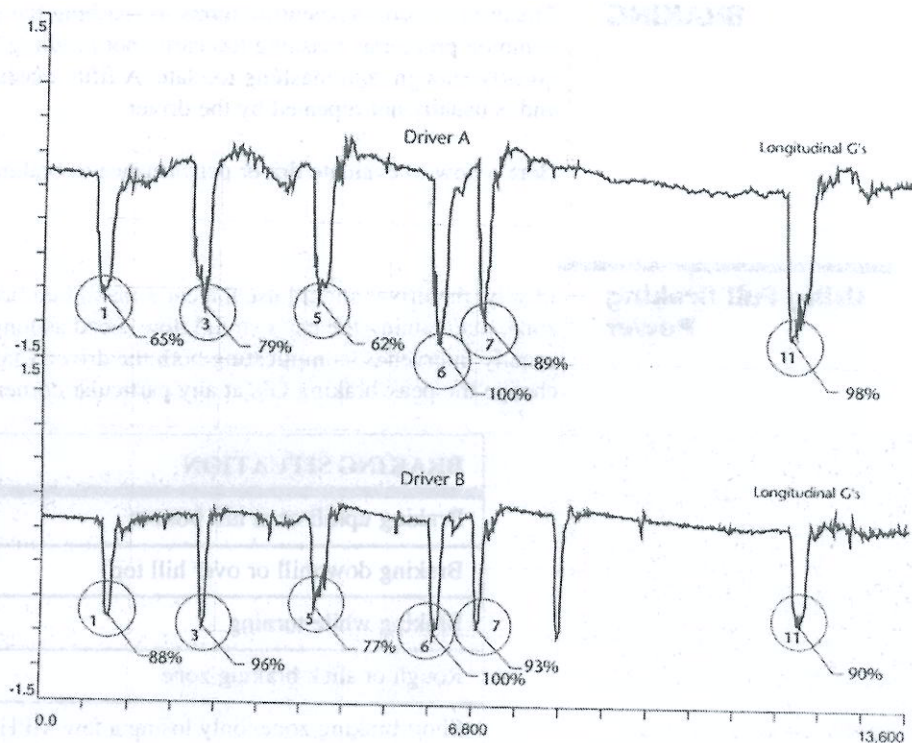
First, let's propose a few *highly breakable* rules for evaluating braking.

- The braking G target for all corners is the car's demonstrated maximum, except as reduced by other braking rules.
- Peak braking G's should reach the car's target, as defined in Chapter 7.

- Any braking zone where the car loses less than 20 MPH probably qualifies as a short braking zone, earning an exemption from further study.
- Uphill braking zones should produce the maximum braking G's for the lap.
- Braking while turning (lateral G's at least 25% of the car's potential) permits a reduction from the car's maximum.

Use a corner with similar geography to compare braking performance. If it's not possible to logically explain the differences in G levels, the driver may need to rethink the corner.

Figure 8.07
Braking Comparison—
Two Drivers
Two drivers in dissimilar cars at Road Atlanta—braking in percentage of maximum G's. Both brake hardest at Turn 6. Driver A gives up time at Turns 1, 3, and 5, while Driver B needs improvement at 11.



In the distance plots in Figure 8.07, Driver A has more straightline speed, better tires, and better brakes by a considerable margin. The graphs reveal his earlier braking points at high speed corners like 1 and 11. At slower corners like 5 and 7, both cars' braking points are essentially the same, testament to Driver A's greater braking power and higher cornering speeds.

Case study—braking power

The two drivers at Road Atlanta in Figure 8.07 are in dissimilar cars, so braking is measured as a percentage of maximum G's.

Both drivers brake best at the uphill, banked Turn 6. Driver A gives up time by braking early and easy in Turns 1, 3, and 5. Driver B gives up time at Turns 6 and 11. They're about equal at 7. Driver B manages to generate 88% of peak G's in Turn 1, despite losing only 12 MPH in what qualifies as a short braking zone for this underpowered car.

What is the optimum braking potential at each corner? The uphill braking zone for Turn 11 has similar geography to Turn 6, and should produce a similar G level, if its bumps don't disturb the car. Since the entry to Turn 3 is a little more level, it

runs a close third. Turn 7 is similar. Due to braking while cornering, Turn 5 has the least G's, even though it is uphill.

What is each driver's biggest disadvantage? Driver A gives up time at Turns 1 and 3. Driver B loses the most at Turn 11.

Saving the brakes

If the driver brakes at less than the car's full potential to save the brakes, you've got a car problem to solve.

Braking While Turning

To estimate the maximum braking G's possible for braking while turning, use the formula for combined G's to define the total tractive effort available.

$$\text{Combined G's} = \sqrt{\text{Lateral G's}^2 + \text{Longitudinal G's}^2}$$

Rearrange the equation, plug in the lateral G's observed in the braking zone, set the combined G term equal to the maximum braking potential for the car, then solve for the braking G's possible. For a car with a 1.4 G braking potential, cornering at 0.6 G's, this works out as follows:

$$\text{Braking while Cornering} = \sqrt{\text{Combined G's}^2 - \text{Lateral G's}^2}$$

Or for this example:

$$1.265 \text{ G's} = \sqrt{1.4^2 - 0.6^2}$$

Cornering levels below about 25% of the car's potential don't significantly hurt braking potential.

A good measure of driver braking skill is how closely the driver approaches this target. Under 85% needs improvement, 85-100% is increasingly good, and over 100% usually indicates either braking late or a corner with poor grip.

Experimentation with the formula indicates that cornering levels below about 25% of the car's potential don't significantly hurt braking potential.

Early, Late, or Just Right

Discover whether the driver applied the brakes early or at the right time by examining the combined G, longitudinal G, and lateral G graphs simultaneously. Late braking is diagnosed differently, as we'll soon see.

The following three examples show Road Atlanta's Turn 6.

Early braking

It's not unusual for a driver to brake early at some corners while handling others well. Early braking is more common when the driver has ample time to anticipate the corner and on corners approached at higher speeds. Even the most stubborn early brakers tend to do a good job when there's not time enough to think.

Figure 8.08
Early Braking—Full G's
Early braking leaves a telltale "valley" in the combined G graph.

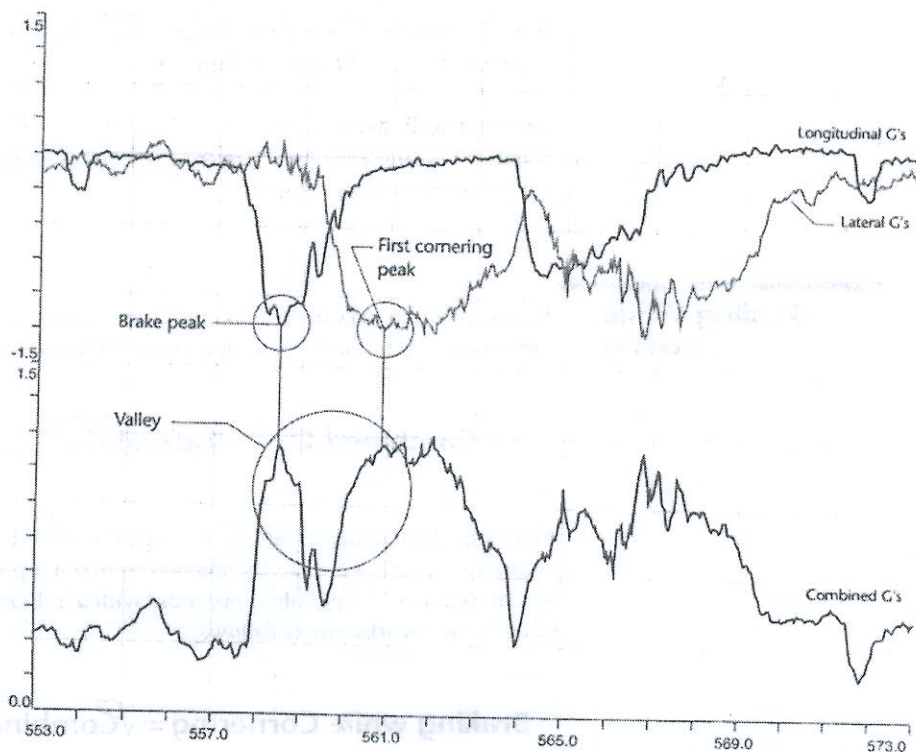
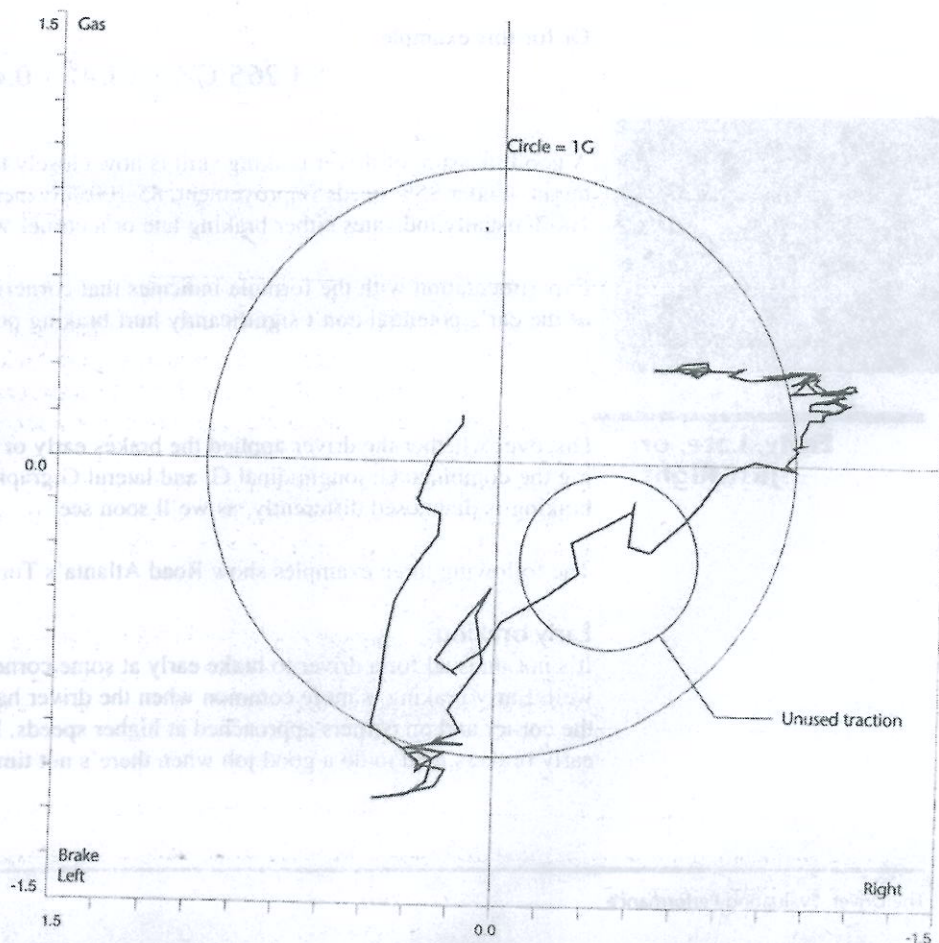


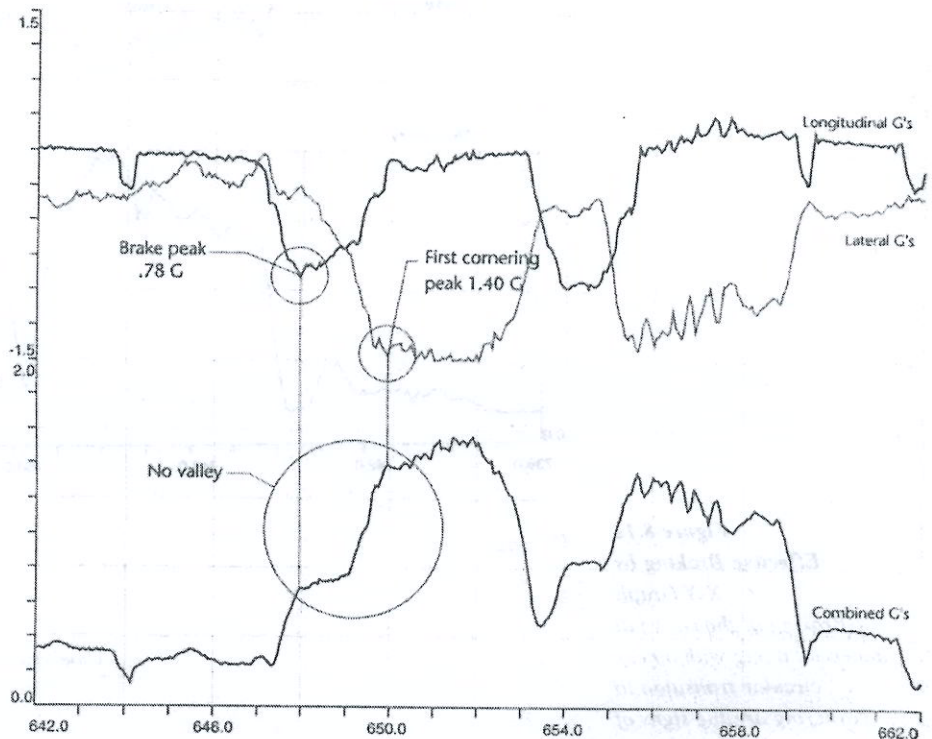
Figure 8.09
Early Braking by X-Y Graph
Early braking doesn't use the full traction potential of the tires in corner entry. A better pattern is more circular in shape. This is the same corner seen in Figure 8.08.



Early braking shows up in two distinctly different patterns. Check for both.

In one pattern, the driver uses the brakes to their fullest, but too early. See Figure 8.08. In the brief period between braking and cornering, the tires aren't fully used. The resulting "valley" in the combined G graph is the telltale. This same corner is seen in the familiar X-Y graph format in Figure 8.09. The telling symptom there is the way the graph proceeds from the braking zone to cornering. Braking late enough causes a generally "round" path between the two, at a fairly constant distance from the origin (0,0) of the graph.

Figure 8.10
Early Braking—
Inadequate G's
Braking early, braking easy!
But the corner entry feels
good to the driver, with
effective trailbraking giving
the feeling of braking later.



The other early braking pattern shows human nature at work. The self-preservation instinct sometimes leads to a subconscious urge to brake a little early. When this happens, the driver enters the corner slower than expected. The next lap, our now embarrassed driver brakes at the same point, just not quite as hard. The corner entry now feels better. We see a good combined G pattern, but the longitudinal G graph shows that the car does not brake at full potential. In Figure 8.10, the longitudinal G graph shows a 0.78 G braking peak in a car with about 1.25 G potential, based on its 1.5 G cornering peak.

Effective braking

A smooth and continuous rise in combined G's, right to the car's full cornering potential, signals correct braking. The driver uses the car's full stopping power, braking late enough to use the tires' full traction through the entire corner entry.

Figure 8.11
Effective Braking
Braking G's reach the car's full potential, while combined G's reveal a smooth transition from braking to cornering.

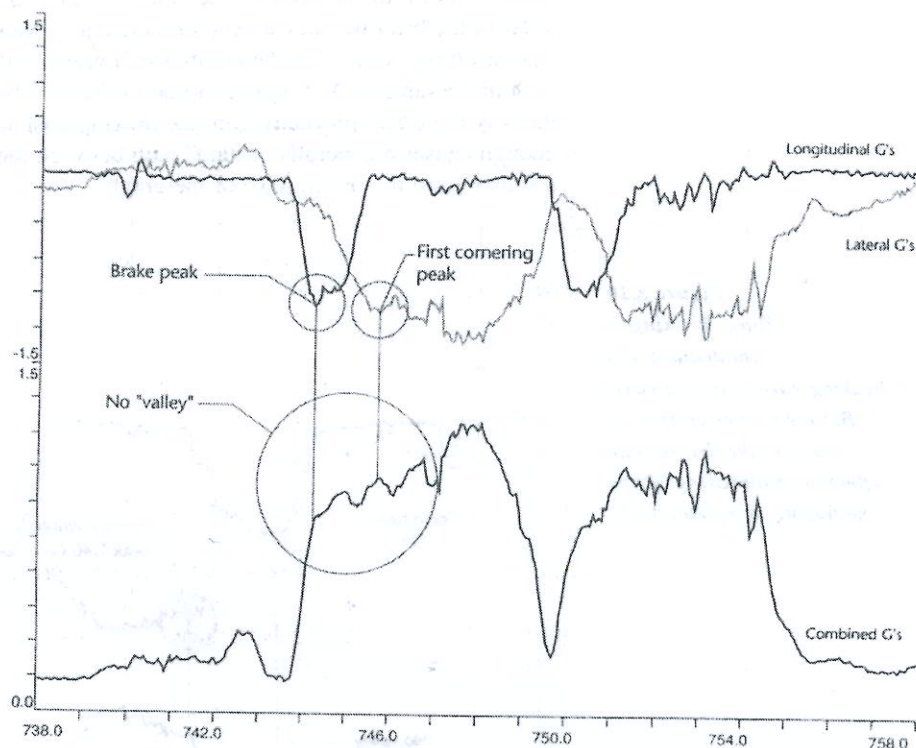
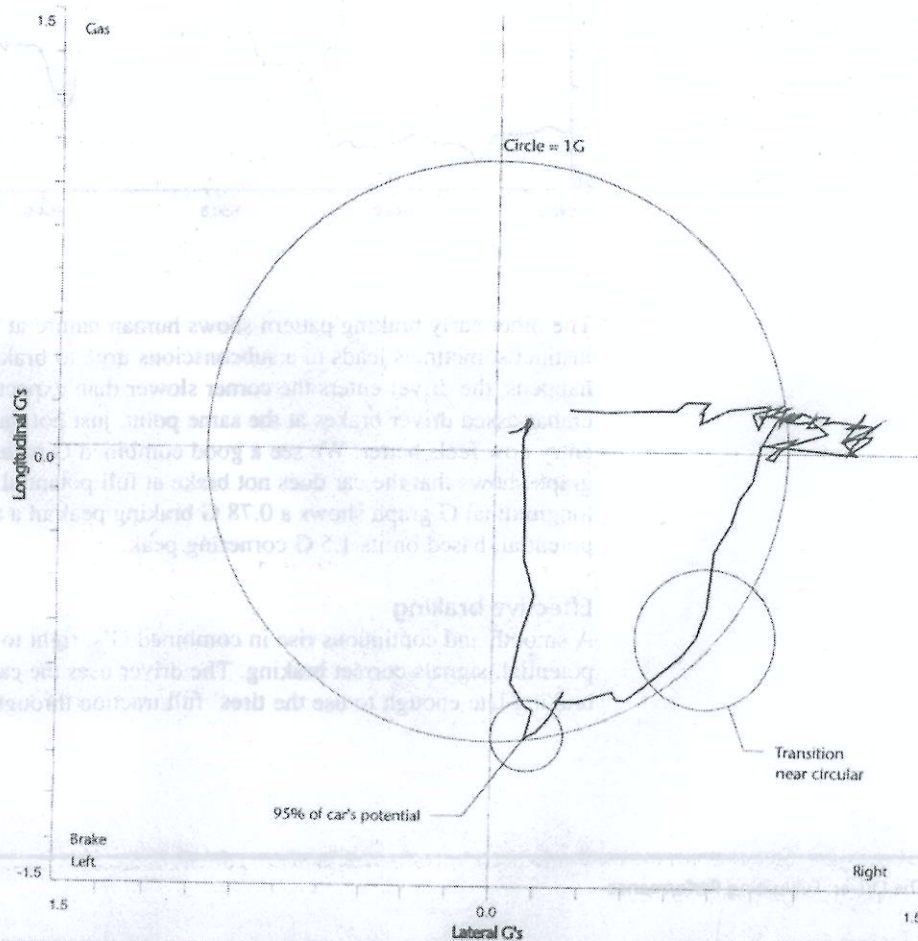


Figure 8.12
Effective Braking by X-Y Graph
Braking at the car's full potential along with a near circular transition to cornering are the signs of ideal braking.



The car and driver shown in Figure 8.11 do it right. The smooth slope of the combined G graph as it proceeds from the brake peak to the cornering peak reflects the car's similarly smooth transition from braking to cornering. The 0.95 G longitudinal G peak is within 0.05 G of the absolute braking potential of this car's street radial tires.

Figure 8.12 shows this same corner in X-Y format. The nearly circular transition from braking to cornering testifies to skillful braking.

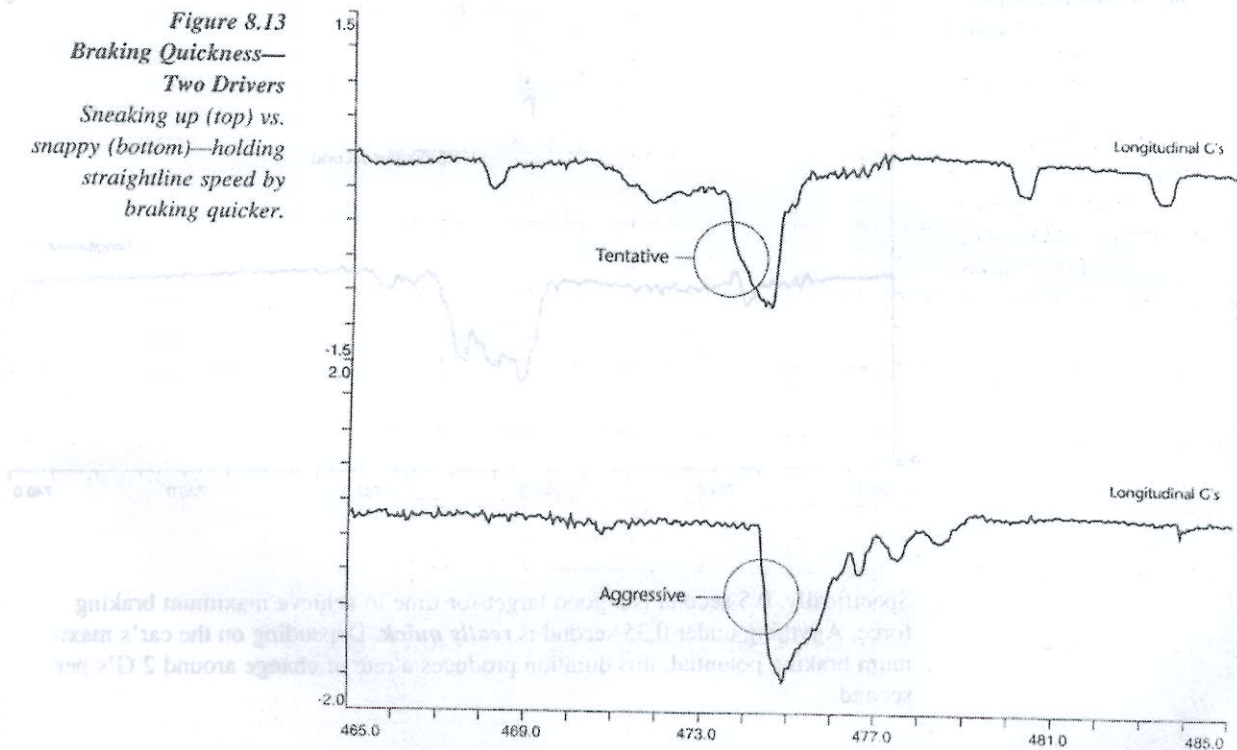
Late braking

Late braking leaves a small catalog of symptoms varying with the corner and the car's reaction. Any of the following may indicate late braking or may simply be problems in their own right.

- Lateral G peak at midcorner or later
- Inability to apply throttle at corner exit
- Corner entry oversteer or understeer
- Brake lockup
- Mid corner oversteer or understeer

Unfortunately, late braking does not have a single symptom unique to it. All these are also symptoms of familiar chassis problems. As always, try first to make a valid case for the indicated chassis problem. If it doesn't make sense, late braking may be the correct interpretation.

Figure 8.13
Braking Quickness—
Two Drivers
Sneaking up (top) vs.
snappy (bottom)—holding
straightline speed by
braking quicker.



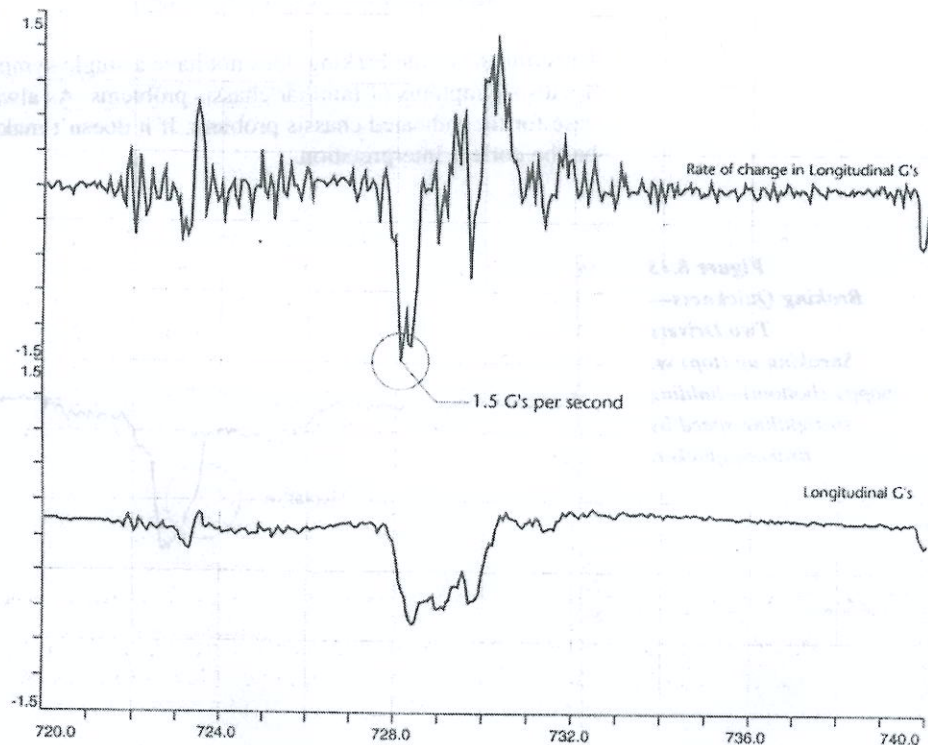
Quickness of Brake Application

Peak braking power isn't the only measure of braking effectiveness. Quick brake application is also important. Tardiness in building up to maximum braking wastes straightline speed as surely as not using full stopping power.

The plunge in the longitudinal G graph at the brake application point should be close to vertical when viewing 30 seconds or more. A driver sneaking up on peak braking makes a pattern like the top graph in Figure 8.13. The aggressive driver in the lower graph builds immediately to full braking.

If the data system software can differentiate a graph (i.e. find the value of slope), braking quickness can be measured numerically. The upper graph in Figure 8.14 is the differential of the longitudinal G graph below it.

Figure 8.14
Braking Quickness—Slope of Longitudinal G Graph
Quantify braking quickness with the slope of the Longitudinal G graph—braking builds up at 1.5 G's per second in this brisk example.

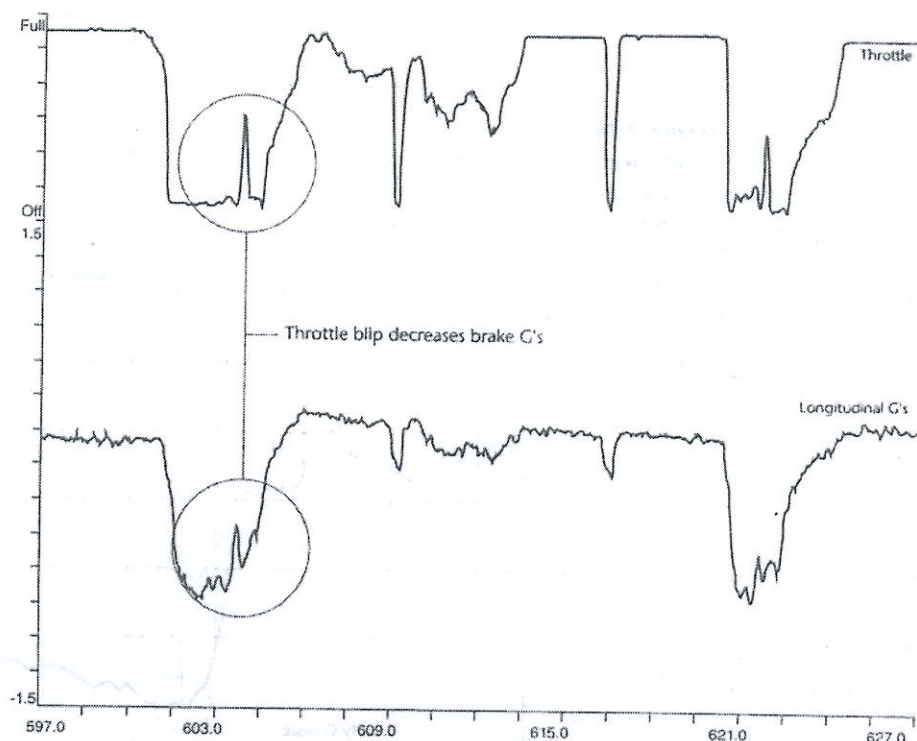


Specifically, 0.5 second is a good target for time to achieve maximum braking force. Anything under 0.35 second is *really quick*. Depending on the car's maximum braking potential, this duration produces a rate of change around 2 G's per second.

Heel-and-Toe Problems

Find footwork problems with the longitudinal G and throttle graphs. If necessary, add the RPM or gear graphs to the display to help find shifts. Two distinct patterns are common.

Figure 8.15
Heel and Toe
The throttle blip for a
downshift momentarily
siphons off braking G's.



In the first pattern, the driver unintentionally reduces pressure on the brake pedal during the throttle "blip" for a downshift, decreasing braking force. See Figure 8.15. The decrease in braking shows as a brief dip in the longitudinal G graph while the driver blips the throttle for the downshift.

The second pattern is the opposite of the first. The driver increases brake pressure during the throttle blip. This produces either an increase in brake G's or lockup in the MPH graph.

CORNERING TECHNIQUE

Data acquisition system graphs don't indicate if the driver took the *wrong line* in a corner. They do, however, reveal what line the driver did take. You and the driver have to decide if the line was right.

Basic Cornering Lines

The lateral G graph peaks where the car turns the hardest, not at the apex. In fact, lateral G's should peak at the opposite end of the corner as the apex, problems with understeer notwithstanding.

Figure 8.16

Late Apex

Dead giveaways of a late apex—lively turn-in, gradually declining plateau at peak G's, and gradual release in the corner exit.

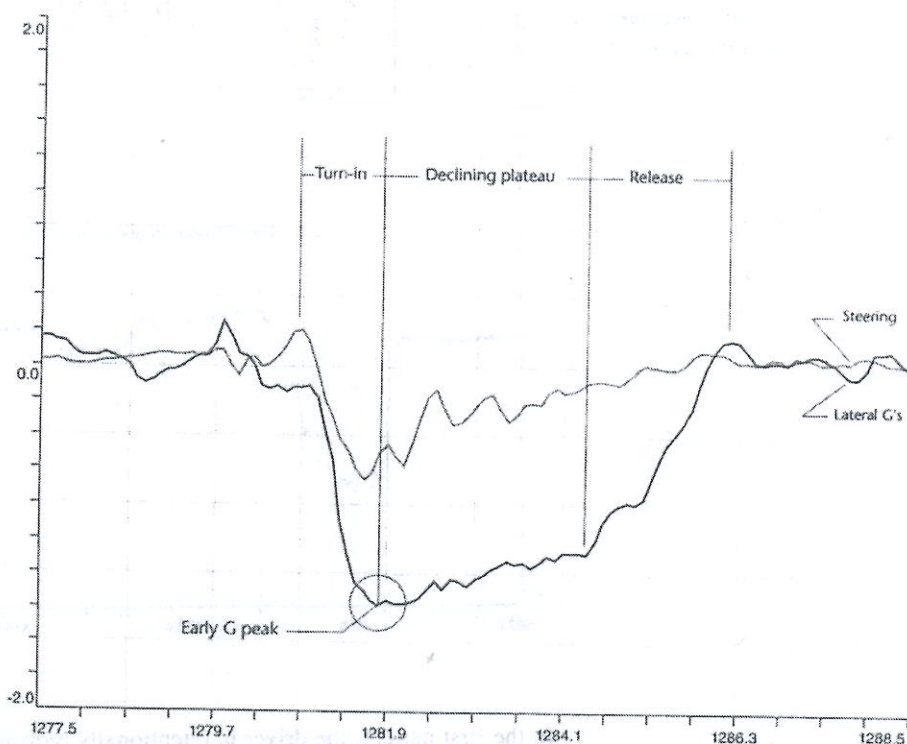
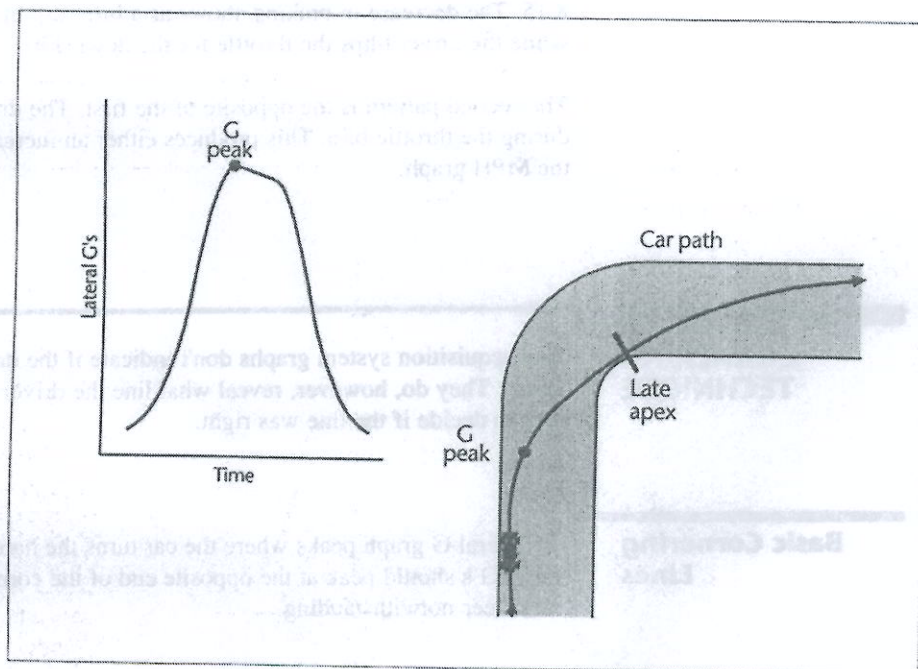


Figure 8.17

Late Apex

A late apex causes an early lateral G peak on the graph, where the corner radius is the tightest.



Late apex

In the classic late apex pattern, lateral G's and steering angle peak early as the driver rotates the car aggressively in the corner entry. Expect a steep slope up to the lateral G peak in the turn-in section of the corner. Longer corners then show a gradually declining plateau. The graph then slopes down more steeply as the driver releases the car from the turn. See Figures 8.16 and 8.17.

This is the desired pattern for corners followed by straights. It shouldn't normally be present in a corner followed immediately by another corner, since it gives up too much speed from the preceding straight. There are always exceptions—the most common is when a faster corner follows the corner in question, and the car accelerates through both corners.

Figure 8.18
Mid-Corner Apex
Corners with coinciding mid-corner apex and G peak are most often found in a series of corners.

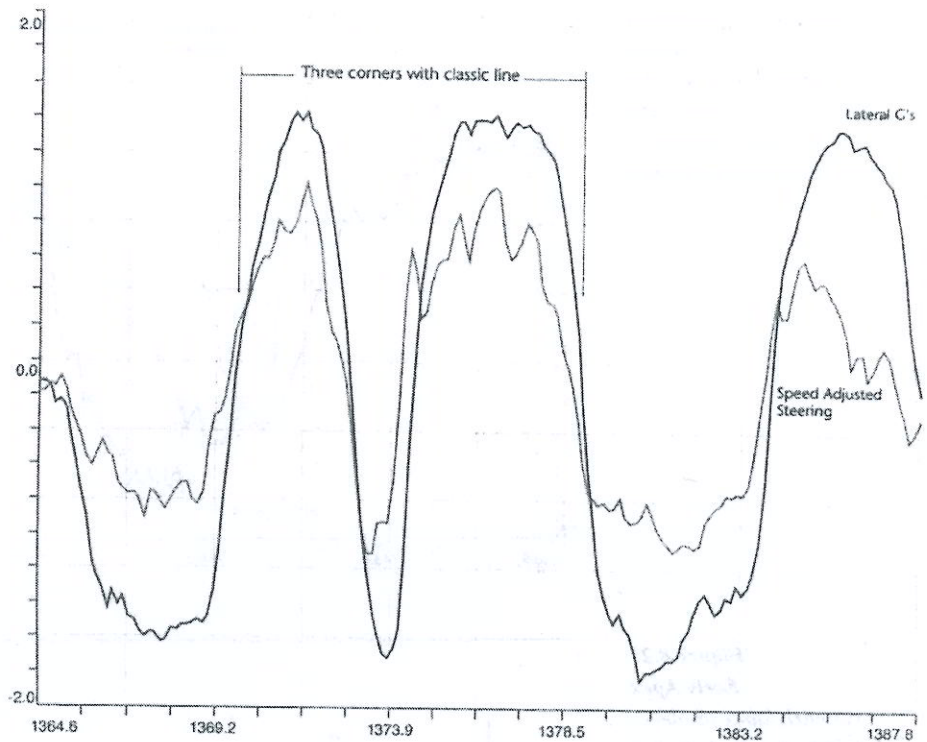


Figure 8.19
Midcorner Apex
Apexing in the middle of a turn produces graphs with the lateral G peak in the center of the turn.

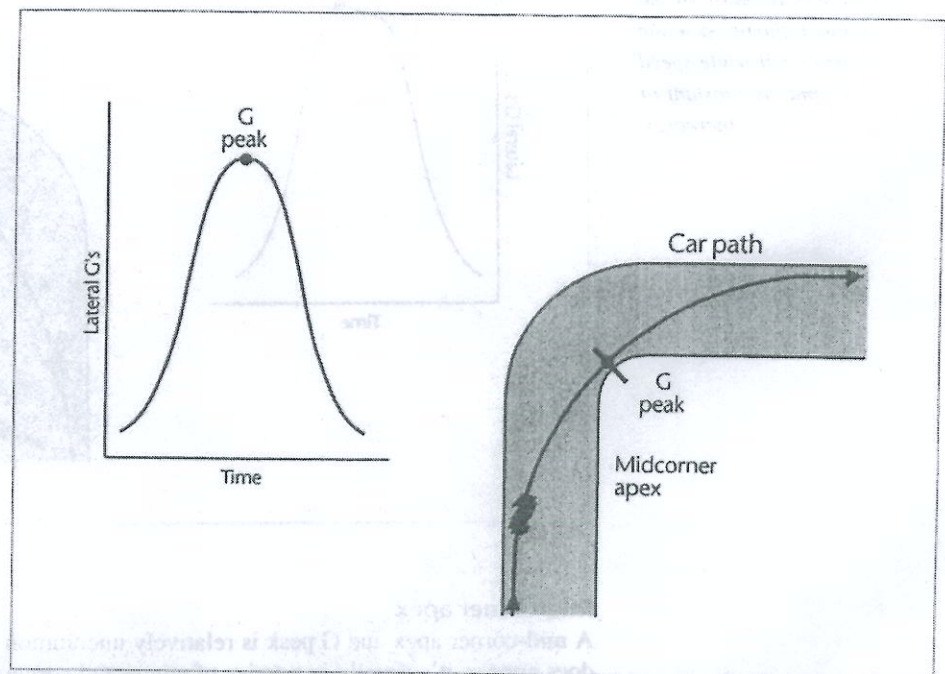


Figure 8.20
Early Apex

The distinctive late apex pattern stems from extending the straight into the corner, yielding a broad turn-in, a increasing G plateau, and a quick release. This car also shows signs of mild oversteer—corrections in the plateau.

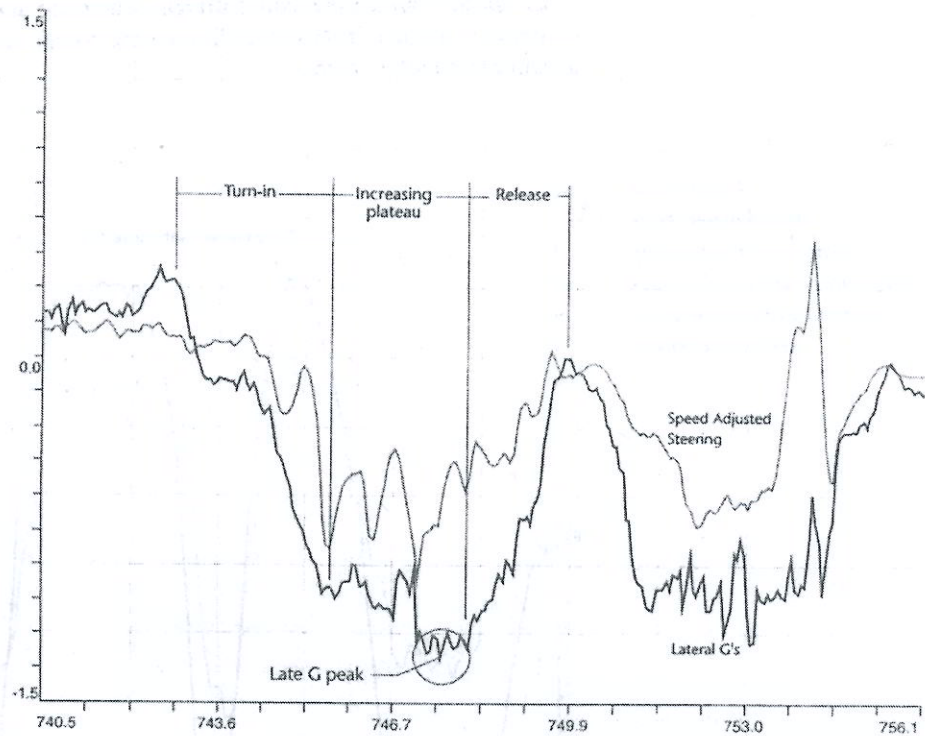
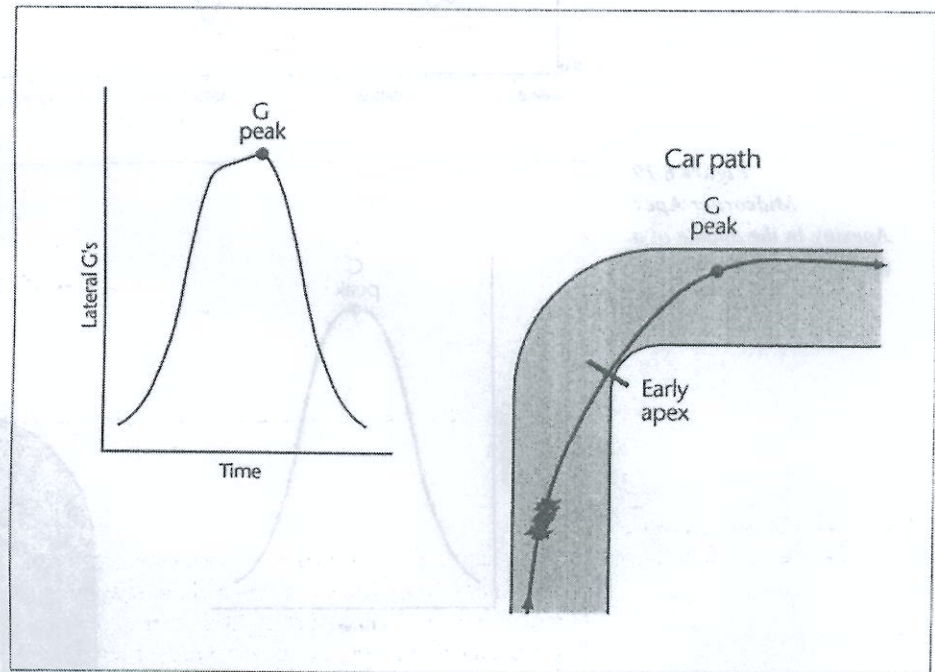


Figure 8.21
Early Apex

An early apex produces graphs with the lateral G peak late in the turn, as the radius tightens up in the corner exit while speed remains constant or increases.



Mid-corner apex

A mid-corner apex and G peak is relatively uncommon in road racing. When it does appear, it's usually in a series of connected corners. It often has traces of early or late apex patterns. Figures 8.18 and 8.19 illustrate.

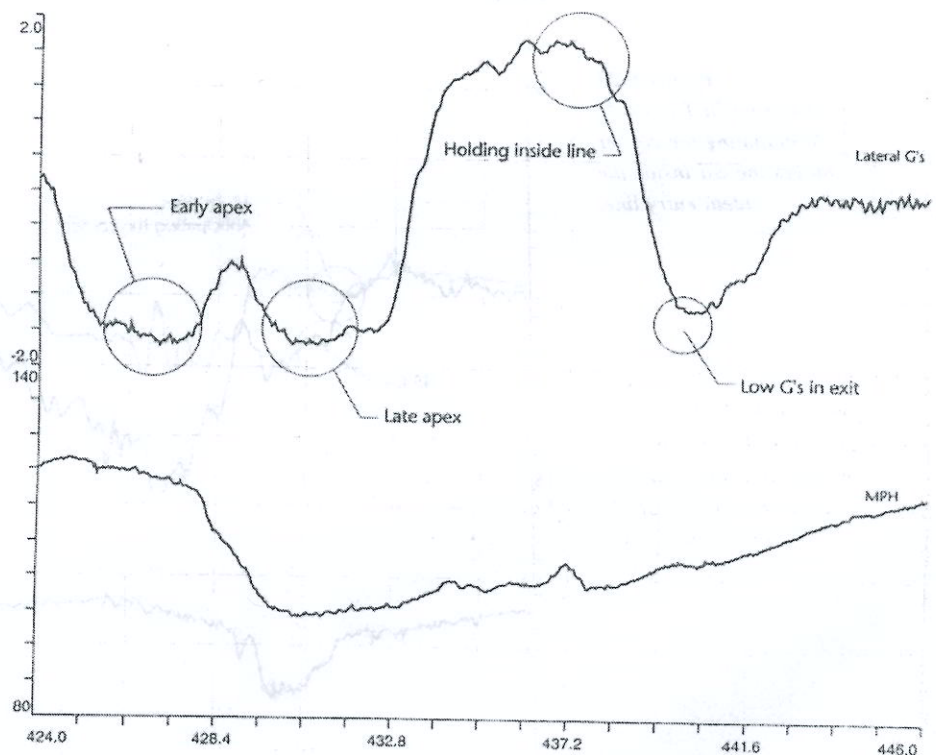
These connected lefts and rights are preceded and followed by straights. The first right has an early apex, then the middle three corners show mid-corner peaks. The fourth corner, a little longer than the rest, features a plateau at the G peak. The absence of slope in its flat top is common to mid-corner peaks. The final two corners, steadily increasing in speed, look more like late apex corners.

Early apex

In early apex corners, lateral G's and steering angle peak late as the driver extends the preceding straight into the corner entry and forces the car to complete the turn after the apex. For sustained corners, expect to see a gradually rising plateau at the G peak, then a more dramatic decrease at the corner exit. See Figure 8.20, Turn 6 at Road Atlanta, and Figure 8.21.

This is a common pattern for corners preceded by a straight and followed by another corner. This car's mild oversteer is evident in the minor steering corrections and the notchy lateral G graph.

Figure 8.22
Series of Corners
A well done series—each corner either extends the preceding straight or prepares for the following one.



Series of Corners

The line through a series of connected corners can be affected by a long list of influences. They include changes in speed, direction of each successive corner, location of the eventual straight, corner geometry, and probably six or eight more. An exhaustive attempt to cover them all would be both futile and boring, so Figure 8.22 shows one good example.

In the first right, the driver extends the preceding straight into the corner entry. He gets to the outside edge of the track quickly, anticipating braking for the second right while still turning.

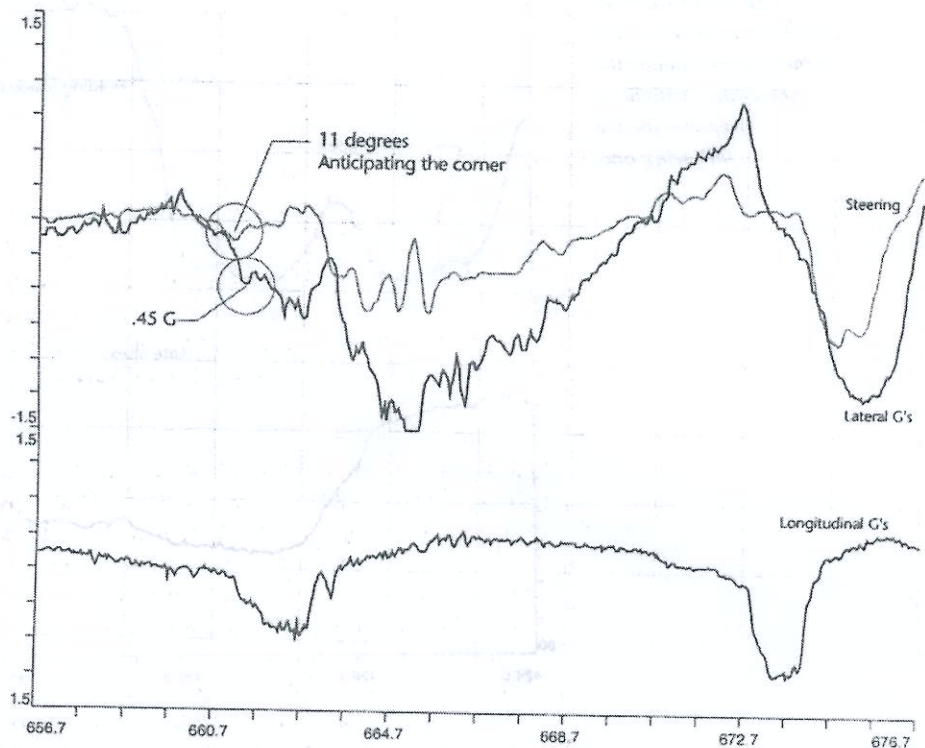
Having lined up his entry into the second right, he is well prepared to accelerate through the turn. The declining plateau shows the early G peak typical to late apexes.

The driver holds the car to the inside of the following left, to straighten out the final right leading onto the straight. This strategy shows in the rising plateau in the G graph for the left. The relatively low cornering G's in the final right turn reveal the success of this strategy.

What could he have done better? Not much. Every action from the second right turn on worked in favor of his exit onto the straight and appropriately so.

This is not a driving lesson, but a way to discern what strategy a driver used in a series of corners. The MPH graph, as always, reveals the correct approach. If there is any question, don't waste time on debate, just try a different approach to see if it works.

Figure 8.23
Turning In Too Early
Anticipating the corner
moves the car inside the
ideal entry line.



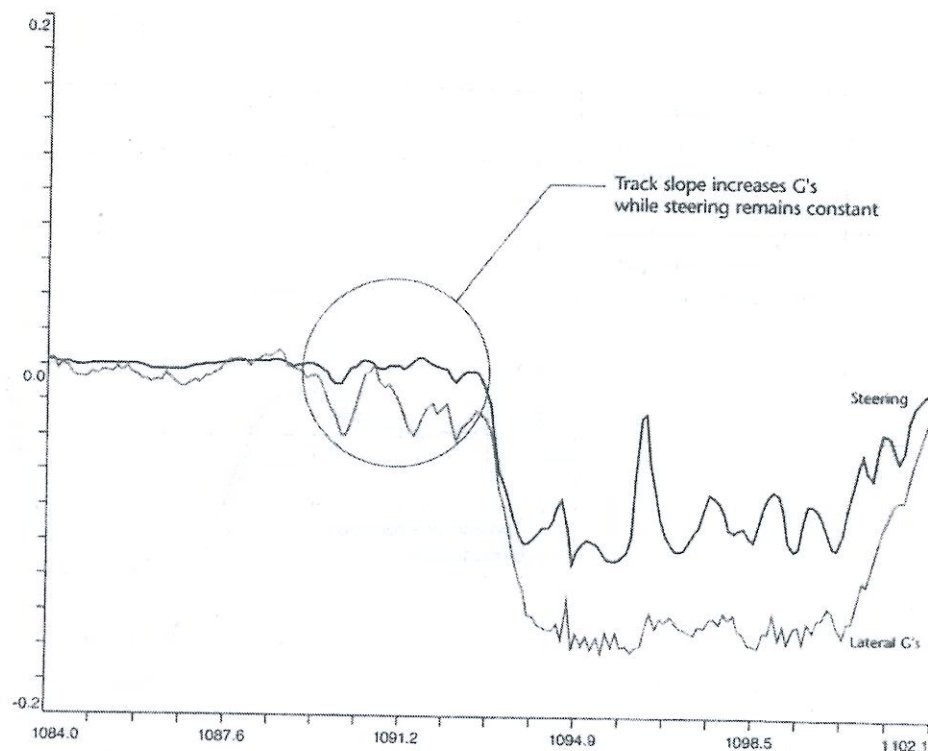
Corner Entry

Since corner entry influences the car's behavior in the rest of the corner, we'll explore several specific cases:

Early turn-in (anticipating the corner)

If the driver anticipates the corner and moves the car toward the center of the track before the turn-in point, it will show in the steering and lateral G graphs. See Figure 8.23.

Figure 8.24
Off-Camber Corner Entry
An off-camber corner entry induces an accelerometer reading without steering.



About a second before the turn-in point, the driver steers 0.03 turns (about 11 degrees) into the corner. This generates about 0.45 G laterally, common for a "lane-change" type maneuver. Helped by weight transfer to the front under braking, the car continues to turn gently until the actual turn-in point, despite a steering correction. This car was about one and a half car widths inside the optimal corner entry line. At the corner exit, the driver had to cope with understeer induced by this entry line.

Under some circumstances, the "creep" in lateral G's may be caused by the track. Figure 8.24 shows a track which slopes off-camber for about 30 yards before the corner entry, tilting the car and inducing a small reading in the accelerometer. The steering angle remains zero despite the increase in lateral G's preceding the turn-in point. Moving the entry line one car width to the inside of the off-camber section produced a crisper turn-in and less push through the whole corner.

Opposite direction "jog" before entry

A driver approaching a corner somewhat to the inside of the ideal turn-in point will sometimes give the car a brief jerk to the outside of the corner before turning in. This action is easily seen in the steering angle and lateral G graphs, as shown in Figure 8.25.

This technique briefly rotates the car away from the corner before rotating it into the corner. The car begins the actual corner entry with whatever behavior it displays in left-right or right-left transients. This may help or hurt, depending on circumstances.

Figure 8.25
"Jog" to Outside of Track
Before Turn-In
 The quick jerk to the left
 before this right generates
 0.5 G and changes the car's
 corner entry behavior.

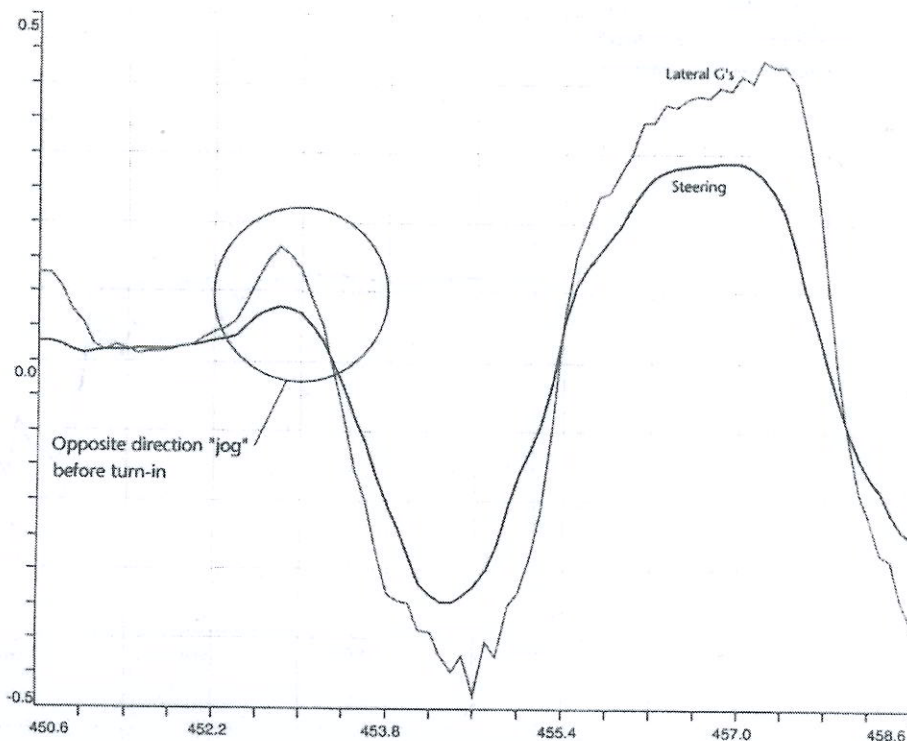
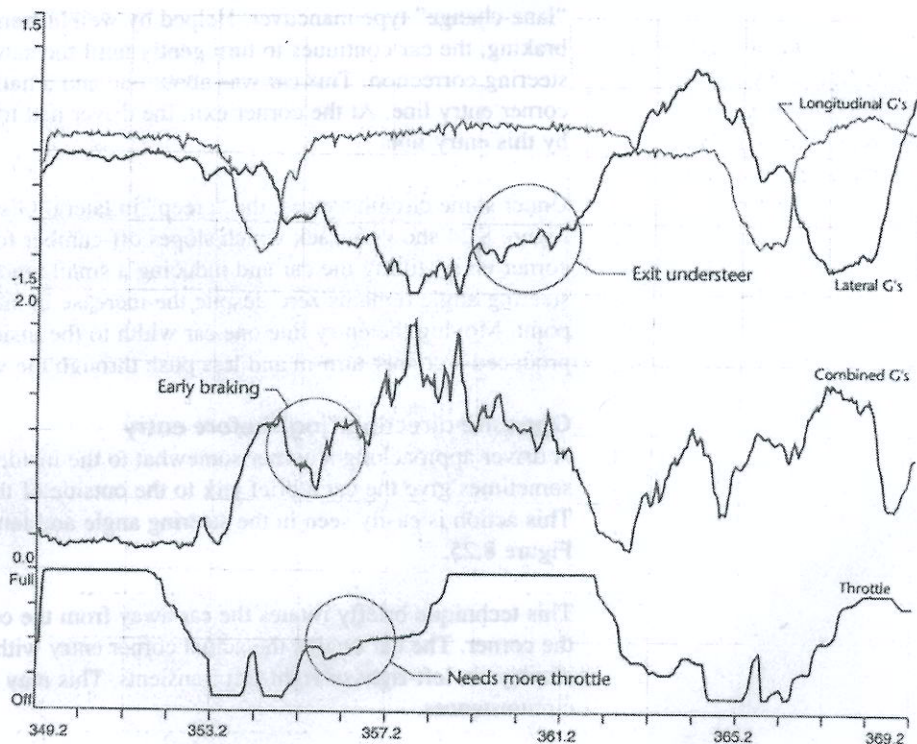


Figure 8.26
Driver-Induced Understeer
 A tentative corner entry
 leads to the characteristic
 plateau of corner exit
 understeer.



Late turn-in

Despite trying, I couldn't find a late turn-in graph. Here's what it should look like.

The main symptom is rapid steering wheel movement in the corner entry. The steering and lateral G graphs would slope nearly vertically at the corner entry. This is expected in quick left-right transitions, but not in most corners preceded by a straight or a corner in the same direction.

There would almost certainly be no signs of early braking. Depending on the car's handling, understeer or oversteer symptoms will follow as the car enters the corner out of shape. Steering corrections may be dramatic.

Driver induced understeer

You don't want to see this pattern often. Figure 8.26 shows a driver whose corner entry technique leads to mild understeer in the corner exit.

The "hole" in the combined G graph shows the driver braking early. He then compounds his sins by turning in early. The flat section in the corner entry portion of the lateral G graph rattles. He doesn't apply enough throttle to balance the car and waits until after the G peak in this high speed corner to apply it fully.

Driver induced understeer usually shows in the corner exit, as it does here. Between turning in early and not using enough throttle early in the corner, some understeer in the exit is almost inevitable. It shows in the squarish edge to the lateral G graph in the corner exit.

Well-balanced cars will usually show relatively subtle symptoms of driver induced understeer, unless the driver brakes late. If so, stronger signs of understeer will be clearly visible.

Evaluating Corner Speed by G's

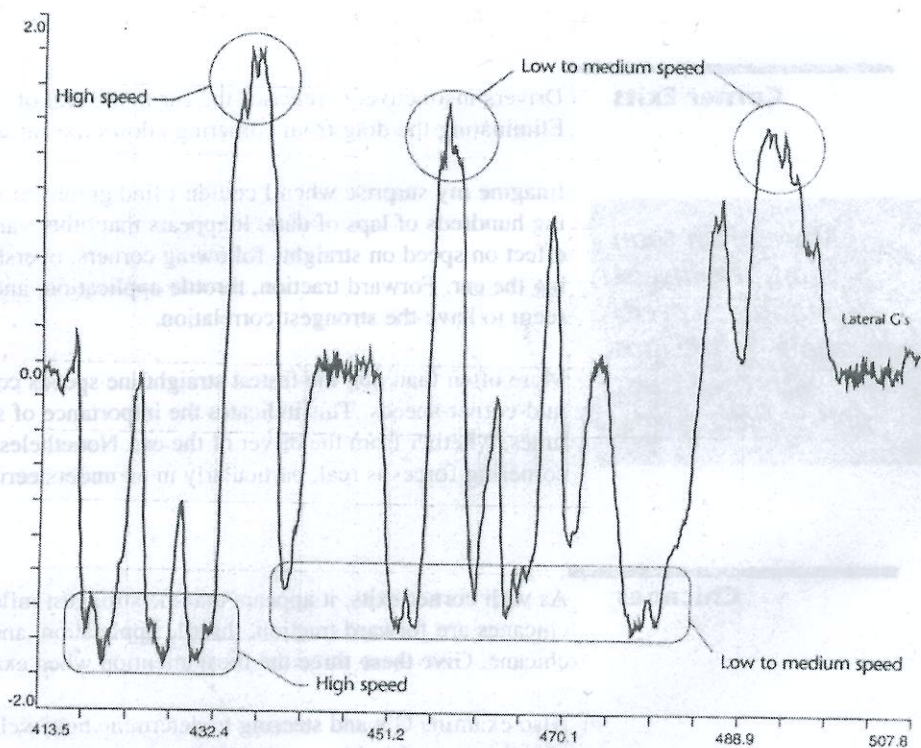
Under ideal conditions, the driver would be able to use the car's peak potential in every corner. By now, it should be no surprise that's only ideal, since peak lateral G's will vary from corner to corner. Some variations come from the track, some from the car, and some from the driver. Some variations bring on more G's, some less. They only complicate trying to determine whether the driver is leaving a little speed on the table.

Lateral G's routinely vary about ± 5 to 10% of the car's maximum potential for cars without serious downforce. Tunnel cars like prototypes, F1, Indy Cars, and Formula Atlantics will vary considerably more, as their aerodynamic aids come into play at speed. Study every corner that varies more than 10% to find out why.

What indicates that the driver is slow in a corner? First, discard the corners that are non-events. Then, on any corner where the lateral G's are less than other corners with a similar speed, try to find a plausible explanation for the missing G's. For example, the corner may be bumpy or off-camber. If no good explanation can be found, there may be some speed left in the driver.

SITUATION	EFFECT
Banked	More G's
Off-camber	Less G's
Uphill	More G's
Downhill	Less G's
Bumpy	Less G's
More downforce	More G's
Oversteer or understeer	Less G's
Abrupt steering	More G's
Corner speed too low	Less G's

Figure 8.27
Cornering Speed by G's—
Consistency
 Consistency at work! This driver reaches the car's full potential in every corner, with lateral G's in a total spread of 0.1 G in each speed range. Corners not circled are non-events.



In the sample lap in Figure 8.27, corners are marked as high-speed, low-to-medium speed, and non-events. The car has mild aerodynamic downforce. The high-speed corners range from 1.74 to 1.81 G, and the low-to-medium speed ones from 1.41 to 1.56 G. This driver set a track record in his class, and the tight range of cornering G's shows it.

Cornering speed varies with the corner radius and G level, as calculated in the formula:

$$\text{MPH} = \sqrt{\frac{32.167 \times \text{Corner Radius in feet} \times \text{Cornering in G's}}{1.467}}$$

This is not an easy formula to remember, nor an easy calculation to make at trackside. For a quick rule of thumb, the following table approximates the loss in speed for 0.1 G in lost cornering force. It's based on cornering at 1.5 G's. Higher cornering power leads to larger losses for each 0.1 G, and vice versa.

RADIUS	SPEED	MPH per 0.1 G
200 ft.	67.0	2.3
400 ft.	94.7	3.2
600 ft.	116.0	3.9

The driver may intentionally sacrifice speed in one corner to gain it in a more important corner. As always, don't jump to conclusions, just consider the facts thoroughly before deciding anything.

Corner Exits

Drivers instinctively "release" the car in the exit of corners leading onto straights. Eliminating the drag from cornering allows the car to accelerate quicker.

Imagine my surprise when I couldn't find graphs to support this idea, after searching hundreds of laps of data. It appears that other variables have a much stronger effect on speed on straights following corners, overshadowing the effect of releasing the car. Forward traction, throttle application, and speed in the corner itself seem to have the strongest correlation.

More often than not, the fastest straightline speeds come on the laps with the fastest mid-corner speeds. This indicates the importance of sheer cornering speed to lap times, whether from the driver or the car. Nonetheless, the drag generated by cornering forces is real, particularly in an understeering car.

More often than not, the fastest straightline speeds come on the laps with the fastest mid-corner speeds.

Chicanes

As with corner exits, it appears that the strongest influences on straights following chicanes are forward traction, throttle application, and minimum speed in the chicane. Give these three the most attention when examining graphs.

Also examine G's and steering to determine how well the driver attempts to straighten out the chicane. Any improvements require a faster entry and exit speed to translate into greater straightline speed, since lower G's in themselves have little effect.

Figure 8.28
Straights Between
Left-Right Sequences
Extending the first turn in
anticipation of the second
extends it and holds back
acceleration.

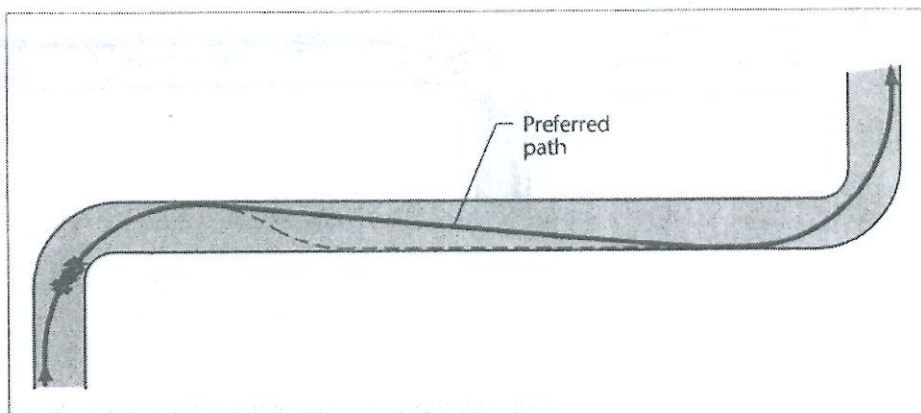
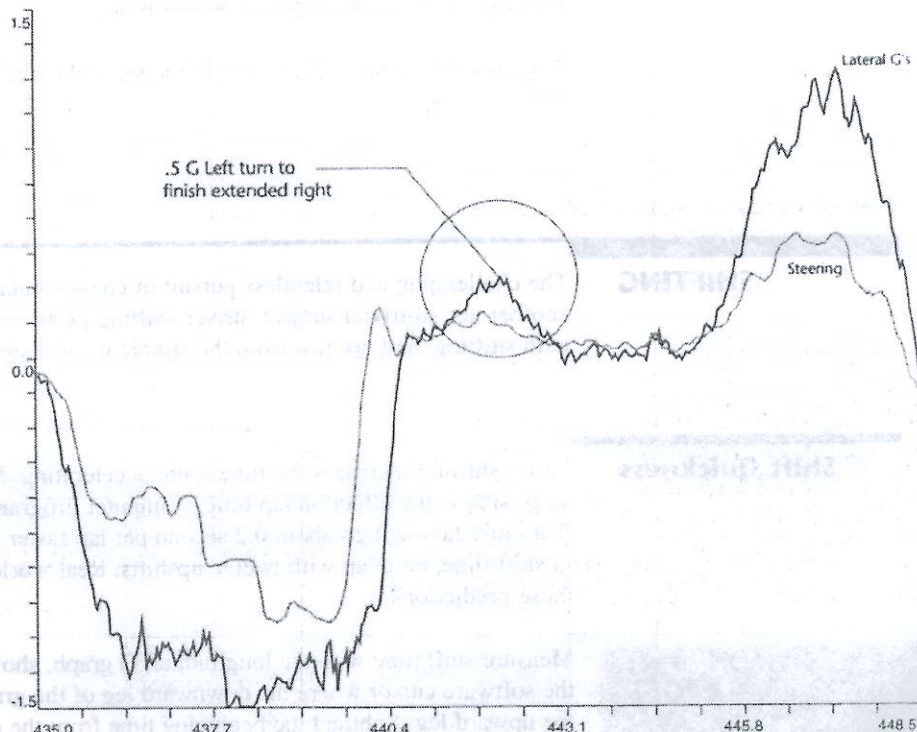


Figure 8.29
Going Straight
on the Straights
Too much turning! This right
turn gets extended to return
the car to the right side of
the track in anticipation of
the impending left.

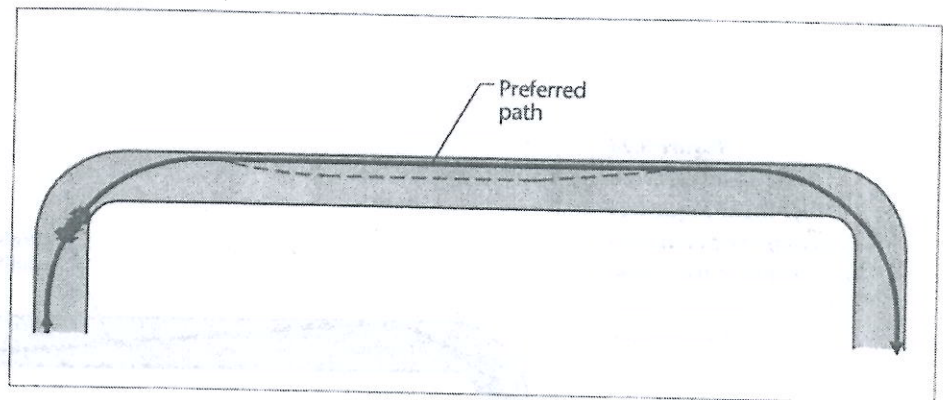


Going Straight on the Straights

Minor "lane-change" corrections on straights can generate 0.5 or more lateral G's. The resulting cornering drag resists acceleration.

Figure 8.28 shows a right turn leading onto a short straight which culminates in a left. Exiting the right, our driver continues the turn to carry the car to the right side of the track, anticipating the approaching left. The gentle left arc to straighten the car shows in Figure 8.29 as a 0.06 turn (22 degree) steering wheel correction producing 0.5 G to the left. The time spent turning can be shortened by changing the path down the straight to "make a beeline" from the trackout point of the first right to the turn-in point for the left.

Figure 8.30
Straights Between
Two Turns in the
Same Direction
Moving away from the edge
of the track too quickly
extends the first turn.



Although this pattern is more common when the successive corners are in opposite directions, it may appear between corners in the same direction. In that case, the driver usually extends the first corner to put a little distance between the car and the edge of the track. Figure 8.30 illustrates.

The lateral G graph will show a quick jog in the opposite direction at the corner exit.

SHIFTING

The challenging and relentless pursuit of chassis balance usually overshadows another not-so-trivial subject: driver shifting performance. Races can be won or lost with shifting, and not just from the simple missed shift, either.

Shift Quickness

Faster shifting increases the time spent accelerating. No surprise, right? More surprising is the effect on lap time. Computer programs for track simulation predict that most cars will go about 0.2 second per lap faster from a 0.1 second reduction in shift time, on a lap with twelve upshifts. Real world experience clearly confirms these predictions.

TARGET:

Dog Transmission
<0.2 second

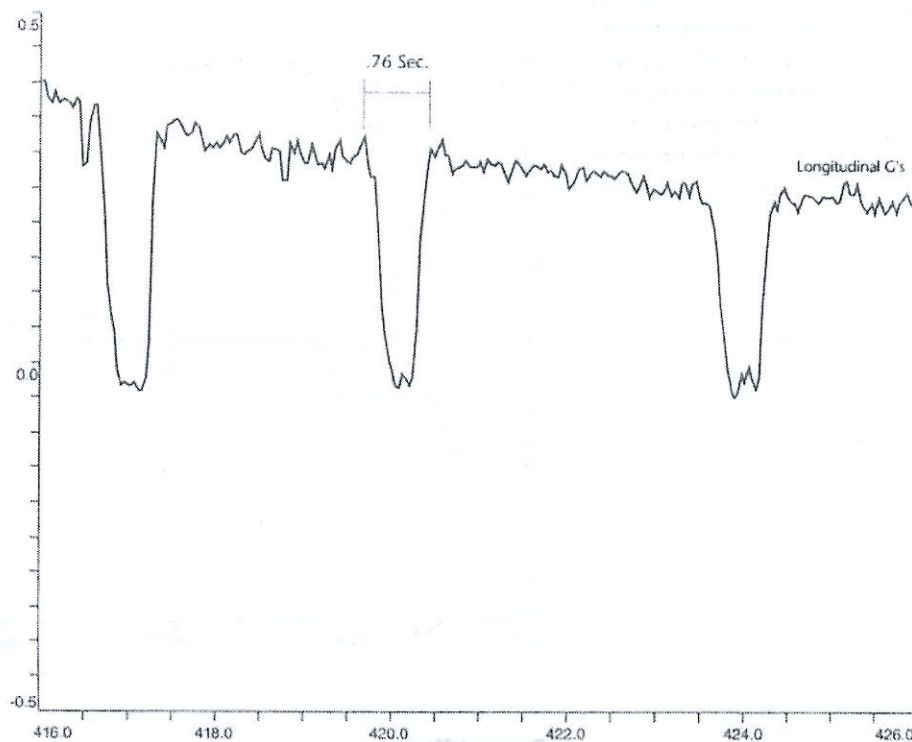
Synchro
Transmission
<0.4 second

Measure shift time with the longitudinal G graph, shown in Figure 8.31. Position the software cursor where the downward leg of the graph begins, then at the end of the upward leg. Subtract the beginning time from the end time for the shift duration. This shift took 0.76 second.

The target for synchronized transmissions is shifting quicker than 0.4 seconds. Non-synchronized transmissions should shift quicker than 0.2 seconds.

The data acquisition system should record at least 25 samples per second for accurate results. Turn off the data smoothing in the software for these measurements. Smoothing masks actual shift duration, making the shift appear longer.

Figure 8.31
Shift Duration
 Measuring shift duration—
 accuracy is best when the
 graph is not smoothed.



Faster shifting is an often an easier and cheaper improvement to lap times than horsepower gains, weight reductions, or chassis improvements. Modify driving technique, shift linkage, or transmission, if necessary.

RPM Matching

Both upshifts and downshifts are subject to mismatched RPM. Analyze RPM matching on the gear (MPH per 1000 RPM), longitudinal G, and throttle graphs.

A short, sharp spike at a shift in the gear graph is the first sign of possible mismatched RPM. Downward spikes come from RPM higher than the next gear needs, while upward spikes are the opposite. Inspecting the longitudinal G and throttle graphs will confirm if the spike is mismatched RPM or if it was between gears.

Upshifts

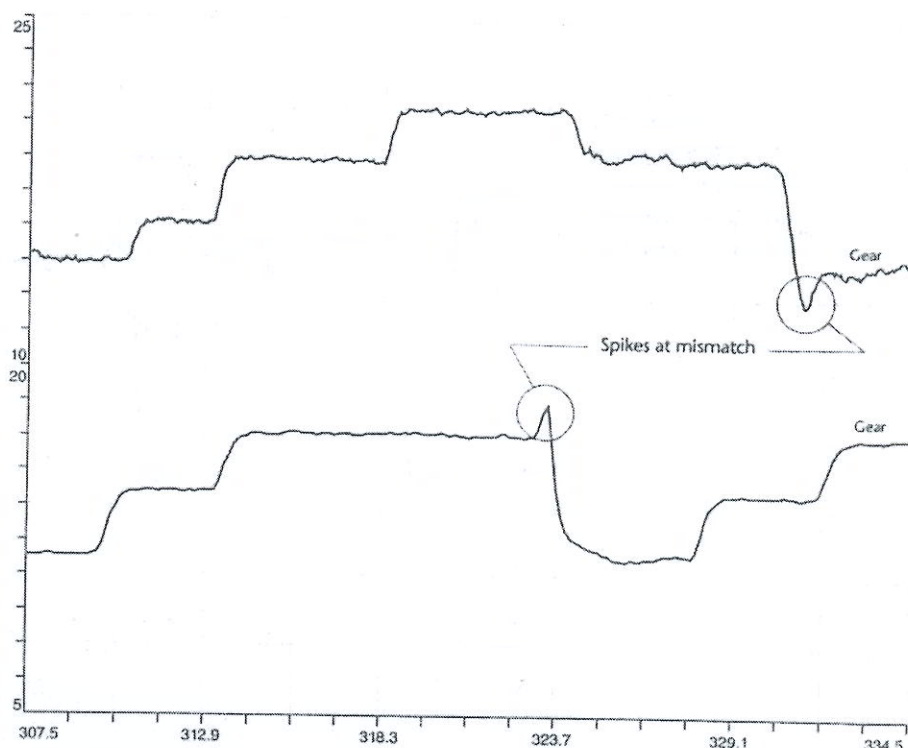
Upward spikes on upshifts probably indicate that the driver nodded off from boredom. They come from the RPM dropping below the proper level for the next gear.

Downward spikes on upshifts often come from really quick shifting, when the driver engages the next gear so quickly that the engine hasn't slowed to the correct RPM for the next gear. The inertial energy stored in the engine's rotating parts gives the car a little "kick," with a corresponding upward bump in the longitudinal G graph. This stresses the drivetrain, but it's a little quicker on the track.

A slower-shifting driver can produce a similar pattern by applying the throttle before engaging the next gear. The only clear way to distinguish this is to check the time required to complete the shift.

Figure 8.32
RPM Matching—
Downshifts

Spikes may indicate the driver dragging the rear wheels by bringing the engine up to speed with the clutch.



Downshifts

A downward spike on a downshift is almost always from the throttle blip to match RPM. It has little adverse effect and does not need further investigation. See the upper graph on Figure 8.32.

An upward spike on a downshift, indicating too little RPM, is potentially harmful. If the driver drags the engine up to speed with the clutch, the abrupt increase in effective rear braking force brought on by engine drag can unsettle or even spin the car in the corner entry. See the lower graph on Figure 8.32.

Corner Exit One Gear Too High

This shouldn't happen, but sometimes it does! A driver can exit a corner one gear too high, usually because it feels more comfortable.

The car in Figure 8.33 has a torque peak around 7500 RPM, yet the driver reaches full throttle in two corners at 5640 and 6180 RPM. The resulting sluggish acceleration shows in the longitudinal G graph, which builds to maximum acceleration as the engine approaches the torque peak. The upward curvature of the RPM graph tells the same story.

This was not a problem with ratios. The RPM was too far below the torque peak (2000 RPM below).

Figure 8.33
Exiting Corner in the Wrong Gear

This driver bogs the car by using the wrong gear—full throttle on corner exit should be near the RPM for maximum acceleration in a gear.

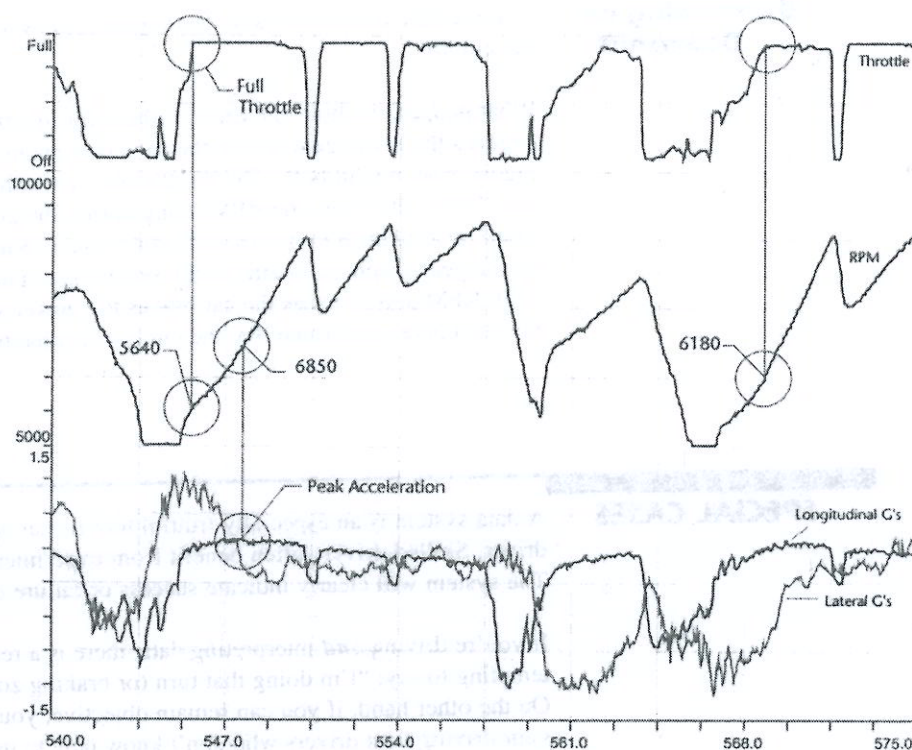
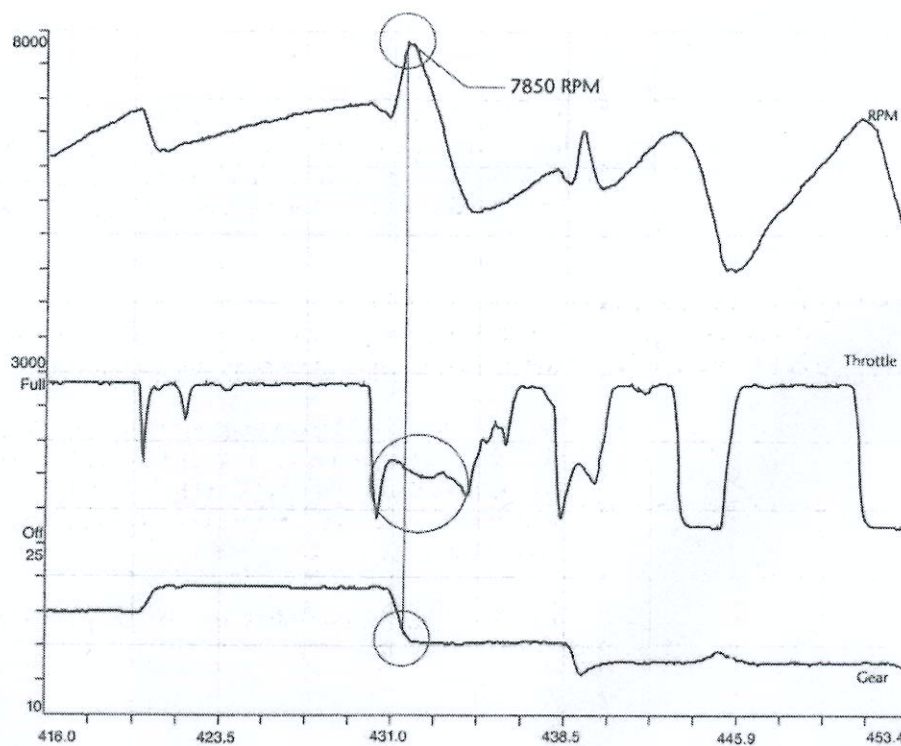


Figure 8.34
Overrevving on Downshift
Premature downshifting and over-aggressive throttle blipping are a common cause of overrevs like the one seen here. Redline was 7200.



Overrevving on Downshifts

If the telltale on the tach says the engine was twisted too tight, a downshift is often the culprit.

What happens is this—the driver either blips the throttle too aggressively or engages the lower gear before the car slows enough. In the example shown in Figure 8.34, he did both. The throttle blip sends the engine to 7850 RPM (redline was 7200), shown by the RPM rising during the gear graph's transition from the fourth gear plateau to the second gear plateau. When the clutch is engaged, shown by the gear graph stabilizing at the second gear plateau, the engine is still at 7850 RPM and slows as the car brakes to a lower speed. The longitudinal G graph, not seen here, confirmed that the entire event happened in a braking zone.

SPECIAL CASES

A data system is an especially fruitful tool for an open-minded and self-confident driver. Skilled drivers often benefit from experimenting with different techniques. The system will clearly indicate success or failure of a new idea.

If you're driving *and* interpreting data, there is a real challenge in store. It is tempting to say: "I'm doing that turn (or braking zone, etc.) as well as possible." On the other hand, if you can remain objective, you will learn *much more* about your driving than drivers who don't know how to use a data system.

