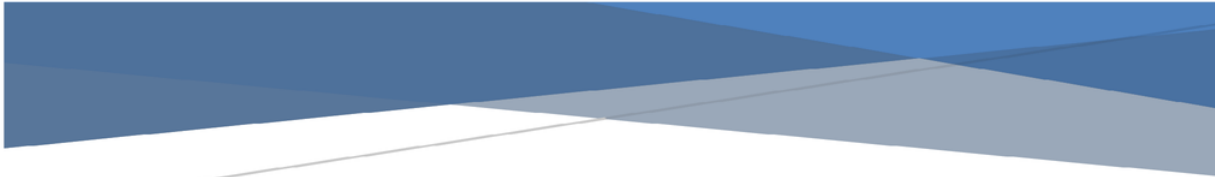


Race Engineering

by Stephen Hutchings

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Driver Comparison through Data Analysis

Race Engineering
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Abstract

Data was acquired from a GP2 race car using a simulated track. A series of key performance indicators which included gear selection, steering techniques, throttle application and braking were then analysed in order to determine the driver techniques of three drivers and to establish how driving techniques can improve driver performance. From the analysis of data gathered and the use of Motec maths channels it was found that correct timing of gear change, braking, steering and throttle application had a great influence on the lap time of each individual driver. Other factors such as pressure applied to brakes also influenced lap speed. It was also discovered that each performance indicator can influence the other; steering techniques affect the throttle position when cornering. It was concluded that data acquisition software was a valuable tool to use in order to improve driving performance.

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1 Introduction

The performance of a vehicle can be evaluated through data acquisition (Segers, 2008). This suggests that engineers can use data acquisition to evaluate track tests to record and analyse data. From information gathered the factors that have an effect on performance can be determined, Knox (2011) suggests that these factors include the conditions of the race track, driver input and the condition of vehicle components. As driver input is a factor that can be analysed through data acquisition, this implies that driver techniques can be improved through the use of data acquisition technology. To add to this further, when analysing data, characteristics such as performance, smoothness, response and consistency should be focused upon when evaluation driving style (McBeath, 2008). As the evaluation of driver performance can improve test results, it is important to measure key performance indicators. Segers (2008) considers that these include throttle application, braking, shifting gears and steering technique.

1.1 Aims

The main aim of this report is to compare and critically analyse driver techniques, therefore, the examination of these driver inputs are essential in order to provide a detailed critical analysis. The report will include secondary research to support the methods used in the track test. A test plan will be produced for the report and data will be collected from a simulated track test using a GP2 racing car, this will then be analysed using Motec. This will be explained further in the methodology section. Findings of the test will then be critically analysed and evaluated.

2 Literature Review

According to Vaudi and Law (2000) "data acquisition can be effectively used in concert with a trained driver's assessment to understand and improve both chassis set up and driving technique". This proposes that data acquisition informs the race team of the changes that need to be made to the setup and how the driver performance can be developed. It appears that data acquisition is a common method used in industry as an approach to driver development. In motorsport, data is collected from a vehicle sensor during track testing and stored for analysis. This is then converted into waveforms using specialist software such as Motec (Southward and Conner, 2008). Therefore, these waveforms can be analysed and used as a tool for driver development. In a study conducted by Mitchell et al (2000) which focused on the analysis and evaluation of driving techniques using data acquisition, it was found that data acquisition allowed drivers to understand the vehicle's reaction to driver action. The study also discovered that data acquisition allowed drivers to detect areas where driving performance may be affected such as during cornering and throttle usage. As the software clearly identified areas that needed to be developed this allowed

driving techniques to be improved. However, Brown (2011) suggests that data acquisition should be used with caution as an improperly configured data acquisition system can lead to inaccurate results. This could then have a negative effect on driver development. To support this, Segers (2008) states that as the chassis and the driver activity are closely linked, close attention must be given during analysis to ensure that the two aspects are mixed up during data analysis.

It can be seen from literature that there several types of track testing approaches, these include test days, where sensors monitor the performance of a vehicle and vehicle simulation, where performance and vehicle parts can be tested on virtual test tracks (Hornsey, 2011). It appears that both approaches will allow improvements to be made to the overall performance of the race car as track testing allows the race team to test the different setup combinations and chassis geometry (Wgengine, 2017). Both approaches allow data to be viewed in real time or after the race has finished (Lopez and Seaper, 2009). Therefore, this allows both driver and team to reflect on and evaluate the performance. To add to this further, track testing can allow the driver to advance their racing techniques.

3 Methodology

In order to compare driving techniques and performance a test plan was devised to ensure that the team members knew what was being tested and in which order (Clifford, 2008). Three drivers were selected in order to analyse their techniques; driver A (colour coded in red in screen shots) had a vast amount of experience racing and therefore was used as the benchmark driver. The techniques of driver B (colour coded in black) and C (colour coded in green) were compared against driver A throughout the test, this was done to enhance the performance of driver B and C. Each team member was given a role and this stayed the same during both sessions to ensure fairness. Roles included selecting and saving appropriate data, relaying data to drivers following warm up laps, observing driving lines, starting and stopping of the simulator, monitoring vehicle data; corr speed, throttle position, gears, throttle, braking positon and finally monitoring sector times from each drivers and informing them of when they need to implement the changes in order to enhance performance.

The track of choice from the simulator was Silverstone and the whole testing time took 3 hours to complete. It was decided that the first session would be used to determine driver techniques, following this analysis on techniques took place, the second session gave the drivers opportunity to take on board points from discussion of analysis and improve techniques. Each driver had 5 warm up laps and then 5 laps in order to become accustomed with the track and correct any

mistakes if necessary (two sets per session). Figure one highlights the fastest time for each session during the first sessions.

	Fastest lap 1 st set	Fastest lap 2 nd set
Driver A	1.37.844	1.37.380
Driver B	1.38.907	1.38.374
Driver C	1.43.943	144.228

Figure 1: fastest lap time for first session

Following the collection of data, the team analysed the data in order for improvements to be made for the next session, the comments are included in figure 2 but these are analysed fully in the results second. One limitation from the first session was that the driver was not debriefed. Not receiving feedback from the driver could have meant that this could have had an adverse effect on future driver performance and future learning (Bentley, 2006).

	Improvements 1 st set
Driver A	Turn 14: (turn earlier) Turn 14: Apply brakes at a later stage
Driver B	Turn 8: take less wide lines Turn 14: use less pressure on brakes into turn Turn 16: use 1 st gear into turn
Driver C	Turn 9: shift on light, do not lift through chicane Turn 16: Use 1 st gear into turn 16

Figure 2: Improvements needed to be made in first session

During the second session all variables stayed the same to ensure nothing apart from driver technique had an impact on performance. Included in figure 3 is the fastest lap times for the second session and figure 4 includes suggestions that were given after the first set in order to aid driver performance. One limitation for the second set was that a debrief was not given between the sets of laps.

	Fastest lap 1 st set	Fastest lap 2 nd set
Driver A	1.37.994	1.38.254
Driver B	1.41.653	1.39.010
Driver C	1.48.498	145.560

Figure 3: fastest lap time for second session

	Improvements 1 st set	Debrief 2 nd set
Driver A	Turn 3-4 (to use Second gear instead of 1st gear) Turn 14 (brake later when entering the corner)	Drivers feedback : Turn 14 Felt like he could have come off the brake sooner on exit.
Driver B	Turn 3-4 (use second gear instead of 1st gear) Turn 6 (Brake later average of 20 meters) Turn 14 (use 1st gear not 2nd)	Drivers feedback : Turn 3-4 felt happier when using second gear but felt he could have still braked later. Turn 14 first gear helped but felt unsettled
Driver C	Turn 7 (use 3rd Gear not 2nd) Turn 14 (ease off the brake) braking to hard	Drivers feedback : Driver was confused when team member was giving out information the wrong time

Figure 3: Improvements needed to be made in second session and debrief feedback

4 Results and discussion

In this section series of key performance indicators will be compared to analyse the driver performance, these include throttle application, steering technique, braking technique and gear selection. According to Seger (2008) this particular type of analysis is used in industry when multiple drivers use the same competition vehicle. Following this, suggestions of improvements will be made for each driver.

4.1 Gear selection

4.1.1 Upshifting

Gear shifting analysis focuses specifically on two aspects; upshifting and downshifting (Hu et al, 2016) From figure one it can be seen that driver C upshifts the gear before driver A and B on several occasions. As upshifting relates driver speed and changing to higher gear (Lopez, 2009), it is important to correlate the RPM and gear shifting during analysis. From figure 4 it can be seen that driver C changes to higher gear at a lower speed than the other drivers.

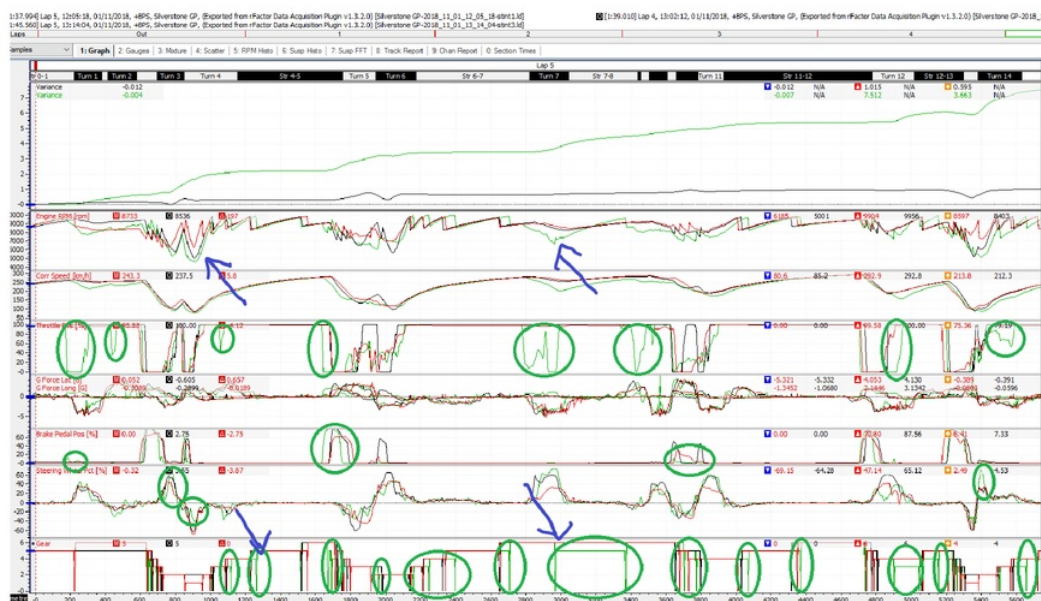


Figure 4: Upshifting gears, driver C

According Segers (2008, page 51) the shifting point “depends on the shape of the power curve, more specifically the total area beneath the power curve situated within the engines operating range”. As this is very similar on driver C’s second test (see figure 5 for second data set and figure 6 for comparison of driver C data) Therefore, in order to make improvements to the driving techniques of driver C, it would be recommended that the shift RPM was increased in order to decrease the area under the power curve.



Figure 5: Upshifting gears, driver C set 2

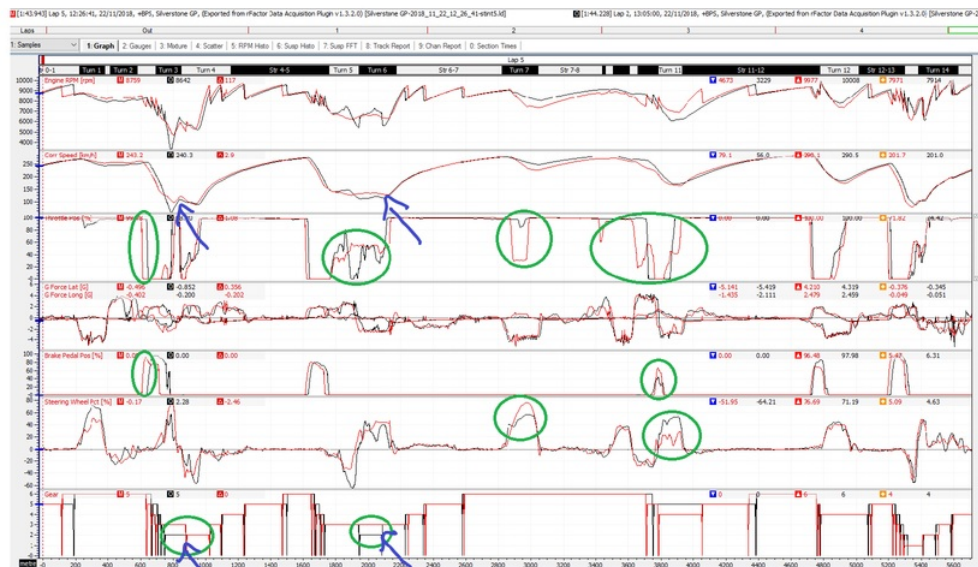


Figure 6: Upshifting gears, comparison of driver C

Looking at the upshifting of driver A (benchmark) and driver B, it is apparent that the upshifting of driver A and B is very similar apart from at the start where driver A upshifts at a lower RPM than driver B (see figure 7 for comparison of driver B against A and C). Also, looking at the comparison of driver A's data for the two tests (see figure 8) it can be established that the shifting point is alike in both sets, suggesting that the optimum gearshift occurs in both sets of data (Brown, 2011).



Figure 7: Upshifting gears, comparison of driver A, B and C

According to Lopez (2009) the shift duration is an important aspect to consider when looking to improve driver performance. From figure 4 it can be seen that the shift duration is more for driver C than the other drivers on several occasions. A maths channel was created to further analyse when each driver shifted gears (see figure 9), from this maths channel it can be seen that driver C upshifts earlier than driver A and B and spend a longer duration. As minimising shift time causes the lap time to reduce (Kegelman, et al 2017) it would be recommended that driver C spends less time between the gears.

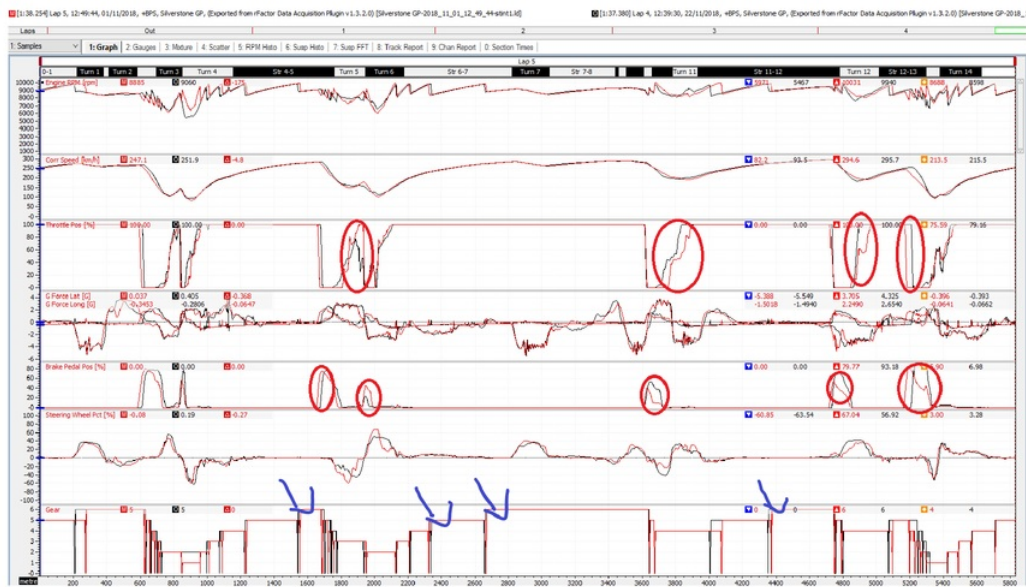


Figure 8: Upshifting gears, comparison of driver A (both sets)

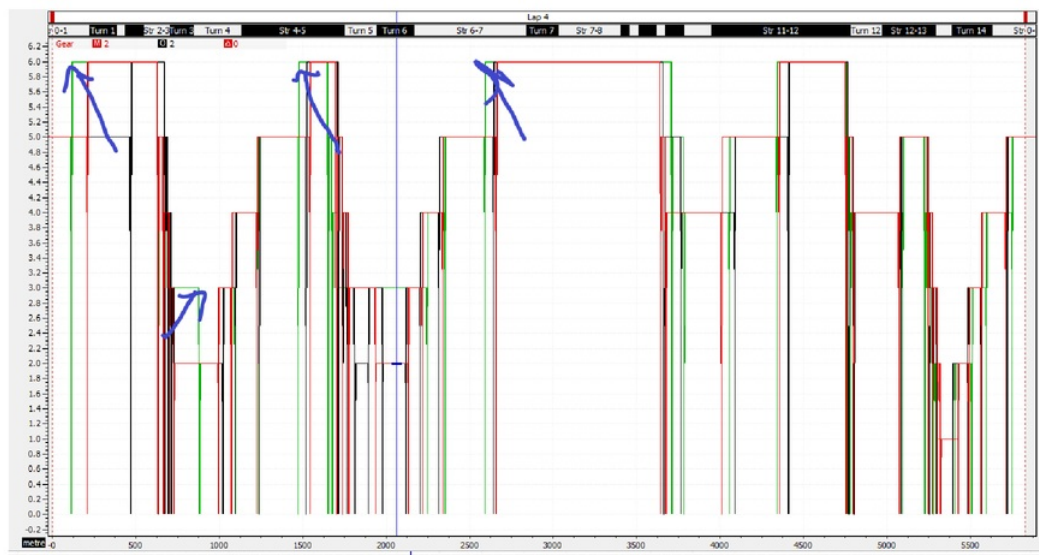


Figure 9: Gear maths channel

4.1.2 Downshifting

Downshifting is associated with the engine speed that the driver changes to lower gear (Brown, 2011). From figure 10 it can be established that there is little difference between the downshifting of all drivers, suggesting that the downshifting of all drivers is fairly efficient throughout the course. Also, the downshifting of all drivers is consistent during both the second and first test. However, it is clear in one section that driver C spends more time downshifting at approximately 1700 meters at the beginning of a corner (see figure 10). As downshifting has an effect on grip and oversteering (Templeman, 2008) this could affect the drivers ability to handle the corner efficiently. Therefore it would be recommended that the driver downshifts less during cornering in order to improve performance.



Figure 10: Comparison of downshifting for all drivers

As downshifting is connected to braking, the braking technique of the drivers will be analysed next.

4.2 Braking

4.2.1 Braking point consistency and hardness

From figure 11 it can be seen that driver C brakes at approximately 200 meters, however as this is rectified during test 2 this suggests this braking episode was caused by driver error. From all figures it is apparent that braking points occur whilst cornering; as the drivers take the corner the

gears are down shifted and the RPM decreases. Therefore, braking episodes of all drivers are consistent. However, it can be established from figure 12 that driver B and C brake harder and slightly before the benchmark during the first test. The time of braking is crucial to performance optimisation, the correct amount of pressure should be put on the brake, according to Driver 61 (No date) "the release of this pressure is critical to the balance of the car when entering a corner". This means that incorrect brake pressure timings may result in the vehicle becoming unbalanced during cornering and therefore will have a negative impact on vehicle performance. Therefore, it would be recommended that both drivers reduce the hardness of braking, however, it can be seen that the hardness of braking is reduced during the second test (see figure 10).



Figure 11: Braking points for driver C



Figure 12: Braking points for driver B and C in comparison to the benchmark (set 1)

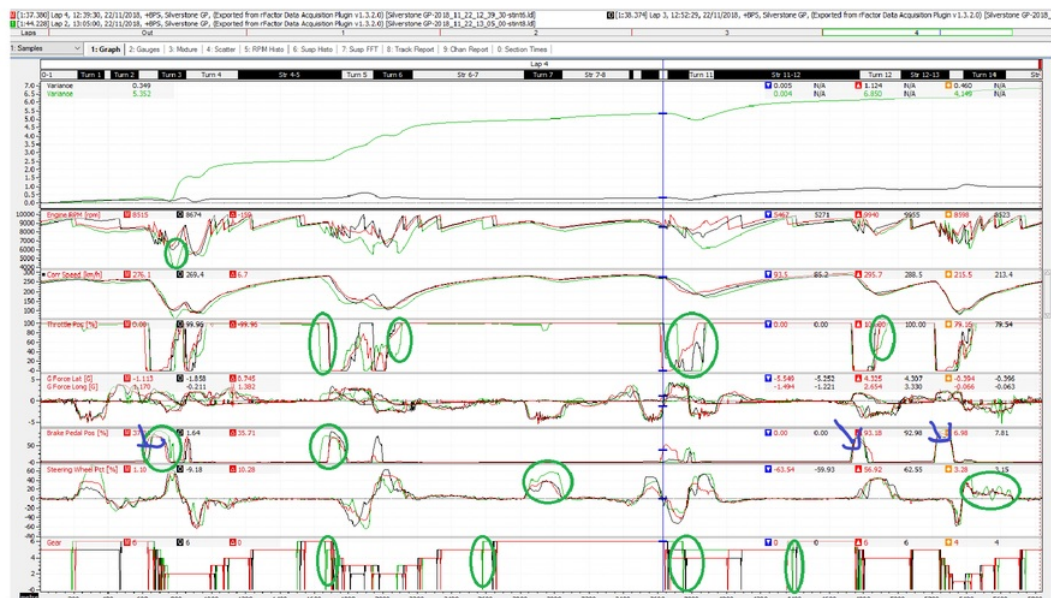


Figure 13: Braking points for driver B and C in comparison to the benchmark (set 2)

4.2.2 Braking pressure

In addition, the braking pressure is greater than the benchmark for driver B and C during both data sets. This suggests that the movement from throttle to brake pedal was slower for driver B and C (Driver 61, no date). This is also confirmed using a maths channel, the calculation for this channel was worked out by using the following formula on Motec: derivative ('brake pedal pos' [%]). Figure 14 shows that driver B spends more time braking during the fastest lap in comparison to the other drivers.



Figure 14: Maths channel for braking pedal position

As too much braking pressure can cause the lap time to become reduced it would be recommended that both drivers apply less pressure when braking. Also it can be seen in figure 15 that the benchmark driver releases the pressure smoothly, whereas driver B and C's braking technique is quite harsh, an example of this is at approximately 3700 meters on the first data set. As the gentle release of brake pressure improves performance (Milligan, 2003) it would be recommended that driver B and C practice the gradual release of pressure after braking. However, it is important to note that the amount of pressure applied and the release of the pressure will vary during every braking episode (Bentley 2017) this can be seen in both sets of data. Therefore, it would be recommended that driver B and C practices the appropriate pressure release for each braking episode.



Figure 15: Brake pressure comparison for all drivers

4.3 Throttle application

The amount of time spent in full throttle can decrease lap times (Smith, 2012). From looking at the screenshots it can be seen that the benchmark driver spends more time in full throttle. In addition, figure 16 illustrates that driver C reduces the throttle on several occasions throughout the track whereas driver A and B do not. This reduction of throttle application could explain why driver C's lap time on the first set is significantly more than driver A and B. However, this is corrected by driver C on the second set (see figure 17) and this could therefore suggest it was caused because the driver was not used to the layout of the track.

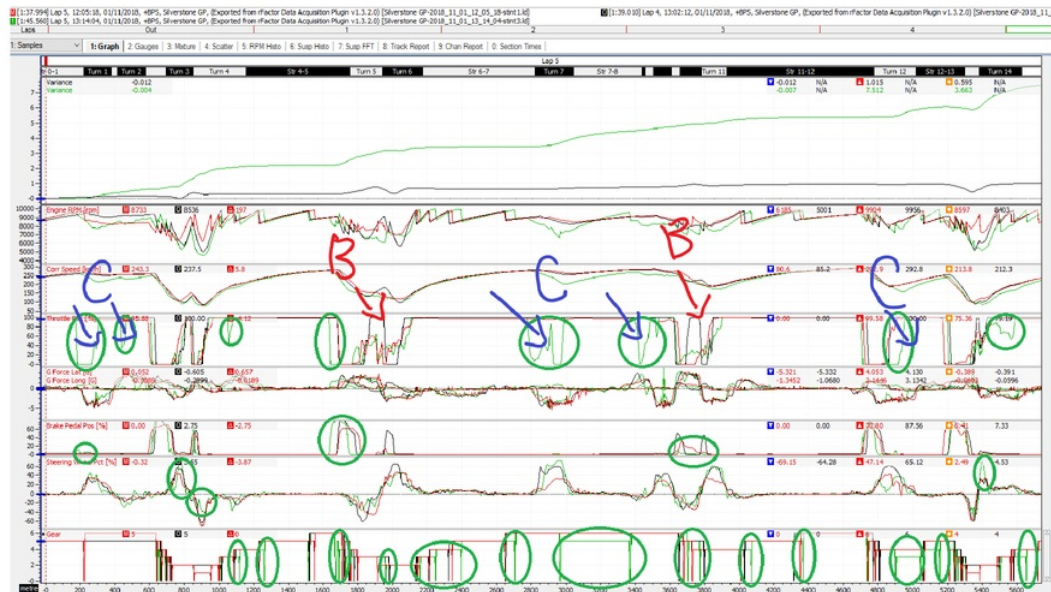


Figure 16: Throttle application comparison all drivers

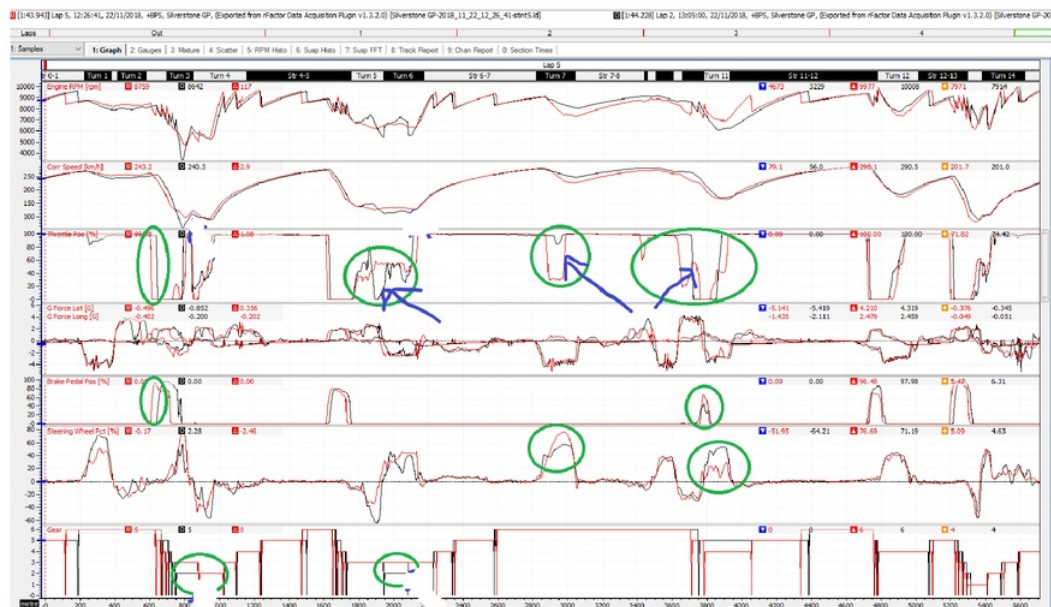


Figure 17: Comparison of throttle application for driver C

From the data it can be established that driver B produces a greater throttle application at approximately 1800 meters and 3700meters (see figure 16) , as the steering wheel position of all drivers fluctuates greatly during these points, this suggests that driver B is producing more throttle than the other drivers during cornering. This is also confirmed by using the throttle speed maths

channel on Motec (see figure 18) , the calculation was: Derivative ('throttle pos' [%]).



Figure 18: Throttle position maths channel

According to Alexander (2012) full throttle application at an incorrect time during cornering could cause unwanted wheelspin and unbalance in the vehicle, therefore it would be recommended that the driver improves on throttle application timing during cornering. To add to this, throttle application must alter appropriately throughout the course in order to enhance performance, for example, if full throttle is applied just before a high-speed corner, the car will become more set and balanced (Parker and Hargrave, 2015). To analyse this further, the throttle position of the benchmark driver was compared using the first and second data set, however there was minimal change in the lap time and therefore not a significant difference. (see figure 19), this screenshot illustrates that driver A applied the throttle at a slightly later time during the second data set (black line = 1st set, red line = 2nd set). As the second set time was quicker than the first, this suggests that full throttle was applied at a more appropriate time during the second set as the lap time was shorter. However, as maximum throttle was applied at an earlier stage during set one this suggests that the steering lock was opened at a sooner stage during the first set, this allowed the driver to exit the corner faster (Driver 61, no date).



Figure 19: Comparison of throttle application for the benchmark driver

4.4 Steering techniques

According to Brown (2011) data gathered from the steering wheel gives the driver an indication of incidences occurring between the front wheels and the track, from all figures it can be seen that the steering wheel angle is consistent between all drivers apart from when cornering. From all sets of data in can be seen that there are irregularities in driving techniques during cornering. It is illustrated in figure 20 (set 1) and 21 (set 2) that driver C has a much greater steering angle during several sections on the course. This can also be seen for driver B at approximately 2000 meters on the first set. According to Bentley (2017) this could indicate that the driver has either understeered or oversteered. As both understeering and oversteering relate to an excessive steering angle (2011) it could be difficult to determine whether the drivers are understeering or oversteering. An indicator of understeering is when the steering angle peaks before the lateral G's (Brown 2011) as this does not significantly happen on the screenshots it is more likely that oversteering has occurred.



Figure 20: Comparison of steering angle for all drivers (set 1)

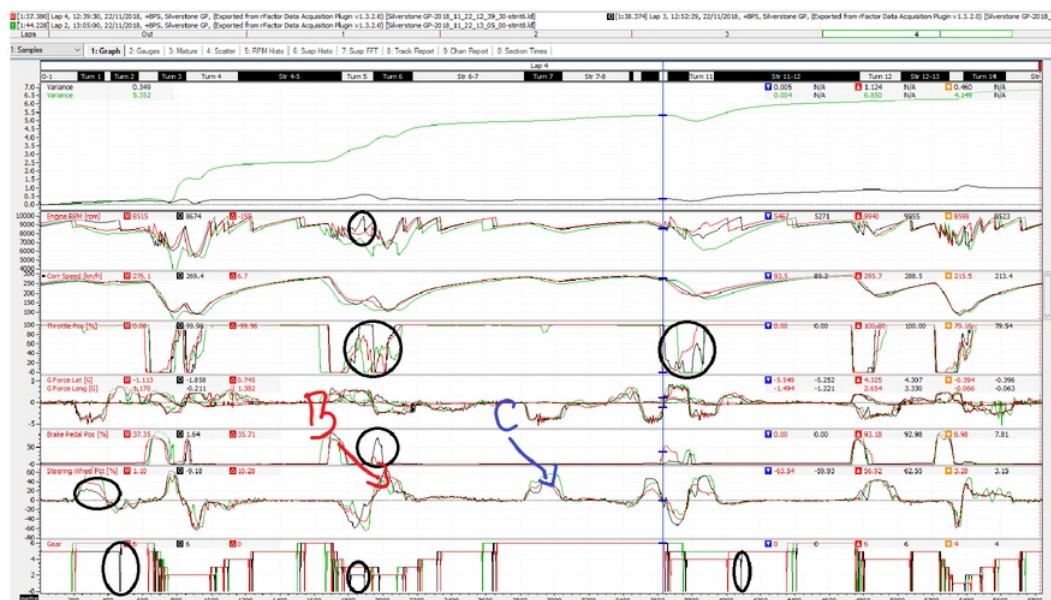


Figure 21: Comparison of steering angle for all drivers (set 2)



Figure 22: steering angle against throttle application for drivers B and C

Furthermore, Segers (2008, page 64) suggests that an indicator of oversteering is “when the vehicle is not willing to accept full throttle” from looking at figure 22 it can be established that the throttle position of driver B is significantly lower than the other drivers during this point of the track. The exact same incidence occurs with driver C at approximately 3000 meters, suggesting that both drivers have oversteered during the course.

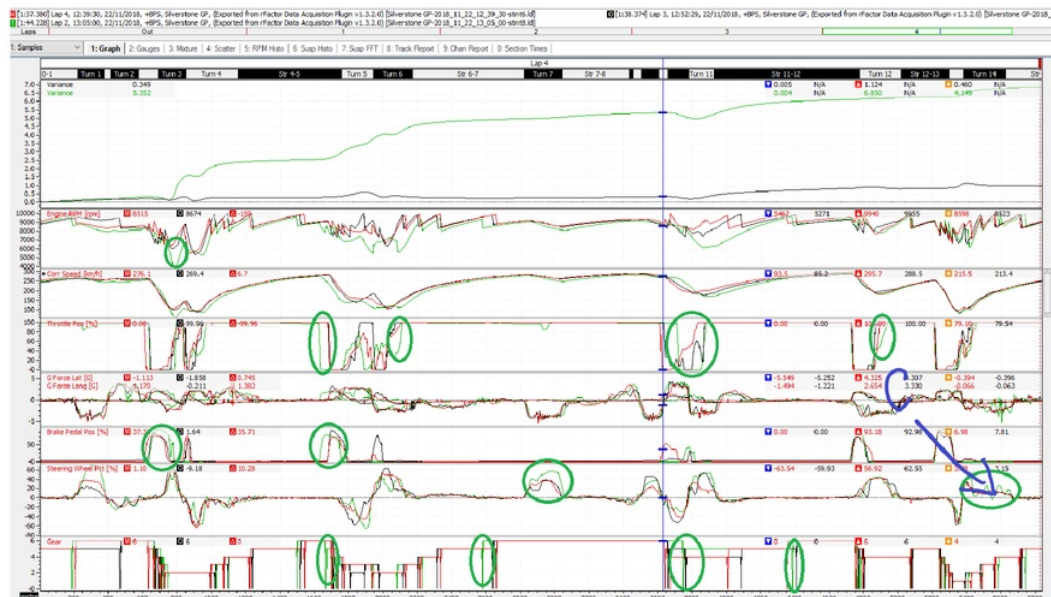


Figure 23: Driver C steering angle fluctuation in comparison with driver A and B



Figure 24: Driver C steering angle fluctuation for both sets of data

Another irregularity in the steering angle occurs at approximately 5400 meters for driver C during the first and second test set. The steering angle fluctuates greatly but this does not happen for the other drivers, this confirms that it is not linked to track surface (Korf, 2016). One explanation for these fluctuations is that the driver is correcting the steering angle (Lopez, 2009). Seger (2008) adds to this further and considers that small dips in lateral G suggest that corrections to oversteering have been made. This can be seen for driver C but not as much for driver B (see figure 23), implying that oversteer is being corrected by the driver. According to Driver 61 (no date), one of the causes of oversteering is braking too much when entering the corner, figure 25 shows that driver B applied significantly more brake pressure when the car oversteered, therefore it would be recommended that driver B applied less brake pressure during cornering. Also a maths channel was created in order to further analyse the lateral G and longitudinal G whilst cornering (see figure 26). From this maths channel it can be seen that driver B and C reach a higher lateral G than the benchmark driver whilst cornering, suggesting that more force is being felt whilst cornering and implying that the racing line of these drivers is not as good as the benchmark driver (Brown, 2011). Therefore, it would be recommended that these drivers work on their braking point and turn-in line more. Also a great difference can be seen between the longitudinal G of driver C in comparison to the other drivers, this could be the difference between the throttle application of driver C and other drivers, this was discussed previously in this section.



Figure 25: Steering angle against brake pressure for driver B

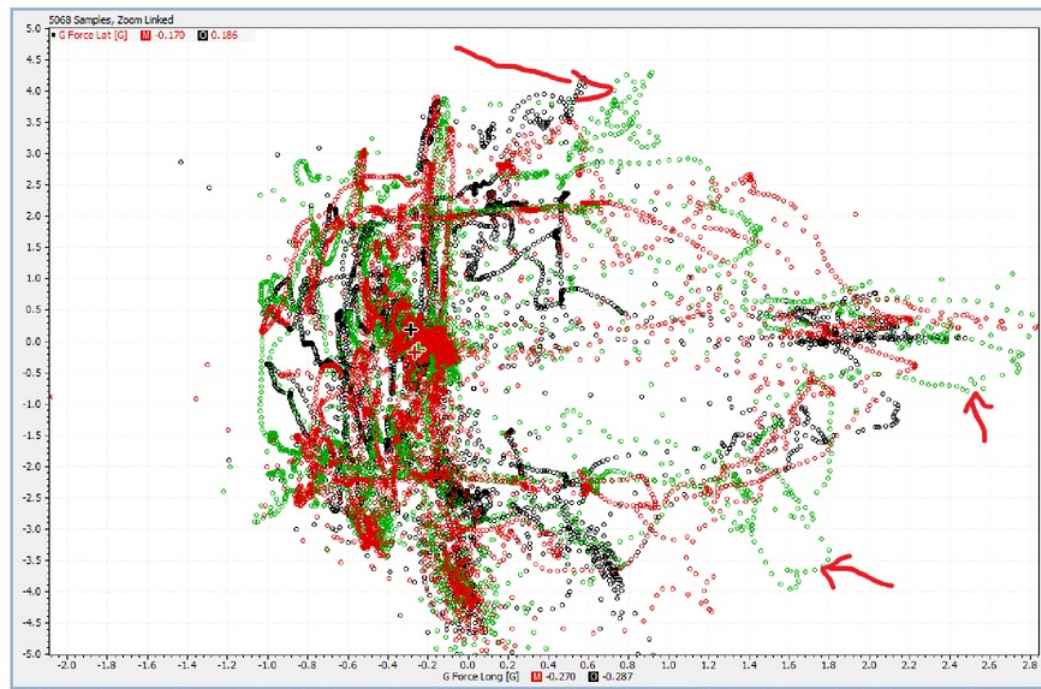


Figure 26: Maths channel longitudinal G and Lateral G whilst cornering

5.0 Conclusion

From this report it can be seen that the driving techniques vary greatly; the benchmark driver had little driving faults and therefore possessed the fastest lap time. Data showed that the driver techniques largely affect the vehicle response and overall consistency of the laps. From data analysis it emerged that factors such as upshifting gears too soon and the time spent changing gears potentially has a large impact on driver performance. In addition, the amount of brake pressure applied and braking consistency also has an effect on overall performance. To add to this, it can be seen that steering techniques can affect the overall control of the vehicle and the ability to apply full throttle, meaning that speed is slower and lap time increases. Therefore, it can be established that driving techniques had a significant impact on the time it took for each driver to complete the lap. Suggestions to improve driving techniques in order to enhance performance were made in the report, however, it is important to note that many of the faults were rectified by the drivers themselves during the second set of data possibly meaning that faults were caused as driver B and C were not used to using simulation software. Recommendations included practicing timings more during gear selection, cornering and throttle application and applying less pressure when braking.

In summary, it can be determined that data acquisition software has been a reliable tool to use in order to analyse the techniques of the drivers from the simulator test and subsequently improve performance. However, it is important to remember that when using data acquisition for real road driving conditions that aspects such as the chassis and driver performance confused with each other as this could cause unreliable results.

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