Video Eyeglasses, iPhone and Multiple Video Cameras - An Effective Data Acquisition System For Motor Vehicle Accident Analysis and Reconstruction

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In the last several years Gorski Consulting has been involved in the development of a variety of instruments that can be used as an inexpensive and effective system to gather and analyze data for the purpose of the reconstruction of motor vehicle collisions. This article will discuss the latest version of this system which incorporates the use of multiple video cameras, a basic driver eye-tracking device, and the accelerometer/gyro functions of an Apple iPhone.

Review of Instrumentation

On February 3, 2014 Gorski Consulting conducted testing of the latest version of a data acquisition system for motor vehicle collision analysis. The testing was conducted on Ashland Avenue, a quiet street in central east London, Ontario, Canada.

Figure 1 below shows a map of the testing site. Figure 2 shows a closer view of the route with the names of the streets that were passed along the test run.

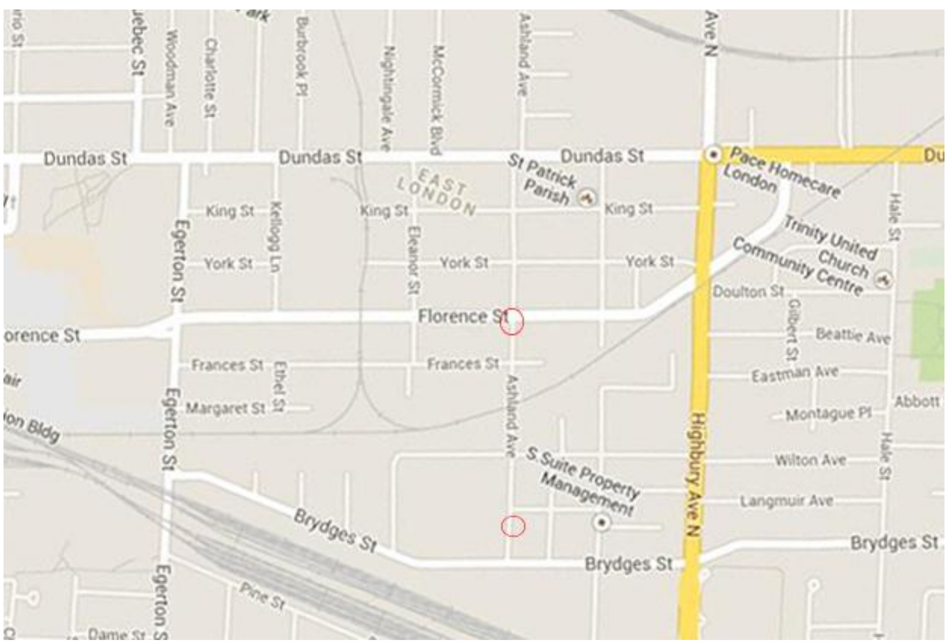

Figure 1: Map of testing site. The red circles indicate the starting and end points of the test route.

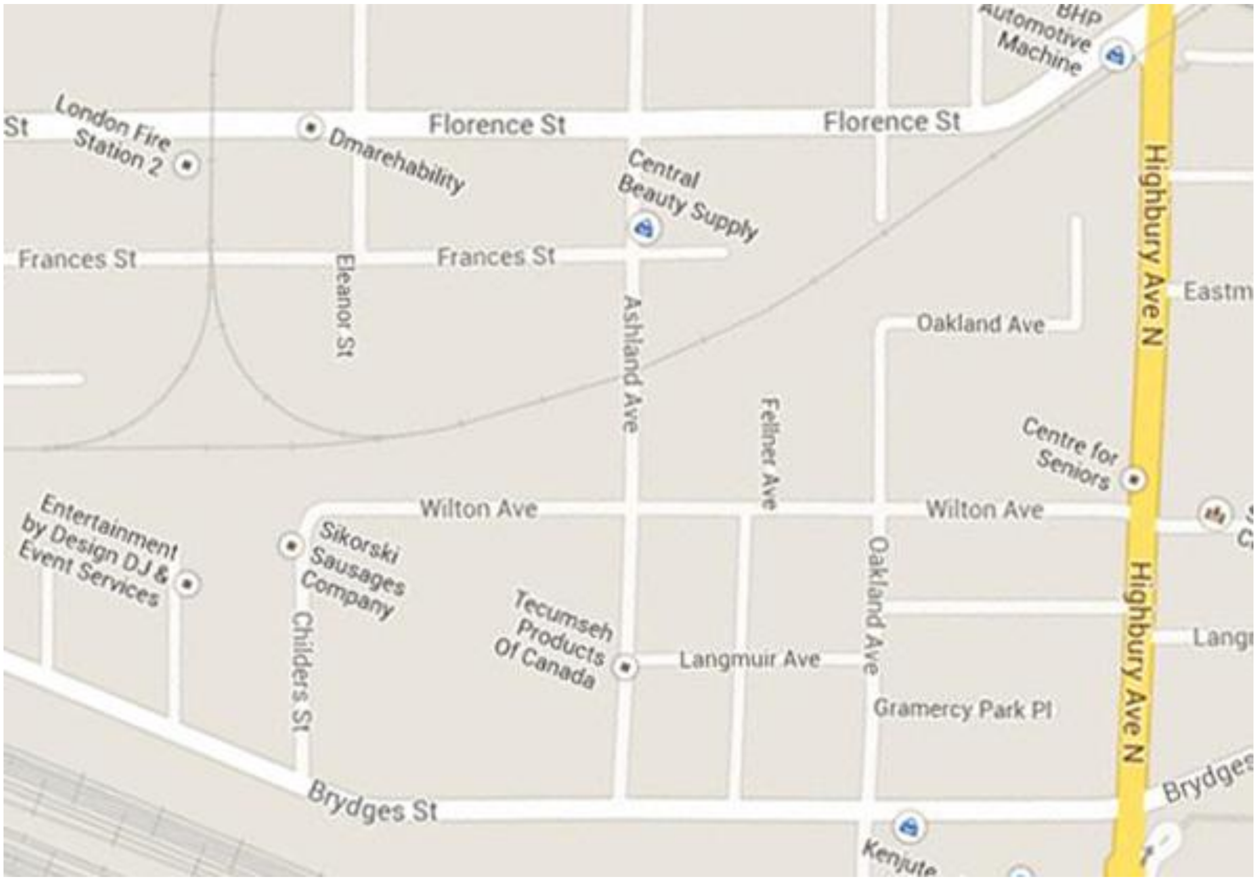

Figure 2: Closer view of test route and names of streets along the route.

As noted in Figures 1 and 2, Ashland Avenue is a short street that runs north/south in an industrial/residential area of the City of London. The red circle at the bottom (south) of Figure 1 is where the test vehicle commenced it motion, just north of the intersection with Brydges Street, and it travelled northward to the point indicated by the second red circle, at the intersection with a four-lane, arterial roadway, Florence Street.

Our test vehicle, a 2007 Buick Allure passenger car, was equipped with eight video cameras. The views from these cameras are shown in the following figures.

GoPro23 was a camera mounted to a bike rack at the back of the test vehicle and this view showed the rear and left side of the test vehicle. The following figures show the views from this camera at several reference locations along the test route.

Figure 3 (below) shows the view from this camera as our test vehicle was stopped at the south end of Ashland Avenue at the beginning of the testing. Figure 4 shows the view from GoPro23 as the test vehicle passed Langmuir Avenue. Figure 5 shows the vehicle approaching the stop sign at Wilton Avenue. Figure 6 shows the vehicle crossing the railway tracks. Figures 7, 8 and 9 show the test vehicle as it approaches the stop sign at Florence Street and comes to a halt. The driver stops at this location for about 40 seconds and makes observations of the cross traffic before making a left turn. Much of our discussion will involve the driver's observations at this stop sign.

Figure 3: View from GoPro23, anchored to a bike rack at the back of the test vehicle. This figure shows the vehicle at the start of the testing at the south end of Ashland Avenue.

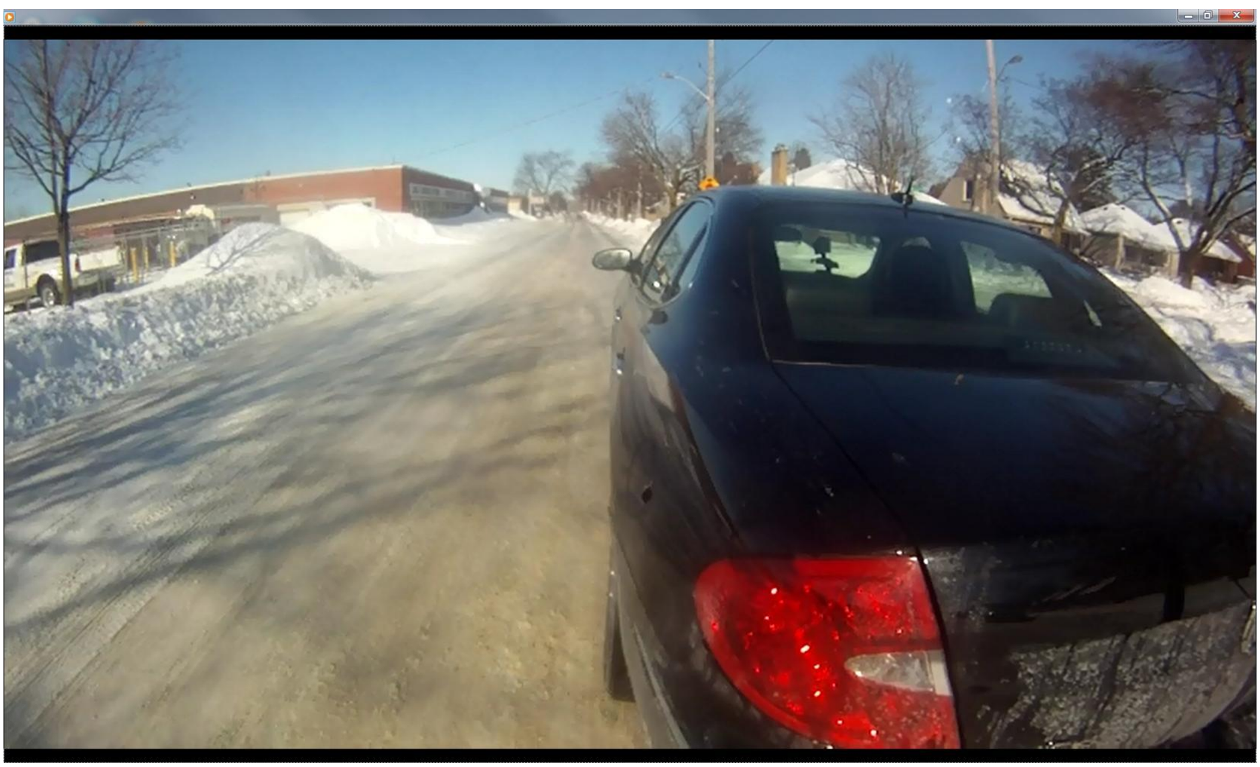

Figure 4: View from GoPro23 showing our test vehicle passing Langmuir Avenue.

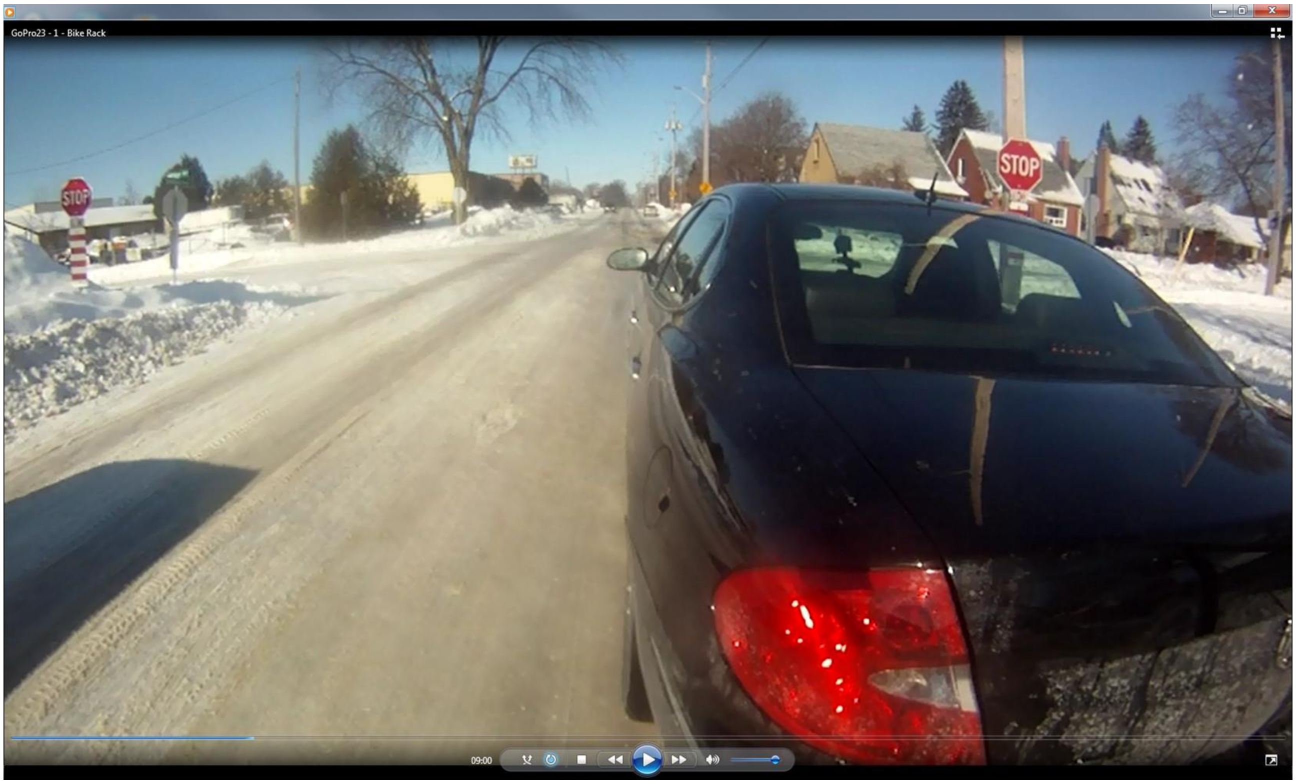

Figure 5: View from GoPro23 showing test vehicle approaching the stop sign at Wilton Avenue.

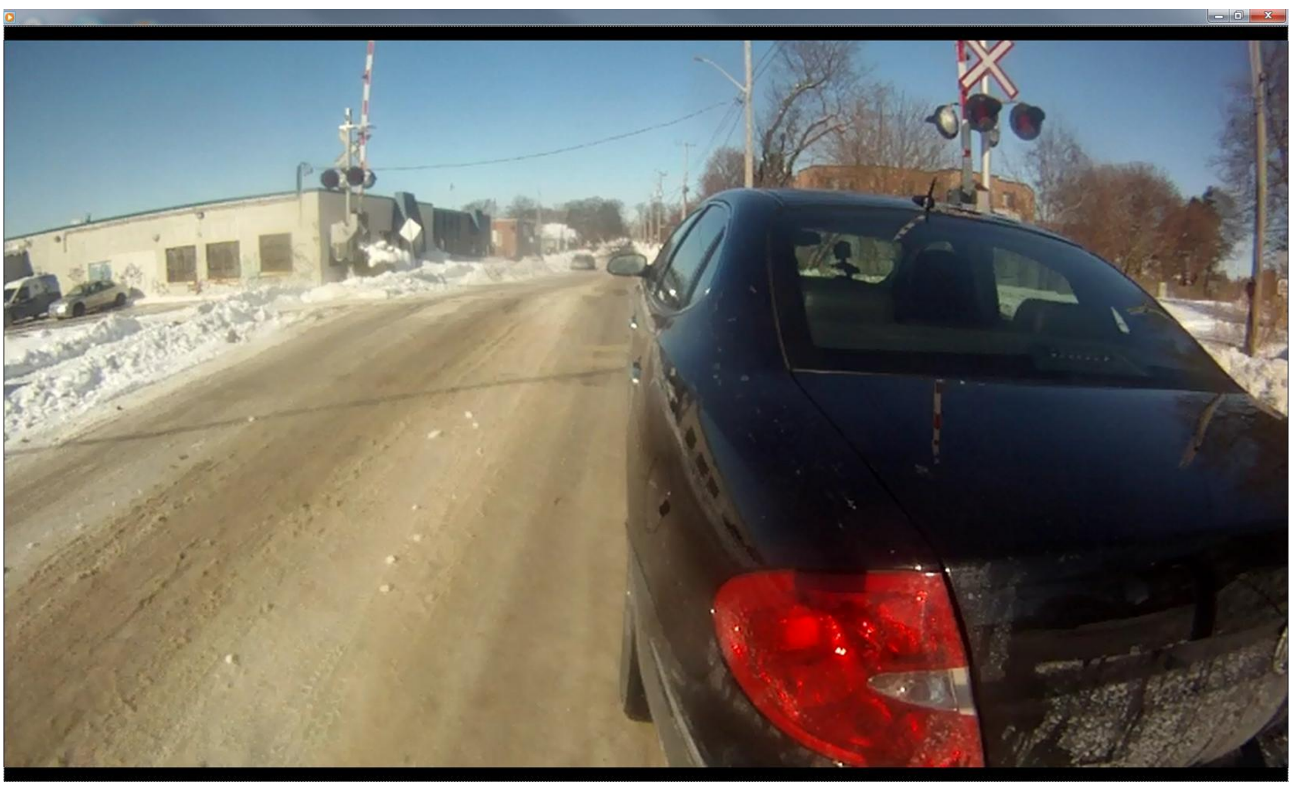

Figure 6: View from GoPro23 showing test vehicle approaching the railway tracks.

Figure 7: View from GoPro23 showing test vehicle approaching the intersection at Florence Street.

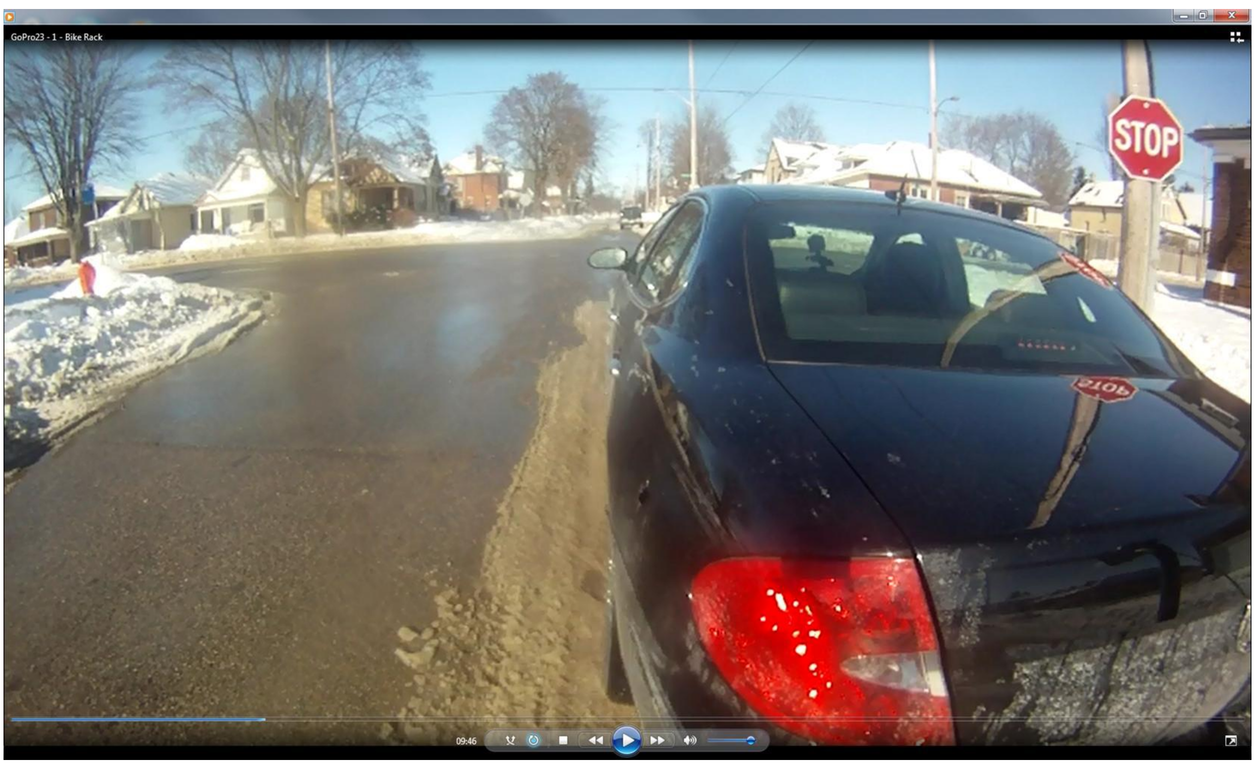

Figure 8: View from GoPro23 showing the test vehicle approaching the stop sign at Florence Street.

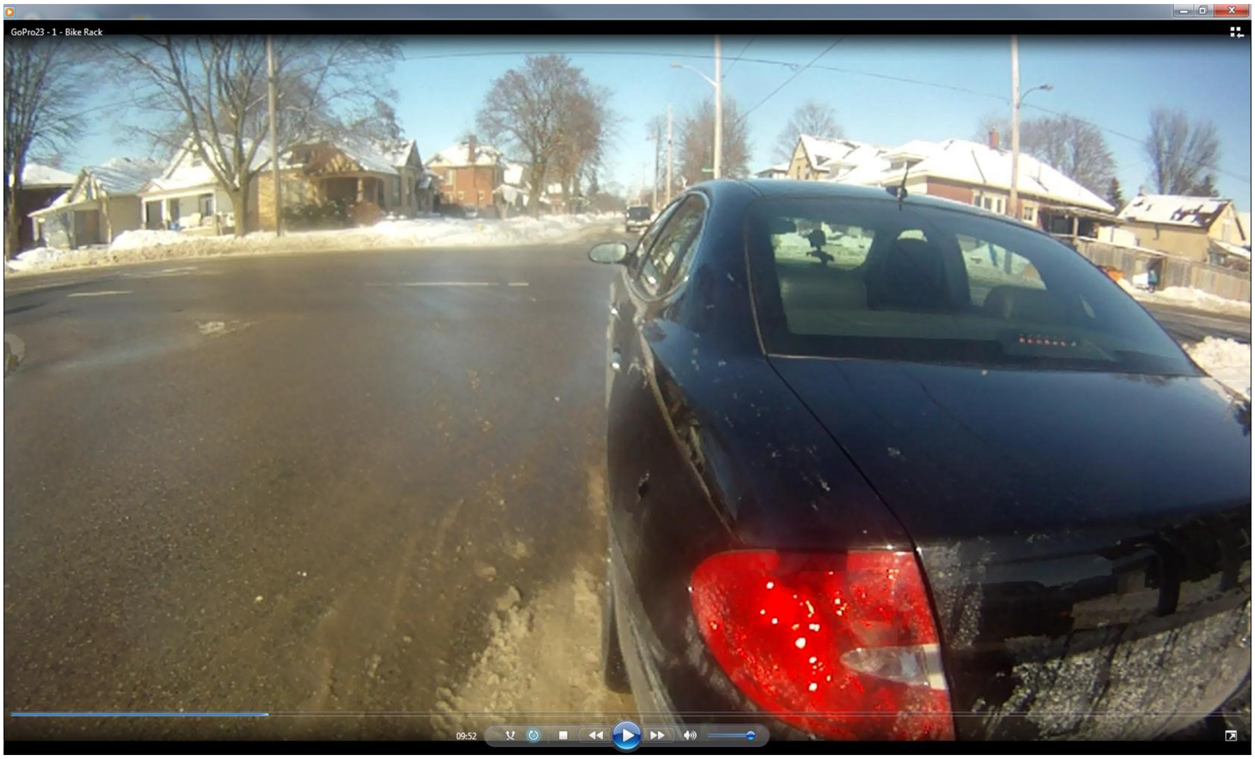

Figure 9: View from GoPro23 showing the test vehicle at its stop position at the intersection of Florence Street.

The next set of figures will show the same set of reference views along the test route but shown from the view of the Canon camera which mounted in the centre of the vehicle's windshield, looking forward, and zoomed in to show a much narrower field of view than GoPro23.

So Figure 10 shows a view from the Canon camera at the start of the testing, which is the same position as shown in Figure 3.

Figure 11 shows the view when the test vehicle is approaching Langmuir Avenue, which is similar to the position shown in Figure 4.

Figure 12 shows the view when the test vehicle is approaching the stop sign at Wilton Avenue, which is similar to the position shown in Figure 5.

Figure 13 shows the view when the test vehicle is approaching Florence Street, which is similar to the position shown in Figure 6.

Figure 14 shows the view when the test vehicle is approaching Florence Street, which is similar to the position shown in Figure 7.

Figure 15 shows the view when the test vehicle is approaching the stop sign at Florence Street, which is similar to the position shown in Figure 8.

Figure 16 shows the view when the test vehicle is stopped at the stop sign at the intersection with Florence Street, which is similar to the position shown in Figure 9.

Figure 10: View from the Canon camera from the start position of the testing at the south end of Ashland Avenue. This is the same location as shown in Figure 3.

Figure 11: View from Canon camera as the test vehicle approaches the intersection of Langmuir Avenue.

Figure 12: View from Canon camera as the test vehicle approaches the stop sign at Wilton Avenue.

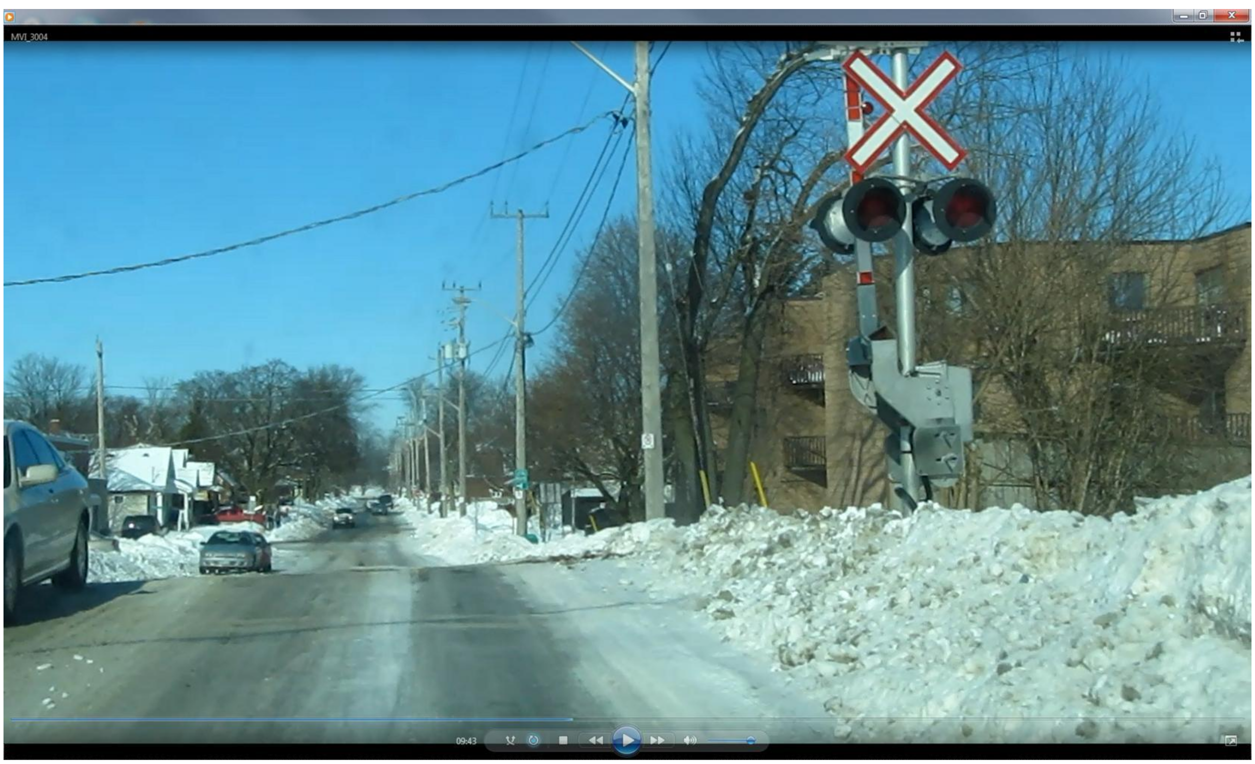

Figure 13: View from Canon camera as the test vehicle approaches the railway tracks , which is similar to the position shown in Figure 6.

Figure 14: View from Canon camera as the test vehicle approaches Florence Street.

Figure 15: View from Canon camera as the test vehicle approaches the stop sign at the intersection with Florence Street.

Figure 16: View from Canon camera as the test vehicle is stopped at the stop sign at the intersection with Florence Street.

As part of our instrumentation we equipped the test driver with a set of eyeglasses which had a video camera attached to the frame approximately at the bridge of the nose, as shown in Figure 17. We developed an anchorage for the mirror that allowed the videotaping of the driver's right eye.

Figure 17: View of video eyeglasses with an attached mirror used to document the motion of a driver's right eye.

Figure 18 shows a view of the interior of the test vehicle taken from a camera (GoPro31) that is attached below the driver's sun-visor and is pointing rearwards toward the driver. The test driver is wearing the noted video sunglasses.

Figure 18: View of test driver wearing the video sunglasses while looking straight ahead in the test vehicle.

Figure 19 is a view from GoPro31 showing the test driver looking fully to the left while stopped at the stop sign at Florence Street.

Figure 19: View from GoPro31 showing the test driver looking fully to the left while stopped at the stop sign at Florence Street.

Figure 20 is another view from GoPro31 showing the test driver looking fully to the right while stopped at the stop sign at Florence Street.

Figure 20: View from GoPro31 showing the test driver looking fully to the right while stopped at the stop sign at Florence Street.

GoPro30 was another camera that was anchored between the two front seatbacks and it was pointed forward to capture the rotation of a large protractor that was mounted to the steering wheel of the test vehicle. A view from this camera is shown in Figure 21.

Figure 21: View from GoPro30 showing the protractor attached to the steering wheel hub to document the speed and magnitude of steering wheel rotation.

We also had a video camera (GoPro28) attached to face the instrument cluster of the vehicle and this documented information such as the vehicle speed, tachometer reading, turn signal activation, odometer/tripometer data, and outside air temperature. The sample view from this camera is shown in Figure 22.

Figure 22: View from GoPro28 showing the instrument cluster of the test vehicle. In the present view the test vehicle is travelling about 21 km/h, the tachometer reads about 1300 rpm and the left turn signal is activated. The outside air temperature reads -7 C.

We also attached a video camera (GoPro26) to the left wall of the floor pan in the vicinity of the driver's foot pedals. A flashlight provided additional lighting so that the video camera could detect the motion of the driver's feet and the application of the brake and accelerator pedals. A piece of yellow tape was attached to the left edge of the brake pedal to make it more visible in the dark conditions so that its motion could be properly documented. A sample view of the brake and accelerator pedals from GoPro26 is shown in Figure 23.

Another video camera (GoPro24) was attached to point down onto the centre console between the two front seats where an iPhone was anchored to a horizontal plate. The accelerometer of the iPhone was used to save a file of the accelerations experienced by the centre-of-gravity of the test vehicle and this file was then transferred via e-mail to a host computer and later transferred into an excel spreadsheet. Charts were created from this data and will be shown in a latter portion of this article.

Figure 23: View from GoPro28 showing the test driver's brown boot pressing on the brake pedal. Yellow tape has been attached to the left edge of the brake pedal for better viewing.

Figure 24: View from GoPro24 showing the face of the iPhone as it is being set-up to start recording of the readings from its accelerometer.

Figure 25 shows a view of what was recorded by the video eyeglasses when the driver looked to his left and into his driver's exterior mirror.

Figure 25: View from video eyeglasses when the test driver looked toward the driver's exterior mirror. The view of the pupil of the driver's right eye is visible in the small mirror in the bottom centre of this figure.

Note in the bottom of the centre of Figure 25 that the mirror that is attached to the frame of the eyeglasses has captured the position of the pupil of the driver's right eye. At this instance the pupil is located centrally within the eye.

Similarly, Figure 26 shows what is was captured by the video eyeglasses when the driver looked at the rear view mirror. Here the pupil is rotated toward the right in the eye.

Similarly, Figure 27 shows what was captured by the video eyeglasses when the driver looked straight ahead.

Figure 28 shows the view from the video eyeglasses when the driver is stopped at the intersection of Florence Street and the driver looks fully to the left.

Figure 29 shows the view from the video eyeglasses when the driver is stopped at the intersection of Florence Street and the driver looks fully to the right.

Figure 26: View from the video eyeglasses as the driver looks into the rear view mirror.

Figure 27: View from the video eyeglasses as the driver looks straight ahead while approaching the intersection with Florence Street.

Figure 28: View from video eyeglasses as the vehicle is stopped at the intersection of Florence and the driver looks fully to the left. Here you can clearly see the driver's pupil is rotated into the far left corner of the eye.

Figure 29: View from video eyeglasses as the vehicle is stopped at the intersection of Florence and the driver looks fully to the right. Note that the driver's pupil is rotated into the far right corner of the eye.

Testing Procedure & Test Results

The testing procedure involved anchorage and start-up of the eight video cameras at another site. Once the video cameras started recording the test vehicle was driven to the location of the test site on Ashland Avenue and parked at the location shown in Figures 1, 3 and 10. While parked, the test driver activated the accelerometer recording of the iPhone. The driver then moved his head to look at all the mirrors to give an indication in the video cameras what those head and eye positions would look like.

Once this initialization was completed the vehicle transmission was placed in Drive, the brake pedal was released, and the driver began driving the test vehicle northbound on Ashland Avenue. The test driver drove the vehicle in a normal fashion past the T-intersection at Langmuir Avenue. The driver came to a rolling stop at the 4-Way stop at the intersection with Wilton Avenue. The driver then travelled over the railway tracks and past the intersection at Frances Street before coming to a halt at the stop sign at the intersection with Florence Street. A number of vehicles were encountered at Florence therefore the test driver was stopped there approximately 40 seconds as he had to look left and right to determine when it was safe to commence a left turn onto Florence.

The testing that is described here occurred over a period of 2 1/2 minutes (150 seconds). It starts at the instant that the iPhone started its recording, when the vehicle was still stopped, and it ended when the test vehicle was proceeding through its left turn after the 40-second stop at Florence.

Several charts have been created to show the value of the longitudinal acceleration of the test vehicle as it travelled along Ashland Avenue for the noted150 seconds. Each chart contains 30 seconds of data and the charts over-lap each other so that one can obtain an appreciation of how the data flowed across the full 150 seconds.

Chart 1 shows the first 30 seconds of acceleration data. Note that in the first 13.5 seconds the test vehicle is stopped while the driver is looking into his mirrors before setting the vehicle in motion. Thus there is essentially no longitudinal acceleration displayed in the first 13.5 seconds. The vertical axis in all the charts has limits of acceleration between 0.3 and -0.3 g.

Once the vehicle begins to move forward we see the values of the longitudinal acceleration displayed as negative values. The negative values are just an artifact of the way we have anchored the iPhone. So, in the present case, negative values indicate actual positive acceleration and vise versa.

In Chart 2 we see the data from 20 to 50 seconds, so there is 10 seconds of overlap between end of the data in Chart 1 and the beginning of the data in Chart 2.

In the first half of Chart 2 we see that the vehicle continues to accelerate and then the acceleration begins to move in the negative direction as the vehicle begins to slow down on approach to the stop sign at Wilton Avenue in the vicinity of about 40 seconds.

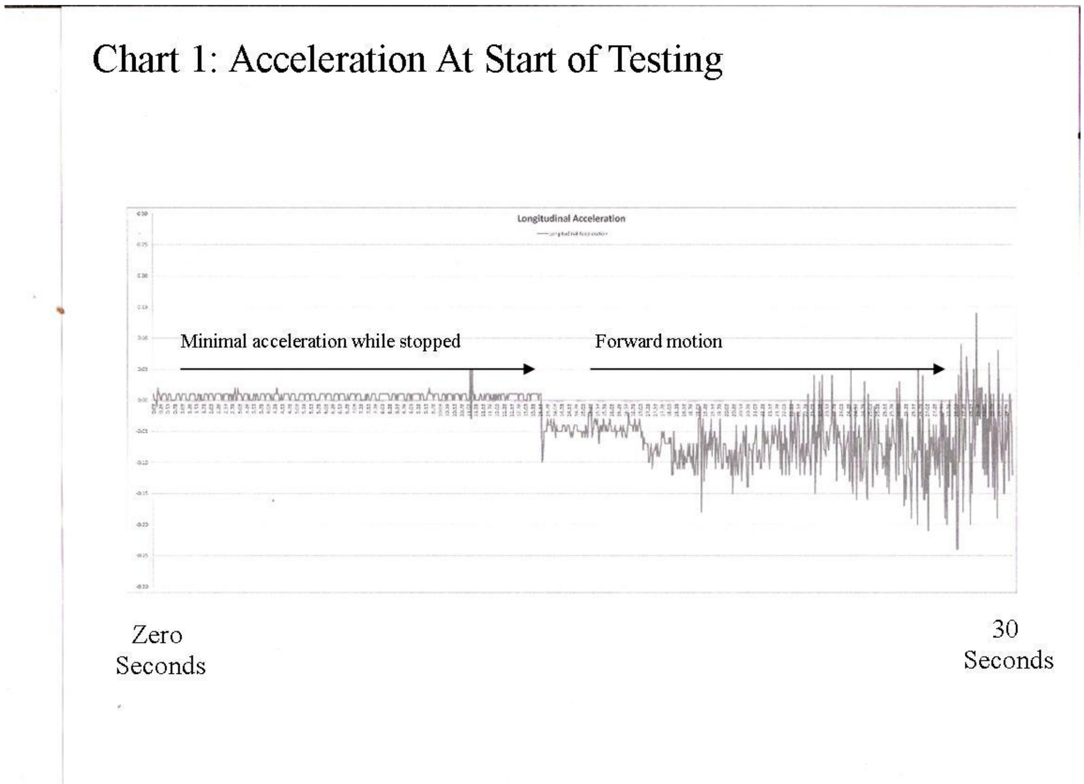

Figure 30: Chart 1 of Longitudinal Acceleration

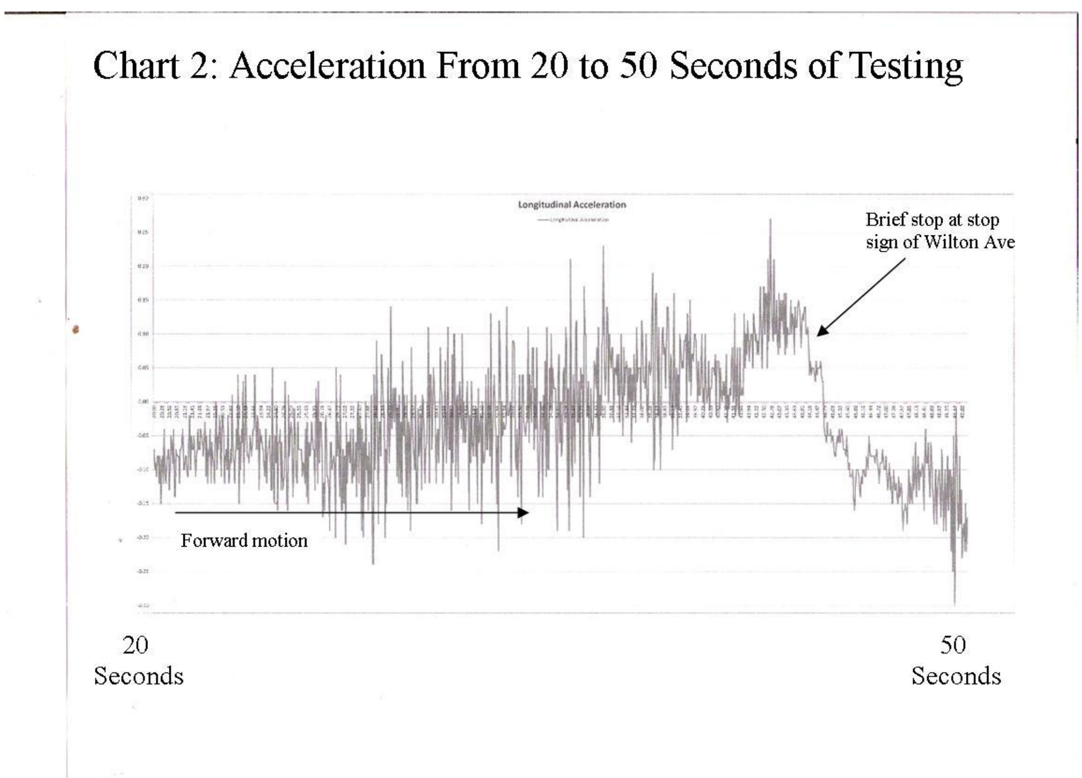

Figure 31: Chart 2 of Longitudinal Acceleration

Chart 3 contains the data from 40 to 70 seconds. As in previous charts the data is overlapped by 10 seconds. Near the beginning of the chart we see the location (about 44 seconds) where the vehicle has performed a rolling stop at Wilton Avenue and this portion of data was also displayed near the end of Chart 2. Then the vehicle commences to increase speed up to about 49.5 seconds as the longitudinal acceleration increases. Following this the longitudinal acceleration begins a gradual tendency toward negative values as the vehicle approaches the railway tracks. There is a high amplitude of positive/ negative acceleration that occurs at about 64.5 seconds as the vehicle crosses the railway tracks.

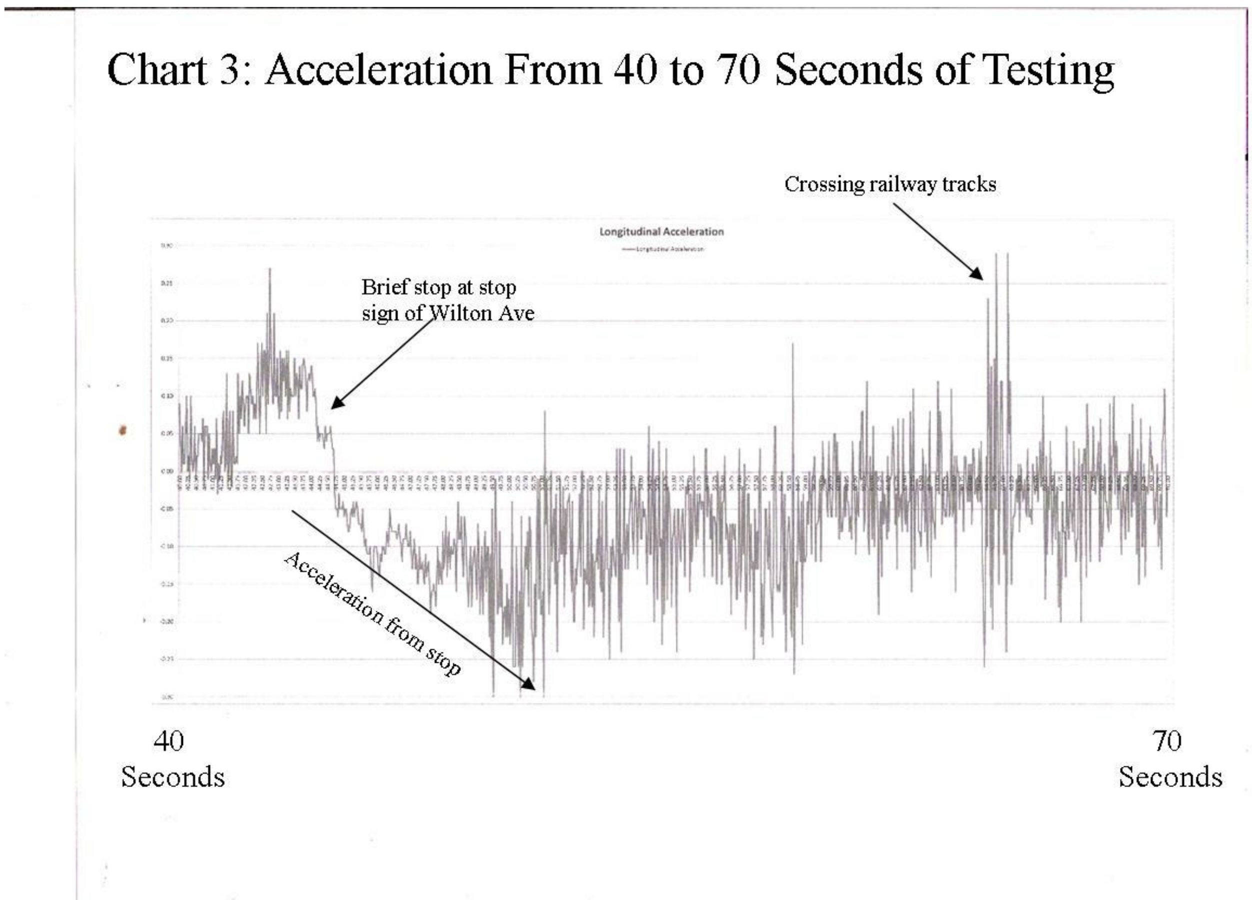

Figure 32: Chart 3 of Longitudinal Acceleration

Chart 4 contains the data from 60 to 90 seconds. Here again we see, near the beginning of the chart, the vibrations caused when crossing the railway tracks and this was seen near the end of the data in Chart 3. One can note the vibrations in the acceleration data as the vehicle travels over the road surface which is covered in compacted snow that is hardened to mimic the hardness of ice. So as there are "potholes" in the otherwise smooth layer of snow this causes the noted vibrations. Near the end of the data the acceleration tends toward negative values as the vehicle begins to slow its speed while approaching the stop sign at Florence Street.

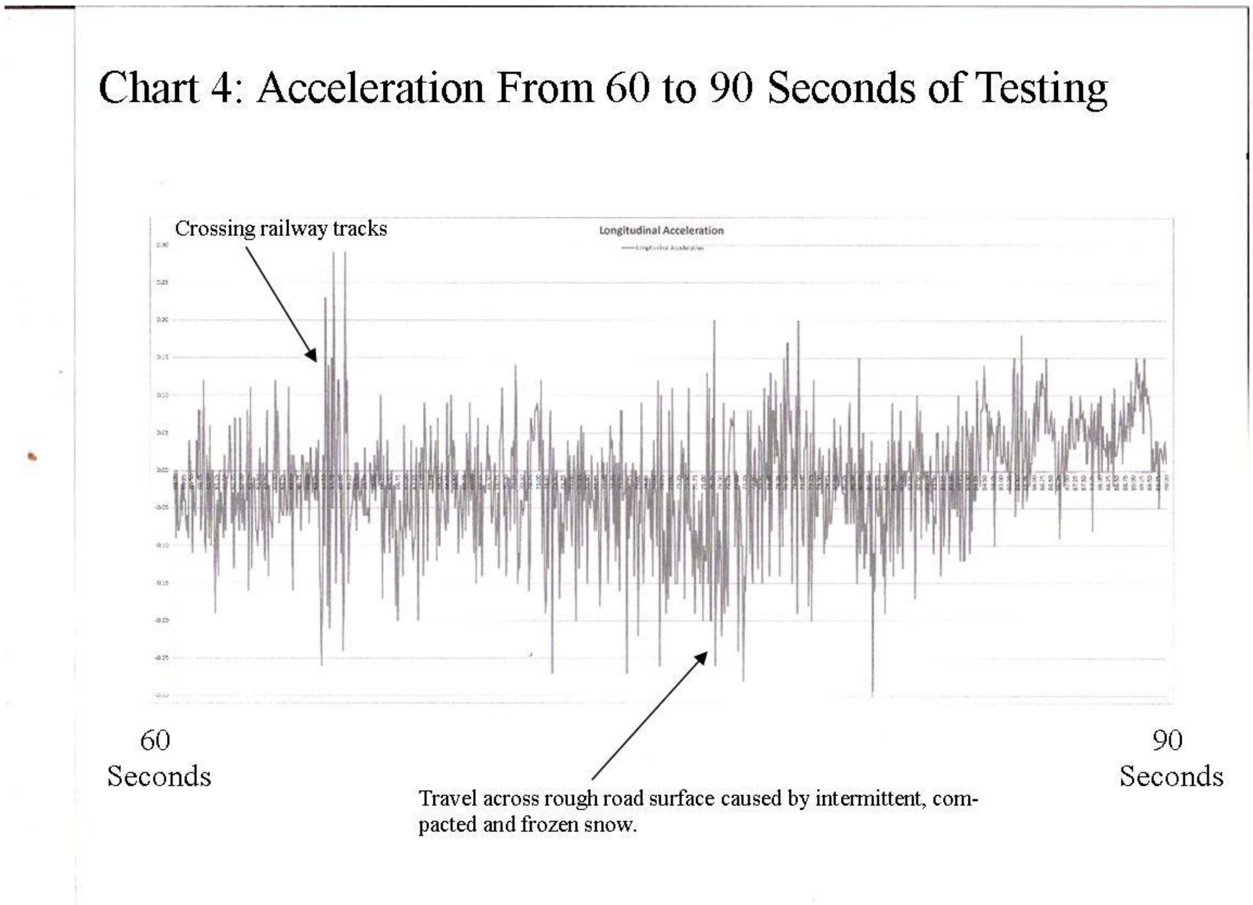

Figure 33: Chart 4 of Longitudinal Acceleration

In Chart 5 we see the data from 80 to 110 seconds. As the data is overlapped for 10 seconds we see at the beginning of the chart that the longitudinal acceleration is negative as the vehicle is slowing to come to a halt at the stop sign at Florence Street. Note that at about 95 seconds the vehicle comes to a halt as the driver is making his observations of the cross traffic on Florence Street. Thus you can see in the last half of the chart that the longitudinal acceleration is steady and minimal.

The display of a slight negative longitudinal acceleration in the last half of Chart 5 likely indicates that the vehicle has stopped at a location where there is a slight incline in the road surface. This is likely the case because, at the beginning of Chart 1 the vehicle is stopped and we see a slight positive acceleration and we know that the road at this stopped location contained a slight downgrade. So the displayed values from the iPhone make logical sense.

In Chart 6 we see the data from 100 to 130 seconds. This is the time that the vehicle is stopped at the intersection with Florence street and the driver is making his observations of cross traffic. Near the end of the data at about 127.5 seconds there is a slight blimp as the driver momentarily releases his brake pedal and then reapplies it.

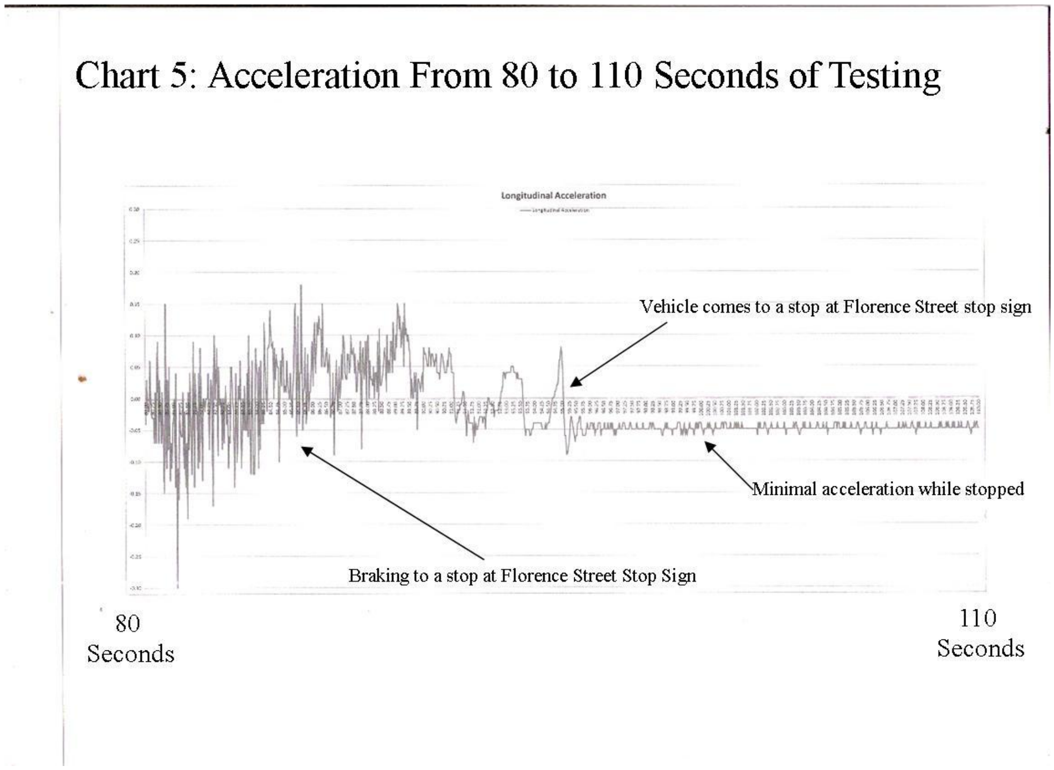

Figure 34: Chart 5 of Longitudinal Acceleration

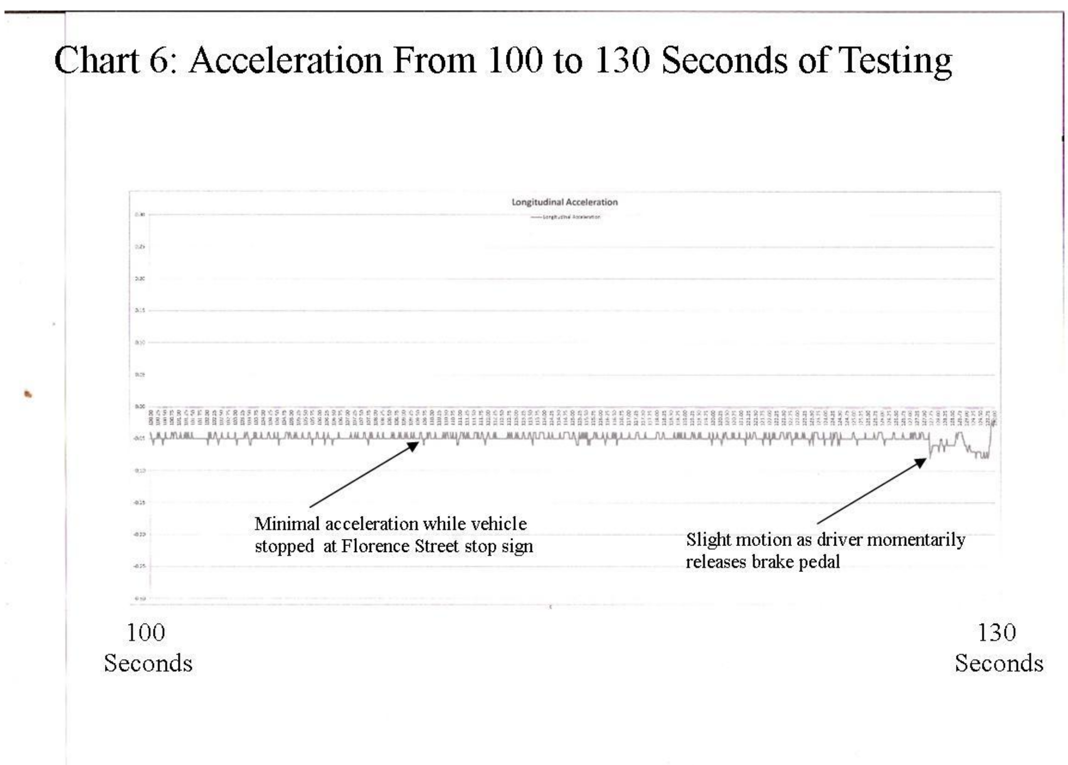

Figure 35: Chart 6 of Longitudinal Acceleration

Chart 7 is the final one showing the data from 120 to 150 seconds. Here we can see the slight blimp in the data once more that was visible at the end of Chart 6. Then we see some more indication that the vehicle is stopped from about 130 to about 136 seconds. Then the vehicle accelerations forward rapidly as it begins its left turn.

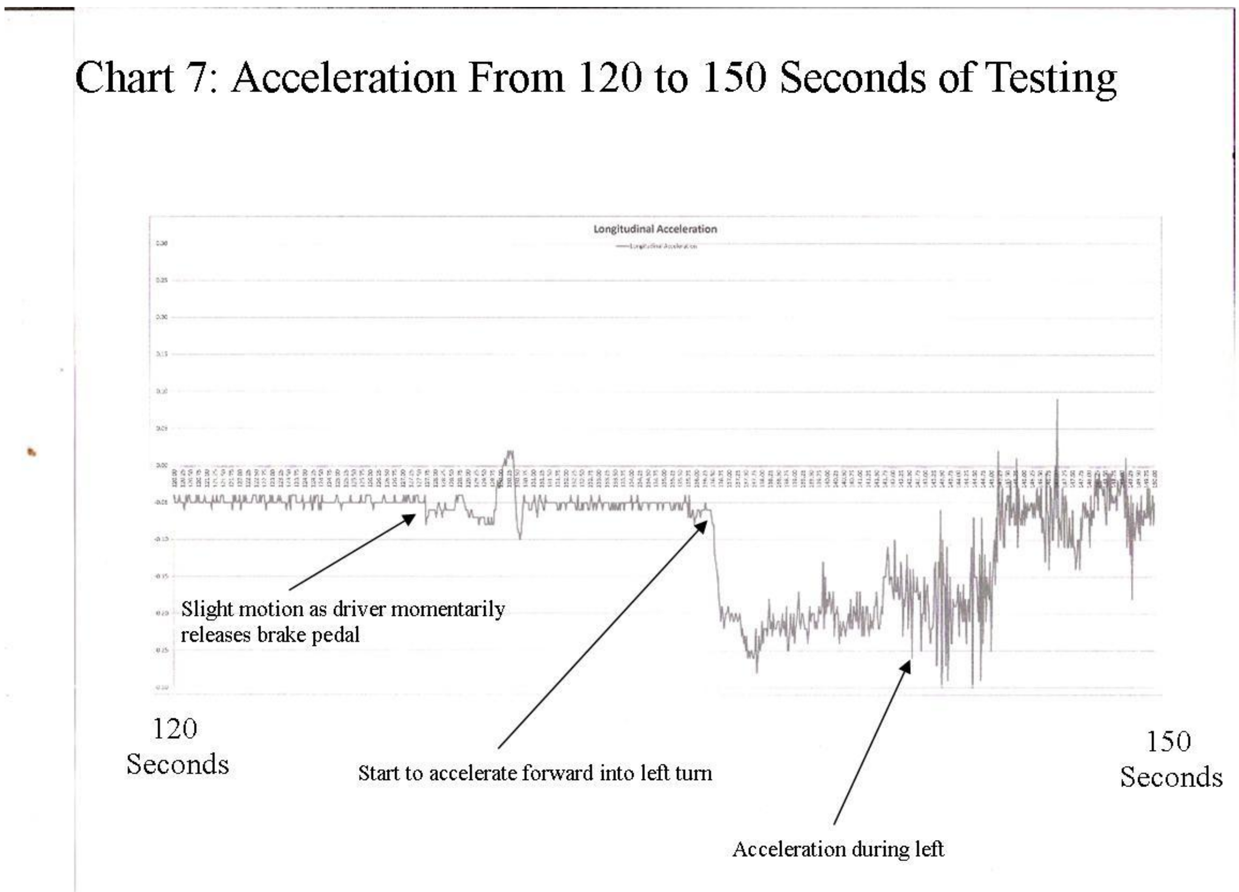

Figure 36: Chart 7 of Longitudinal Acceleration

The testing was also studied by combining all the video camera views in a video editting program (Adobe Premiere) as shown in Figure 37. The video from all eight cameras was synchronized so that we could see what was taking place at the same time from any of the cameras.

For example, the scene shown in Figure 37 was taken from the project at time-code "00;08;54;23". Since the first camera started recording at time-code "00;00;00;00", the present scene exists at 8 minutes, 54 seconds and 23 frames since the beginning of the recording. This was the time when our test vehicle was parked at the south end of the test site and final preparations were being made for the testing.

Figure 37: Example taken from the Adobe Premiere project created by inserting all the views from the 8 video cameras in a synchronized order.

When attempting to incorporate the data from the iPhone with the visual data from the video cameras it is important to obtain a precise match between that visual data and the iPhone data. In other words, if we were interested in the effects that the railway tracks had on the actions of the driver we would want to know precisely when the vibrations were recorded on the iPhone in comparison to the precise instant when the video cameras showed the vehicle crossing over the tracks. Unfortunately, when one receives the iPhone data in an e-mailed file it is not necessarily clear precisely when the iPhone recording commenced. This problem was alleviated by videotaping the face of the iPhone and thus noting precisely when the finger of the investigator pressed down on the record button.

One can see in Figure 37 that the content of the videos can be arranged in whatever fashion one desires. Also, certain views can be enlarged. So one can see in Figure 37 that we magnified the video from the eyeglasses so the eye of the test driver was much larger because the motion of the driver's eye was important to us.

Also, projects can be created incorporating just a select few videos and thus the full size of the computer screen can be used to observe some details of these videotapes, if necessary. In Figure 38 we see how the views from just three videos are used while the video of the driver's eye is magnified. Similarly, the view from the video eyeglasses can be incorporated on its own and magnified, as shown in Figure 39. And finally in Figure 40 we demonstrate that we can add various shapes and text into the video project to use as references when wanting to study the motion of the driver's eye.

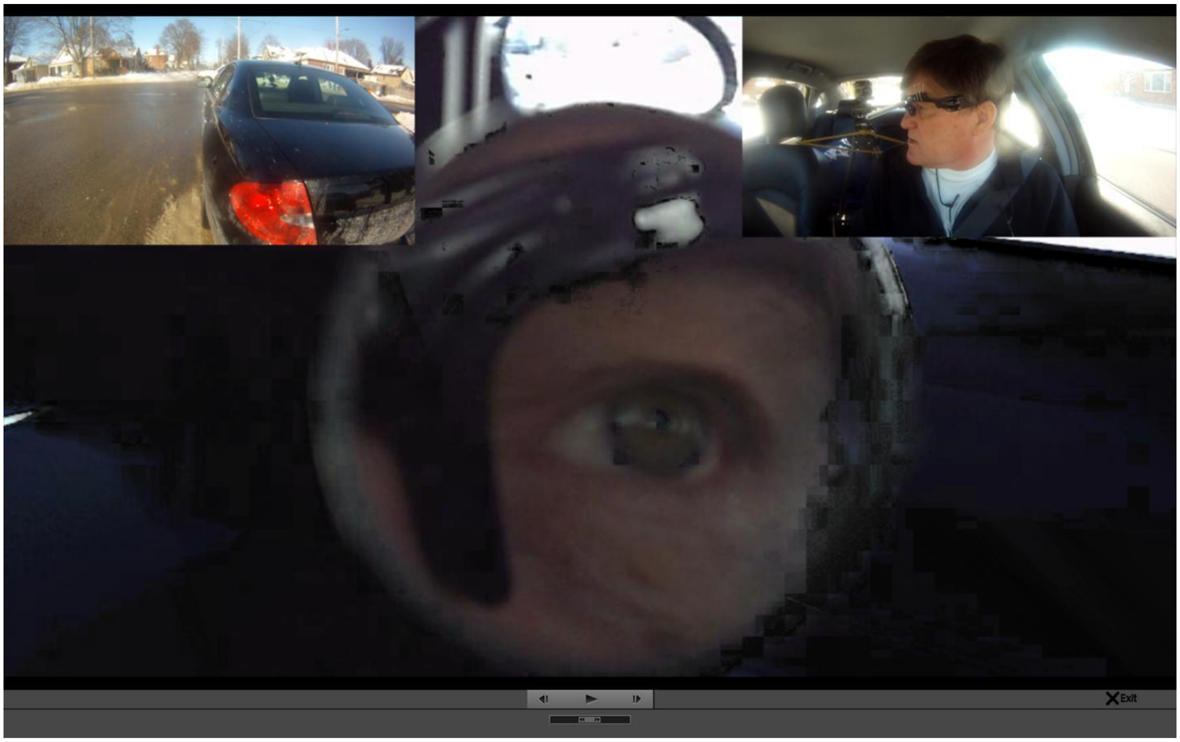

Figure 38: Example of using two video views along with a magnified view of the driver's eye to allow a more detailed study of the eye motions.

Figure 39: Example of using just the single video from the eyeglasses and magnifying it to enlarge the driver's eye.

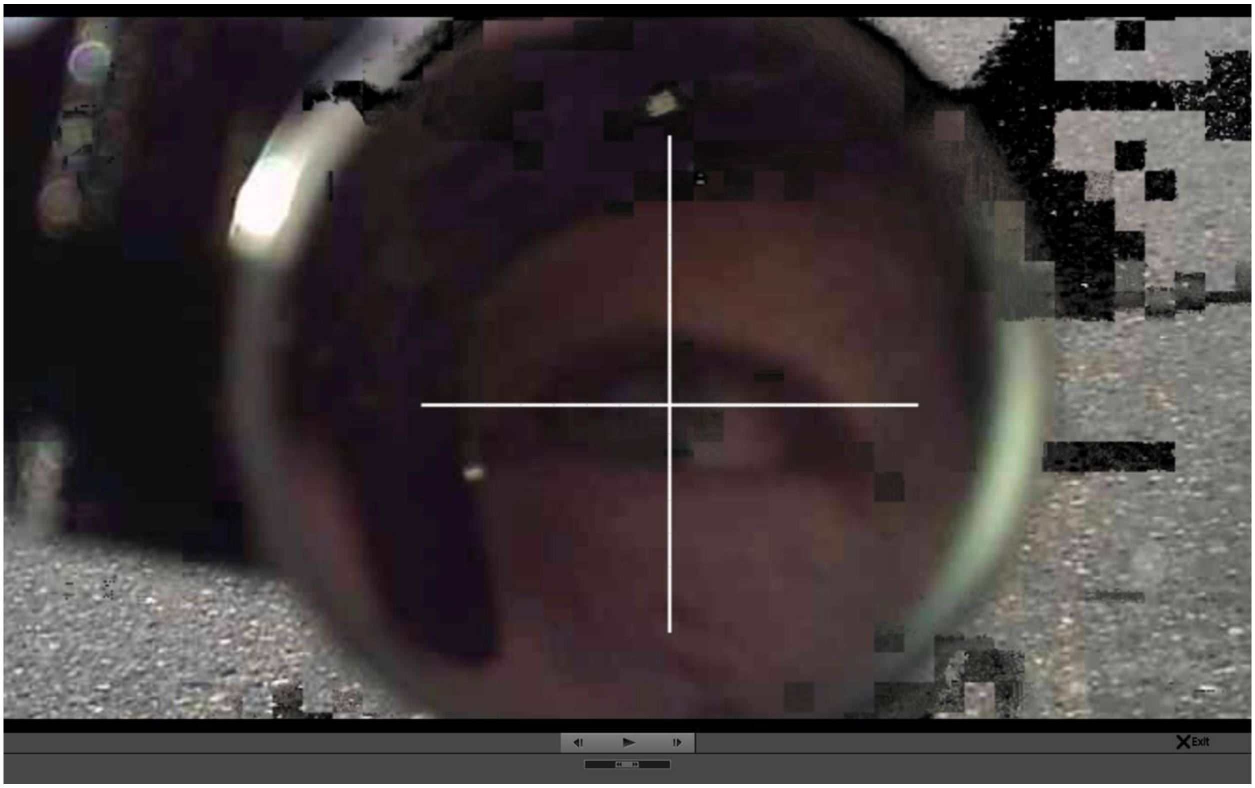

Figure 40: Example of incorporating a set of cross-hairs onto the eyeglasses video to study the driver's eye motion.

Using these techniques it is possible to evaluate and compare driver actions to the events occurring to and around the vehicle. As an example, the table in the following three pages is a summary of our study of the driver's actions as he approached the stop sign at Florence Street, combined with information about the vehicle speed, location of the test vehicle and the condition of cross traffic on Florence. The data in the table is referenced according to the timing of the driver action based on the time-code in the video project that was analyzed.

As an example, the table data begins in the first row as the test driver is approaching the stop-sign-controlled intersection at time-code "00;10;08;28" . At this time-code the driver begins a verbal comment "Coming to the stop sign at Florence". At this time the vehicle is travelling at a speed of 22 km/h and will be slowing to make its stop.

In the next row of the table, at time-code "00;10;10;00", we observe in the video project that the test driver begins to turn his head to the right and the speed of the vehicle has been reduced to 19 km/h.

In the next row of the table, at time-code "00;10;10;18", the driver has completed turning his head to the right and the vehicle's speed has reduced to 17 km/h.

In the next row of the table, at time-code "00;10;10;21", the driver begins to turn his head to his left and the pupil of the driver's eye appears to be in the centre of the eye. The speed of the vehicle has been reduced to 16 km/h.

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Time Code	Verbal Discription of Action	Approx Vehicle Speed (km/h)	Status of Cross Traffic	Comments By Driver
00;10;08;28	Start Driver Comment	22		"Coming to the stop sign at Florence"
00;10;10;00	Begin turning head to R while test vehicle approaching stop sign	19		
00;10;10;18	Completed turning head to R;	17		
00;10;10;21	Begin turning head to L; Pupil appears centred in eye	16		
00;10;10;23	Pupil positioned to far L;	16		
00;10;11;13	Completed turning head to L;	14		
00;10;11;17	Start Driver Comment	13		"Just pulling ahead...looking in both directions..."
00;10;11;17	Begin turning head to R; Pupil appears rotated to L	13		
00;10;12;04	Completed turning head to R; pupil rotated to R	11		
00;10;12;08	Begin turning head to L; Pupil rotated to R	10		
00;10;13;02	Completed turning head to L; Pupil rotated to L	7		
00;10;13;11		7	Front end of EB Van crosses L side of test vehicle	
00;10;13;19	Begin turning head to R;	5		
00;10;14;04	Completed turning head to R	5		
00;10;14;14	Begin turning head to L; Pupil rotated to R	5		
00;10;15;08	Start Driver Comment	4		"...to see what traffic there is...looking to the left..."
00;10;15;10	Completed turning head to L; Pupil rotated to L	4		
00;10;16;20	Test vehicle comes to a halt as per camera at bike rack	2		
00;10;17;05	R Eye is closed	2		
00;10;17;06	Begin turning head to R; Pupil rotated to L	1		
00;10;17;11	Right Eye is open	1		
00;10;17;23	Completed turning head to R; Pupil rotated to R	0		
00;10;18;10	Begin Rotating head to L	0		
00;10;18;13	Start Driver Comment	0		"...looking to the right...the van is still behind me but there is a fair amount of traffic here..."
00;10;18;18	Stopped head rotation to look at van behind in rear view mirror	0		
00;10;19;01	Begin turning head to R; Pupil begins rapid rotation to R	0		
00;10;19;07	Completed turning head to R; pupil rotated to R	0		
00;10;21;17		0	Front end of WB Red Van crosses L side of test vehicle	
00;10;23;21		0	Front end of WB Silver SUV crosses L side of test vehicle	
00;10;24;11	Begin turning head to L; Pupiul begins slow rotation toward L	0		
00;10;24;21	Start Driver Comment	0		"...I just have to wait for it..."
00;10;25;01	Completed turning head to L; Pupil rotated to L	0		
00;10;26;14	Begin turning head to R; Pupil rotated to R	0		
00;10;27;01	Completed turning head to R; pupil rotated to R	0		
00;10;27;10		0	Front End of EB Burgandy Van Crosses L side of test vehicle	
00;10;27;10		0	EB L-turning vehicle crosses L side of test vehicle	
00;10;27;20	Start Driver Comment	0		"...still a long line of traffic..."

Time Code	Verbal Discription of Action	Approx Vehicle Speed (km/h)	Status of Cross Traffic	Comments By Driver
00;10;28;05	Begin turning head to L; Pupil rotated to L	0		
00;10;28;29	Completed turn head to L; Pupil rotated to L	0		
00;10;29;17	Begin turning head to R; Pupil straight ahead	0		
00;10;29;18	Right eye begins to close	0		
00;10;29;21		0	Front end of WB black car crosses L side of test vehicle	
00;10;29;24	Right eye re-opens	0		
00;10;30;03	Completed turning head to R; pupil rotated to R	0		
00;10;30;09	Start Driver Comment	0		"...coming ah..."
00;10;31;23		0	Front end of WB black car crosses L side of test vehicle	
00;10;32;01	Start Driver Comment	0		"...westbound and then it should be clear in another block or so."
00;10;34;24	Begin turning head to L; Pupil rotated to R but starting to rotate to L	0		
00;10;34;25		0	Front end of WB white pick-up truck crosses L side of test vehicle	
00;10;35;17	Completed turning head to L; Pupil rotated to L	0		
00;10;36;12	Start Driver Comment			"But then I'm also looking over to my left..."
00;10;37;22		0	Front end of WB white car crosses L side of test vehicle	
00;10;38;12		0	Front end of WB small red pick-up crosses L side of test vehicle	
00;10;39;14	Start Driver Comment	0		"...two more cars coming from my...three more cars coming from my left..."
00;10;40;26		0	Front end of WB small white car crosses L side of test vehicle	
00;10;44;05	Start Driver Comment			"...four more cars coming from my left."
00;10;44;18		0	Front end of EB black car crosses L side of test vehicle	
00;10;45;02	Begin turning head to R; Beginning to close R eye	0		
00;10;45;09	Beginning to re-open R eye; Pupil is rotated to R	0		
00;10;45;18		0	Front end of WB burgandy car crosses L side of test vehicle	
00;10;45;22	Completed turning head to R; pupil rotated to R	0		
00;10;46;14		0	Front end of EB white SUV crosses L side of test vehicle	
00;10;46;22	Begin turning head to L; Pupil rotated to R but starting to rotate to L	0		
00;10;46;29	Look in rear view mirror while panning head rotation to L to observe van	0		
00;10;47;21	Completed turning head to L; Pupil rotated to L	0		
00;10;48;01	Start Driver Comment	0		"Van still behind me, another row of cars coming from my left."
00;10;48;27		0	Front end of WB Tan Ford Taurus crosses L side of test vehicle	
00;10;49;05	Begin turning head to R; Pupil in centre of eye but rotating to R	0		
00;10;49;06	Observe R foot releasing brake pedal, slight motion back and forth	0		
00;10;49;15	Possible brief pause in head rotation to look in rear view mirror	0		

Time Code	Verbal Discription of Action	Approx Vehicle Speed (km/h)	Status of Cross Traffic	Comments By Driver
00;10;50;06	Completed turning head to R; pupil rotated to R	0		
00;10;50;17	Right eye is closed	0		
00;10;50;17	Begin rotating head to L	0		
00;10;50;21	Right eye begins to open	0		
00;10;50;28	Completed head rotation to L; Pupil rotated to L	0		
00;10;53;27	Start Driver Comment	0		"...OK, maybe after this ah..."
00;10;51;11		0	Front end of EB dark van crosses L side of test vehicle	
00;10;52;14	Re-application of brake pedal with no additional motion	0		
00;10;54;05		0	Front end of EB white Van crosses L side of test vehicle	
00;10;54;27	Begin turning head to R; pupil rotated to L but starts motion to R	0		
00;10;55;23	Completed head rotation to R; Pupil rotated to R	0		
00;10;56;17	Begin head rotation to L; Pupil already rotated past centre on way to L	0		
00;10;56;20	Start Driver Comment	0		"..snowplow I should be OK...here we go..."
00;10;57;11	Observed beginning of release of brake pedal	0		
00;10;57;13	Completed head rotation to L; Pupil rotated to L	0		
00;10;57;15	Observed high-mounted brake light extinguish	0		
00;10;57;21	Observed beginning of forward motion from camera at bike rack	0		
00;10;58;02	Begin head rotation to R; Pupil already rotated past centre on way to R	0		
00;10;58;09		0	Front face of plow attachment of Pick-up crosses L side of test vehicle	
00;10;58;09	Observed needle of tachometer begin to rise	0		
00;10;58;26	Completed head rotation to R; Pupil rotated to R	0		
00;10;59;01	Observed needle of speedometer begin rise	1		
00;10;59;03	Begin head rotation to L; Pupil already rotated to centre on way to L	1		
00;10;59;26	Completed partial head rotation to L; likey looked in dr exterior mirror (?)	5		
00;10;59;29	Start Driver Comment	5		"...OK..."
00;11;01;21	Start Driver Comment	15		"...pull out..."

As one follows the content of these descriptions one can see that, as the driver is approaching the stop sign he is already looking to the right and left to appraise himself of the conditions of the cross-traffic even though the vehicle has not reached its stop location. Using the time-code values we can determine precisely how long it takes for the driver to turn his head. We can also determine how long the driver's eye is fixed at a specific direction. The driver's comments help us to understand what the driver is observing, what decisions the driver is making and the timing of these actions.

A brief review of the above chart reveals that the driver completed 18 head rotations. These rotations were the type where, for example, the driver would have been looking fully to the left and then rotated his head fully to the right. In this small set of data there was a slight difference in time required to rotate the head to the left (0.76 seconds) versus rotation to the right (0.56 seconds) however, the overall average time for the 18 rotations was 0.66 seconds. This is an example of the considerable amount of objective information that can be gathered and used to evaluate collisions that might contain similar factors.

If the study happened to be a situation where the timing of inputs such as steering, braking or acceleration were involved then clearly this information can easily be gathered from the video.

if the issue was one where we wanted to evaluate some condition of the road, such as a depression or some geometric anomaly, then this too can easily be obtained from the iPhone acceleration data. What has not been discussed here is that the iPhone is not only capable of recording accelerations but the built- in gyros can also provide information about how the angle of the vehicle changes in space and also how quickly the angle of the vehicle is changed. Thus, when a test vehicle strikes a pot-hole on the road, the accelerometer will document the longitudinal, lateral and vertical accelerations of the vehicle. But then the gyros will also document how much the vehicle's front end is displaced upwards or downwards, how much the vehicle's left side is lifted or its right side is dropped, and it can also determine whether the vehicle's pointing angle is changing and therefore the vehicle in entering into a common, yaw, loss-of-control rotation. Not only are these data documented but the rate at which these changes occur is also sensed by the gyros and documented in the iPhone file.

In the study of loss-of-control collisions there are many instances where investigators locate the physical evidence (yaw marks, impact gouges, etc.) that is close to the area of impact which tells them what happened in the immediate few seconds surrounding that impact. But there is rarely any objective evidence that exists which can tell them what might have caused that loss-of-control. This is an important issue when considering that a very large number of rural, fatal and serious-injury collisions commence from an initial vehicle loss-of-control. Data acquisition systems like the one we have discussed in this article can be taken to the site of such a collision and test runs can be made to document the forces exerted on the vehicle and also the actions or reactions of the driver. Such an objective analysis can provide important clues to the analyst about what might have led to that loss-of-control.

It is no wonder that we should consider this simple iPhone "cell phone" as an extra-ordinarily powerful accident evaluation tool that , because of the gyro data, provides much more information than much of the sophisticated , tri-axial accelerometer hardware that has been traditionally used by analysts.

One might be surprised at the low cost of the equipment used in this demonstration. Much of the equipment, such as test vehicles, cameras, cell phone, computers and software would already be available to most persons whether they are collision analysts or members of the general public.

The "apps" used to create the iPhone data files cost no more than $10.

The GoPro cameras used in this testing were purposely selected, not only because of their low cost, but because of their robustness. GoPro cameras operate in the most extreme temperatures and even in driving rain. In fact, for this type of analysis it is the lower resolution video that is best because when we combine a number of these videos into a video-editting program the software can become overwhelmed if three or four of the videos are high definition. Even when shooting video at the lowest resolution we must create "shrunk" copies of the original GoPro videos for insertion into the video editting program. Then when something of particular interest is located we can revert to the original, high definition video for further explorations.

Our exploration and refinement of the presently-described data acquisition system continues. As technology advances there undoubtedly will be further improvements to the system as it exists.

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