Driver Fatigue and the Vehicle Control Interface during long distance rallies

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Abstract

It is assumed that the interaction between a vehicle and its driver alters as that driver becomes fatigued. Using long distance rally driving as its context, this study based upon the analysis of in-car video recordings, investigates the changes in driver movement patterns over many hours at the wheel and draws conclusions as to the changing relationship between driver and the vehicle control interface (VCI). In a rally car there is the additional factor over a road car of a co-driver from whom the driver receives instructions as to the vehicle's required direction and speed.

Video capture reveals that as time at the wheel accumulates and the driver becomes fatigued essential actions are seemingly increasingly prioritised over inessential actions. Fewer inessential movements of the driver's head and limbs are evident as fatigue builds up. Eventually only the essential actions needed to keep the vehicle on course are undertaken by the driver. In a rally driving situation where driver and co-driver are both trained and experienced this prioritisation can result in the enhancing of concentration and an improvement in competitive result. It is concluded that this study offers reinforcing evidence for the location and prioritisation of major and minor items within the VCI.

Introduction

Driver fatigue is acknowledged as a contributor to impaired driver performance and a consequential factor in vehicle accidents (Brown 1994, Lal & Craig 2001). This pilot study used long-distance regularity rally driving events as its data source in a study of one driver and his reaction to fatigue over many days of prolonged driving.

Since 1988 long distance regularity rallies for historic cars have been organized in Europe and North Africa (CRA). These events promote accurate timed driving over long distances on varied road surfaces. Drivers are predominately amateurs, owners of the classic cars invited to participate, but sometimes ex-professional or even current professional race and rally drivers participate in the more high profile of these events. Each driver will have a co-driver or navigator to guide them in the competing car and the aim of each crew is to drive as accurately to a set time schedule as possible. Deviations of even one-tenth of a second from this set timing can result in penalty points (ACM). The crew with the lowest penalty points win the rally. The roads used in these events are generally open to normal traffic and are covered by the traffic regulations in force in the country concerned.

Organised throughout the year, these rallies encourage accurate, safe and capable road driving. Road and weather conditions can vary from the ice and snow of an Alpine or Arctic winter to arid desert driving on sand. Distances of events vary with the longest covering many thousands of kilometres in several weeks of driving (ERA).

One of the features of these regularity based events is the large number of hours spent at the wheel by drivers. Events such as the *Rallye Monte Carlo Historique* require drivers to spend over 20 continuous hours at the wheel during its early stages

(ACM). This requirement makes dealing with driver fatigue during such an event a necessity and so a useful source of data for study.

The pilot study reported upon in this paper is intended as a precursor to a more extensive study of how fatigue affects driver actions at the wheel, and the lessons that can be learned for the design and layout of the VCI in a motor vehicle.

Methodology

Recording technique
Using in-car camera equipment supplied for the project by research partner *ChaseCam UK* fitted to our test vehicle two data gathering journeys were made during 2010. An internally mounted camera was fixed at head height, slightly behind and between the driver and co-driver. This camera, which had a wide field of vision, clearly showed movements of the driver's upper body, arms and head. In daylight facial expressions and movement could also be viewed via two rear view mirrors.

Winter driving
The first journey at the end of January and start of February utilized the *Rallye Monte Carlo Historique* as its setting. This mid-winter rally held in and around the Alpes Maritimes in southern France exposed our test crew to ice and snow conditions throughout a 50+ hour driving experience. This experience was spread over five days and two nights with the longest session, the opening *Etape de Concentration,* comprising a 21 hour drive from Reims to Monaco overnight. Following a break of 16 hours the *Etape de Classification* took our crew from Monaco to Valence in the Ardeche region during a 10.5hour session. Then following another break of 14 hours the *Etape Commune* took competitors in a circuit around the mountains of the Ardeche back to Valence in 8 hours. Another 16 hour break and then the final session of the *Etape Commune* and *Etape Finale* combined back to the finish at Monaco took 16hours. In all 55.1hours driving including the drive to Reims from the UK.

Three videos totaling 31'25" were taken in controlled driving conditions, one after 2.3hours, one after 22.3hours and the final session after 50.1hours of driving

Summer driving
The second journey examined was during the *Rallye des Alpes Historique* in June. This journey comprised five 8hour shifts at the wheel during the competitive sections of the event on minor roads high in the Swiss, Austrian and Italian Alps. In addition overnight drives were made from the UK to the start in Geneva and back to the UK from the finish at St.Moritz totaling 48hours at the wheel. This journey, being made during the lightest month of the year and with less continuous hours at the wheel was less stressful than the winter driving experience above but nevertheless of sufficient duration for valuable data to be gathered.

Four videos totaling 41'40", were taken in controlled driving conditions, one after 7.3hours, one after 18.3hours, one after 22.3hours and the final session after 38.3hours at the wheel.

Driving conditions
The sections of the rallies chosen for video capture were as homogeneous as possible. In each case but one sections were chosen where the crew were attempting to maintain a constant speed over the roads they were driving upon. The only exception to this was a short sequence recorded at the start of the winter driving journey as a baseline sequence.

These competitive sections, known as *regularity sections*, require crews to maintain an average speed along a defined course of anything up to 60km or more in some cases. To achieve this requires skill and concentration on the part of both driver and co-driver. Despite the need for concentration the effects of fatigue can be seen and have to be taken into account and dealt with by an experienced crew.

Video analysis
The videos were analysed noting the time of each gesture or significant movement by the driver. Movements were categorised firstly by their nature (voluntary or involuntary) and then by their significance (essential or inessential). Gestures were taken to be voluntary and of inessential significance. Involuntary movements include movements due to the motion of the car. Examples of essential voluntary movements were gearchanges and steering movements. Examples of inessential voluntary movements were adjusting ventilation and clothing.

The numbers of gestures and inessential/essential voluntary movements were totaled for each video sequence and graphs plotted of the percentage frequency of each class of behaviour. These graphs were then compared to the accumulation of time at the wheel and trends sought.

Driving diary
In addition to the video analysis driving diaries were kept by the co-driver for the summer journey noting the time of day, time at the wheel of each session and the fatigue state of the driver at the end of each session. This qualitative information was used as confirmation of the results of video analysis of that journey.

This diary (taken at the end of each session) noted date, time and location, the length of the driving session, the state of fatigue of the driver, the driver's control of the vehicle, his/her state of alertness, his/her responsiveness, his/her ability to obey instructions, any unnecessary movements by the driver, state of driver awareness of vehicle surroundings, the driver's current ability to obey road traffic laws and finally an opinion on the driver's current safety state.

A cumulative diary was also kept showing accumulating hours at the wheel and the location in time of each of the video samples.

The driving crew
For ethical reasons and for practicality the author drove the car in question using his regular co-driver. Although this self-experimentation naturally raises questions as to the efficacy of this study, the extreme length of the driving sessions and their cumulative effect meant that no distortion of results was discernable by reviewers. The effects of fatigue were so marked that possible subject bias was not considered to be an issue.

As a pilot study to a larger project involving several drivers, this self-experimentation can be seen to have value.

Initial results

Winter driving sessions
Analysis as above of the videos of the three winter driving sessions showed the following results:

Session 1 **Reims** after 2.3 hours driving

Date	29.1.10
Duration of video	04mins 41s
Duration of driving sequence	04mins 41s
Total number of driver actions	13
Number of essential actions	1(8%)
Number of inessential actions	12(92%)

Session 2 **Col de Turini** after 22.3 hours driving

Date	30.1.10
Duration of video	10mins 18s
Duration of driving sequence	10mins 18s
Total number of driver actions	13
Number of essential actions	9(69%)
Number of inessential actions	4(31%)

Session 3 **Col de la Madone** after 50.1 hours driving

Date	2.2.10
Duration of video	16mins 26s
Duration of driving sequence	16mins 26s
Total number of driver actions	35
Number of essential actions	32(91%)
Number of inessential actions	3(9%)

Analysis

It can be seen from these analysis that as hours at the wheel accumulate, the number of inessential actions as compared to the total number of actions decreases. From 92% inessential actions after just 2.3 hours at the wheel to 3% after 50.1 hours at the wheel.

It can also be seen that the total number of actions of all kinds decreases as time at the wheel increases: 13 actions in 4mins 41s after 2.3 hours at the wheel (2.77 actions per minute) compared to 35 actions in 16mins 26s after 50.1 hours at the wheel (2.13 actions per minute).

Summer driving sessions
A similar analysis of the four summer driving sessions showed the following results:

Session 1 **Jaunpass** after 7.3 hours driving

Date	21.6.10
Duration of video	15mins 47s

Duration of driving sequence	12mins 11s
Total number of driver actions	28
Number of essential actions	18(64%)
Number of inessential actions	10(36%)

Session 2 **Nufunen Pass** after 18.3 hours driving

Date	22.6.10
Duration of video	12mins 31s
Duration of driving sequence	11mins 57s
Total number of driver actions	39
Number of essential actions	29(74%)
Number of inessential actions	10(26%)

Session 3 **Rickenbach** after 22.3 hours driving

Date	23.6.10
Duration of video	15mins 18s
Duration of driving sequence	14mins 41s
Total number of driver actions	37
Number of essential actions	27(73%)
Number of inessential actions	10(27%)

Session 4 **Oftenpass** after 38.3hours driving

Date	25.6.10
Duration of video	05mins 19secs
Duration of driving sequence	02mins 51s
Total number of driver actions	9
Number of essential actions	7(78%)
Number of inessential actions	2(22%)

Analysis

In the case of these summer driving sequences the same general trends apply as in the winter driving sequences. The proportion of essential actions increases from 64% to 78% as the total rate of actions decreases from 2.30 actions per minute to 1.69 actions per minute.

Competition results

During the winter driving sessions the same competitive stage, Col de Turini, was traversed twice. The first time (after 22.3 hours of driving) the crew completed the stage in 83rd position. The second time (after nearly 50 hours of driving) the same crew completed the stage in 33rd position. This improvement of 50 places could be attributed to several factors including road conditions, time of day and weather conditions. However these general conditions applied to all 300 plus competitors.

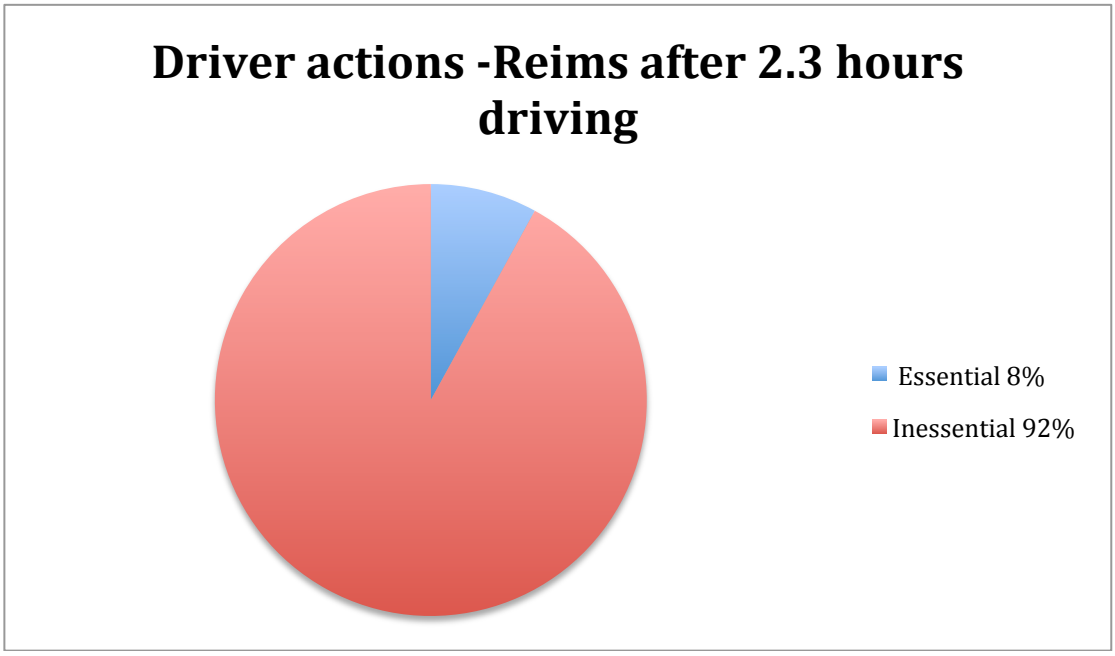
It was felt that the ability of driver and co-driver to cope with fatigue was also a deciding factor in how well the crew fared in competition during the latter stages of the RMCH.

Graphical results

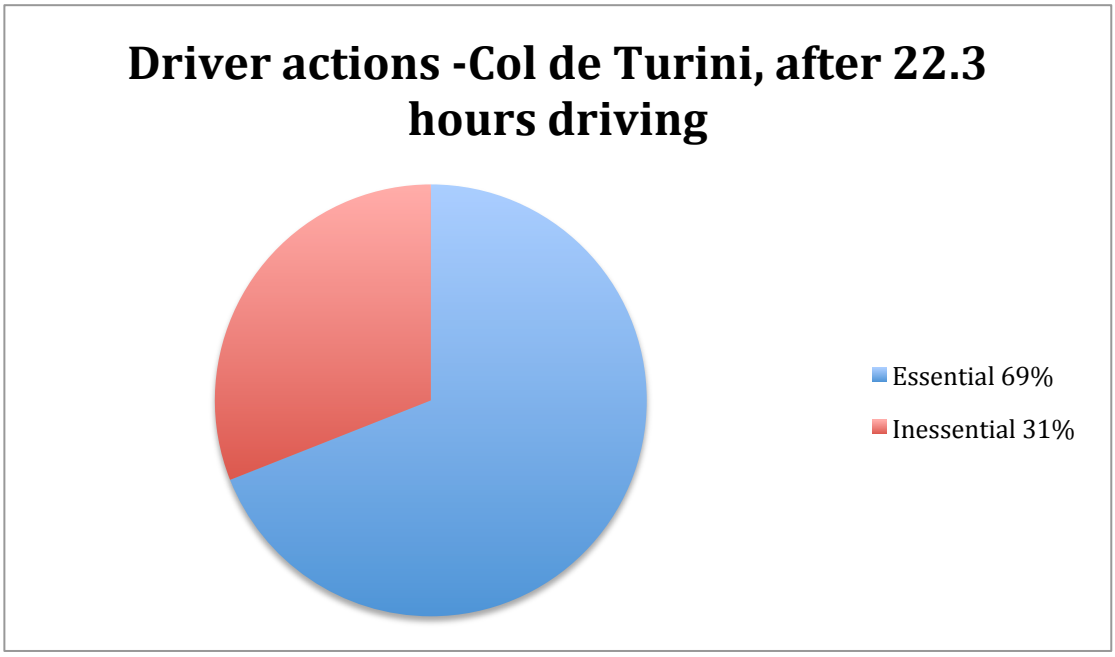
The results of the driving sessions are displayed below in graphical form:

Winter driving sessions

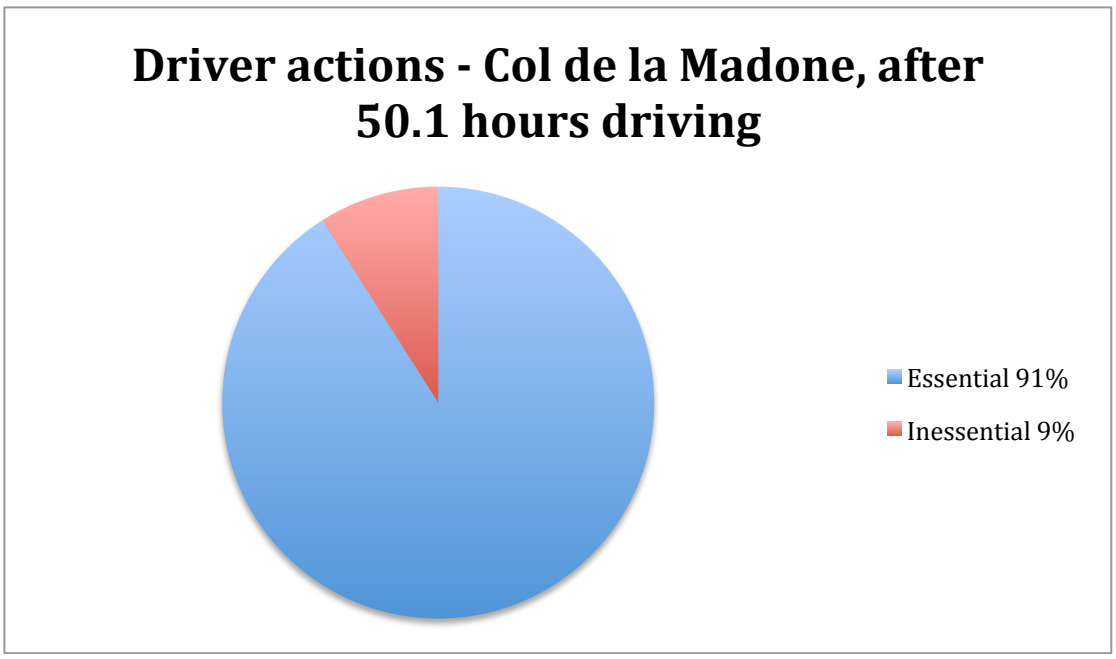
Winter 1 – Reims



Winter 2 – Col de Turini

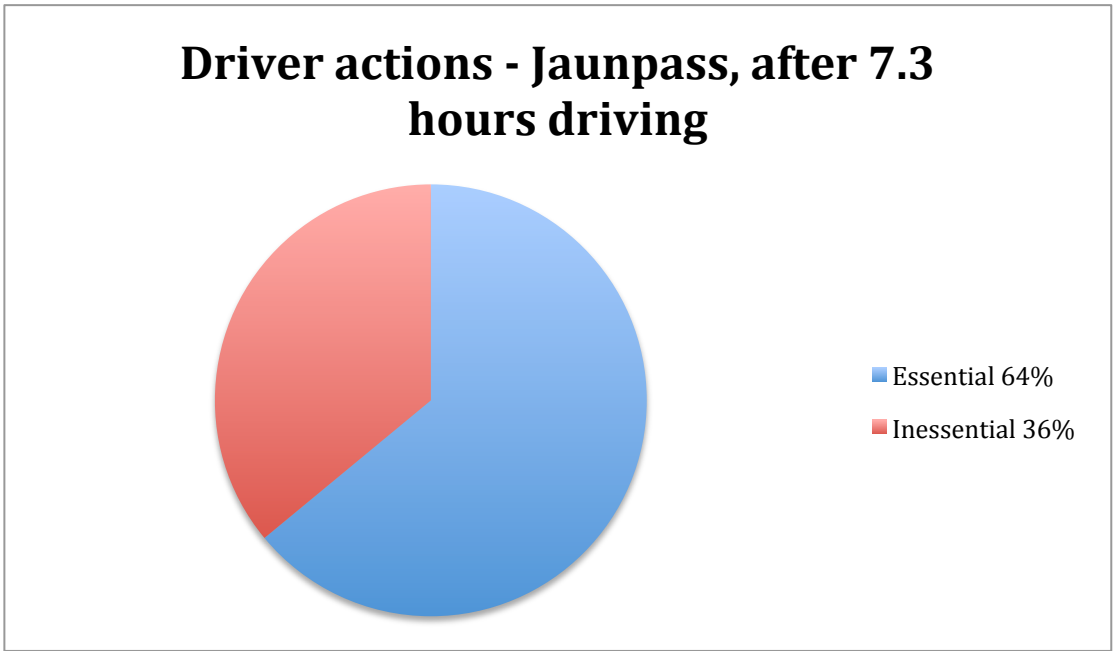


Winter 3 – Col de la Madone

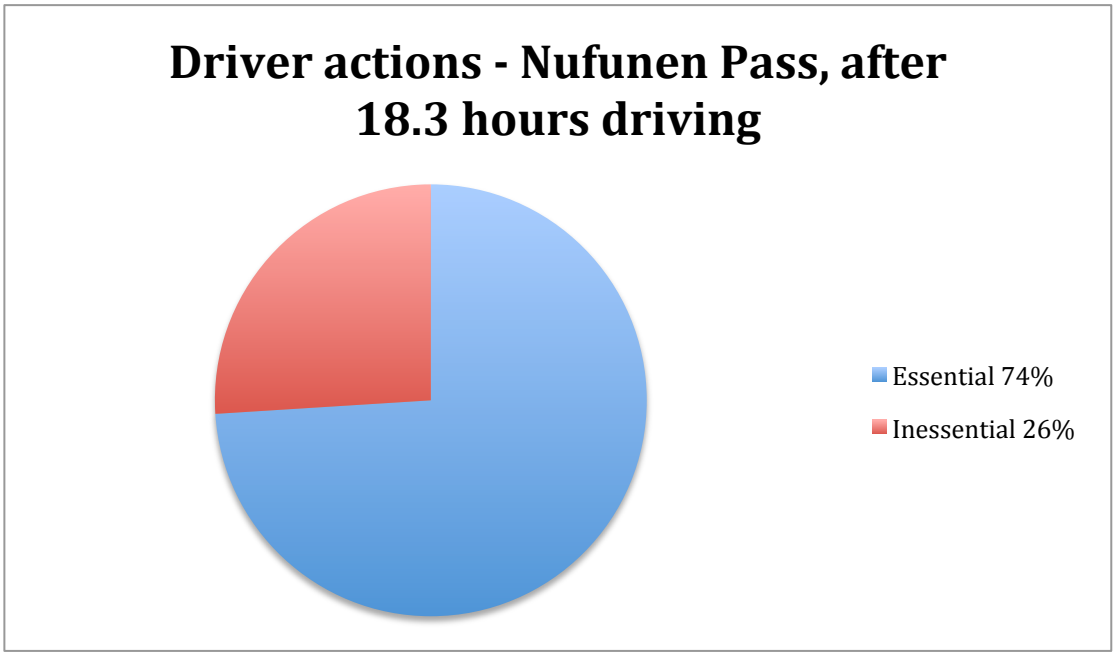


Summer driving sessions

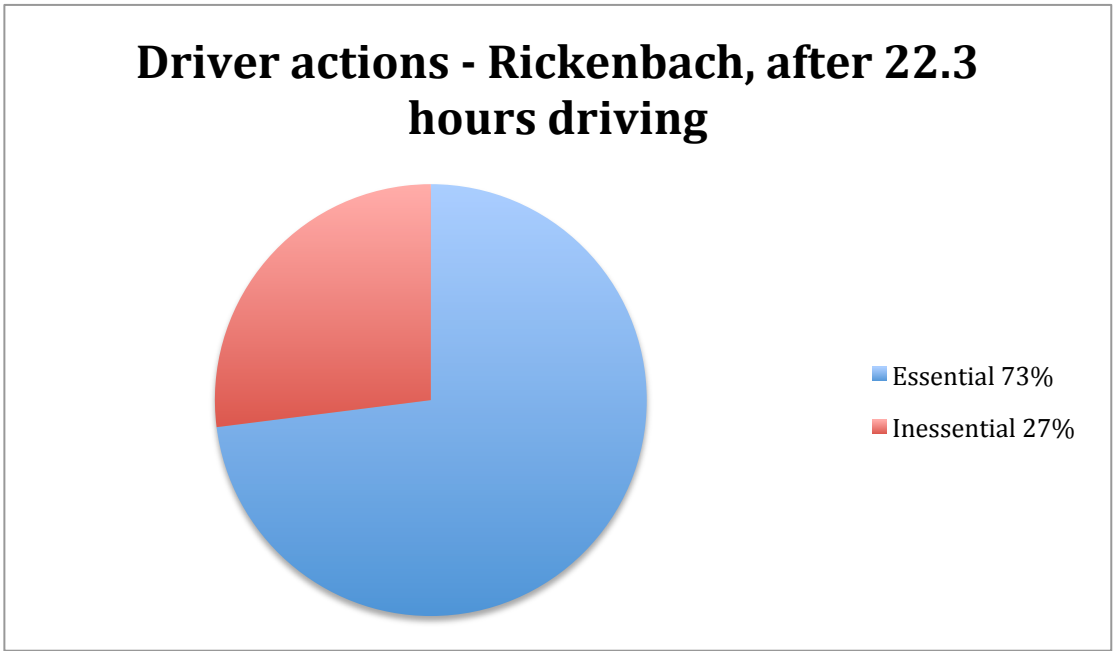
Summer 1 – Jaunpass



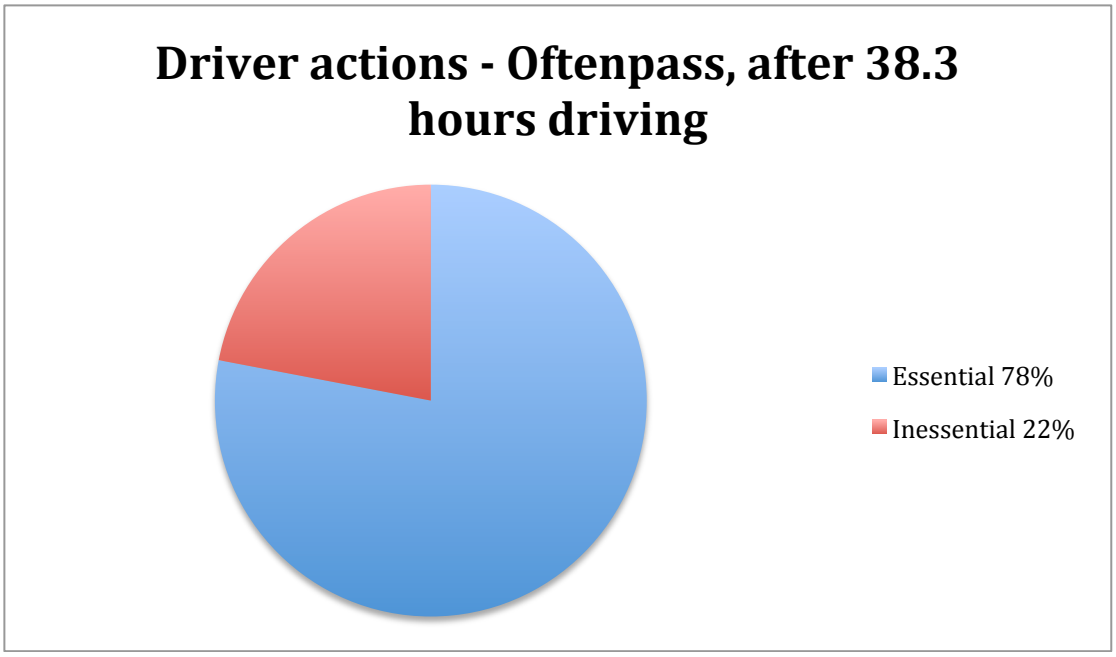
Summer 2 – Nufunen Pass



Summer 3 – Rickenbach



Summer 4 – Oftenpass



Both summer and winter driving sessions clearly display the same prioritisation with a more marked effect during the winter driving sessions.

Conclusions

From this pilot study it can be provisionally concluded that:

1. With accumulating time at the wheel the driver seemed to prioritise essential driving actions over inessential actions.
2. Prioritisation was found to be more acute in winter driving sessions where both day and night driving were included.
3. The increase in focus represented by prioritisation towards essential actions can be beneficial in encouraging concentration upon essential driving tasks by an experienced driver.
4. Further studies are needed to establish the expected level of prioritisation towards essential tasks by general road drivers.

References:

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Lal, Saroj K.L. Craig, Ashley **A ctitical review of the psychophysiology of driver fatigue** Biological Physiology Volume 33, Issue 3, 1 February 2001, Pages 173-194

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Automobile Club de Monaco (**ACM)**
http://www.acm.mc/rmch/rmch_main.php?page=2011/accueil_2011.php