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Literature review of race driver fatigue measurement in endurance motorsport

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Abstract

Driver fatigue in endurance motor racing, has been problematic for driver safety and optimal performance. Historically in this sport focus has been primary on improving mechanical performance; making the racecar light, faster and improving grip (aerodynamics and suspension geometry). Driver safety has come secondary. A series of fatal accidents that were attributed to fatigue have led to rule changes; however, these were made with little understanding of the driver fatigue (type/level). As the literature indicates few publicly available studies into driver fatigue take into account all of the identified stresses for endurance motor racing. Technology has progressed where it is now easier to quantify self with the use of appropriately selected and placed sensors. This literature review aims to highlight the need for sports engineers to develop a new electronic system for fatigue measurement in endurance motor racing and is the first part of a major research project in the development of a system for race driver fatigue measurement.

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1. Introduction

Motor racing has evolved well beyond being a recreational pursuit; it is now a multi-million dollar sport demanding the highest level of physical and mental fitness similar to that of any other athlete. Endurance drivers, like the cars they drive, are complex from a physiological perspective. However, unlike the cars they drive, driver-

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athletes have not been comprehensively examined, evaluated, and tuned to the same degree. Wearable health-monitoring systems are becoming very popular, especially in enabling the non-invasive diagnosis of vital functions on the human body [1]. The purpose of this review is to present literature relevant to driver fatigue in endurance motorsport and state the design direction towards the development of a new type of electronics system to be used in the quantification of driver fatigue.

2. Reviewed Literature

In this section a review of the most relevant literature to racing driver fatigue, monitoring and detection is presented.

2.1. *The case for driver science in motorsport: a review and recommendations*

A review carried out by Potkanowicz and Mendel has shown that the influence of stress and strains exerted on race drivers is not well understood or known about the combined effect [2]. While trainers and sports scientists try to simulate the racecar and race event environment with their training regimens (e.g. hot yoga, loaded steering wheel resistance training, reaction testing, and training), without quantifiable data of the driver's experience, these regimens do not take full advantage of the training principle of specificity [3]. Providing quantifiable data through additional research will help to validate the driver as an athlete. In uncovering this information, the scientific community has an opportunity to contribute to racing becoming that much safer, that much more competitive, and that much more comprehensive for the driver, the team, and the sport [2].

2.2. *Bioenergetical and cardiac adaptations of pilots to a 25h-team kart race*

Fatigue along with excessive speed and alcohol is the main factor in road accidents in the general community. In motor racing, when the drivers are highly trained and adapted to the condition, fatigue is known to compromise final performance by lowering anticipation movements affecting force exerted to control vehicle trajectory [4]. Furthermore, the lack of precise recommendations on maximal driver duration in relation to vehicle type, expose the driver to potentially dangerous levels of fatigue which may cause crash events [4]. Durand studied heart rate (HR) over the course of a 24 hour go-kart race at Le Mans, France. The research aimed to statistically correlate driver HR with energy expenditure (EE) of the driver. The research concluded that driving a kart for 45 minutes before driver change at around 60 km/hr resulted in a 300 kcal EE, corresponding to a 5.6 Mets (Metabolic Equivalent of Task, energy cost of physical activities). This effort is responsive for a + 73 beats per minute (BPM) increase in HR, reaching 82% HR maximum intensity (157 BPM). These high values were repeatable between each successive driving instance, but not statistical enough to prove that increased HR induced physiological fatigue. The research also reported they did not take into account effects of vibration on the whole. The researchers did not evaluate the combined effects or the frequency of vibrations the driver reported, and a role for this factor on EE elevation and fatigue development cannot be eliminated [4].

2.3. *Influence of vibration on vehicle occupant fatigue*

Fatigue caused by extended hours of driving a car has considerable influences on driver alertness, performance and therefore can lead to compromise transportation safety. However, fatigue caused by vibration is not well investigated or reported in the available literature. The relationship between vibration magnitude and vibration frequency of vehicle occupant and associated fatigue has been established without sufficient research. This is because fatigue is a complex phenomenon, and there is little quantitative data in existence characterised specifically to motor racing [5]. Research by Amzar and Fard proposed that low-frequency vibration may induce drowsiness and cause a reduction in alertness [5]. To test the hypotheses an experiment was conducted where ten individuals, one by one, were secured into a seat that was mounted to a vibration shaker table that was configured to vibrate in a

frequency range of 1-15Hz. With vibrations intensity levels limited 0.3 m/s² root mean square (RMS). An electroencephalogram (EEG) head band was placed on the test subjects. Beta and theta brain activity was observed in the frequency domain utilising Fast Fourier transformation (FFT) and power spectral density (PSD) within each of the brain activity bands. The results of the study for all ten subjects found that the measured beta brainwave activity, which indicates alertness level, decreased in both random and sinusoidal excitation. However, the drowsiness effect in sinusoidal vibration was more pronounced compared to random vibration condition. The test methodology was a good indication that vibration is a contributing factor to drowsiness and mental fatigue. However, the environment protocol was not realistic as the test participants were not stimulated in the same way a driver would be operating a motor vehicle (the participants were asked to sit comfortably with their back on the backrest and hands on their lap) [5]. As the environment was not replicated then it would be difficult to deduce if the effects of fatigue were induced by vibration or lack of mental stimulation.

2.4. The Clipsal 500 Studies; (CO), dehydration and heat stress

Australia's race circuits such as the Adelaide Street Circuit include environmental factors such as high temperature, high solar radiation, and low wind which when combined with Carbon Monoxide (CO) from race car exhaust gases, exert unique physiological demands on motor sport participants [6]. AIMSS researchers made observation of a control group of drivers at the Australian V8 Supercar championship (Clipsal 500, Feb 2008). Measurements were made in cabin temperatures and CO levels as well as driver specific effects, such as fluid loss due to dehydration and body core temperature. Driver cabin CO levels were above 100ppm for significant periods of time (up to 15mins). Although the research indicates several metrics for evaluation, it falls short on quantifying how each of the metric (CO, body temperature, hydration) affects the driver. Excessive exposure to CO can cause acute disturbances highly relevant to the task of controlling a racing car, including impaired coordination, reduced accuracy in determining a vehicles position, slower reaction times and impaired ability to attend to multiple tasks. CO also increases sweat rate and temperature rise, thus increasing the effects of hyperthermia and dehydration on psychomotor performance. Dehydration is fluid loss due to the normal functioning of the body, mainly via perspiration and breathing. It increases susceptibility to fatigue and muscle cramps. Inadequate fluid replacement before, during and after physical activity causes dehydration which may lead to fatigue, heat exhaustion or heat stroke. Optimal hydration levels are vital, not just for motor sport participants to perform at their best physically and to maintain mental function; they also help ensure safety and maintain long-term general health [6]. Driver weight changes for Race 1 and 2 showed mean losses of 1.5% and 1.8% of body mass, respectively [7]. There was considerable variation, which indicates some drivers were drinking sufficiently during the race to match sweat loss, other were not [8]. This suggests that there is a need to capture driver fluid intake, to better understand the relationship between hydration and the fore mentioned stresses. Additionally the study above totally neglects the contribution of whole body vibration, as the study was focused on the effects of CO, hydration and temperature awareness.

2.5. Don't sleep and drive – VW's fatigue detection technology

Fatigue in general is a very complex phenomenon; the resulting micro-sleeps are merely a subset of the potential causes of accidents, which can be traced to a lack of fitness or performance capability on the part of the driver. Around 20% of fatal road accidents involve driver fatigue. According to VicRoads, around 30% of severe single vehicle crashes in rural areas involve the driver being fatigued [9]. In an attempt to tackle these problem automotive manufacturers have developed driver fatigue monitoring systems for consumer vehicles [10]. An example of such a system is the Driver State Monitoring System developed by Volkswagen (VW). VW researchers identified human error to be a casual factor in many public road accidents. Human error is explained by shortcomings in perception, interpretation of information, decision-making, information recall and direct performance of an action. However, general physical and cognitive aspects such as attention and fatigue also play an important role, because they affect other cognitive processes [11]. When drivers are tired, they fail to take action to avoid an accident. This is especially

the case of incidents requiring braking or steering inputs. Fatigue impairs perception and the ability to make the decision to react, and it also degrades the performance of the action(s).

VW summaries the effects of psychological fatigue into four categories:

- Physiological (regulation of the vegetative and nervous system)
- Cognitive (perception and information processing)
- Motor (behavior)
- Subjective (experience)

Table 1. Classification of fatigue category and effects

Category	Fatigue effects
Physiological	Reduced psycho-physiological stimulation
Cognitive	Reduction in alertness and vigilance. Informed processing and decision-making takes longer.
Motor	Reaction time increases when critical event occurs. Control reactions are more variable and less effective. Reduced Preparedness to react.

There are difficulties with the methods that are used to assess the driver's state and the driver's fatigue level in particular. This in turn creates a problem when an attempt is made to test the suitability of fatigue recognition technology. The VW Driver State Monitoring System implements a non-intrusive observational approach; blink rate, head movement (nodding) and eye pupil position. The system uses two dashboard mounted cameras focused toward the drivers face, detection algorithm processes the data to determine the likely hood of the occurrence of a micro-sleep or abnormal driver distraction. If the system detects any of the three indicators of fatigue, then will alert the driver with audible / visual alarms [11]. The VW type system is an effective and efficient tool in combating fatigue in medium to long road trips in consumer auto mobiles. In motorsport the driver is a trained athlete and the likelihood of the driver experiencing the same type of fatigue, or pre-fatigue such as lack of sleep or stimulation is minimised if not eliminated by professional athletic preparation. As the stressors and strains placed on the driver in motor racing are caused by environment, rather than sleep debt. Additionally the driver's race safety equipment, such as helmet, head restraints and fire retardant balaclava render optical tracking and facial feature recognition inoperable.

3. Literature conclusion

Endurance motor racing, is a team sport that requires the driver, the car and the team to be at the peak performance [12]. The technology currently used in motor racing is well suited to measuring electro-mechanical phenomenon of the car and logging the data for further analysis, but is not designed to specifically interface with the driver or identify the occurrence of driver fatigue. More research is required to further understand the complex relation of driver fatigue in endurance motorsport. What makes an effective and efficient system for consumer vehicles, does not necessarily translate to the world of endurance motor racing, understanding the athlete and the environment is of vital importance and the differentiating factors of how an endurance racing fatigue monitoring system shall operate and what should be the inputs for fatigue detection algorithms [13]. By examining the literature, it becomes evident that heart rate, respiration, carbon monoxide levels, hydration, temperature, and whole body vibration are

contributors to a driver's physical and mental fatigue in motor racing. Despite this no studies have implemented an approach which allows the combined effects of all the stressors to be established. Ongoing work conducted by the authors focused on the development of an electronic system, which integrates and logs relevant sensory input, designed specifically for the driver and environment. It is hoped that the research will lead to the development of a tool that can be used to allow for further research towards developing an understanding of the complex relationship between the stressors and driver fatigue.

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* The author would like to mention that the field of wearable wireless health monitoring is new and the role that this technology would play in motor racing is yet to be defined. Competitive edge in this sport has limited the amount of public domain information as the reference list reflects.

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