Quantifying mental workload in performance driving: The motor racing load index (MRLIN)

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ABSTRACT

Within the upper echelons of motorsport, it is usual for teams to spend tens or even hundreds of millions of pounds developing aspects of their cars to achieve best performance. Despite this, costly, and potentially dangerous errors occasionally occur due to the complexity of steering wheel-based interfaces. Investigations into improving usability of steering wheel-based controls should employ a range of metrics, one important aspect being the measurement of mental workload. The NASA task load index (NASA-TLX) represents a well-validated method that has been applied to many domains, a derivative of which, called the driving activity load index (DALI) was developed to focus solely on the driving task. However, motorsport differs considerably from conventional road driving – the competitive nature of the task, combined with high levels of physical and emotional stresses indicates that the domain may benefit from a specific derivative of the NASA-TLX. This paper examines the motorsport domain with respect to the NASA-TLX Index and DALI to identify suitable adaptions that may improve the suitability and usefulness of the workload evaluation. A motor racing load index (MRLIN) might provide a more domain-focussed description of racing drivers' mental workloads, and therefore provide insight into potential areas of improvement, not just in terms of steering wheel-based control usability, but also other aspects of car design and team function.

KEYWORDS

MRLIN, motor racing, load index, NASA-TLX, DALI

Introduction

Motorsport teams, particularly at high levels, invest considerable sums in order to maintain a high level of competitiveness. Despite this, there are documented incidents of drivers losing control of their vehicles, or performance being reduced due to the complexity of their steering wheel-based interfaces (Gkikas, 2011). To address this issue, an analysis of driver tasks using a range of human factors approaches should be employed in order to gain a sufficient understanding of the domain. Quantifying the mental workload of drivers would potentially provide valuable data that could aid the design of user interfaces. Drivers and teams in the past have often employed a tenths metric (Jenkinson, 1962) as a method of expressing workload. It is a subjective method by which to describe the level of a driver's resources that are being expended on the (race) driving task. The workload of the driver is expressed as a fraction, with ten tenths representing the maximum optimal primary task effort of an individual. This is the point beyond which overload occurs and performance begins to suffer (Young et al., 2015). Whilst this provides a coarse quantification of driver effort/available resources, it may be more useful to decompose the primary task into distinct elements. The NASA task load index (NASA-TLX) (Hart and Staveland, 1998) and the driving activity load index (DALI) (Pauzié, 2008) derived from it provide the basis for the generation of a motor racing load index (MRLIN). This is separated into six factors, based partly on those employed in the NASA-TLX and DALI, taking into account the specific and unique demands of motor racing. By gaining a deeper insight into the mental workload of racing drivers, it may be possible to identify how factors interact, and how individual drivers cope differently. This can then inform a variety of aspects such as interface design, how to manage drivers' pace to conserve tyres and fuel, and even vehicle setup with a view to reducing mental workload to reduce error rates and improve performance.

The racing driver's tasks and stresses

Bertrand (1983) describes five stresses that Formula One (F1) drivers experience: muscular effort, g loadings, emotion, temperature and vibration. These in combination place drivers under considerable stress, particularly in terms of cardiac stress (Watkins, 2006), and all affect cognitive usability (Brown et al., 2018). The primary task of a racing driver is a combination of two separate driving tasks carried out simultaneously (Henderson, 1968). The first is a tracking task: racing drivers seek to maintain their car on a racing line (the path around a track that results in the fastest lap time). The second task is compensatory, whereby drivers are required to actively utilise all available tyre adhesion, providing frequent control inputs as necessary. Drivers are also expected to carry out multiple secondary tasks, steering wheel-based controls are often employed multiple times a lap to adjust settings. Teams are in regular contact with drivers via radio and will provide feedback on aspects of performance and advise on settings. Interacting with traffic can be a complex and demanding task, with visibility often compromised by cockpit and helmet design.

NASA-TLX/DALI

Whilst other subjective metrics exist, the NASA-TLX (Hart and Staveland, 1998) is widely employed in human factors research. It represents a valuable and well-validated method by which to measure mental workload (Hart, 2006). Indeed, Baldisserri et al. (2014) employed it as part of a set of methods designed to estimate workload in dual task scenarios within motorsport. The later DALI represents a variation designed specifically to quantify mental workload in drivers (Pauzié, 2008). These metrics employ specific factors (Table 1) that are subjectively scored on a scale by participants, the results of which are then weighted by the contribution of a factor to the workload of a task, or simply employed in their raw form.

Table 1: NASA-TLX and DALI Factors

NASA-TLX Factors	DALI Factors
Temporal Demand	Temporal Demand
Mental Demand	Effort of Attention
Effort	Visual Demand
Performance	Auditory Demand
Physical Demand	Interference
Frustration Level	Situational Stress

Deriving motorsport-specific mental workload factors

In order to derive the MRLIN factors (Table 2), it was necessary to examine the existing factors used in the NASA-TLX and DALI (Table 1). These were then considered within the context of the unique demands of motor racing as defined by Bertrand's five stresses (Bertrand, 1983).

Table 2: MRLIN factors, descriptions and relations to existing mental workload factors.

MRLIN factors	Motorsport description	Related NASA-TLX factors	Related DALI factors
Physical demand	How demanding is the environment due to muscular effort, g forces, vibration, temperature, etc.?	Physical demand, effort	N/A
Situational stress	To what level were emotions such as fear, fatigue, competitiveness experienced?	Frustration level, temporal demand	Temporal demand, situational stress
Interference	Level of distraction caused by secondary tasks, radio communications, external flags, etc.	N/A	Interference
Car control demand	How much mental and physical work is required to maintain control of the car at the given pace?	Mental demand, effort	Attention
Situation awareness demand	How much attentional demand was required observing track and other cars, mirrors, in-car display, flags, etc.?	Mental demand, effort	Visual demand, auditory demand, attention
Performance	How successful were the completed laps? Were you satisfied with the performance?	Performance	N/A

The original NASA-TLX factor of physical demand is highly appropriate as the nature of motorsport is physically demanding (Brown, et al., 2018), and the addition of secondary tasks and an uncomfortable environment can generate additional workload. Situation stress is a DALI factor (Pauzié, 2008) that, with respect to motorsport, encompasses many of the emotions such as excitement and fear that lead to the production of stress hormones (Watkins, 2006). This also includes the element of competitiveness and the degree to which the driver is striving to achieve the best performance. Interference is a DALI factor (Pauzié, 2008), that constitutes disturbances due to secondary tasks. Within motorsport, these can be caused by the necessity to makes changes to vehicle settings (Galloway, 2014). Car control demand represents a factor unique to MRLIN. It is highly dependent upon scenario, such as vehicle setup, track condition, tyre wear and the temporal demand on the driver. Situation awareness demand is another uniquely defined factor within MRLIN – the rationale for its differentiation from attention is the high level required in motorsport. Visibility is limited due to seat position and the use of a helmet, mirrors are often small, therefore gaining sufficient situation awareness is challenging. Performance is a factor shared with the original NASA-TLX (Hart, 2006) – the description is identical and it represents the success level achieved and level of satisfaction.

Conclusion

The MRLIN factors represent an initial attempt at defining a metric by which the mental workload of racing drivers can be measured. Further work will be necessary to validate and potentially refine the factors. Input from racing drivers to confirm or adjust factors and provide weightings would be a logical next stage prior to validation in a simulator. On-track validation would also be necessary to ensure the effects of the full range of driver stresses are examined. One potential limitation of the MRLIN is that in order to gain the best results, it would be necessary for drivers to select their ratings directly after experiencing the measured task. This is not possible during racing conditions but should be possible during practice and qualifying sessions. In addition to this, ratings could potentially be given via radio, once the car is stationary in the pit-lane or even on the main straight during a cool-down lap. It should also be noted that there are some interdependencies between factors: for example, physical demand and interference can cause situational stress. However, there is also an element of interdependence between the original TLX factors. It is hoped that the MRLIN could provide a deeper understanding of mental workload in racing drivers, therefore providing insight into improving multiple areas of usability. The specific effects on each factor of individual aspects, such as driver pace and secondary task complexity could be studied as independent variables, revealing areas for improvement. The heterogeneity of racing drivers and their unique methods of balancing mental workload and performance could aid team engineers in identifying how best to manage their driver with regards to pace, how complex their interface should be, and the level of guidance that they will require.

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