The usability of F1 driving interfaces

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ABSTRACT

The complexity of driver's interfaces in Formula One has increased dramatically in the last 25 years. This has resulted in criticisms from drivers and has been blamed in several cases for accidents due to distraction or mode error. Technologies adopted by Formula One to improve performance have led to additional interface requirements and the resultant interface design adaptations. Specific regulatory changes have also been identified as significant factors in dictating the driver's interface workload. Research is currently ongoing into the empirical analysis of the interfaces. Even minor design decisions can have a large effect on usability. These findings have confirmed the challenges facing human factors engineers tasked with designing interfaces featuring large amounts of functionality for use within high cognitive workload conditions.

KEYWORDS

Interface complexity, motorsport, driver distraction

Introduction

There are multiple documented occurrences of driver errors in Formula One that can be linked to the design complexity of their interfaces (Gkikas, 2011). In motorsport these errors not only have high risks associated with them but are expensive when the vehicles sustain damage. Even in the cases where major errors do not occur, distraction or interface-based mistakes can have a negative impact on the driver's performances (Baldisserri et al. 2014), resulting in significant financial costs due to lost points and potential sponsorship deal losses.

Within the context of motorsport, interface induced driver errors appear to primarily fall into two categories, control misuse and distraction. In 2016, Nico Rosberg selected an incorrect setting on the steering wheel of his Mercedes, which ultimately resulted in the retirement of both Mercedes' cars. In 2014 Pastor Maldonado crashed during a practice session, stating afterwards that he had been distracted by the number of settings that required adjusting.

Harvey and Stanton (2013) define driving as a complex activity comprising multiple tasks, sub-categorised as primary or secondary. Primary tasks comprise the control of the vehicle via the steering, pedals and gears. Hedlund et al. (2006) define secondary tasks as those that are non-essential or not directly pertaining to vehicle control, such as steering wheel-based controls. Knowles (1963), describes the finite pool of resources available for primary and secondary tasks. In the event of a primary task requiring the majority of resources, those remaining for any secondary task are limited, potentially to the detriment of task performance, the inverse also applies (Wickens, 1991). This fundamental aspect of capacity theory reveals the importance of reducing the complexity of secondary controls in motorsport. Baldisserri et al. (2014), reported the notable impact secondary task type had on lap times in a motor racing simulator-based experiment employing the Multi-Attribute Task Battery methodology.

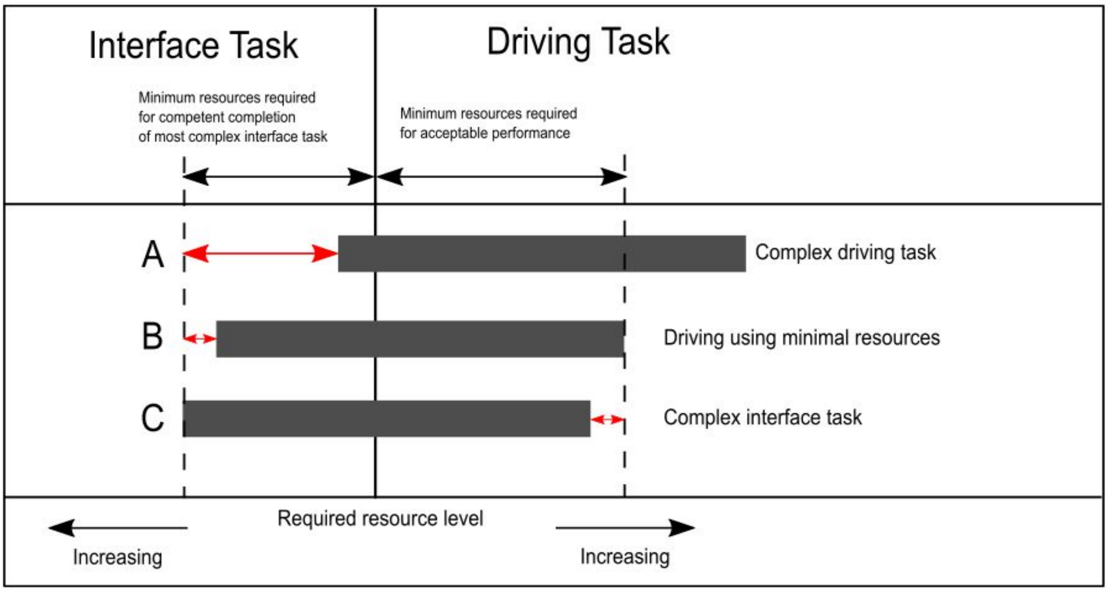

Figure 1: Driver's resource allocation in three scenarios of use.

Figure 1 above illustrates how a hypothetical driver's resources might be allocated in three scenarios, with deficits highlighted by arrows. The grey bar represents the driver's resources. Scenario A illustrates a driver undertaking a highly complex task such as racing in close quarters or in heavy rain. Their primary task requires more resources, leaving little in reserve for interface based secondary tasks. It is under these conditions that interface based errors are likely to occur. Scenarios B and C represent how a complex interface task could influence both primary and secondary task performance.

By optimising the interface to reduce the resources required for secondary tasks, the errors associated with resource deficits could be reduced. In turn, this should reduce the probability of distraction and mode error occurring, improving both performance and safety.

Historical analysis

A historical analysis of interface design in F1 was carried out to identify how controls and instruments have evolved with respect to technological and regulatory changes. The instrument panels and steering wheels of championship winning cars from 1950 to 2016 were assessed, and the number and types of controls recorded. Data was also recorded for the steering wheel-based controls of Ferrari F1 cars constructed between 1995 and 2017. Major technological and regulatory changes were also identified and mapped onto a timeline.

Figure 2 shows how the number of steering wheel-based controls tended to be influenced by the introduction, and removal, of technologies that afforded the driver with additional settings for improving performance. For example, between 2002 and 2008, the number of controls present on Ferrari's steering wheels remained static at 22. The increase in controls on their 2009 car to 30 may have been a result of the regulatory change that introduced the Kinetic Energy Recovery System (KERS). KERS provided cars with the ability to generate electrical energy during braking that could later be deployed to aid overtaking, however, additional controls were necessary to activate it and adjust settings. The following year, the number of controls reduced to 23 and stabilised, this could be indicative that Ferrari deliberately reduced the complexity of the wheel.

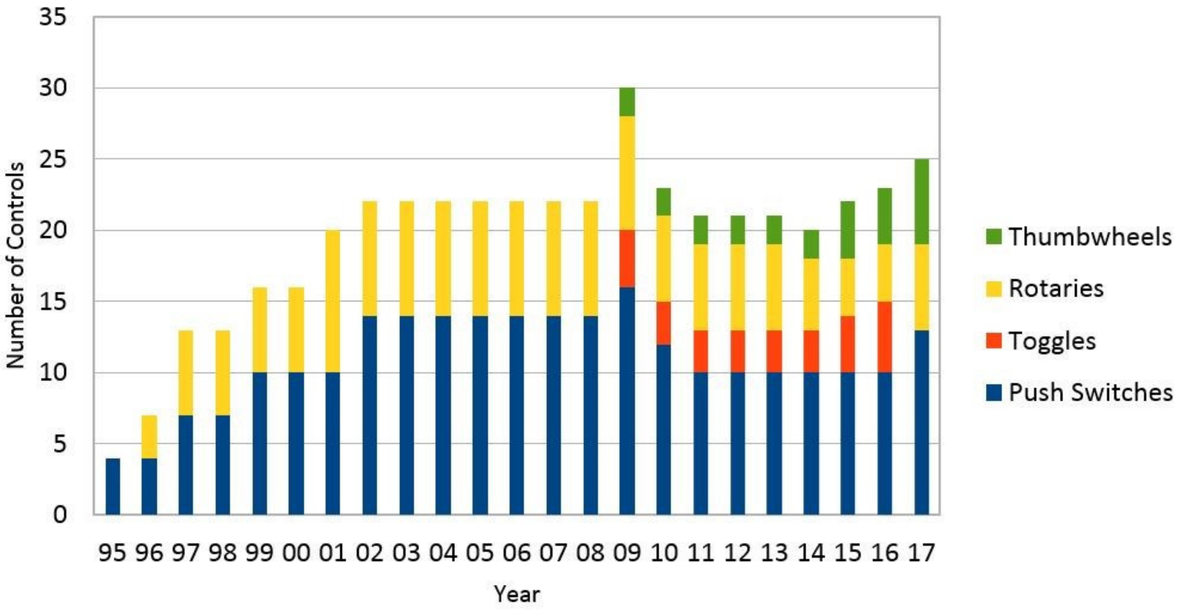

Figure 2: Ferrari steering wheel control types

One explanation for this could be that the high number of controls present may have caused it to appear visually cluttered, which can result in confusion (Rosenholtz et al., 2005). Rosenholtz, Li and Nakano (2007), suggest that visual clutter can degrade visual search performance, exceed short term memory limits and adversely affect object recognition performance. The latter may have resulted in the need to provide more labels and colours, as the number of controls has increased over the years; this can in itself result in increasing visual clutter further, see figure 3.

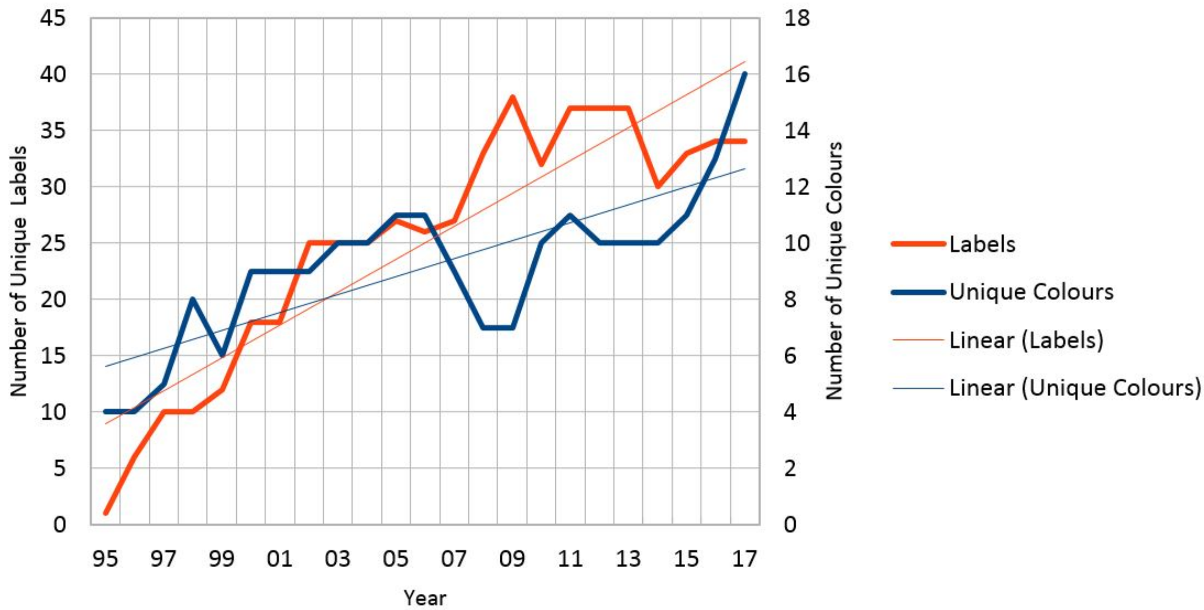

Figure 3: Ferrari F1 Steering Wheel Colours and Labels

There is clearly a balancing act between providing the driver with the ability to adjust multiple settings to improve performance, and not presenting them with so many controls that they cannot use them without compromising their own interface or driving task performance.

Driver's environment

Racing drivers are subject to an environment with specific physiological effects. Some of these have resultant cognitive effects that should be considered during the interface optimisation design process. The interface should ideally be calibrated to the driver's least able state; so it is necessary to understand the nature of that state and its causes. Watkins (2006), expands on the work of Bertrand et al. (1983), describing five stresses experienced specifically by Formula One drivers:

- Emotional Stress
- Driver Temperature
- G Forces
- Vibration
- Muscular Effort

Research was carried out into each of the five stresses to reveal the effects that were likely to influence interface usage. It was found that driver temperature can have a significant effect on cognitive abilities, Jacobs at al., (2002), and Wyon et al., (1996), reported an increase of less than 1 degree was sufficient to reduce the hand/eye coordination of road car passengers. Gopinathan et al. (1988) outlined a possible correlation between a reduction in cognitive abilities and dehydration. Whole body vibration (WBV), such as that experienced in F1 cars, can directly influence fine motor control, perception and cognition, in addition to causing physical effects (Conway et al., 2007). In high G loading situations, the driver not only has to brace themselves (Jacobs et al., 2002); (Yamakoshi, 2009), but they also may experience some difficulties with vision (Potkanowicz and Mendel, 2013). In terms of muscular effort, a study by Beaune, Durand and Mariot, (2010), found a direct relationship between fatigue and driver mistakes.

Empirical assessment of F1 interfaces

To gain insight into the usability of current interfaces, four 2017 F1 steering wheels were analysed; dimensions, coordinates and types of control were recorded. (See Figure 4). A scenario of control usage was then generated, using publicly available on-board footage of F1 races. A spreadsheet was employed to generate a list of when each control was activated over a whole race distance. Software was written to carry out link analysis over a race distance using the control coordinates for each wheel, and scenario data. This allowed the frequency, nature and importance of links between controls to be identified (Stanton et al., 2013), and provided data on potential layout optimisations. Control coordinate data also allowed transition distances to be calculated, and the addition of control dimensions enabled the calculation of Fitt's law measures. The index of difficulty is known to correlate highly with control usage duration (MacKenzie, 1992). This, combined with link analysis data are valuable metrics within the motorsport context due to the biomechanical and cognitive distraction caused by operating controls (Young, Regan and Hammer, 2007). The results of this empirical assessment are currently pending.

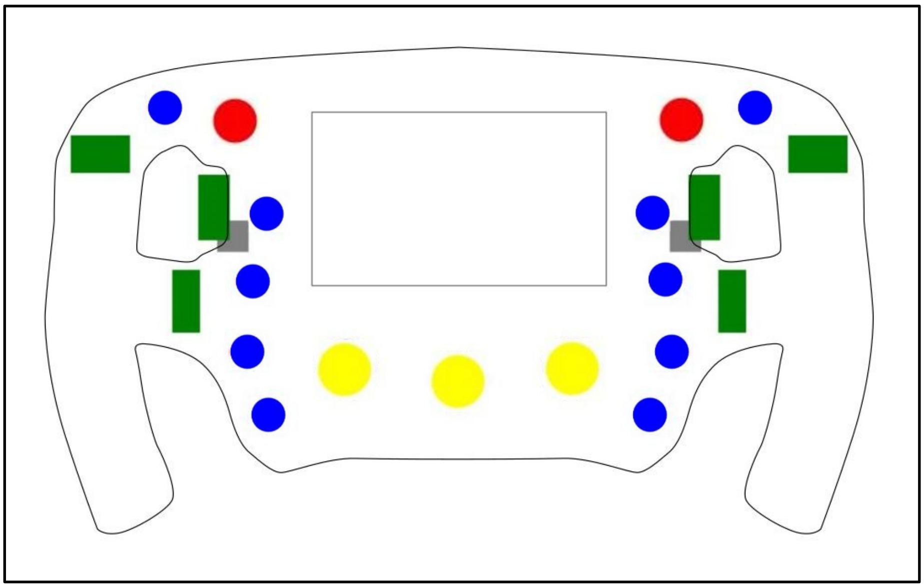

Figure 4: Software mapping of the 2017 McLaren MCL32 Steering wheel based controls, displaying thumbwheels as rectangles, buttons as small circles and rotary controls as the three large circles at the base. Image is prior to link analysis application.

Discussion

There is a clear rationale for improving the usability of the racing driver's interface, however, it is a complex field involving many factors. The research into three disparate areas, physiological, historical design and empirical analysis all revealed information pertinent to optimising the design from different dimensions. This paper highlights the necessity to examine usability from these multiple diverse perspectives, to gain the required awareness of the influencing factors. The physiological aspects and their associated cognitive effects provide useful insight into how a usable interface may become less so when a driver experiences duress. This might lead to design decisions aimed at simplifying certain operations; or reducing their frequency towards the end of races at venues with high ambient temperatures or those that carry a particularly high physical workload. Factors such as vibration will have been accounted for in current designs, in terms of the selected control types. However, with the environmental factors well defined and understood, these control types may be further optimised or redesigned. The historical data illustrated the influence of technological and regulatory changes on the interface complexity and design. The plateau of controls at approximately 20 on Ferrari wheels between 1995 and 2017, shown in Figure 2 may be indicative of a value considered through experience to be the upper bound. The data also revealed information regarding potential frequency of use and importance through the consistent placing and type of some controls either as buttons near the driver's thumb positions or rotary switches mounted centrally. It is known that drivers are allowed to place controls based on their preferences; however, whilst this may have the short-term benefit of familiarity, they may not be optimally placed in terms of usability. Empirical outputs of control layouts, such as the index of difficulty of controls based on scenarios of usage, highlighted the importance of assessing combinations of control interactions. The total interface traversal distance also potentially provides an indicator of design optimisation levels. The bespoke nature of Formula One cockpits means that interfaces will be adapted specifically to the drivers' individual physical dimensions. These dimensions will need to be combined with empirical data to derive the optimum interfaces. Feedback represents an additional important factor in potential designs. However, due to the levels of noise, vibration and the requirements for fire-proof clothing, audio and tactile systems are likely to be less effective, although drivers are known to be presented with an audio cue at the optimum time to change gear.

Current display interfaces do provide some button press confirmations, such as brake bias changes, although there is scope for future research in this area.

Conclusion

There are a set of clearly defined motives for improving the usability of interfaces in motorsport; however, it is a complex field involving many factors. Formula One in recent years has seen a dramatic increase in interface complexity which has resulted in multiple documented instances of driver error. These errors carry with them not only significant risks in terms of driver safety but also costs to the teams; repairs are expensive, lost points and sponsors even more so. This paper analysed Formula One interfaces from the multiple dimensions of history, physiology and empirical human factors methods to explore potential interface usability optimisations. Historical analyses revealed trends in control priorities, and the major influences driving the complexity increases. Physiological research provided the complexity bounds due to associated cognitive effects in specific high demand scenarios. Human factors methods highlighted potential optimisations through minimising driver movement and cognitive requirements. The balancing act between the performance affordances of a complex interface in terms of vehicle tuning and the risk of error due to overloading the driver requires considerably more research. Employing a multi-faceted approach to understanding the domain provided valuable insight to augment future analyses and optimisations.

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