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# At the cross-roads: An on-road examination of driving errors at intersections

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ABSTRACT

A significant proportion of road trauma occurs at intersections. Understanding the nature of driving errors at intersections therefore has the potential to lead to significant injury reductions. To further understand how the complexity of modern intersections shapes behaviour of these errors are compared to errors made mid-block, and the role of wider systems failures in intersection error causation is investigated in an on-road study. Twenty-five participants drove a pre-determined urban route incorporating 25 intersections. Two in-vehicle observers recorded the errors made while a range of other data was collected, including driver verbal protocols, video, driver eye glance behaviour and vehicle data (e.g., speed, braking and lane position). Participants also completed a post-trial cognitive task analysis interview. Participants were found to make 39 specific error types, with speeding violations the most common. Participants made significantly more errors at intersections compared to mid-block, with misjudgement, action and perceptual/observation errors more commonly observed at intersections. Traffic signal configuration was found to play a key role in intersection error causation, with drivers making more errors at partially signalised compared to fully signalised intersections.



## 1. Introduction

Intersections are an integral part of the road system. They are, however, also one of the most dangerous because they represent a point where road users converge and potentially conflict with each other. In Australia, the majority of urban crashes and a substantial proportion of rural crashes occur at intersections (McLean et al., 2010). For example, between 2001 and 2005 in the state of Victoria, 47% of car and pedestrian crashes, 58% of cyclist crashes and 38% of motorcycle crashes occurred at intersections (VicRoads, 2011). A range of factors have been found to contribute to crashes at intersections, including intersection design, traffic signal phasing (e.g., whether turns are fully (protective) or partially (permissive) controlled), environmental conditions, vehicle maintenance issues, as well as the errors made by drivers and other road users (Devlin et al., 2011; Greibe, 2003; Preusser et al., 1998; Sebastian, 1999).

Driving error has been identified as a prominent causal factor in road traffic crashes. Research suggests that up to 90% of all road crashes involve some form of driving error (Treat et al., 1979). Despite its prevalence, an in-depth understanding of driving error, including its nature, the role of different error types in road crashes, and the role of wider systems failures in error causation, is yet to be achieved (Salmon et al., 2010). A major limitation of many previous intersection error studies is that they have typically relied on the use of retrospective crash data analysis to identify the errors involved in intersection-based crashes. The retrospective crash method has a range of limitations that can constrain our understanding of driver error. First, when using crash data analysis for error identification purposes, the data involved are often not comprehensive enough to support the accurate classification of errors or to identify the causal factors or error recovery strategies associated with them. Another limitation is that the data are often focused on the driver and thus it is difficult or even impossible to identify the systems-wide factors that may have contributed to the errors (Salmon et al., 2010).

While driving errors occur at all points in the road network, they may be particularly prominent at intersections. Also, given the complexity of intersections, the nature of errors that occur there may differ to those made at other sections of the road network (e.g., mid-block). There is therefore a pressing need to identify the nature (number and type) of errors made by drivers at intersections, including the factors that can both contribute to and mitigate these errors from occurring.

A range of studies have examined driving errors that contribute to intersection-based crashes (e.g., Lee et al., 2004; Obeng, 2011; Schepers et al., 2011). Notably two recent studies sought to classify the different error types and contributing factors involved in crashes occurring at intersections (Gstalter and Fastenmeier, 2010; Sandin, 2009). Sandin used the Driving Reliability and Error Analysis Method (DREAM; Ljung, 2002) to establish whether

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common patterns of interlinked contributory factors could be found in crashes occurring at 26 urban intersections. Causation charts were aggregated for six defined risk situations based on the most common errors and violations occurring at intersections (i.e., a failure to yield, or running a traffic light or sign). Four risk situations were defined for drivers without right of way and two for drivers with the right of way. For two of the risk situations, a clear pattern revealed that the other vehicle was not observed by drivers due to distraction and/or sight obstructions. Distraction also played a role in drivers missing a sign or red light signal or misjudging the timing of an amber light. Other common patterns found included drivers not behaving as expected by driving at high speed and drivers believing that they had right of way and did not expect other vehicles to cross their path.

Gstalter and Fastenmeier (2010) examined human error probabilities at intersections in an on-road study involving 62 drivers from different age groups. Two trained observers recorded driver errors during the drives, which were then classified by driving task and intersection segment into various error categories. Errors varied across driver age group and intersection segment and type. The highest errors occurred for non-signalised intersections and a roundabout. The older drivers' also made significantly more errors than the younger inexperienced and experienced groups. Errors when approaching intersections were relatively rare, although the inexperienced drivers made substantially more errors at this point, which included approaching in the wrong lane, lane changes and braking too late. Errors commonly made in the inner area of intersections included inadequate lane use in queuing space, driver entering inner area when intersection is not yet cleared, unassertive clearing, persistent following and driving too far into crossing traffic. The vast majority of the errors observed were attributed to high task loads during the intersection tasks.

In recent times researchers have made a strong case for the 'systems' approach when considering road user behaviour (e.g., Larsson et al., 2010; Salmon and Lenné, 2009); since the road transport system is a complex, sociotechnical system and road safety is an emergent property arising from the interactions of all parts of the system, there is a pressing requirement for road safety research to consider the entire system, as opposed to component parts in isolation (e.g., the driver). In the context of driving errors, emphasis is thus placed not only on the driving errors themselves, but also on the interactions of other parts of the system that play a role in them. Under this philosophy intersection errors do not simply arise from aberrant driving behaviours; rather they are likely to be a product of the interaction between various factors, such as intersection design, driver training, road rules and regulations, environmental conditions, and the behaviour of other road users. Previous research focussing on driving errors at intersections has largely been driver-centric, focussing specifically on driver-related causes. Taking a systems approach will not only enhance our understanding of these errors, but also will lead to more appropriate countermeasures, since the systemic failures are focussed on (as opposed to the driver in isolation). Further, systems-based research augurs well with the currently popular systems-based road safety strategies (e.g., Vision Zero; Johansson, 2009), The Netherlands' Sustainable Safety Approach (Wegman et al., 2008). These strategies require that all aspects of the transport system (i.e., roads, vehicle speeds, vehicles and the users of the system) work together to achieve the highest possible safety outcomes. Any investigation of driving errors at intersections must, therefore, consider the role of wider system factors in contributing to errors.

The present study set out to investigate the nature and sources of driving errors at intersections through the conduct of an on-road study. It is important to note that the focus of this study is on the occurrence of errors under everyday driving conditions, not on the occurrence of more safety-critical incidents and events. The study utilised a multi-method approach, involving the use of in-vehicle error observation and video recording and a suite of human factors methods to investigate the number and type of errors made by drivers at intersections and to examine an element of the wider system that may contribute to these errors – traffic signal design. Of particular interest was whether and how errors occurring at intersections differ from those occurring at mid-block. Establishing if errors made at intersections and mid-block are different or similar can provide important insight into where the performance failures are occurring. For example, if error types and numbers are similar across the two road segments, it suggests that intersections are not simply just contributing to more or different error types occurring, but that there is something about the intersection environment that leads to breakdowns in error recovery; hence, why the same errors lead to higher crash rates at intersections. Understanding whether and how errors differ across different road segments can lead to improved and better targeted error mitigation strategies (e.g., improved error tolerance rather than error prevention).

In line with the systems approach, also examined was how the complexity of intersections, as measured through traffic signal design, affects the number and type of errors made at intersections. It is likely that partial signalisation of traffic controls contribute a higher number, and possibly different types, of errors because they require drivers to make a greater number of decisions and generate higher workload than fully controlled traffic signals (Hancock et al., 1990; Shebeeb, 1995). They are also associated with higher right turn crash rates than fully signalised intersections (Bui et al., 1991). It is important to identify and better understand the specific error types occurring at fully and partially signalised intersections in order to develop effective countermeasures.

## 2. Method

### 2.1. Participants

Twenty-five drivers (15 males and 10 females) aged 19–59 years (mean = 28.9, SD = 11.9) took part in the study. Sixteen participants held a valid full driver's license while the remaining nine held a valid probationary (P2) license. Participants were recruited through the weekly on-line Monash University newsletter and were compensated $50 for their time and travel expenses. The study was approved by the Monash Human Ethics Committee.

### 2.2. Materials

The study used a range of different approaches for collecting detailed data on driver performance and errors.

#### 2.2.1. On-road test vehicle (ORTeV)

The MUARC on-road test vehicle (ORTeV) was used to drive the urban route. The ORTeV is an instrumented vehicle equipped to collect two main types of data: vehicle-related and eye tracking data. ORTeV is also equipped with seven unobtrusive cameras recording forward and peripheral views spanning 90° each respectively as well as three interior cameras and a rearward-looking camera. For the purposes of this study, only the video-based data were used to verify the errors made and determine the role of any system-wide factors in their occurrence.

#### 2.2.2. Driver verbal protocols

Verbal protocol analysis (VPA), or 'think aloud' protocol analysis, was used to elicit data regarding the cognitive and physical processes undertaken by drivers while driving. Participants provided verbal protocols continuously as they drove around the test route. The verbal protocols were recorded using a digital dictaphone and transcribed verbatim post-trial.