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Looking and failing to see, or gazing and failing to cognise appropriately?

"Looked but failed to see error" refers to a set of circumstances where a driver accounts for an accident in the terms of failing to notice an approaching vehicle. Often thought as a prototypical form of such accidents are collisions between motorcycles and cars. Research into causality of motorcycle accidents tend to make two basic assumptions. Firstly, that the offending driver looks but then fails to see the motorcyclist. Secondly, that this failure can be explained in terms of the relative lack of conspicuity of the motorcyclist when compared to other road users. Are the physical properties of the approaching object the sole determiner of its successful detection, or does the psychological state of the driver have a role? This research therefore attempts to explain motorcycle accidents within the framework of psychological models of visual search, selective attention and expectancy.
My work can be described as eclectic. My current research investigates how a driver through experience develops an efficient search strategy enabling them to emerge onto a main road. This research involves the measurement of driver eyemovements in a laboratory environment. Other ongoing research involves collaborative work with Sussex police investigating driver speed perception.

Can object recognition theories explain visual search failures at junctions?

Drivers' visual search at junctions can be very rapid. Models of human object recognition, such as Biederman's Recognition By Components (RBC) theory, provide a theoretical account for how we can rapidly comprehend the semantics of a scene, despite short display times. Can such theories account for failures in driver's search at junctions? Inspired by RBC theory, this laboratory study attempts to understand changes in search behaviour by drivers at differing levels of experience. Each subject watched video clips of an approaching vehicle in a traffic scene, as viewed from the perspective of a driver at an intersection. In one of the clips, the vehicle was replaced by an animated shape. This was either a vertical bar moving in the same way as a motorcycle; a horizontal bar moving in the same way as a car; or a pixelated "rippling" distortion. Drivers' decision times were recorded in response to differing search instructions: they were asked to search either for a motorcycle or for any motor vehicle. Experienced drivers - but not non-drivers or inexperienced drivers - treated the animated shapes as vehicles, provided the search instructions matched the shapes orientation. Thus if the shape was a vertical bar and the instructions were to search for a motorcycle, experienced drivers were more likely to believe that a vehicle was present than if they had been asked to search for any vehicle. An unexpected finding was that police traffic officers treated the "rippling" distortion as a cue to a vehicle's presence; possibly movement is all that is required by such highly trained drivers. We suggest that with experience, drivers may develop shorter search times at junctions and may extract from complex traffic scenes only a minimal amount of information, based on prior expectancies about what they are likely to see.

`Looking and Failing To See Error' The cost of experience?

Abstract

The Transport and Road Research Laboratory coined the phrase `looked but failed to see error' referring to a set of circumstances where a driver accounts for an accident in the terms of failing to see. A prototypical form of such accidents involves collisions between motorcycles and cars. Motorcycle accidents tend to involve another road user who often claims not to have seen them in time to avert a collision. Research into the causes of motorcycle accidents has tended to make two basic assumptions: firstly, that the offending driver actually looks but then fails to see the motorcyclist,. secondly, that this failure can be explained in terms of the relative lack of conspicuity of the motorcyclist. This laboratory experiment suggests an alternative explanation for such accidents. Experienced and inexperienced drivers viewed video tape clips of approaching traffic at intersections. Subjects' eye movements were recorded in response to different search instructions. Under the conditions of this experiment, experienced drivers appear to use 'pre-programmed' search patterns directed towards areas of the road environment which are informationally rich; there was little evidence of these in the eye-movements of inexperienced drivers. Experienced drivers appeared to start their search at a midpoint in the scene whist inexperienced drivers started their search nearby. One consequence of this was that experienced drivers took longer to detect motorcyclists who were nearby. (i.e. to the left of the initial point of fixation.)

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An investigation of the role of vehicle conspicuity in the ‘Looked but failed to see’ error in driving

by

Martin Paul Langham

Thesis presented for Doctor of Philosophy

I hereby declare that this thesis has not been submitted either in the same or different form, to this or any other university for a degree

Signature

Abstract

Accidents involving motorcycles tend to occur at intersections where a car driver claims to have 'looked' but failed to have 'seen' them. Motorcycle accidents accounted for by the 'looked but failed to see error'(L.B.F.S.) are traditionally explained in terms of the motorcyclists relative lack of conspicuity compared to cars. After reviewing the literature and assessing the diverse methods available to investigate the L.B.F.S. error this thesis refines previous experimental methodologies. Evidence is then gathered from a police accident database, and by laboratory and field studies to support the view that poor physical conspicuity is not the only explanation for motorcycle L.B.F.S. accident.

The theoretical stance taken is that driver expectancies may account for, at least in part, some of these accidents and that the functioning that human attentional systems during driving may aid the understanding of this error.

Experimental chapters investigate the amount of time drivers search at junctions and consider if object recognition theories can account for possible detection failures of uncommon vehicles such as motorcycles. These studies are complemented by investigations of driver eye-movements in the laboratory which compare detection performance of novice, experienced and expert drivers.

Results suggest that experienced drivers adapt through time to perform driving as possibly an automated process neglecting uncommon vehicles that may be encountered on the highway, even if they are conspicuous in sensory terms. To illustrate this, the final experimental chapter reports accidents involving conspicuous police vehicles which are hit by drivers who claim that they did not see them.

Tentative conclusions drawn suggest that experience need not mean expertise and that the L.B.F.S. error may be a cost of experience.

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Foreword

Why does a car driver emerge from a junction and hit a motorcyclist, who was there to be seen, claiming that he 'looked but failed to see' (L.B.F.S. error) the motorcyclist? The explanation up to now has been that motorcyclists present a particular problem in their detection by car drivers because, compared to cars, they are relatively inconspicuous. Previous research has taken the driver's statement that s/he 'looked but did not see' literally. Because the driver claimed s/he did not 'see' the motorcycle, and this was the only reason for the accident, the solution has been to make the motorcyclist as physically conspicuous as possible. However, some argue that physical conspicuity has very little to do with accident potential, as it is unlikely that any accident has a single exclusive cause. Several alternative explanations have been suggested together with a critique of previous methodology.

Methodological weaknesses have included an over-reliance on accident statistics without thorough investigation of the facts, dubious laboratory methods that poorly reflect the task of a driver, and experimental designs which do not have the rigour of other psychological research investigating visual search and human attentional mechanisms.

Limited alternative explanations to why drivers 'look' but do not 'see' suggest that the motorcycle may be 'seen' by the car driver but, because of its rarity on the road, the car driver fails to recognise it as a motorised vehicle. Others point to the fact that motorcycles can appear in parts of the road environment where one would not expect to see a car, and have consequently argued that the car driver does not 'look' in the appropriate place. Finally the driver may not see the motorcycle simply because it is small. This thesis investigates these three alternative explanations after modifying and improving previous methodology.

The literature suggesting that physical conspicuity is the only answer to the L.B.F.S. problem is investigated and complemented with a review of human visual attention performance. A processing model is developed to understand how the limits of human attention may account for the error (Chapter 1). Whilst the single explanation for this type of accident is evident, diverse methods have been adopted and are reviewed (Chapter 2). One of these previous methods has been to cite evidence from local police accident databases to support the claim that drivers truly 'look' but fail to 'see'. The Sussex Police Accident Database is examined to substantiate previous claims and aid in the construction of laboratory stimulus materials (Chapter 3). A further critique of previous methodology is that of stimulus display time. An observational study of driver behaviour at intersections reports on the appropriate display time needed for the laboratory (Chapter 4). Previous research has typically used a repeated measures design showing film slides containing many motorcycles to the subject, whilst asking the subject to specifically search for a motorcycle. Motorcycles are however relatively rare on the road and drivers don't search just for motorcycles. Previous methodology is thought to be ecologically unsound (i.e. it poorly reflects the task of the driver) and Chapter 5 contrasts experimental designs and instructions given to participants.

Alternative explanations for the L.B.F.S error indicate that a driver fails to recognise the motorcycle as a motorised vehicle. 'What' is a driver expecting to see and how does s/he recognise vehicles for what they are in a dynamic

environment at a glance? Perhaps object recognition theories can help (Chapter 7). If an alternative explanation is that drivers are searching in the wrong place to successfully detect a motorcycle, then 'where' do drivers look (Chapters 6)? Finally if motorcycles are not detected because of their small visual size, are large objects also involved in L.B.F.S accidents? Chapter 8 reviews cases of car drivers failing to see highly conspicuous stationary police motorway patrol cars. Chapter 9 provides a conclusion.

1. General introduction and literature review

1.1 *Introduction*

In terms of human evolution driving is a relatively recent activity. Yet, after comparatively basic training, we can manoeuvre a motor vehicle at speed with apparent ease. However, crashes do occur and accident statistics show that in the EU as a whole there are some 45,000 fatalities per year (ETSC 1997).

Since the mid 1950s the understanding of motor vehicle accidents has taken a multi-disciplinary approach involving engineers, physiologists and police officers. In more recent times the understanding of driver error has received interest from psychologists (e.g. Shinar 1985). Although driving a motor vehicle is a familiar task, it often tests our perceptual and cognitive abilities to the limits of human performance, and for this reason the skills required to drive a motor vehicle have attracted attention from psychologists. In this thesis by examining driving skills we can test current psychological theories in a dynamic environment.

It is often claimed that 90% of the information necessary for driving comes from our visual system (Cummings 1964, Hartmann 1970, Moore 1969). Although Sivak (1996) claims that vision is important, the attribution of an exact percentage is, at best, doubtful. The majority of psychological research investigating driver error has focused on the perceptual abilities of the driver. This thesis examines the process of visual attention - the selection of a part of the available information for greater processing - considered vital in driving (Hills 1980) which depends on many factors. In broad terms these are the nature of the scene and the expectations, needs and goals of the observer (Yantis 1996). The relative importance of each one of these factors has been a difficult and contentious issue (Hills 1980). This thesis considers one particular suspected failure of the human perceptual system - the 'looked but failed to see' (L.B.F.S.) error.

1.1.1 The 'Looked but failed to see' error

The 'looked but failed to see' error or 'looked but did not see' (Sabey and Staughton 1975, Staughton and Storie 1977) refers to a set of circumstances where a driver accounts for an accident in terms of failing to detect another road user in time to avoid a collision. The explanation of 'looking and failing to see' (L.B.F.S) also implies that the other vehicle was there to be seen by the offending driver. The term 'L.B.F.S. error' is used by Sabey to refer to accidents in which, during the post accident interview, the driver of the offending vehicle claimed not to have detected the other road user before the accident occurred. Sabey *et al.*'s (1975) teams found that 44% of 2036 accidents appeared to have been produced by a perceptual error and in their judgement post accident interviews revealed that 'distraction' and 'looked but failed to see' errors were the most common form of perceptual errors made by drivers. Cairney and Catchpole (1995) estimate that 69-80% of all intersection accidents are failures by one driver to 'see' another until it is too late.

"Seeing without perceiving" (Dahlstedt 1986) or "looking but they are not seeing" (Rensink, Oreagan and Clark 1997) is not a problem exclusive to the UK. Dahlstedt (1986) from German research claims that looking 'without seeing' is a common phenomenon with obvious potentially fatal consequences, especially in

road traffic manoeuvres. Rumar (1990) describes late detection or L.B.F.S. error as a common problem accounting for the majority of multi-vehicle accidents throughout Europe. A detection error is the basic cause, claims Rumar, because without detection no further processing of information, or decision processes can take place. Rumar identified two important causes of the late detection error:

- A lapse of cognitive expectation, illustrated by the failure to scan for a particular class of road user, or a failure to look in the appropriate direction.
- A difficulty with perceptual thresholds, illustrated by the failure to discern the relevant stimuli in lower levels of ambient illumination or in situations where vehicles approach in the peripheral visual field.

In a review of driver vision and vehicle visibility Hills (1980) describes the L.B.F.S. error as a problem of the misjudgement of speed and distance and incorrect interpretation of information by the driver. He points out that an individual vehicle accident is: "not normally due to one single cause but, rather is the result of a combination of causes" (p184). Wulf, Hancock and Rahimi (1989) also conclude that there are many variables which may affect an accident, some of these only occurring in interaction. The number of factors or variables would at first appear to be numerous. McKnight (1972) for example claims to have identified some 1300 independent variables that can affect driver behaviour and accident potential. Hills (1980) presents a table (Table 1-1) of the possible reasons for the 'looked but failed to see error', many of which are discussed in this thesis.

Table 1-1 Possible causes of the 'looked but failed to see error' From Hills 1980 (p 185).

1 Impaired driver vision
2 Visual and perceptual limitations of the normal driver
    Limitations of visual search / peripheral vision
    Limitations of contrast sensitivity, acuity
    Need for target conspicuity
    Limitations of human attention
    Expectancy
    Problems of interpretation
3 Physical restrictions to visibility and conspicuity
    Reduced visibility due to night time glare
    Restricted visibility due to own vehicle or passenger
    Interposed traffic
    Obstruction due to road geometry and roadside furniture, etc.
4 Interaction between causes

1.1.2 Two types of L.B.F.S. error

The term 'looked but failed to see' is used in two principal contexts where the operator fails to detect an object or hazard. The first and more widespread, is when a driver of a car, after rapidly searching for other traffic, emerges into a main road and fails to detect another road user. The second, is typified by pilots and train operators who fail to notice an object which has been visible for some time. In the case of train drivers these are warning signals or other trains (Edkins and Pollock, 1997, Leibowitz, 1983) and in aviation accidents, it is the pilot's failure to detect other aircraft, (reviews in Hurst and Hurst 1982, O'Hare, Roscoe, Vette and Young, 1990). (See Sections 1.8.7.5 & 8.1 for elaboration).

1.2 Motorcycles and the L.B.F.S. error

Studying the L.B.F.S. error is made all the more difficult because of the likelihood that the error may not have a single cause (Hills 1980). One solution is to understand and isolate where this type of error is most likely to have occurred. Accident statistics suggest that motorcyclists are one of the most vulnerable road user groups. They are more likely than other road users to be involved in an accident and, once involved, are more likely to be injured as a result (Carrano 1979, Casualty Report 1996, Wick, Muller, Ekkernkamp and Muhr 1998). Statistically, motorcyclists appear to be involved in more accidents where the car driver failed to detect them in time (e.g. Hurt, Oulett and Thom 1981, Williams and Hoffman 1977).

Most previous research has also focused on one, and only one, possible explanation of the L.B.F.S. accident - physical conspicuity. Although later chapters of this thesis expand the L.B.F.S. error away from motorcycles, it is the motorcycle accident that forms the focus of this investigation. Firstly, let us consider what happens at the most common accident site for the motorcyclist - the intersection (Hurt *et al.* 1981).

1.2.1 Accident Data

Accident statistics reveal that accidents involving motorcycles tend to occur in daylight at junctions and from post accident forensic evidence, the angle of collision between the vehicles implies that the motorcyclist's right of way was violated (Polanis 1979). Many motorcycle accidents involve a car turning across the motorcyclist's right of way (Cercarelli, Arnold, Rosman Sleet and Thornett, 1992, Hurt *et al.* 1981, Peek-Asa and Kraus 1996, Williams and Hoffman 1973) and Smith (1974) found that over 60% of daytime motorcycle accidents are the car driver's fault. Similar figures were found: by Allgemeiner\Deutscher Automobil-club (1987) and by Waller (1972) (68% and 62.2% respectively). The probability of a car driver causing a L.B.F.S. accident with a motorcyclist is 80% higher than a motorcyclist causing an accident with an automobile (Meiszies 1984).

Post accident interviews with the offending driver often find that either the driver claims not to have seen the motorcyclist until it was too late (Hurt 1981) or the driver claims to have been 'looking without seeing' (Dahlstedt 1986). Appel, Otte and Wistemann (1966) cited in Wulf *et al.* (1989) found that motorcycle accidents are under-represented in daytime non-intersection accidents but over-represented in intersection accidents. Figure 1-1 shows the three most common violations of the motorcyclist's right of way (Casualty report, 1996, Thomson 1979) and represents evidence from database studies for the most likely cause of these violations. Since compared with the US and the rest of Europe, driving in the UK is on a different side of the road, the data have been simplified into these three most common forms and converted to British driving patterns. The figures will be referred to during this thesis to avoid the confusion of left and right turn violations. Figure 1-1 shows the three most common manoeuvres of vehicles at intersections when a motorcycle is hit

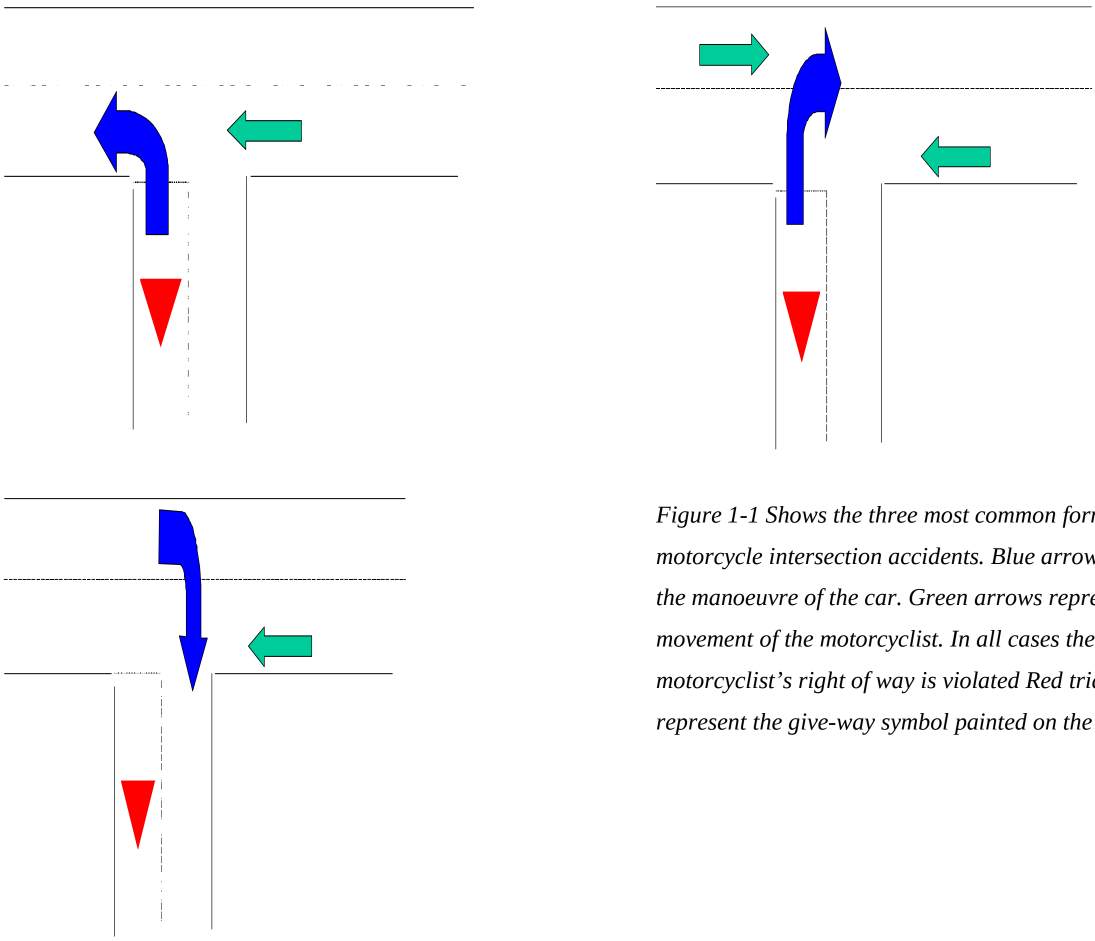

Figure 1-1 Shows the three most common forms of motorcycle intersection accidents. Blue arrows represent the manoeuvre of the car. Green arrows represent the movement of the motorcyclist. In all cases the motorcyclist's right of way is violated Red triangles represent the give-way symbol painted on the road

The evidence from accident databases and the relatively small visual size of the motorcyclist (when compared with a car) have led researchers to take at face value the statement of the offending car driver of 'failing to see'. Compounded by on the spot interviews such as Sabey *et al.* (1975), and the drivers claim of failing to see has been taken by the research community as meaning that the car driver made an active effort to search for the motorcycle and then failed to see it. Moreover, it has also been assumed that the driver's inability to 'see' the motorcyclist was caused by the relative lack of conspicuity of the motorcyclist. Reiess and Haley (1968) believe that conspicuity was the problem and comment:

"A large number of motorcycle/automobile collisions are related to the fact that the motorist does not see the motorcycle until too late .." (Reiess and Haley 1968, p 2-3).

Researchers therefore have considered that the driver was actively 'looking' but did not 'see' because the motorcyclist was inconspicuous. This has led to the conclusion that motorcycle accidents tend to be a conspicuity failure especially in daytime (Abrams 1990). For example, from the analysis of motorcycle accidents in Victoria, Australia, Williams and Hoffman (1977, 1979) estimated that relatively poor motorcycle conspicuity was a contributory factor in 64.5% of accidents.

Four assumptions have been made in previous research: and these are the topics of investigation for this thesis:

- Motorcycles are particularly difficult to detect

- Motorcycles present a particular problem for other road users
- Drivers ‘look’ but fail to ‘see’ motorcyclists
- Motorcycles are difficult to detect because they are inconspicuous

1.3 Current explanation of the L.B.F.S. motorcycle accident

1.3.1 A working definition of conspicuity

Conspicuity, within its usual interpretation from laboratory research, refers to the target’s size, luminance, contrast and colour in relation to its background (Cole and Jenkins 1984, Connors, 1975, Engel, 1972, 1974, 1977, Jenkins and Cole, 1979, 1982, MacDonald and Cole 1988). Conspicuity will later be redefined considering the literature reviewed here. In the meantime, a working definition of ‘raw’ conspicuity can be defined partly as the ability of an object to ‘pop out’ (Treisman 1986, review in Enns, 1990) from its background, either by its comparative novelty, comparative brightness or by the target’s own intrinsic properties to attract attention. Hills (1980) gives a definition of conspicuity that, as we shall see, is echoed in the early stages of motorcycle conspicuity research which examined only the intrinsic physical properties inherit in the target. Hills says of conspicuity:

“It can be defined partly as the extent to which the object is above the just visible limit. It is therefore subject to the same factors as visibility, the most significant of these being the visual size of the object, its contrast with its background against which it is seen the ambient light levels and any source of glare”
(Hills, 1980, p192).

1.3.2 Previous Motorcycle conspicuity research

Research into accidents involving motorcycles echoes Hills’s 1980 description of conspicuity and has focused on the luminance, size and colour of the motorcyclist and motorcycle.

Riding with headlights on, (e.g. Dahlstedt 1986, Fulton, Kirby and Stroud 1980, Janoff 1973 and Janoff and Cassel 1971) has been shown to improve motorcyclist detectability as have the positioning and power of motorcycle’s lights (Donne and Fulton 1985, Stroud 1985). The use of high beam headlights in both cluttered (urban) and uncluttered (rural) environments also increases noticeability (Williams and Hoffman 1979) and the use of additional auxiliary coloured lamps (Mortimer and Schuldt 1980) may appear novel enough to a car driver to attract the driver’s attention. Differences of detection ability in relationship to lighting and vehicle size were found by Kirby and Fulton (1978). The use of modulating headlights has also been found to improve detectability (e.g. Olson Hallstead-Nussloch and Sivak, 1979, 1981). More extreme examples are rotating prismatic lighting and rotating warning devices (Ramsey and Brinkley 1977). Improvement in the physical conspicuity of the motorcycle by increasing its visual size has been investigated. The fitting of a fairing to the motorcycle was found by Williams and Hoffman (1977, 1979) and by Thomson (1979) to increase detection of the motorcyclist by other road users.

Research into the characteristics, noticeability and conspicuity of the motorcyclist has focused on clothing - helmet, jacket and waistcoat. Research has tended to focus on certain colours for their noticeability and high background contrast. Some colours that are relatively uncommon in nature have been adopted as

conspicuity enhancers, in particular lime yellow (Henderson, 1983, Siegal and Federman, 1965). Generally, fluorescent materials for garments are detected more readily than non-fluorescent materials (Dahlstedt, 1986, Donne and Fulton 1985, Fulton *et al.* 1980, Stroud *et al.*, 1980). The most important issue with clothing is the contrast the motorcyclist makes with his background. Watts (1980) found that cyclists wearing dark colours against a light background were detected more easily than when wearing certain retro-reflective materials although this has received little research to date (Abrams 1990).

1.3.3 Other vulnerable road users

The intersection L.B.F.S. right-of-way violation is a problem not just for motorcyclists, but also for other vulnerable vehicles such as cyclists (Casualty Report 1996) and pedestrians (Blomberg-Hale and Preusser, 1986, Lesley 1995, ETSC 1997). Research concerning accidents involving cyclists has also tended to focus on the same physical features (e.g. Cairney, 1995, Watts, 1980) and the importance of not being ‘seen’ by the offending driver. Other vehicle types are also investigated for their noticeability (Sivak 1987), such as police motorway patrol vehicles (Cook 1996). The strategies recommended by previous research for both vulnerable road users and motorcycles is therefore to focus exclusively on physical conspicuity alone as an explanation for the accidents. Although a comparatively high number of accidents involve vulnerable vehicles, these are referred to only within this conspicuity hypothesis.

To illustrate how the words 'conspicuity' and 'motorcycle' are linked, a keyword search on both Bath Information Services Directory (BIDS) and Psyclit (American Psychological Association) was performed. This simple keyword search, inspired by Sivak (1997) shows that in respect of motorcycle safety research the word ‘conspicuity’ is linked with ‘motorcycle accidents’ in 72% of the published articles. As Abrams (1990) explains in his review: “Conspicuity is a word you will be seeing and hearing frequently whenever motorcycle safety is the issue.” (Abrams 1990, p 26).

1.4 Reasons to doubt the conspicuity hypothesis as the sole explanation - the need for research

Why should we not accept the offending driver’s explanation for the accident that they simply did not see the motorcyclist because it was inconspicuous?

1.4.1 A simple problem with physical conspicuity

A consideration only of the conspicuity of an object when considering motor vehicle accidents may be problematic. Firstly, in terms of conspicuity (as defined above) an object that is conspicuous in one environment is easily lost in another. In terms of Signal Detection Theory (SDT) (Green and Swets, 1966), the strength of the signal from the target against one background will change very rapidly against the background or ‘noise’ of another location. A motorcycle that is a light colour and whose rider is wearing light coloured clothing may be conspicuous in one environment, say for example against dark foliage but will be easily lost against a bright background (e.g. an advertising hoarding). It seems intuitively plausible that complex backgrounds will affect detectability (Boersema, Zwaga and Adams, 1989, Jenkins and Cole, 1982), and this may be particularly so for

motorcyclists. Both these types of environment - often referred to as ‘uncluttered’ and ‘cluttered‘ - (e.g. Langham, 1995, Williams and Hoffman, 1979) may be encountered by the motorcyclist within a very short space of time. Therefore by focusing only on the conspicuity of the motorcyclist (target) motorcycle research may not reflect the causality behind the L.B.F.S. error.

1.4.2 Detection and accident potential

Many papers report improvements in ‘detectability’ when a conspicuity enhancer is used (e.g. a fairing). Detectability is not necessarily important for accident prevention. In many of the laboratory studies outlined above, the motorcycle was detected faster by the participant when it was fitted with a conspicuity enhancer. However, the simulated distance that the motorcyclist was from the viewer when it is detected by the participant would not actually affect accident potential. For example Hole and Tyrrell (1995) showed that motorcycle conspicuity enhancers affected detection when the motorcyclist was more than 50 metres away from the viewer but not when the motorcyclist was close. At a distance of 50 metres, if the driver failed to detect the motorcyclist the rider could take avoiding action. To affect accident potential, the enhancers must also aid detection when the motorcyclist is very close to the viewer. Motorcycle accidents according to Hurt *et al.* (1981) occur when the motorcyclist is within a 40° angle either side from the driver and when the motorcyclist is less than 2 seconds away from the viewer when travelling at 29 miles per hour.

1.4.3 Late detection is not just a problem for motorcycles.

A further reason to doubt the conspicuity hypothesis is that late detection accidents are not the exclusive domain of small vulnerable vehicles - ‘looking and not seeing’ can also be attributed to many other accidents (Rumar 1990). The late detection of large railway engines by car drivers (Leibowitz, 1983) and bus drivers (Draskoczy, 1989) also occurs at railway crossings. Olson (1989) concludes although the L.B.F.S error is used most often to explain the accident failure to detect an oncoming vehicle is a common problem in all types of multi-vehicle accidents.

Cercarelli *et al.* (1992) demonstrates from accident database studies that many car-car crashes are also L.B.F.S. errors and reports that many drivers claim that they did not see a car or even sometimes a large truck. Further evidence for car-car incidents and the L.B.F.S. error comes again from Rumar (1990). The erroneous nature of the motorcycle conspicuity hypothesis can be illustrated thus: in considering the circumstances of a L.B.F.S. error accident between two cars, where one driver failed to see another, accident research has not focused on the physical conspicuity of one car alone.

1.4.4 Conspicuity enhancers do not guarantee detection

1.4.4.1 Daytime running lights

The use of motorcycle lighting as a conspicuity enhancer has resulted in increased detectability by participants in laboratory experiments (e.g. Fulton *et al.*, 1980, Janoff and Cassel, 1971). However the use of daytime running lights (DRLs) appears to have little effect on the reduction of motorcycle accidents between periods of compulsory and non-compulsory usage (e.g. Waller and

Griffin 1977). Comparisons between countries or US states where their use is compulsory and countries or states where DRLs are not compulsory, are also inconclusive (Olson 1981). Countries within the EU, where non compulsory headlight use operates, have a lower fatality rate than countries where headlight use is mandatory (Accident Fact Sheet 10, 1996). What may be important here is the contrast a motorcyclist makes with its background. Compulsory light usage in Australia for example, appears not to have reduced accidents and has recently been abandoned (Haworth and Schulze, 1997).

Voluntary daytime headlight use by the majority of motorcyclists might endanger those not using lights. It has been suggested that car drivers might search for ‘lights’ rather than for motorcyclists per se. Hole and Tyrrell (1995) showed that headlight-using motorcyclists were more quickly detected than unlit motorcyclists, especially when they were far away. However, repeated exposure to headlight-using motorcyclists significantly delayed detection of an unlit motorcyclist. It was shown that this delayed-detection effect occurred when only 60% of the motorcyclists shown were using their headlights. Under laboratory conditions, at least, participants readily appear to develop a 'set' for responding on the basis of headlight-use, even when this is an unreliable guide to the motorcyclists presence. Hole, Tyrrell and Langham (1996) found environmental influences on motorcyclist conspicuity - ‘clutter’ - behind the motorcyclist. Three of their experiments indicated that the effectiveness of conspicuity aids used, especially clothing, may depend on the situation in which the motorcyclist was located - bright clothing and headlight use may not be infallible aids to conspicuity. Brightness contrast between the motorcyclist and the surroundings may be more important as a determinant of conspicuity, rather than the motorcyclist's brightness per se.

Olson *et al.* (1979) shows that improvements in detectability by motorcycles using lights do not constitute good evidence that motorcyclists are particularly difficult to detect because they are inconspicuous. Olson claims that the reasoning behind previous research is, that if better daytime detection is found with motorcycles using conspicuity enhancers then motorcycles must have a conspicuity problem. He however points to the falseness of these conclusions. Firstly, not all studies find that daytime lighting improves detection (e.g. Muller, 1982, 1983, 1984). Secondly, similar studies using DRLs for vehicles other than motorcycles have found that lighting also aids detection (Sparks, Neudorf, Smith, Wapman and Zador 1993, Kirkpatrick, Baker and Heasily 1987). Of compulsory DRLs, Olson concludes that:

“therefore a change in motorcycle crash frequency associated with the use of head-lamps during the day does not provide support for the conspicuity hypotheses. It may merely demonstrate that all vehicles can be aided this way in their detection but detection does not mean that the vehicles’ presence is the subject of further cognitive processing.”
(Olson *et al.* 1979, p 145)

1.4.4.2 Fluorescent clothing

Some studies have found little effect of clothing as an aid to successful detection, e.g. Woltman and Austen (1974). Watson and Lander (1972) claim that conspicuity of cyclists and motorcyclists is aided by the use of the wearing of fluorescent/reflective jackets but they report that the problem of ‘failure to detect’ continues to be of concern. Coyne (1996) points out to users of conspicuity

enhancers when riding a motorcycle that: “Do not assume because you are conspicuous you are safe”.

1.5 *Alternative explanations of the L.B.F.S. error*

Does the car driver truly ‘look’ but then fail to ‘see’ the motorcyclist or are there other explanations?

1.5.1 Blockages in the visual field

Sometimes a psychological explanation of an accident may be overcomplicating matters. As pointed out by Olson (1989) the driver after the accident would still claim that s/he ‘looked but failed to see’ rather than s/he ‘looked but could not see’. Olson (1989) argues that because motorcycles are smaller than other road users, the view of the offending driver in a L.B.F.S accident may sometimes simply be physically obscured. Olson reworks data from two separate studies (Hurt *et al.* 1981, Williams and Hoffman, 1977) to conclude that in 48% of cases where there was a violation of the motorcyclist’s right of way the view of the offending driver was obscured. Olson claims no mention is made of this in either study. Other physical restrictions have also been implicated, as a possible explanation of the L.B.F.S. error. Langley (1995) reports that cars may have door pillars so thick that an 5.2m wide vehicle or object at 50m away from the driver, could be completely hidden.

1.5.2 Judgement errors

Others have questioned whether poor conspicuity research is actually evidence of a L.B.F.S. error. commenting on previous research Olson (1979) states:

“ One of the problems with the other studies stems from an apparent assumption that poor conspicuity equals “failure to see”. Actually the trends in the crash data ... could be explained by failure to see any one or all of the following:

Misidentification as a low-performance vehicle
Errors in speed-spacing judgement
Deliberately perverse behaviour on the part of the car driver”

(Olson *et al.* 1979, p 5)

Olson describes ‘judgement errors’ as an alternative explanation for the L.B.F.S. error - other than the motorcycle was not seen because it was inconspicuous.

For example Olson claims that because motorcyclists are smaller than a passenger car, the driver might detect the motorcycle but may underestimate its distance away from the junction. Olson claims that the motorcycle is seen by the driver but its distance away is underestimated (i.e., looked but failed to **judge** error). Olson says that Nagayama, Mortia, Miura, Watanabe and Murakami (1980) believe that drivers will emerge into traffic leaving a smaller gap between themselves and the oncoming lead vehicle if that lead vehicle is a motorcycle. Olson claims that this is evidence that the speed of the approaching motorcycle is underestimated. However perhaps Nagayama *et al.* are measuring not speed perception but the gap in traffic a driver will accept (a critique of similar methodology is contained in Chapter 2). Mortimer, Hoffman, Poskicil, Jorgeson, Moore and Olson 1974) found that speed judgement, for all vehicle types, is often underestimated.

However, as Olson *et al.*(1974) comment, most people underestimate the speed of motorcyclists. Speed perception may well be the problem (see Chapter 2 p.57).

1.5.3 Speed Estimation and Time to Collision

Caird and Hancock (1994) argue that because motorcycle accidents are over-represented at intersections this may imply a specific problem of speed estimation. Speed estimation or the time a subject believes it will take for an object to contact another, has many definitions and involves various experimental techniques. Measurements of a subject's ability to judge speed or relative closure have different terms dependent on the author. These terms may include 'time to contact' (TTC) (Schiff, 1965), 'arrival time' (DeLucia, 1991, 1992) and 'time to collision' (Hoffman 1968). However, all these terms generally refer to an experimental participant's ability to judge the time it will take for an oncoming object to pass them or the time or distance between them and a vehicle or object in front to collide. Studies are, therefore, interested in a subject's ability to measure or estimate time and distance variables, either between two objects or the relative closure between themselves and another object. These estimations can be either in absolute terms with the viewer stationary, or with the viewer undergoing some motion.

Caird and Hancock (1994) have offered alternative explanations for motorcycle intersection L.B.F.S. accidents. Caird's work is derived in part from laboratory evidence which found that the speed of smaller objects is significantly underestimated (DeLucia 1992).

Caird and Hancock (1994) argue that the small motorcycle does not provide enough information for the car driver to judge its speed and distance correctly (see Herstein and Walker 1993 and Hoffman and Mortimer 1994). Caird and Hancock's argument is based on previous research that suggests that motorcycles being smaller need to travel further than an automobile at the same speed before a change in image size occurs on the retina (Olson, Hallstead-Nussloch, and Sivak, 1979), which may lead to a motorcycle being underestimated in its speed (Mortimer *et al.* 1974). Caird and Hancock's view implies that the driver may well 'look' at the object and then 'detect' it but then fail to appreciate its speed.

However Transport Statistics (1996) show that of all vehicle types motorcyclists are the most likely to be speeding. Secondly, the Hurt study (1981) found that median crash speed was 29.8 mph. Chapter 2 discusses many of the methodological problems involved in speed or TTC. A point I shall return to, is made by Olson *et al.* (1979), that speed estimation, and detection of vehicles appears to be less accurate if the target is presented to the viewer in the periphery. Peripheral presentation may be particularly problematical causing speed estimation problems because some evidence suggests that motorcycles are primarily detected in the periphery of vision (Williams 1976).

1.6 The position so far

Late detection accidents are a major cause of injury to both pedestrians and vulnerable road users and are over-represented in casualty statistics. The offending driver's statement claiming s/he did not 'see' the motorcyclist suggests the L.B.F.S. error was the likely cause and this has been taken literally. It has been assumed that the driver looked and the motorcyclist was there to be seen

but was inconspicuous. Motorcycle accident causality is therefore explained by the motorcyclist being less conspicuous than other road users. Although other factors are seen as important, for example perception of vehicle speed, there is a significant overemphasis on the conspicuity hypothesis as an exclusive explanation of motorcycle accident causality.

Since the early 1970s the conspicuity hypothesis has been questioned. Review articles conclude that no evidence actually existed to support exclusive explanation of the L.B.F.S. error in terms of physical conspicuity for motorcycle accidents (e.g. Wulf *et al.* 1989). Later research has further shown that physical conspicuity is not the sole determiner of a motorcyclist's safe detection. Nevertheless the conspicuity hypothesis is still a major influence amongst accident prevention workers and road safety organisations (ETSC 1997) still argue that a solution to the L.B.F.S. accident is to make the motorcyclist more conspicuous by compulsory DRLs even though evidence from countries using DRLs and other conspicuity enhancers is mixed.

1.7 A more sophisticated understanding of the L.B.F.S. error.

This section considers two issues raised by previous research (e.g. Rumar 1990, Wulf *et al.* 1898). Firstly an expansion and reworking of the definition of conspicuity is considered. Secondly in the light of a new definition of conspicuity what is the role of expectancy in driving?

1.7.1 Is conspicuity solely determined by signal-to-noise ratios?

Does conspicuity only involve the physical conspicuity implied by the previous research? The original working definition of conspicuity reflects previous motorcycle accident research by examining only the signal to noise ratio.

Previous motorcycle conspicuity research, by focusing purely on the physical attributes of the target, has assumed the viewer to be an idealised passive signal detection machine (Brooks 1989). However the driver at an intersection has goals (emerging rapidly at junctions) beliefs and expectations about the environment in which s/he is searching which will ultimately affect detection performance. However Abrahams (1990) concludes that understanding these beliefs and expectancies which may be particularly important in understanding motorcycle accidents, has received little research.

Cole and Jenkins (1980) have proposed that conspicuity might be defined as the property that leads to a target object having a high probability of being detected within a very short amount of time. If it is eventually detected irrespective of time then it can't be described as being conspicuous.

Different terms have been used that differentiate the importance of the physical properties of the target and reflect the goals of the observer:. Cole and Hughes (1984) suggest 'search conspicuity' and 'attention conspicuity', 'cognitive functioning of the observer' suggested by Tomson (1982) and 'sensory conspicuity' and 'cognitive conspicuity' (Wulf *et al.* 1989). Cole and Hughes classify conspicuity into two types and define these as: 'search conspicuity' (its ability to be readily located by visual search) and 'attention conspicuity' (the propensity of an object to attract attention when it is unexpected).

1.7.1.1 Search and Conspicuity

In a series of experiments, Cole and Hughes (1984, 1986) investigated the role of search and attention conspicuity. Cole and Hughes considered whether the driver could successfully report or fixate either conspicuous or low sensory value targets located within the environment. Subjects' attention was either drawn to the target by the physical properties of the target alone or participants were specially instructed to search for them. They (1986) argue this shows that a driver is unlikely to always detect an object if s/he relies on the intrinsic properties of the target to elicit a fixation. However the two kinds of conspicuity were found to be related in a systematic way: physical conspicuity was not strongly dependent on either object reflectance or size. An important determinant was the angle at which the object was displaced away from the line of sight. They also concluded that in some cases the goals of the observer were changed by the instruction to search - a theme which is returned to in Chapter 5.

1.7.1.2 Cognitive conspicuity

Wulf *et al.* (1989) have postulated on a more important role of the observer in the understanding of conspicuity which may be particularly relevant for motorcycle accidents. They argue that motorcycle accidents occur because of both low sensory and low cognitive conspicuity. Wulf *et al.* believe that motorcycles have a low sensory **or** attention conspicuity shown by a lack of fixation by the offending driver under high levels of task demand - for example in heavy traffic where an information overload occurs. They illustrate their claim of low cognitive conspicuity by firstly stating that previous studies have:

"focused on conspicuity as a factor inherent to the object. Yet an object may have physical characteristics that render it conspicuous but may well be overlooked because it has no relevance to the observer"
(Wulf *et al*. p171)

and concludes:

"the lack of experience of most automobile drivers with motorcycles reduces cognitive conspicuity which is based on interest and experience"
(p173)

Important in a definition of viewer dependent conspicuity is the time spent searching at a junction (Cole and Jenkins 1980) and the relevance the target has to the viewer. What is relevant or salient (Theeuwes 1992) to the viewer may be based on the driver's expectations of what they are likely to see at an intersection. How conspicuity is going to be defined and understood, together with issues in measurement will be one of the themes of the thesis.

1.7.2 Expectancy and awareness of drivers

The central role of expectation in perception has been well documented but hypothesised as important only in motorcycle L.B.F.S. accidents (Hills 1980). Hills (1980) highlights the possible role of expectancy in motorcycle L.B.F.S. accidents. He writes:

"It is believed that these expectancies could partly explain why anecdotally a driver can look straight at a cyclist or motorcyclist and then drive straight into them. It is thought that the driver is looking for cars or larger vehicles".

(Hills 1980, p 454).

The influence of expectancy and physical conspicuity on successful detection was investigated by Shinar (1985). Normally drivers are not searching specifically for pedestrians and the pedestrian's safety relies on physical conspicuity enhancers for detection. However Shinar demonstrated that night-time pedestrian detection distance can be increased over free search conditions when the driver is expecting to see a pedestrian. When the subject actively seeks a particular type of hazard the chance of detection is improved. Such research may be particularly relevant for all vulnerable road users.

Hallstead-Nussloch *et al.* (1986) comment that motorcycles are relatively rare in the road environment. As motorcycles are rare - accounting for less than 1 in 44 road users (White and Toomath 1980) - drivers are not expecting to see a motorcycle. When reviewing their data they concluded that conspicuity was only a factor in 40% of the cases. Hills (1980) claims that if motorcycles were more frequent in traffic then the critical role of expectancy would be less. Wulf *et al.* (1989) also agree that the low frequency of motorcycles in traffic may be an important issue. Drivers "do not expect to see them" (p173). Driver expectancies or sets may develop through experience or the growth of expertise (Groeger and Chapman, 1996).

1.7.2.1 Short hand codes

If the driver is expecting to see certain types of vehicle this might colour his perceptual ability and hence ultimately his success in detecting these vehicles. If a visual search at a junction is being conducted with certain expectancies do time restrictions then force the development of certain 'short hand codes' (Hole and Tyrrell 1995) or strategies based on these expectancies? Hills (1980) likens our expectancies to neurological triggers that are 'set' for certain orientations or shapes. The short hand codes developed by the driver may be set to look for one shape over another. He comments that the two-wheeler accident may be because the neurological priming is for a certain shape. Is the vehicle's shape therefore important when the driver is limited by the amount of time that is spent looking at a junction? The L.B.F.S. accident can therefore be seen as a complex interaction of many unfortunate factors. Understanding the accident in terms of physical conspicuity alone appears inadequate. To understand the L.B.F.S. error better requires a more sophisticated understanding of human perception.

1.8 Towards a more sophisticated understanding of human perception

The understanding of the intersection accident begins with the understanding of the perceptual information available to the driver (Hills 1980, Lee 1976). Review articles (e.g. Olson, 1989, Wulf *et al.* 1989) suggest that physical conspicuity alone is not the complete explanation for the L.B.F.S. error. Hills (1980) suggests 'higher order cognitive factors' may play a part and urges a more basic understanding of human perception. The preceding text suggested the importance of driver expectations and cognitive conspicuity. This section contextually reviews some of the limits of human performance. However the review is brief and highly selective. Each experimental chapter contains a more detailed discussion in the context of individual experimental hypotheses.

1.8.1 Cognitive style

Field Dependency refers to individual differences found between participants in their ability to extract a target from a confusing background (Witkin 1950). Field Dependency may play a part in driver error particularly with motorcycle accidents claim (Wulf *et al.* 1989). Shinar (1978) found a limited correlation between Field Dependency and driver visual search behaviour. McKenna, Duncan and Brown (1986) also found a limited relationship between field dependency and driver accident rate. More relevant to motorcycle accidents, Langham (1995), in a laboratory investigation, showed that it was only when the motorcycle was unlit and some distance away that the subjects' cognitive style had a detrimental effect on the detection of a motorcyclist. The distance at which field dependency affected performance would not affect accident potential.

1.8.2 Vision

Functional limits of the human visual system might account for the L.B.F.S. error (Hills 1980). Humans have limited field of view and acuity (Sekuler and Blake 1994).

1.8.2.1 Driver Vision

One very simple explanation of the L.B.F.S. error could be that the driver simply could not see the motorcyclist because of poor acuity. The offending driver may gaze in an appropriate direction but because of poor acuity simply could not see a small object. However, it is a legal requirement in the UK to meet certain standards of visual acuity (see The Highway Code 1999). Drivers are recommended to check their own visual standards regularly and data suggest that only between 2% and 4% of drivers fail to reach this standard (e.g. Davidson and Irving 1980). However, evidence suggests that even drivers with poor visual acuity do not have increased accident involvement (Burg, 1975, Hills and Burg 1977). Paradoxically, although the majority of information about the road environment is visual, there appears little evidence that poor acuity affects driver performance (Hills 1980).

1.8.3 Vision direct or constructed

A bottom up view of perceptual processing places the emphasis on the stimuli in our environment and the nature of the scene. The alternative, top down processing, focuses on how previous encounters with similar environments and stimuli direct our visual systems. Therefore top down models are 'goal directed' (e.g. Gregory, 1972, 1980, Neisser, 1967). Bottom up processing focuses on the nature of the target, how bright it is, how conspicuous it is against its background, its novelty of shape and colour or comparative orientation (e.g. Gibson 1966, 1979). Top down processing or constructive theories consider that perception is active and the perceptual event is not given directly by the stimulus alone but occurs together with expectations and knowledge of the observer. Therefore as perception is influenced by the expectations and the goals of the observer it is not always accurate. As Kundel and Nodine, (1983, p 356) put it:

"The psychological event that leads to the perception of a picture is largely conceptual not perceptual".

For psychological models of human visual perception the focus of research directed towards the understanding of the L.B.F.S. error, has focused on the

physical properties of the object alone. Research has generally considered the motorcyclist's relative brightness, luminescence and visual size. Remarkably little research has focused on the needs, expectations and goals of the driver who fails to see the motorcyclist.

1.8.4 Central versus peripheral vision.

The retina is not uniform in the distribution of rods and cones across its surface. Consequently there is no uniformity in the ability of the eye to detect light (Sekuler and Blake, 1994). The central area known as the fovea has the highest acuity and constitutes only a minimal amount of the surface of the retina. The fovea accounts for between 1° and 2° of the field of view (Polyak 1941). Sensitivity to luminance decreases with increasing retinal periphery under photopic light (Aulhorn and Harms 1972) and colour sensitivity decreases with increased eccentricity (Moreland 1972 Hurvich 1981). The two areas not only differ in their sensitivity but in the way they respond to motion.

Peripheral vision is thought to be important in accident causality. Its importance is because although our possible field of view is large we process such a small amount of the available information. For a fixation of a possible hazard to be made it is likely to have to been detected in the periphery (Finlay, 1982, Hills, 1980). However acuity, and consequently form identification, is rather inefficient in the periphery. Therefore vehicles that often have to be identified outside the fovea because of road position (Olson *et al.* 1979) may be detected less often (Olson *et al.* 1979, Thomson 1979, Wulf *et al.* 1989). The driver may also have greater difficulty in estimating the speed of objects in the periphery. Do these simple physiological limits play a part in understanding motorcycle accidents? Leibowitz, Post, Brandt and Dichgans (1982) discuss motor vehicle accidents in terms of the operation of two visual systems. Leibowitz *et al.* postulate not a peripheral and fovea physiological distinction, but conceptualise these differences in performance as 'focal' and 'ambient' systems. Leibowitz *et al.*(1982) suggest that the focal visual system allows the driver to read road signs while ambient vision allows the driver to maintain the vehicle in its lane and negotiate his way around bends. Leibowitz (1983) speculates that railroad crossing accidents involving large conspicuous railroad trains may be caused because of speed estimation problems of large moving objects appearing in the periphery.

1.8.5 Periphery filtering and motorcycle accidents?

Olson *et al.* (1979) cite evidence that has led many researchers to postulate differing processing modes for foveally and peripherally presented stimuli. Olson *et al.* argue that the periphery when driving is involved primarily in monitoring and detection processes, while the fovea is involved in identification. The fovea requires sequential shifting to different spatial locations resulting in serial identification processes whilst the detection process within the peripheral visual field is parallel. As the periphery is large, not all targets located in the periphery will be processed because of limits in human performance. Peripheral processing, argues Olson, determines where foveal processing will then occur:

"In other words a peripheral filter is postulated which gates the information irrelevant to the task in order for the relevant information to be inspected by the fovea".
(Olson *et al.* 1979, p30)

The argument therefore is that a motorcycle is not relevant to the car driver's needs, goals and expectations. Evidence from eye-movement studies and driver attention would, claim Olson *et al.* (1979), suggest that a fixation will only be elicited to larger, brighter, or more contrasting stimuli. Therefore, by implication, those targets in the road environment that do not meet these requirements will not be detected in the periphery and not be fixated upon (Olson *et al.* 1979, p31). This is an appropriate time therefore to discuss eye-movement research.

1.8.6 Driver eye-movements

Chapters 6 address this issue in more depth. Is the L.B.F.S. error not a case of failing to 'see' but a case of failing to look in the correct place? The available view to the car driver at an intersection exceeds 180° (Noon 1992) and the drivers need to point their eyes at certain locations within the environment. We sample from our environment with a series of relatively brief fixations that move from one point to another in a series of rapid jerks known as saccades (Kowler 1990). Studies of human eye-movements have been performed in many research areas, but underlying their rationale is that the way we move our eyes tells us something about human cognition (Ellis 1986). In the context of driving research, eye-movements are believed to reflect the amount of processing that is occurring (e.g. Olson *et al.* 1979) the depth of processing (e.g. Miura 1992) and to where attention is being directed (Crundell and Underwood 1998).

Wulf *et al.* (1989) link the L.B.F.S. error to driver eye-movements. They claim that it is because of failures in 'cognitive conspicuity' that the motorcyclist will not be detected in the driver's peripheral vision and a fixation elicited. Differences in eye-movements between different types of driver and type of task in which the driver is involved appear well documented. These differences are found according to the type of licence the driver holds (Nagayama *et al.* 1979), the level of driving experience, (Land, 1992, Mourant and Rockwell, 1972, Unema and Rotting 1993), type of junction (Laya, 1987, Theeuwes and Hagenzieker, 1993), road curvature (Land and Horwood, 1995, Shinar, McDowell and Rockwell, 1977) and volume of traffic (Rahimi, Briggs and Thom, 1990, Robinson, 1972).

Two eye-movement studies have discussed driver visual search as being particularly important for vulnerable vehicles. Robinson's (1972) comments that the amount of cognitive processing may be important in understanding motorcycle accidents because of the motorcyclist's relatively small visual size. Kito, Haraguchi, Funatso, Sato and Kondo (1989) believe the understanding of driver eye-movements to be particularly important to drivers of vehicles with limited visibility when they are trying to detect pedestrians, motorcyclists and cyclists.

If drivers are expecting to see certain types of road user are they expecting to look at certain parts of the road environments? Early work by Lashley (1951) argues that eye-movements are organised into structured sequences whose main feature is the spatial and temporal integration of distinctive elements into an effective purposeful activity. This was later echoed by Kay (1972) who considers that if driving is a structured automated process then it would appear likely that driver eye-movements are structured through time and experience (Cohen and Hirsig, 1979). Therefore a causal relationship exists between successive fixations, which is determined by 'internal' as well as externally oriented components. Where the driver looks or where the highest acuity area of the eye is directed may be particularly important in the understanding of motorcycle accidents. Driving a motor vehicle and searching for a potential hazard at a junction involves a visual

search. In urban environments, where the majority of motorcycle accidents occur (Casualty Report 1996), the complexity or the level of clutter in the environment may require the driver to exert greater effort to extract relevant information. As a result, suggests Wulf *et al.* (1989), the average eye fixation time is prolonged and the total number of fixations reduced giving the possibility according to Cohen (1980) for the overlooking of essential targets.

With the increase of foveal vision demands, the effectiveness of peripheral vision may be reduced (Ikeda and Takeuchi 1975). Thus the functional visual field is decreased and a form of tunnel vision may ensue (Mackworth 1957) so that only the fixated target may receive further processing. If visual search at an intersection is rapid and eye-movements are structured into a spatial and temporal organisation, then a possible cause of the L.B.F.S. error for motorcycles may simply be that the driver is not fixating where the motorcyclist is. Motorcycles because they are more manoeuvrable than cars, can appear in many different areas of the visual field - in urban environments whilst the retinal effectiveness is maintained the useful field of view is reduced and a motorcycle however conspicuous may be overlooked. Miru (1987) found that a driver's response eccentricities were reduced in situations of increased cognitive demand. He also found that reaction times for peripherally presented stimuli increased in more complex traffic environments. This implies a narrowing of the functional visual field and that in urban environments where the driver is making a rapid visual search the number of fixations will decrease. Thus claims Wulf *et al.* (1989) this may lead to the overlooking of small targets in light traffic - i.e. the motorcyclist. Where a driver looks may be important in accident involvement particularly for a motorcyclist. Summala, Pasaen, Rasanen and Sievanen (1996) found that in bicycle accidents which have a similar accident profile to motorcycle accidents (Casualty Report 1996), a driver approaching a right turn may not look to the left in contra-flow bicycle lanes. Summala argued that drivers:

"develop a visual scanning strategy which concentrates on detection of more frequent and major dangers but ignores and may even mask visual information on less frequent dangers"
(Summala *et al*. 1996, p 147)

Olson (1979) argues in essence for a gating system that may have a specific cost for the motorcyclist. Whilst he argues that at an intersection a fixation towards the flow of traffic is likely, any smaller objects appearing in the periphery will be ignored with fixation not being elicited towards the smaller secondary target. The driver when searching usually once in one direction, unless very cautious, will detect only the larger moving vehicle in the periphery. The gating process of a peripheral filter, would mean that the maximum of two vehicles would be processed and recognition would occur. In heavy traffic the gating system will not be sensitive enough for a motorcycle to be detected. Relating this to SDT Olson claims that the amount of traffic has an effect on decision criteria but not on sensitivity. At an intersection Olson suggests that a maximum of 2-4 fixations per second are made in heavy traffic leading to the non-fixation and non-recognition of the smaller motorcycle. Olson therefore concludes that the physical features of motorcycles make them more likely to be closer or below peripheral thresholds so even if detected in the peripheral area motorcycles are less likely to trigger a foveal fixation than cars. Therefore the probability of the motorcycle would occupy the area of the retina that is most effective in motion detection or has the greatest acuity and colour discrimination - the fovea - is reduced in comparison to that of an automobile.

Hills (1990), Wulf *et al.* (1989) and Olson (1989) appear to suggest that in respect of the L.B.F.S. error accidents there is a great deal of top down control of where a driver looks to elicit information. Therefore Chapter 6 (p 111) will focus on driver eye-movements when searching an intersection and consider the influence of top down processes which may either direct eye-movements to one location over another or where eye-movements are involuntarily drawn.

1.8.7 Attention

William James (1890) realised the central role of attention in perception. What drivers may be capable of seeing may be different from what they are actually perceiving as a conscious event.

"Millions of items of the outward order are present to my senses which never properly enter into my experience. Why? Because they have no interest for me. My experience is what I agree to attend to. Only those items which I notice shape my mind - without selective interest, experience is an utter chaos. Interest alone gives accent and emphasis, light and shade background and foreground - intelligible perspective in a word"
(p 381)

The role of attention in the L.B.F.S. error can be described in the context of two separate attentional systems. One system is referred to as 'selective attention', the other 'sustained'.

Selective attention can be described as the process by which portions of the available sensory information can be selected out for object recognition and localisation (Theeuwes 1992, Van der Hejden 1992). What of course is selected depends on the properties of the environment and the expectations, beliefs and goals of the observer. Attention can be captured by a salient stimulus (bottom up influence) or attention may be voluntary directed towards an object relevant to the observer (top down goal directed). Models of selective attention are heavily influenced by the idea that humans have a limited capacity to perceive and understand their environment. Models echoing James' described above show how so much information 'out there' is reduced to what is salient to the observer. Chapter 5 provides a more detailed examination of these issues.

As we shall see, the thrust of research concerning motorcycle accidents has focused on the properties of the object and its ability to attach attention in a bottom up way.
Implicit in previous motorcycle crash research is that attention is captured purely by the properties of the stimulus and is enhanced by bright coloration - physical conspicuity. Conspicuity enhancers catch the driver's attention, possibly even in an involuntary way.

Selective attention and limits of attention performance may be particularly important for motorcycle accidents which have been described as 'attention failures' by Hancock and Hurt (1985). A correlation is found between a subject's ability to perform laboratory selective attention tasks and self report accident records (e.g. Arthur, Strong and Williamson, 1994, Kahnemen, Ben Ishal and Lotan, 1973). Shinar (1985) suggests a driver's ability to rapidly attend to relevant stimuli is important for driver performance especially under conditions of high workload. The drivers fail to attend to the less frequent motorcycle because they do not expect to see a motorcycle (Fulton *et al.* 1980, Nagayama *et al.* 1980, Wulf *et al.* 1989).

1.8.7.1 Pre-attention, selectivity and top down processes.

One debate in research on visual attention is therefore the extent to which selection for further processing is based on the observer or the properties of the stimulus (Theeuwes, 1994 1996,). Moreover, before selective attention occurs is there a pre-attentive rapid process that performs some ‘basic’ analysis segmenting the visual field into functional perceptual units (e.g. Neisser, 1967)? Furthermore is this based on the intentions and beliefs of the observer or is it stimulus driven (Theeuwes, 1996)?

When a driver approaches a junction and prepares to ‘look’ does the driver intensively inspect each part of the environment or does s/he make a global assessment in a pre-attentive stage before s/he attends to the scene? Does the driver make basic assumptions about the scene from this global analysis which guide what Neisser (1967) would describe as subsequently slower, more analytical processes. When searching a intersection are drivers using some form of global interpretation of the scene relying on expectancies of clustered shapes and forms with meaningful relations? Our perception is guided by what we expect to see or know what we are looking for. Mackworth and Morandi (1967) have shown by eye-movement traces that people inspecting pictures use ‘local clusters’ to decode where to look next. Biederman, Glass and Stacey (1974) have shown that participants can scan faster and remember more when objects are familiar and in familiar locations than random juxtapositions. Rabbitt and Mueller (1989) claims that this shows that human visual search is therefore guided by previous encounters with the world. Clearly these processes are not open to introspection. Perhaps with the unfamiliar motorcycle, the driver is making only a pre-attentive stage search which has been reinforced through experience that global descriptions of the familiar scene are enough. This attentional strategy in the majority of times may be successful in detecting cars but may fail when encountering the uncommon motorcycle.

Masking experiments reveal that our subjective experience of perception being constant and uniform may be illusory. When participants are presented with one scene then a blank scene and then the original scene they are particularly bad at noticing changes (e.g. Rensink *et al.* 1997). Rensink whilst investigating the L.B.F.S. error found that major changes can be made to a scene without a subject noticing any change to it. Importantly in the context of this thesis they claim that:

> “Identification of changes becomes extremely difficult even when changes are large and made repeatedly. Identification is much faster when a verbal cue is provided showing poor visibility is not the cause of the difficulty. Identification fixation is also faster when objects are considered important in the scene. These results indicate that observers never complete a detailed representation of their surroundings ... attention is guided by higher level interests”
> (Rensink *et al.* 1997, p368)

1.8.7.2 Selective Visual attention for Spatial locations or for Objects and Forms?

A major issue in the understanding of the L.B.F.S. error is whether attention is directed to regions of space (the ‘where’ in the environment), or if attention is directed to objects (the ‘what’ in the environment). An important component of

routine visual behaviour is the ability to find one item in a visual world filled with other distracting items. Theeuwes (1993) argues that it is the identification of objects in the environment that plays the important role in everyday life particularly in driving. Luck and Ford (1998) argue it is also necessary to differentiate between attentional mechanisms that influence the identification of a stimulus or target from non-targets, and those mechanisms that operate after perception is complete, to identify and then recognise objects. Research has distinguished between a pre-attentive, massively parallel stage that processes information about basic visual features (colour, motion, various depth cues, etc.) across large portions of the visual field and a subsequent limited-capacity stage that performs other, more complex operations. (Review in Pashler, 1998).

1.8.7.3 Objects

How do we distinguish a motorcycle from a truck and a car from a bus? A need to identify these as different traffic types may be necessary because they may present different types of hazard within the road environment - for example they travel at different speeds. Olson *et al.* (1974) comment that generally speaking, other drivers identify motorcycles based on the motorcycles' motion, colour, form, shape, size and luminance or some combination of these cues. Many drivers probably use a special priority ordering or combination of these cues to identify a motorcycle. However we do not currently know what the actual patterns are which car drivers use to identify motorcycles. A motorcycle is an unusual vertical orientated shape when compared to a car's horizontal shape (Caird and Hancock 1994). Each time we search a junction it is a unique scene. Objects may be at differing distances and orientations and some objects may be occluded by others. Yet as drivers, we appear to be able to interpret a scene very rapidly. If attention and subsequent recognition is based on objects, how can this affect the L.B.F.S. error?

There are many different psychological accounts of such a complex process and the rapid recognition of shape and form has attracted much research (review in Humphreys 1992). In general terms the first stage of the analysis of visual information can be described as a creation of a basic representation (Ullman 1984). Marr (1980) and Marr and Nishihara (1979) suggest that early representations can be divided into two types: the primal sketch which is a representation of the incoming image, and the 2 1/2 D sketch which is a representation of the visible surfaces in 3 dimensional space. Do drivers use these representations in the rapid understanding of the naturalistic scenes? Moreover, do these representations contained in memory mean that the motorcycle is represented differently to that of a car which could lead to a L.B.F.S. error? Biederman (1995) focuses on the nature of the mental representations used to store a shape in memory and argues that our visual systems decompose objects and scenes into specific types or parts, which are then compared to representations stored in memory. Do drivers look for certain objects or primitive shapes over others? Is the L.B.F.S. error a case of a driver searching for one expected object over another? Theeuwes (1991, 1993) suggests the general notion of visibility as a two stage process. Firstly, the 'where' in the perceptual field and secondly an object recognition stage of 'what'. The 'where' in the visual field that attracts attention is dependent on the vehicle's conspicuity and the 'what' he argues is:

"dependent on the extent to which an object has the properties that are prototypical for such an object. Thus it may take longer to recognise a tractor as a potential hazardous vehicle because the physical appearance of a tractor (its contours) and its speed do not match those of a prototypical passenger car"

(Theeuwes *et al.* 1997, p 236)

Chapter 7 returns to these issues (p 133).

1.8.7.4 Knowing 'where' to look

Driver eye-movement studies imply that we may use previous knowledge about our environment to gather further information. Knowledge of 'where' - the precise spatial position of the target - improves detection performance (speed or accuracy) that can result in and give the opportunity to 'direct attention' to that position (Duncan 1981). Laboratory evidence suggests visual search is an active interrogation of the visual world where to detect a target we use learned meaningful patterns of relationships. Such meaningful patterns would suggest rules of where to look first and sequences where to seek further information (Rabbitt 1979, 1989). These search strategies suggest that an optimum location strategy develops (Sheridain and Johnson 1976). However if such patterning exists can this be evident in driving?

Research suggests that we direct our eyes to areas where information may be located in the road environment (Moray 1990) and experience affects the way in which we monitor the road (Land 1995). Summala *et al.* (1996) showed that drivers at intersections do not appear to search at locations that may contain a cyclist. Studies which directly address the issues of where drivers may search at junctions have illustrated that a driver may search according to the experience which has developed his search pattern (Theeuwes and Hagenzieker 1993). These findings therefore may be applicable to motorcycle L.B.F.S. accidents. Chapter 6 addresses this issue.

1.8.7.5 Attention and two types of L.B.F.S. error

I am going to argue in this thesis that there are two types of L.B.F.S. error which are mirrored and best conceptualised by the understanding of selective and sustained attention. The *Type I* failure is the selective attention failure found in drivers at a short visual search at an intersection and the *Type II* is where a driver fails to notice an object that may have been apparent in the road environment for some time. (e.g. as described in the context of aviation, by Hurst and Hurst 1982, Section 8.1)

1.8.7.6 Sustained attention

Driving a motor vehicle, operating a train or flying an aeroplane cannot be described as a series of selective attention exercises. The operator must remain vigilant. The study of sustained attention has tended to be within an applied setting. Earlier in this review I discussed a type of L.B.F.S. error which was not typified by a short visual search. The type of L.B.F.S. error made by airline pilots suggested a failure in sustained attention or vigilance.

Studies of vigilance or sustained attention tend to focus on tasks where the subject needs to monitor and report possible minor changes to either a display screen or report if a target is present in a changing scene. These studies are heavily influenced by Signal Detection Theory. Posner and Boies (1971) suggest that the concept of sustained attention generally encompasses three subdivisions:

- the alertness or the ability to maintain optimal sensitivity to external stimuli.

- the selection or the ability to concentrate awareness upon one source of information rather than another.
- the limited processing that people show when trying to do two tasks at once.

In essence therefore the study of vigilance according to Davies and Parasurman (1982) is concerned with the first two areas. Warm (1984) says that what is of interest in the study of vigilance is the ability of observers to maintain their focus of attention and remain alert to stimuli over prolonged periods of time. Monk (1984) summarises the difference and relationship between visual search and vigilance by citing five factors. These can be categorised as:

- signal spatial variability
- signal temporal variability
- non-signal spatial variability
- non-signal temporal variability
- the degree to which the viewer is forced to attend

Monk describes vigilance as being where non-signal temporal variability is often comparatively low and there is neither signal or non signal variation. Vigilance studies have usually a high level of signal temporal variability and a low level of forcing the subject to attend. Non-signal temporal variability is usually low and typically neither signal nor non-signal spatial variability is considered. In visual search tasks the characteristic property is a high-signal spatial variability with the other variables being relatively low. Therefore we can think of vigilance as search that has been transferred from the spatial to the temporal domain.

1.8.7.7 Selective or sustained attention?

So which attention system in theoretical terms supported by laboratory evidence is being used by a driver at an intersection? Are drivers using sustained attention - conceptualised as driving from ‘a’ to ‘b’ or is the driver doing a series of selective attention activities? In the first instance with the weight of experimental evidence associating attentional failures of operators to failures of sustained attention, the emphasis should be on an interpretation of sustained attention problems (review in Mackie 1977). If each individual activity is considered as a searching at the first junction the driver comes to or when attention is directed to locate a turning sign, then the activity is best considered in psychological terms as a process of visual search or a selective attention task.

Therefore in this thesis accidents occurring at intersections typified by a short visual search will be conceptualised as a failure of selective visual attention. Later chapters which investigate drivers who fail in essentially a vigilance task on motorways will be conceptualised as a failure of sustained attention.

1.8.8 Conclusion

Although the driver has a large field of possible view. it is in practice limited by the iphysiological limitation of the human eye. The part of the retina with the greatest acuity is directed by eye-movements to areas of the road scene that drivers possibly with experience have found to be informationally rich. Selective attention processes may mean that only part of the information from the environment gathered by selective saccades may be processed. Information not selected may have little or no processing. Even if the eyes are pointing in the correct direction then the approaching hazard needs to have even more cognitive processing to

recognise it as a object that needs to be attended to. All of these processes appear to occur very quickly.

1.8.9 Experience and expertise

Drivers change their performance as they gain experience of the road environment. (Rumar 1990). Accident statistics (e.g. Casualty report, 1996) suggest that younger drivers are more likely to be involved in accidents. The literature so far suggests that the observers' goals affect what the observers deem important or relevant. These goals and expectancies are not innate and must be honed by experience.

We normally associate experience with expertise. The development of visual scanning surely must assist us in locating hazards. However driving becomes a fairly automated process as Currie (1975) describes:

> "In the driving situation the experienced driver develops habitual responses which serve him well most of the time"
> (Currie 1975, p 435)

and Kay (1971) as cited in Currie describes accidents caused by the experienced driver as occurring because:

> "...the individual has to switch from a highly organised efficient pre-programmed mode of operation to an environmentally controlled S-R mode"
> (p 436)

As we gain experience we learn to search more effectively. This may be time efficient but may not result in a complete search of the available environment. However, one way of interpreting the studies discussed above is to ask firstly if we do develop those scanning patterns and expectancy sets. Then secondly, do these strategies develop to deal with the most commonly expected vehicle on the roads? Is the cost of experience the overlooking of a motorcyclist?

Is there any other cost of experience? The Hurt study (1981) found that older drivers (55+) are over-represented as offenders in accident data. Is this because they are poor at speed estimation and have different expectancies and visual search patterns? The problem is that older drivers show an increase in accident rates in all types of accident. It is difficult to separate the gradual deterioration associated with age from a specific decrement in cognition (Salthouse 1985). Evidence for a cost of experience comes from Duncan, Williams and Brown (1991) who assessed the driving skills of trained experts, 'normals' and novice drivers. Using an instrumented car driven in normal traffic they found that simple experience on the road is not sufficient to produce improvements in all driving skills. On 6 out of 12 skill measures, the normal, experienced drivers performed worst in scanning patterns, anticipation, and safety margins. For many aspects of driving skill, experience was found to be no guarantee of expertise. Importantly Duncan and his colleagues claim that failures made by experienced drivers tend to be associated with tasks that are infrequent or rarely required. Does an experience driven change in scanning pattern, anticipation and safety margin mean that a vulnerable vehicle such as a motorcycle may be overlooked?

1.9 Motorcycle accidents considered in relation to an information processing model

1.9.1 Model introduction

The preceding discussion suggests that failure to detect another road-user could in principle occur at any one of a number of stages in the driver's information processing behaviour at a junction. The following model summarises these stages and shows how failures at each stage might give rise to a L.B.F.S. error.

An information processing model has also been suggested by Wulf *et al.* (1989) and Hallstead-Nussloch, Sivak, Olson and Sturgis (1986) who suggest an information processing model to enable a basic understanding of the L.B.F.S. error. Wulf *et al.* (1989) suggests two stages: Detection/ Identification and Decision. Hallstead-Nussloch *et al.* (1986) indicate there are three stages of cognitive processing where a failure to detect could occur. They are: 'Detecting it', 'Identifying it' and then 'Deciding what to do'.

The following model is not proposing information processing failures - for example Shinar (1993) argues that representations are passed between systems and this is where the failure may lie. The model is to provide a theoretical orientation of the issues and processes that a driver is engaged in at a junction. That is: Search - Detection - Decision - Action. Although not exhaustive I suggest the following model :(Figure 1-2)

Figure 1-2 The possible stages of an information processing model of a driver at a junction,

Stage	1 Search	2 Detection	3 Recogntion	4 Evaluation	5 Decison	6 Action
Likely action of the driver	Point Eyes to parts of the road environment	Detect basic physical properties of the target	Is the object that has been detected a vehicle and what type of vehicle is it	Judge speed and distance of target	Asses risk cost and benefits	Brake accelerate or Search for other target
Limitations	Limited by Physiology and Road design	Limited by target conspicuity and background complexity	Limited by Experience and expectancy	Limted by experience expertise and expectancy	Limited by experience and expectancy	Limted by experience and expectancy vehicle perfomance
Area of Psychological Investigation	Eye-movements Usable field of View Visual accuity Selective Visual Attention	Conspicuity Visibility Selective Visual Attention	Object recognition theories	Risk Models Reasoning	Risk models Human error models	Error Modelling Bio-mechanical ergononmics

At any of these information processing stages a mistake can be made. The majority of motorcycle accident research focuses on stage 2 only even though review articles such as Wulf *et al.*, Olson, Shinar etc.) are suggesting that stages one to five are important.

In this model the driver firstly searches the road environment (stage 1) hoping (stage 2) to detect the hazard, and because different vehicles have different performance properties, the driver has to recognise (stage 3) the type of vehicle which is approaching. Once the driver has recognised the hazard for what it is, s/he has to evaluate its approach speed (stage 4) and make a decision based on his previous experience as to whether to emerge into the traffic (stage 5). Once the driver has decided to emerge s/he needs to perform a complex series of hand, arm and leg movements (stage 6).

1.9.2 What happens at each stage?

Stage 1 - Search
If the driver searches, then s/he must point his eyes at one place first over another and then start the search for a hazard that might prevent him from safely emerging into the traffic on a main road.

We position our eyes in areas of the environment we expect to be informationally rich - these fixations being brought about through experience. Because the motorcycle is rare drivers do not gain enough experience for them to point their eyes in parts of the road environment that may contain a motorcycle. What role does peripheral vision play in the motorcycle accident and does the detection of the motorcycle involve only a peripheral awareness? If evidence suggests that peripherally presented targets have poor detection success and motorcycles may be in unusual road positions, where drivers are looking is important.

Stage 2 - Detection
The majority of previous research has focused on the physical properties of the target to explain the detection failure. This thesis aims to understand if detection is solely determined by the physical characteristics of the target.

Stage 3 - Recognition
What defines in rapid search the representation from memory that triggers the response that a motorcycle is present? Do we perceive every detail of our environment or do we extract simple information from it? Is this 'simple' information in the form of primitive shapes? The motorcyclist appears either too similar under rapid visual search to other non-motorised road users or too different from the expected passenger vehicle. Is the problem then a recognition failure? Chapter 7 returns to this issue (p.133).

Stage 4 - Evaluate Although the eyes are directed in the appropriate direction and the oncoming vehicle is recognised as a motorcycle the driver may not judge its approach speed correctly. However as Chapter 2 will suggest, speed perception may be difficult to measure.

Stage 5 - Decision The driver may simply use a risk model. Risk homeostasis theory argues that there is no human behaviour with total certainty of outcome, (review in Simonet and Wilde 1997) and all behaviour may be viewed as risk taking. Notions such as risk perception and risk acceptance are, therefore, central to the understanding of behaviour in traffic (Simonet and Wilde 1997). Violating

the motorcyclist's right of way may to the driver prove less of a hazard than emerging in front of another vehicle. Therefore the motorcyclists may be 'seen' but unconsciously ignored or as Olson comments 'consciously ignored' (Olson 1989). Vehicles or situations that present less of a risk may not be perceived or at least part of the mechanism that perceive them may be a problem. (Summala, 1996).

Stage 6 - **Action** Failures at stage six may be explained by Reason's error modelling. He (Reason 1979, Reason, Manstead, Stradling, Baxter, and Campbell, 1990) provides a theoretical framework for everyday errors. Reason has found correlates between simple everyday mistakes and self report accident records (Parker, Reason, Manstead and Stradling 1995). Although unlikely to be the whole explanation for motorcycle L.B.F.S. errors, such conceptualisations may account for some. Reason's model also gives good accounts of failures of sustained attention. Edginess and Pollock's (1997) retrospective analysis of 112 train incidents according to Reason's (1992) Generic Error Modelling System revealed a propensity of skill based errors across the more common types of rail mishaps.

This stage model provides a structural framework for this thesis. It will be used to understand the relationship between the activities of the driver at an intersection and psychological theories that may account for the failure. The thesis will concentrate on the first four stages.

1.10 Conclusion

Many types of vehicle are involved in L.B.F.S. accidents. Although motorcycles with conspicuity enhancers may be detected in laboratory studies more rapidly than those without enhancers there is little evidence that a real world failure to detect motorcycles is due to a lack of conspicuity. Reviewing the crash research it may be evident that previous research appears fixated on the physical properties of the target alone to attract attention. The thrust of the work appears to suggest that the problem of the detection failure is related to the signal strength of the motorcycle being too low against its background to elicit a fixation. The accepted way to overcome the problem is to increase the strength of the signal so that it may be detected. Many reviews have criticised this 'conspicuity hypothesis' and raised alternative hypotheses for the L.B.F.S error: however these have been seldomly seriously considered or empirically researched. Olson *et al.* (1979) speculate that psychological and physiological limits of human performance are the areas to be investigated. However Olson *et al.* (1979) conclude that it is unlikely any single study will come to a conclusion and in the meantime the best way is to continue to try and evaluate conspicuity enhancers.

It may appear that in our evolution, the physiological performance of the eye, the development of our cognitive system and the way that we selectively attend to one stimulus over another, together with our expectations at an intersection, may all conspire against the motorcyclist being detected. I say conspire with some reservation. If we conceptualise the task of driving from a sustained attention model then high temporal and spatial uncertainty together with low event frequency would predict that such targets would be poorly detected. If we conceptualise the drivers at the intersection performing a visual search for a motorcyclist then if attention is directed to locations in space the motorcycle may not be detected because of its unusual road position. If selective attention is for detecting objects then the motorcycle will not be detected because of its unusual

shape which may be similar to other non-targets present in the scene. If experience leads to a pattern of eye fixations in an automated task this may also mean the motorcyclist is overlooked.

A more sophisticated understanding of driver error and a stage model of driver behaviour shows that the L.B.F.S. error is more complicated than first envisaged and illustrates the need for further research. This thesis therefore examines the driver, where s/he looks, how long for and what s/he is expecting to see. Above all do these expectancies and looking patterns mean the uncommon motorcyclist is overlooked? In rapid visual searches do driver expectancies or experience driven ‘short hand codes’ mean we would even miss a conspicuous motorcycle?

1.10.1 Issues in methodology

Several alternative explanations have been offered to suggest that the driver of the car may ‘look’ but fail to ‘see’ the motorcyclist. What a more sophisticated understanding of either the L.B.F.S. error or a greater understanding of human perception can tell us, is limited by the methodology that can be used. Chapter 2 therefore reviews some of the diverse techniques already used and updates some of the methods in the light of this literature review.

2. Measuring the rare event: Issues in methodology, and measurement

2.1 Introduction.

In contrast to the one exclusive explanation of motorcycle accident causality in terms of 'conspicuity' that has been proposed, there are many diverse methodologies that claim to demonstrate the L.B.F.S. error. Many of the research techniques in this domain are designed to assess the comparative merits of different conspicuity enhancers (Thomson 1982). Review articles (Olson 1979, 1989, Wulf *et al.*, 1989) have been as critical of methodological practices as they have been with the exclusive explanation of motorcycle accidents in terms of conspicuity. Methodological problems in motorcycle safety research are numerous and multi-faceted.

This chapter describes the previous methods in L.B.F.S. research. Most of this section is a critique of the previous methods - why they are methodologically flawed and psychologically inappropriate. Each of the experimental chapters will return to issues in methodology.

This chapter seeks to clarify three issues:
A. What to measure
B. How to measure it
C. Do A & B reflect the driving task and encapsulate the L.B.F.S. error under scientific conditions?

Previous research methodology can be divided into three distinct areas
- Accident database and Accident Statistics
- Laboratory studies
- Field studies

This chapter deals with each area in this order.

2.1.1 Converging methods.

The motorcycle L.B.F.S. error is possibly not easy to encapsulate in a single laboratory experiment. Investigating the subtle combination of 'unfortunate factors' (Hills, 1980) that lead to an accident may not be replicable in the laboratory. Previous studies therefore, often even within one research project, use a variety of experimental methods and techniques (Olson *et al.* 1979 and Williams and Hoffman 1979).

2.1.2 Methodology: Applied and Basic Research

One of the challenges, as in all applied psychology, is to understand the relationship between basic and applied research described by Leibowitz (1996) as a 'symbiosis'. He says that although a relationship between the application of the fundamentals of psychological knowledge and solution of a societal problem may be at first apparent, the major hurdle is not just the understanding of the fundamentals themselves, but the changes which are necessary in the

methodology between the basic laboratory research and investigation of the real world problem in the field. This thesis will reflect this.

In considering the review in Chapter 1, alternative explanations will be offered from, broadly speaking, the 'fundamentals' of visual attention to explain the 'societal' problem of L.B.F.S. error. I will argue that visual search tasks, conducted during investigation of selective attention (for a review -Egeth and Yantis 1997, Theeuwes 1993) may emulate a driver searching for hazards at an intersection. The challenge will be in converting the laboratory methodology of selective attention to the problem of the L.B.F.S. error when methodological techniques of previous motorcycle research tend to focus on the conspicuity hypothesis alone. The measures used by selective attention research may equally be inappropriate for understanding the L.B.F.S. error.
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2.2 Accident Statistics

2.2.1 Overview

If previous research has indicated that motorcycles have a higher chance of an L.B.F.S. intersection accident, then it appears appropriate to study the motorcycle accident. Evidence from accident databases is cited in support of the conspicuity hypothesis (Williams and Hoffman, 1977). The rationale seems to be ecologically valid and plausible, that if something is difficult to detect then it may be involved in more 'failed to see' accidents. Therefore studying summary accounts of those accidents will highlight something about the perceptual error. Surveys of accident databases have featured extensively in earlier research and can be subdivided into differing sources of information and methods of data collection.

2.2.2 Sources and techniques

Information about motorcycle accidents originates from diverse sources and collection methods. A selection of these is considered in Table 2-1.

Table 2-1 Diverse sources in data collection

Post accident interview -

Sabey *et al.* (1975) - teams of researchers interviewed drivers after the incident.

Hurt *et al.*(1981)- accident data from police authorities and post accident investigation.

Police accident databases -

Williams and Hoffman (1977) - reviewed police databases in Victoria Australia.

Hospital accident records -

Sun Kahn and Swan (1998) Peek-Asa *et al.* (1996) - data was gathered from hospital admission records, hospital mortuary/inquest information or military records e.g. Blaustein (1977).

National accident statistics -

Rutter, Chesham and Quine (1993) - the interpretation of Casualty reports by psychologists

2.2.3 Accident data and conspicuity

Reviewing crash data only tells us about accidents, not conspicuity nor much about driver error. Let us examine some of the factors that may undermine the notion that accident data provides information about motorcycle conspicuity.

2.2.3.1 Lighting

Lighting, contrast, and luminance are all central to understanding conspicuity (Donk 1993, Engel 1977), yet are seldom recorded in accident statistics. While methods exist for adding both weather and lighting details such as time of sunset, these data are seldom considered. Typically, (e.g. Radin *et al*.1996), no consideration is made of background lighting and only a minor consideration is made to overall light levels (Williams 1976). The data from Cercarelli *et al.* (1992) was grouped into accidents at dusk, dawn and at all other times. These measures poorly reflect relationship between target and its background.

2.2.3.2 Background

The effects of the background against which the motorcycle appeared can not be derived from such data. Understanding visual search performance usually requires the complexity of the background to be considered. Yet, although in accidents, motorcycles may appear against a unique range of background complexity, accident databases do not record this. The background against which the motorcyclist appeared can vary greatly with different levels of clutter (Langham 1995, Williams and Hoffman 1977). If we are to measure the conspicuity of the object, and we believe that conspicuity is the degree to which an object disrupts the background (Donk 1993), it is vital to have knowledge regarding the background against which it appears. A motorcyclist against a background in a rural area is a different visual target from one in a city environment.

2.2.3.3 How conspicuous was the target?

In daylight accidents (Cercarelli *et al.* 1992, Peek, Ass *et al.* 1996, Smith 1974, Radin, 1996), no record is made of whether traditional conspicuity enhancements were in use, thus affecting contrast. Authors of the Hurt (1981) study, recorded in a post publication interview, stated that they believed motorcyclists who wore orange garments were under-represented in the data. However, this did not appear in the original text (Cited in Caird and Hancock 1994). If, for example, a motorcyclist was hit while using daytime headlights, can such studies still be measuring a physical conspicuity failure? This is a problem with all database studies.

Accident data are often used in the evaluation of the effectiveness of DRL's fitted to motorcycles. The usual methods compare pre-compulsory usage and post-compulsory usage: comparisons between countries or states where usage is either mandatory or voluntary (e.g. Janoff, Cassel, Fertner and Simierciak 1970, Muller 1984); after driving campaigns and periods of evaluation (Radin 1996). Generally, the effect of headlights on accident database evidence is minimal. Before and after studies are distorted by the increase in road traffic through time (Wulf *et al.* 1989). Studies which make comparisons between states underestimate the difference between countries' or states' transport needs (Prower 1985).

2.2.3.4 Conclusion

It is clear that accident statistics fail to provide sufficient detailed information about factors relating to the motorcyclist conspicuity, yet evidence from database studies is used to claim that conspicuity is the problem. For example Williams and Hoffman 1977) claim that 67% of all motorcycle accidents are conspicuity failures This is stated when it is unlikely that the most basic details about the luminance of the target or background complexity has been recorded.

2.2.4 Culpability

Earlier work, such as Smith (1974) assumes that if the right of way is violated then the driver of the offending vehicle is at fault. However, contributory factors that may have led to this violation, for example speeding, are not then taken into account. In other words, in interpreting accident statistics culpability is always assumed but not actually confirmed. If conspicuity is measured by relative accident rates, then it is important to establish who is at fault. But in many studies using accident statistics (e.g. Radin *et al.* 1996 Cercarelli *et al.* 1992). The establishment of culpability is too uncertain Other research (e.g. Thomson 1978) has concentrated on junctions where one party is readily determined to be at fault and, from the nature of the junction, liability is clear. Typically this is at a 'give-way' junction where the target vehicle (motorcycle) is on the main road and a driver emerges into its path. If fault can be determined, we can assess which party failed to see or react to the other. Some (e.g. Thomson 1982), have claimed that an understanding of culpability is essential to understanding the L.B.F.S. error.

A way of side stepping the issues of culpability is used by Radin (1996) who declares all accidents involving a motorcyclist to be conspicuity failures. He writes:

"Conspicuity-related motorcycle accidents are defined as all accidents involving motorcycles travelling straight or turning onto a right of way and colliding with other vehicles or pedestrians"
(Radin 1996, p 326)

This appears an unusual understanding of accident culpability.

2.2.5 Sources of accident data

Motorcyclists tend to be more vulnerable, and when involved in an accident, more likely to be injured (Allgemeiner Deutscher Automobil-Club 1987) than other road users. Therefore motorcyclists may be more likely to appear in accident databases. Cercarelli *et al.* (1992) uses data obtained from three sources: casualty crash records; the hospital mortality file; and the St. John's Ambulance Brigade records. All these sources imply that the only data that were collected were from serious or fatal road traffic accidents. These are relatively rare when compared with minor impacts (Casualty Report 1996). The sample would be skewed for several reasons. Firstly, all minor collisions and near misses, even if they were caused by conspicuity problems, would not be recorded. Secondly, if only crashes that resulted in fatalities were recorded, motorcyclists who have less protection than a car driver would be included more often in the sample (this is important as Cercarelli compares car and motorcycle accidents).

2.2.6 Accuracy in databases

What is contained in a database, its scientific worth, and the conclusions that can be drawn depends heavily on the quality of information going in. Accident database information can be inaccurate. Lapidus, Braddock, Schwartz, Banco and Jacobs (1994) found 30-40% of the content of UK police accident databases to be inaccurate. Chapter 3 (p.77) returns to the issues of recording and accuracy when examining a police accident database.

2.2.7 Post accident interviews and forensic studies

If accident statistics alone cannot provide a sound understanding of driver error (Brown 1990) then post accident interviews or in-depth knowledge about the actual incident might be fruitful. Sabey *et al.* (1975) interviewed drivers after an accident and obtained verbal reports of accident causality. However the possible subjective nature of the recording of the interviewer has to be taken into account as does the veracity of the driver as to the cause of the accident. Sabey *et al.* (1975) categorised accidents not by a free description of the incident but rather imposed categories of explanation (for example 'error of judgement' and 'failed to avoid'). Here research teams needed to fit the account of the accident into certain formats. In many incidents therefore, culpability or actual causality were coded by the teams as 'failures of perception'. The greater knowledge obtained after accidents by interview and forensic reconstruction contained in the Hurt study can show details that may be more relevant to a psychological investigation..

2.2.8 Conclusion accident and forensic data

Understanding motorcycle accidents from crash data alone may be a problem because factors that are important in the understanding of physical conspicuity are not recorded. What may have led a driver to 'look' but then 'fail to see' is a complex interaction of many human factors not highlighted by the accident statistics alone. Accident databases fail to give details that adequately describe the cognitive state, expectancies and goals of the driver who commits the L.B.F.S. error. Neither accident statistics, nor post accident interviews give information in a way that is concordant or similar to psychological investigations of selective visual attention or cognitive conspicuity. Known features of selective or sustained attention and visual search, do not 'map onto' the knowledge provided by accident statistics. In fact, knowledge of accidents does not give the information which is necessary for a laboratory investigation of visual search. Yet accident databases and accident interviews are used as evidence that motorcycles are difficult to see. Accident database studies are useful, because they attempt to show that motorcycles/car accidents are different from car/car accidents and provide basic information of typical accident scenarios - but they are strictly limited in their usefulness.

2.2.9 Accident data in this thesis

Chapter 3 reports an investigation of accident data that will attempt to overcome some of the methodological weaknesses discussed above. A police database will be used to understand the L.B.F.S. error, by using all the information collected at an accident site rather than summaries. New statistical techniques available to Police authorities - such as 'Strada analysis' and 'geo-locationary' search may give more details of the accident than earlier reported studies. This will be complemented by reviewing fatal accident files containing details of conspicuity

enhancers which are completed by specially trained officers. The results will be used to guide the construction of stimulus materials for further laboratory investigation.

2.3 Laboratory studies

2.3.1 Overview and case example

Many studies have attempted to assess motorcycle accidents in the laboratory (e.g. Donne, Fulton and Stroud 1985, Stroud and Kirby 1976). Laboratory studies are popular because the possible hazardous nature of the research can then be avoided. One much cited paper by Williams and Hoffman (1979) is typical of its genre. By describing their methodology I can discuss the problem with laboratory based studies in general.

The motivation behind Williams and Hoffman's study came from the analysis of accident crash data. They investigated the detectability of three devices to aid frontal conspicuity of motorcycles. Williams and Hoffman showed colour slides of motorcycles with different conspicuity enhancers, against either a cluttered or uncluttered background. The slides were presented in the peripheral vision this was achieved by asking participants to fixate on a small flashing light : the slide was then shown to the left of this point. The subject's task was, the authors claim, to be different from that required of motorists in crash situations because:

- the participants knew they were to concentrate on detecting a motorcyclist.
- they knew most slides would contain a motorcyclist.
- they knew where on the screen it would appear.

Subjects' reactions were noted by means of a five way decision box. The less conspicuous the target is to the subject, the more difficult it is to identify, resulting in a longer time to detect. The critique concerns the stimuli used, and. the procedure adopted.

2.3.1.1 The stimuli

Colour slides, while allowing high definition and a controllable measurable stimulus do not allow for important cues present in a real world situation. Colour slides are popular in applied conspicuity research (Donne, Fulton and Stroud 1985, Hole and Tyrrell 1995, Isler, Kirk, Bradford and Parker 1997). One problem is that participants cannot use cues of motion (Wulf *et al.* 1989). The motion of an approaching target may be a powerful tool that motorists may use when deciding to emerge at an intersection (Caird and Hancock 1994).

A major problem with Williams and Hoffmans' study was that participants concentrated on detecting the motorcyclist, not the traffic. Also, when a slide contained a motorcycle it was always presented in the same place on the screen. Cueing of participants as to where to look is common practice in conspicuity research. However, implicit in the study of conspicuity research in a laboratory is a notion of search (Donk 1993). The subject in a real world situation needs to search a traffic scene and does not know where in the scene the motorcyclist is to appear. In, for example, a scene of moving traffic approaching the viewer, the motorcyclist can appear at varying distances from the viewer and in unusual road positions (Olson 1989). These distances can be from just a few metres to a few

hundred metres away. Therefore, the study fails to take account of context and expectancy cues.

2.3.1.2 Directly measuring conspicuity or conspicuity enhancers?

The 'conspicuity hypothesis' as the only explanation of motorcycle accidents is eloquently criticised by Thomson (1982) and Olson (1989), who discuss methodological issues both in field and laboratory experiments investigating motorcyclists' conspicuity. Thomson criticises the methodology thus::

"by investigating (so called) 'conspicuity enhancers' on motorist behaviour towards motorcycles".. "Most of these studies have investigated the latter with researcher accepting that conspicuity is a problem their aim being to determine which 'enhancers' really improve conspicuity"
(Thomson 1982, p 771).

And Olson *et al*. (1979) writes

"...the conspicuity hypothesis has not been seriously challenged. Almost all investigators have accepted it as fact concentrating their efforts on means to improve conspicuity rather than whether the hypothesis is correct."
(p 143)

Thomson comments that it appears unusual in research to take a driver's explanation for the cause of an accident at face value, without investigating alternative explanations. Then, claims Thomson, it is also unusual not to research the problem of failing to 'see' directly, but instead to investigate an assumed improvement device. What Thomson argues is that research has not measured conspicuity but the relative effectiveness of the performance of different conspicuity enhancers on detectability of the motorcyclist by the car driver. Wulf *et al.* (1989), claim that the need is to understand conspicuity not in isolation but to obtain :

"recognition of the specific factors that determine motorcycle conspicuity and how they interact with factors that induce failures in the offending vehicle drivers visual information processing capability. This can form the bases of strategies to promote effective counter measures for automobile-motorcycle collision."
(p156)

Therefore the measurement of only the relative merits of each conspicuity enhancer fails to determine whether motorcycles present a specific detection problem for the car driver.

2.3.1.3 The procedure

A further major problem is that in one condition Williams and Hoffman asked the participants to view the slides in 'the peripheral vision area'. The claimed rationale for this was that when drivers approach a junction to look at the road, they were looking at an oblique angle of more than 30°. Human peripheral vision has, however, some weaknesses that Williams and Hoffman have overlooked. In our peripheral vision, unlike fovea vision, feature and colour discrimination is relatively limited, as is luminance (Sekuler and Blake 1994). If the central thrust of their paper is that conspicuity is the detection of (in this case) small detailed figures that sometimes may be highlighted by bright colours, then results obtained may be affected by their presentation in the periphery. A small movement in the human peripheral vision means that a fixation is elicited and attention drawn to it. Unfortunately Williams and Hoffman's study used static cues meaning that the

validity of displaying the stimuli at an oblique angle was lost if no movement was present. To some extent they have set the experiment up to encourage their participants to use the conspicuity aids present.

2.3.1.4 Similarity of Task to driving

Williams and Hoffman's study also used a five way decision box in a "darkened room". More typically, a two-way button box is used (e.g. Hole and Tyrrell 1995). The decision box, used by Williams and Hoffman would mean that the manual dexterity required by the subject would not reflect the driving task. The participants were also asked to push one of the buttons to "indicate which enhancement was used" (p 622). This, initially may appear a minor weakness. However drivers do not search specifically for a motorcycle and once it has been located, do not assess what type of conspicuity enhancer is fitted.

2.3.1.5 Display time

The amount of time a subject is permitted to search the scene is under the control of the experimenter. Display time has not been considered as an issue in motorcycle conspicuity research so far. Consequently practices are varied in the amount of time the subject is given for this task. Chapter 4 directly addresses this issue.

2.3.2 Laboratory studies in general

Therefore, do measurements of motorcycle conspicuity, in the laboratory, really measure conspicuity effects if all we are measuring is an artefact of the experimenter's manipulation of a series of events (Thomson 1978,1982)? How laboratory studies relate to a real world situation is debatable. However, Cole and Hughes (1986), in a comparative study of laboratory and field evaluations of conspicuity, claim a good reliability of laboratory results compared to the real world. In Williams and Hoffman’s case however, the frequency of the appearance of the motorcyclist in the slides was different to their frequency in the real world. Motorcycles are usually an infrequent sight on public roads (less than 2% of traffic exposure - Thomson 1980, Transport Statistics 1996). Several researchers have claimed that low expectancy is a contributory factor in the L.B.F.S. motorcycle accident (Olson *et al.* 1979, Sanders 1980, Wulf *et al.* 1989).

2.3.2.1 Searching for ‘what’

Thomson (1979) argues that with many laboratory investigations the participants are searching for a motorcycle. Typically, experimenters ask the participants to signify only when a motorcyclist is present. In the real-world with limited numbers of motorcycles present, the driver at an intersection is not participating in a ‘spot the motorcycle’ competition. The car driver is searching for any hazard. Asking a subject to search for one category of road user may only measure the relative effectiveness of the conspicuity enhancer. Hole and Tyrrell (1995) showed that drivers may just search for a feature of the motorcyclist like its lights when they are instructed to search for a motorcycle. In such a case the experimenter is measuring the subject’s ability to detect a conspicuity enhancer rather than all motorcycles. In laboratory experiments two issues must be considered. Firstly, the relative frequency of the appearance of the motorcyclist and secondly what happens when the subject takes part in a free search trying to detect all hazards

and not just motorcycles. Chapter 5 considers this issue by comparing participants who specifically search for a motorcycle and those who are instructed to search for any hazard. Previous laboratory studies fail to deal with the fact that driver behaviour is not solely dedicated to finding the motorcycle. Laboratory studies illuminate driver behaviour better than the study of accident records, but they still do not uncover the complex activity that is driving.

2.3.3 New technology, Video and film.

Both Wulf *et al.* (1989) and Thomson (1982), contended that the use of dynamic cues is needed, so laboratory studies should therefore use video or film presentation. However, with video presentation, participants gain movement cues but lose the quality and definition of slides. With slide presentation, many of the features that are most likely to be investigated in conspicuity research, are already lost such as luminance and reflectivity of the relative conspicuity enhancers. Retroflective and fluorescent materials simply do not show up in slides in the same way they do in life. Some previous studies use 35 mm film but this is uncommon as it is expensive and difficult to present in silence in a small laboratory. Video technology has advanced rapidly and, at the start of this thesis, the best commercially available was SVHS hi-band. This equates to ‘u-matic’ but is not of total broadcast quality.

2.3.4 Driving simulators.

Laboratory research of driver error is often conducted in driving simulators (e.g. Crundell and Underwood 1998). However, what is being simulated? Most driving simulators, like aircraft simulators, replicate very well the interior of the vehicle and its control surfaces but not the view of the driver sitting at an intersection looking for hazards. Most simulators use comparably poor representations of the real world by representing it sometimes in the form of computer generated blocks (e.g. Hancock and Mansier 1995). The problem of the L.B.F.S. motorcycle accident is not suspected to be a failure of the operation of the control of the vehicle, but rather the way in which a driver searches (or perceives) his environment. Therefore, what needs to be simulated is but the world in which the driver is searching - the controls are irrelevant. For the purpose of this study the representation of the road environment needs to be as ‘real’ as possible not the control surfaces of the vehicle. However, I am very mindful of the limitations of asking someone to push a button to indicate that they would normally perform a series of hand/leg movements to pull away at an intersection.

2.3.5 Laboratory Measures

2.3.5.1 Reaction time

Reaction time (RT) data are possibly the most widespread measures used in the study of L.B.F.S. error (Wulf *et al.* 1989, table 2). Reaction time has been a subject of interest to psychologists for many years. Donders (1868) (review in Hole and Langham, 1997) identified three types of reaction time (a, b,& c) and these are used in the following methodology. Type ‘a’ refers to the simple time taken to react to the presence of a stimulus by the subject hitting a single button to indicate ‘I see it’. Types ‘b’ and ‘c’ are ‘choice’ reaction times. These mirror more realistically what a subject does when driving. Type ‘b’ describes the RT taken when a subject needs to make one of two responses, according to which stimulus is present. Type ‘c’ is when a subject needs to make a response, usually

the same response to when one stimulus is present but not another. Thomson (1982) claims the use of subjects' reaction times can be problematical in understanding L.B.F.S. errors at intersections. Thomson writes,

"it is not known whether reaction time measurers are valid indicators of accident potential..."
(Thomson 1982, p 776)

Typical reaction time data for drivers to search at an intersection are not known. The typical reaction time paradigm studies of driving involves a driver reacting to an unexpected event, for example, the brake light coming on in the car in front (for a review see Hole and Langham, 1997b or Olson 1989b). Very little is known about the time it takes to react to a vehicle during visual search at an intersection. Most research in this area has asked the subject to merely signal the detection or absence of a motorcycle. However, behavoiur at a junction may involve more than a decision of 'presence' or absence - it may involve detection plus identification and evaluation in what is seen How long this process takes is simply not known, Let's consider the response from the experimental subject 'Yes I see it'.

2.3.5.2 Yes I see it .

Many studies (e.g. Williams and Hoffman 1977) require the subject to push the button when they detect the hazard. What do the button depressions actually mean? Participants in the laboratory can make one of four responses on a simple two way button box. Table 2-2 illustrates the possibilities

Table 2-2 What does a key depression mean?

Correct positives
"Yes, I see and have identified a motorcycle correctly" or
"I pressed the button by mistake".
False positives
"I thought there was a motorcycle present" or
"I meant to push the 'no' button".
Correct Negatives
"I don't see a motorcycle" and
"no motorcycle is present"
False negatives
"I thought there was no motorcycle present" or
"I meant to push the 'yes' button".

2.3.5.3 Detection and accident potential.

The preceding chapter raised the issue of detection and accident potential. Improved detectability, found in some previous laboratory studies, would not always affect the chance of an accident occurring. A subject's ability to detect a motorcycle over 100 metres away from the viewer would not affect accident potential because if the subject when driving failed to notice the motorcyclist at that distance the motorcyclist will have time to brake. The need is for stimulus material to reflect a scenario that when a subject fails to detect the target motorcyclist that failure will result in an accident. Specialist software now exists that can ensure the generated stimulus material will contain motorcycles at distances that either will or will not affect the L.B.F.S. error. This thesis will prepare all stimulus materials using this software. Chapter 3 returns to this issue.
zxc

2.3.5.4 What do reaction time data mean?

Many laboratory studies rely on reaction time or 'time to detect' to illustrate that certain conspicuity enhancers aid detection. Thomson (1980) makes a further point here:

"Probability of detection may be far more important than the detection time. The relationship between the two needs to be clarified."
(p 776)

Variation in decision time is wide between different participants. However variation in a decision time to different stimulus materials within participants, is usually only between 20 and 100 milliseconds (Lock and Beger 1993). In psychological experiments a difference between experimental conditions may be only 20 milliseconds in typical average reaction time of 180 - 200 milliseconds. This is complicated by the fact that the more targets that need to be identified the longer the reaction time will be. A relationship between response time and the number of possible choices yielded a mean RT of 200 milliseconds for a single decision and a mean of 350 milliseconds for two possible choices. Each additional choice adds about 0.05 seconds (See Damon *et al.* 1966 for a review of Hicks Law) Experimental design may be critical here.

2.3.6 Alternative measures

Alternative measures to reaction times used in motorcycle research have included the time taken to report orally the different type of conspicuity enhancer in use (Williams and Hoffman 1977, experiment 2). This is where participants report if a vehicle is fitted with a fairing or has lit headlights. A 'feeling of confidence' score concerning whether a described conspicuity enhancer was in use at the time of a slide display found differences in participants' responses (Williams and Hoffman 1979). Freedman (1972) used a paired comparison between conspicuity enhancers requiring the subject to specify which of the two enhancers, was in their opinion, more conspicuous. Dahlstedt (1986) used an estimation technique where participants rated numerically the visibility of different motorcycles compared with a car. Dahlstedt's methods meet with some of the problems of all such estimations, such as speed. Wulf *et al.* (1989) describes these methods as rather dubious. All these techniques poorly reflect the actual role of the driver searching at an intersection. Chapter 7 returns to these issues. Drivers may have developed a search strategy to search for motorcycles based on the presence or not of conspicuous clothing (Hole and Tyrrell 1995, Thomson 1982).

2.3.6.1 Speed perception

Chapter 1 suggests that the L.B.F.S. error might be caused by offending drivers' inability to perceive the speed of a motorcycle or its distance away from a junction correctly (Caird and Hancock 1994, Herstein and Walker 1994). The rationale behind such studies is that motorcycles' relative speed and distance judgements present a particular problem to the car driver. What is actually measured is referred to as 'time to collision' (TTC) 'arrival time' or 'perception of speed'.

2.3.6.2 Disappearance Methods

The methodology involves showing a video or film clip which displays an approaching vehicle at one point in the scene, and then, either stopping the video and asking the subject to report when the object would have hit them if the film

was still played (Caird and Hancock 1994), or removing the object or target from the view of the scene (the 'disappearance technique').

The problem with this type of procedure is that participants are in effect merely estimating time. The major concern is the method of measurement of time. Therefore all that is really recorded is purely subjective estimates of time and not speed perception.

Hoffman and Mortimer (1993), for example, show they measure time not speed. In one condition participants see a film clip for 0.68 seconds and then need to estimate 43 seconds which represents the actual time had the film continued by which the two targets would have collided before they should depress the switch. Human ability to estimate time under cognitive load is, at best, problematical. Many studies (Galinat *et al.* 1987, Krus *et al.* 1986) imply that under a cognitive load such as described in this experiment, time estimation by the participants, would vary by as much as 50% compared to the actual time elapsed. Therefore, the reaction times could not be considered as a completely accurate description of the actual task being measured and are subject to large individual variations.

2.3.6.3 TTC measures are too diverse

We also need to understand what cues the participants are using in order to give a response. What is the subject measuring when asked for subjective TTC estimation? Is the subject's judgement of distance or velocity, or distance divided by velocity (Schiff and Derwiler 1979). Findings from various forms of measurements of TTC in accident research have found differences in driving experience (Cavilo and Laurent, 1986); angle of approach or viewer eccentricity (Schiff and Oldak 1990); type of response - verbal or non-verbal (Schiff Oldak and Shah, 1992); complexity of background (Schiff and Derwiler 1979); gender (Caird and Hancock 1994) and age (Schiff, Oldak and Shah, 1992). Complications over speed estimation can be found particularly with motorcycle accidents. Shew, Polito and Winn (1977), (cited in Wulf *et al.* 1989) found that motorcycles not using conspicuity enhancers are perceived as travelling more slowly than those using their lights.

In their review Caird and Hancock (1994) found that comparisons of arrival time provided by drivers between motorcycles and cars suggest that drivers substantially underestimate arrival time in all circumstances, especially in response to threatening images such as trucks and give a safety margin that may not be found in the field.

2.3.6.4 Instructions in TTC Experiments

Participants may take the disappearance methodology literally. How well does the instruction given by the experimenter reflect the task of driving? In many experiments, the participants are asked to signal when they believe the object would reach the viewer. Typically instructions are to "push the button when the vehicle would have reached you" (Schiff and Derwiler 1979). The subject is then providing not an estimate of when they would pull out in front of the vehicle at an intersection but rather when it would have passed. Participants are, therefore, not providing any evidence for actual accident involvement. Stoffregen and Riccio (1990) believe that there are consistent under-estimations of TCC and larger safety margins. This is found across all conditions and all experiments because the subject is thought to be trying to avoid the negative consequences of an

accident and is not reflecting what they may do in the real world. Other studies like Herstein and Walker (1994) have asked participants to respond to questions such as "would you be prepared to walk across the road" (p 567.) Clearly, participants would give a greater underestimation and, therefore, safety margin, when asked if they were going to walk across a road, rather than drive.

In the disappearance methodology a time gap exists between the video or film clip disappearing and the required response. During the waiting time, before the subject pushes a button to indicate when the disappeared target would have passed, the experimental subject may be involved in what Jagaicinski, Johnson and Miller (1983) describe as temporal factors, related to subjective strategy decision making and motor responses - where participants may manipulate different mental representations of the object. This may be particularly important for motorcycles because as Caird and Hancock (1994) comment, motorcycles present an uncommon image, size and shape that may be more difficult to manipulate mentally than a familiar car shape.

2.3.6.5 Ecological Validity of TTC

Caird and Hancock (1994) raise the issue that the TTC task de-couples the subject from the action and task; cars or motorcycles do not simply vanish. Sometimes they may be occluded by other road users, but parts of the moving vehicle are often still visible. In the disappearance method all cues have gone (Flach 1990). This raises the issue of how similar the laboratory task is to that undertaken by the driver. Firstly, of course the actual viewing time. Typically, the viewing time of this type of experimental paradigm does not reflect the suspected short amount of time the driver spends looking at a junction.

2.3.6.6 Conclusion of TTC and arrival time

Overall, previous research has suggested that arrival time or TTC by disappearance methodology, may be measuring something other than speed perception. Participants consistently underestimate arrival time of all vehicles so all that can be discussed is the amount of inaccuracy involved in subjects' estimations between motorcycles and other vehicles (Caird and Hancock 1994). It is also not known what are the critical factors in estimation of TTC. If angular velocity is important, then the standard intersection accident with many different angles or different traffic scenes will affect subjects' responses. The main problem remains that we do not know what we are measuring and the task itself appears divorced from the real world.

2.3.7 Experimental design

2.3.7.1 Measures

If repeated measures are used, the individual variation in reaction time between participants will be avoided. However, repeated measures will mean that a subject sees more than one experimental condition. If motorcycles are already a rare event then simply viewing two experimental conditions in a typical conspicuity research task, would mean that the subject would see more motorcycles than the average driver. Typically, motorcycles are less than 1/112 of vehicles seen on the road (Thomson 1974) and represent less than 2% of taxed vehicles on the road in the UK. (Transport Statistics 1996). Repeated measures designs however, do

mean that subjects' reaction times could be more easily compared, because driver reaction times show great individual variation in an independent measures design. I shall return to this in Chapter 5 (p.94).

2.3.7.2 How representative is the sample?

Many studies investigating driver error use undergraduate students as participants to participate in laboratory experiments. These tend to be young, fit and normally relatively inexperienced as drivers (e.g. Herstein and Walker 1993). They are not representative of the normal driving population. Therefore, in this thesis, an attempt will be made to employ more representative samples of the population under test.

2.3.8 Laboratory studies in this thesis

With some exceptions the weakness highlighted above can be overcome. The challenge is to make the laboratory task as near to the task of the driver under normal driving conditions as possible. In the first instance, therefore, we need to understand how much time the driver spends looking at an intersection.

Laboratory studies will, use the highest definition of video available at the University of Sussex thus alleviating to some extent Wolf's (1989) concerns. The stimulus material will be based on the findings of a review of the Sussex police accident database. Speed and distance calculations will be made in conjunction with police accident investigators so video clips will be as realistic as possible. Target event rate (the motorcycle) needs to be shown less frequently in the experiments although an event rate suggested by Thomson (1974, 1978) of one motorcycle in 112 vehicles is impractical.

2.4 Field Studies

2.4.1 Overview

If the general critique of laboratory tasks is that they are divorced from the real world task, then it should follow that experiments carried out in the field should be more appropriate. This section considers 'gap acceptance' and a range of diverse methods.

2.4.2 Gap acceptance

This methodology, typically, involves a motorcycle with different conspicuity aids driving along different parts of a highway with the experimenter recording the reaction of other road users to the motorcyclist. These reactions are measured by the motorcyclist driving at a set distance from the vehicle in front, also driven by a member of the research team. As the 'convoy' approaches a junction where traffic was attempting to join the highway, the waiting driver makes a decision as to whether the space between the two approaching vehicles is sufficient for him to emerge with safety. The rationale of this experiment is that a highly conspicuous motorcycle would mean that a driver emerging onto the main road would:

- see the motorcyclist
- react to him by requiring a larger gap before emerging into the stream of traffic.

Implicit is the notion that high visibility leads to other road users giving more space to more conspicuous objects. One advantage of the methodology, is that it is in the field and drivers are unaware that they are under investigation.

2.4.2.1 Gap Acceptance problems

Before making the correct decision, the driver must detect both the vehicle in front of the gap and the vehicle after the gap, and then assess if the gap is sufficient. Detecting a gap is a commonly executed task while driving in urban environments, and the frequency of failure is very low. Therefore an experimenter is unlikely to capture or witness such an error (review Thomson 1982). There is no guarantee that the stimulus, which is being tested actually affects the drivers decision making process. The subject when emerging at the junction may still accept the gap between the vehicles because he has panicked (Thomson 1980). To assume that an error in gap acceptance means that there is a conspicuity problem of the vehicle after the gap, is flawed, because all that is being measured is the gap acceptance procedure. For example, the driver emerging onto the highway may react to the headlight of a motorcycle but there may not necessarily be a conscious link between the driver’s reaction to a bright light and the fact it was attached to a motorcycle or because the motorcycle was novel (Thomson 1982). It is a large leap to say that because a driver did see the light this meant the motorcycle was more conspicuous. The driver may be reacting to the unaccustomed headlight or the novelty value of vehicles with lights during the day (Currie 1976).

A further problem is how to define gap acceptance. Olson (1979), who has used this methodology, shies away from an exact methodological description, but it may constitute one of three techniques. Firstly, the time gap may be measured between the lead vehicle and the test vehicle (the motorcyclist with conspicuity aids). Secondly, the time taken to accept or reject the gap at the conflict point (the conflict point being the point at which the vehicles would collide) may be measured. Or thirdly, the last available time from the conflict point that the observer will admit that a decision is made by the driver (Thomson 1982). Using different definitions of the methodology has lead to a range of gap acceptance times by the driver (Bottom and Ashworth 1978).

2.4.2.2 Gap acceptance measures

Gap acceptance methodology generally disregards the possible novelty of the enhanced motorcycle, such as a motorcycle fitted with differing headlight positioning and power (for example Fulton, Kirby and Stroud, 1980, experiment 4). The gap acceptance method leaves many questions unanswered. With a method of accepting or rejecting a gap, what was the feature of gap rejection? What are the criteria for rejection? Gap acceptance studies can be said to uncover far more about the L.B.F.S error than understanding conspicuity from accident records. It clearly attempts to avoid the problems inherent in laboratory experiments. What however is lost, is the control and precise measurement of all the factors that when combined, constitute a driver's behaviour. Above all the participating motorcyclists in a gap-acceptance study are at great risk if someone does fail to judge the gap.

2.4.3 Other methods used in the field

2.4.3.1 Recall during an interview

One technique that is featured in field studies is to ask the driver or sometimes a pedestrian (Fulton *et al.* 1980, Janoff 1973) if they recall seeing a motorcyclist who either had different types of conspicuity enhancer or a differing road position. Recall studies appear quite popular - Janoff and Cassel, (1971), Kirkby and Fulton, (1978), Ramsey and Brinkley, (1977), Stroud and Kirkby (1978). Here, recall is said to reflect on the effectiveness of the conspicuity aid. Although the ‘where’ and ‘what’ the driver will be looking for will not be affected by the experiment (Wulf *et al.* 1989) the data may reflect one of three factors. Firstly the ability of the driver to detect, secondly the driver's ability to store the information and finally recall from memory. More conspicuous objects are more likely to be noticed - stored - recalled. This technique therefore tests a driver's ability to recall what s/he has seen, not what s/he may have overlooked and reflects poorly the driver’s claim not to have ‘seen’ the motorcyclist.

More representative of the type of accident that motorcyclists are actually involved in, is a field study by Donne and Fulton (1987). Using a technique similar to Watts (1980), drivers seated in a stationary car firstly had to monitor a task described as ‘occupying their central visual system’ and secondly had to indicate when they became aware of a vehicle approaching at a 60° angle. Although this technique allows for the use of dynamic cues and possibly replicates actual accident potential by allowing the car driver to use only their peripheral vision, participants were aware of the purpose of the experiment. Other work by Donne (Donne and Fulton, 1985, Donne, Fulton and Stroud, 1985) uses a shutter to obscure the front of the driver’s view. The shutter opens very rapidly and allows the subject to view the road in front of the stationary vehicle. The subject then needs to decide rapidly if a motorcycle is present or not. However, as Wulf *et al.* (1989) comment over the Donne series of experiments,

> “Essentially subjects were engaged in a task not requiring the active responses associated with driving”
> (Wulf *et al.* 1989, p 169)

2.4.4 Observation studies

Chapter 4 (p 82) will report on an observational study of driver behaviour at an intersection. Brown (1990) believes that observational studies can provide a sound understanding of driver error. Although relatively uncommon in the study of motorcycle accidents they can provide measures of driver’s awareness by, for example, measures such as change in search time at an intersection, (Bottom & Ashworth, 1978, experiment 2); presence of police vehicles as a deterrent (Shinar and Stiebel, 1986); flow at uncontrolled intersections (Lovegrove, 1978); reactions to traffic control devices (Worthman and Matthias 1983). One relevant observational study is by Summala, Pasanen, Rasanen, and Sievanen (1996) who consider bicycle L.B.F.S. errors at intersections. I shall return to this in Chapter 4 (p 82).

2.4.5 Conclusion.

If a research project is investigating vehicle accidents it is best to study them where they happen. Studies outside the laboratory tend to focus on either the perception of vehicle speed, or the minimum gap that a driver will accept between

a motorcycle and a following car. Speed perception was highlighted by the literature review as an area requiring study. However, gap acceptance has many problems as highlighted above. Speed perception measures only the ability of the subject to attach a meaningful label to the speed of a vehicle. In the field, speed perception is contaminated by judgements of relative speed of the oncoming vehicle and sound. In the laboratory, speed perception is likely to be inaccurate because of poor video reproduction. Both field and laboratory speed perception measures do not reflect what the driver is doing at a junction. If the driver of the offending vehicle is claiming not to have seen the motorcyclist this implies a complete failure of detection, rather than a relative failure of speed perception.

2.5 Conclusion

Reviews (e.g. Olson 1989, Thomson 1982; Wulf *et al.* 1989) have been as critical of methodological practices as they have been of the explanation of motorcycle accidents exclusively in terms of physical conspicuity. Methodological problems in motorcycle safety research are numerous and multi-faceted. Previous studies have methodological flaws which that mean data is difficult to interpret. Database studies, for example, provide a basic understanding of where accidents are likely to occur - the intersection - but little detail likely to interest the psychologist. Database evidence suggests that poor conspicuity may be a cause in motorcycle accidents, but these conclusions are rather tentative and based on many assumptions.

Laboratory studies may lack ecological validity, with the type of task the subject is engaged in being divorced from the role of the driver, but are less hazardous than field studies. Stimulus materials represent scenes that are far removed from those found in the real world, but this is not easily remedied by the use of driving simulators. Driving simulators simulate the operation of a vehicle well, but fail to simulate the visual scene the driver is searching and the real world consequences of making a mistake. Field studies using gap acceptance methodology are measuring many variables at the same time and are often inconclusive. Recall and interview techniques test recall from memory and poorly reflect the visual search failure.

Previous studies are psychologically inappropriate. Studying conspicuity enhancers does not map onto psychological theories of selective attention. Studies claiming to understand conspicuity in the field do not consider issues which are considered important in the laboratory. Theories of selective attention comparing detection skills of an individual to detect a target among a set of distracters, do not provide a taxonomy of the likely activities of a driver searching for a hazard at an intersection among a cluttered, dynamic environment. Previous L.B.F.S. error research has very limited methodology that can be considered to aid the understanding of selective attention or visual search. Conversely, search in naturalistic scenes from basic research appears not to be easily adaptable to the L.B.F.S. error problem.

Previous research does show that when researching a rare event that there is a need to attack the problem from a variety of angles: different methodologies, equipment, stimulus materials and sources of data. Equally, any theoretical perspective brought to the error needs a variety of psychological perspectives possibly highlighted by the model discussed in Chapter 1 (p 42).

Issues in methodology, both design and evaluation, are the subject of (Chapters 3-5) The next chapter considers whether the L.B.F.S. error is still a problem by examining an accident database and considers if the study of an accident database, even with improvements can prove useful to the psychologist.

3. What can accident statistics tell us about the L.B.F.S. error?

3.1 Introduction

This chapter reviews accident data and accident survey methods. Accident statistics are used to support the view that:

- motorcycles are particularly difficult to detect
- motorcycles present a particular problem for other road users
- drivers ‘look’ but fail to ‘see’ motorcyclists
- motorcycles are difficult to detect because they are inconspicuous

Chapter 2 discussed the popularity and influence of studies reporting accident statistics, accident data, and post accident interviews as a means of understanding motorcycle L.B.F.S. errors and how different methods of data collection and data interpretation have influenced the conclusions of previous research. (e.g. Foldvary, 1967, Nagayama *et al.* 1980, Olson *et al.* 1979, Sabey *et al.* 1975, Smith, 1974, Thomson, 1978, Radin *et al.* 1996, Umar *et al.* 1996, Williams, 1976, Williams and Hoffman, 1977)

The data reported here are from the Sussex Police Accident Database (SPAD), National Accident Statistics, and fatal accident reports. These sources are used to consider the following issues:

- Does the L.B.F.S. error still occur?
  Accident statistics (Accident fact sheet 10 1996 and ETSC 1997) suggest that motorcycle accident rates are decreasing.
- Can engineering and road transport issues be separated from the psychological factors?
  For example, Olson (1989) discusses motorcycle accidents as being caused by environmental obstructions to the driver’s line of sight - an important issue but not relevant for psychology.
- Are accident statistics a good measure of the L.B.F.S. error?

Chapter 2 demonstrated that motorcycle crash statistics are cited as evidence of a conspicuity failure. Can data relevant for a psychological investigation be obtained?

- The data will be used to provide a more precise account of the relatively rare motorcycle accident.
- Where does it happen? What role does experience, expectancy and age of the driver have?
- To guide the construction of stimulus material to be displayed in subsequent laboratory studies
- Investigate L.B.F.S. error accidents involving conspicuous motorcycles.
- Can the conclusions of the Hurt report (Hurt, *et al.* 1981) be substantiated.

3.1.1 Relevance to previous accident database studies

During the late 1960’s (e.g. Foldvary 1967) accident statistics showed that motorcyclists were at a higher risk than other road users. The starting point for many studies was the regional police database (e.g. Williams and Hoffman 1977).

Let us take some of the claims of previous research already described together with the findings of the Hurt Report (1981) to see what factors are present in SPAD and are psychologically relevant. Hurt's findings are mirrored in many other studies (e.g. Olson *et al.* 1979, Nagayama *et al.* 1979, Thomson, 1978, Umar *et al.* 1996).
The aim is to:

- substantiate Hurt's findings in this accident database
- investigate what accident data reveals about the L.B.F.S. error
- consider how much the data are psychologically relevant for understanding of conspicuity and the L.B.F.S. error

The results and discussion section therefore take each of the major findings of previous research and substantiate if the data can be obtained and then asks if the data is psychologically relevant. Firstly let us consider where the data comes from.

3.2 Method

3.2.1 Period of statistical knowledge.

The study selected a period 1990 -1995 for a number of reasons. Firstly, this was the most up-to-date information available. The study excludes detailed analysis for the period before 1990 because of:

- major engineering changes to the roads and traffic flows in the county.
- the commencement of Compulsory basic training (CBT) for motorcyclist.
- changes in motorcycle performance..
- changes in motorcycle usage. *
- changes in motorcyclist age profile. *

 * From Transport Statistics (1996)

3.2.2 Where do the data come from?

Sources for this study are:

- Transport Statistics (1996).
- The Causality report and Accident Fact Sheet 10 (1996).
- Sussex police accident database (SPAD).
- Fatal accident reports from Sussex police force.
- Confidential reports of involving conspicuous police vehicle accidents.

3.2.3 The contents of these statistical databases

3.2.3.1 The casuality report and transport statistics

The Department of Transport (DOT) collates information from 43 police forces. Police officers are responsible for the gathering and completion of road accident statistics under the Road Traffic Act 1972. The information is collected by way of a 'Stats 19' data collection form. The 'Stats 19' is a 6 page accident summary form which allows police officers to collect details about road traffic accidents. This is summarised and forms the annual casuality report. The DOT publication does not report factors such as the type of licence held, direction of travel, or offences contributing to the accident.

3.2.3.2 Sussex Police Accident Database

The SPAD contains accident records since 1981 and has details of 1,148,000 incidents. Generally, the database contains incidents where police officers attended and incidents that involved injury, therefore accidents involving motorcyclists may be over-represented (See Chapter 2 for a review of the issues).

3.2.3.3 Fatal Accident Files

Fatal accidents are attended by specialist accident investigation officers from the local police force. 34 accident files were reviewed.

3.2.3.4 Police Vehicle accidents

Sussex Police provided data from 982 police vehicle accidents for the period 1990-1995.
Those involving police motorcycles were divided by the duties undertaken:
- Pursuit - 6
- Emergency call - 7
- General duties - 47

3.3 Methods of data analysis

3.3.1 Strada Analysis by accident cause code

Strada analysis allows a search of the database using specific ‘cause codes’. The cause code constitutes a nation-wide coding system for the primary cause of an accident. Every incident that the police attend and complete a ‘Stats 19’ for is reduced to a single code. By using cause codes specific details of each motorcycle accident are considered. Data reported by Strada analysis reports 3498 motorcycle accidents[1].

3.3.2 Geo-location software search

The initial aim for using this technique was to construct laboratory stimulus material - for example one issue raised in most conspicuity research is the type of background against which the target is appearing (Cole and Jenkins, 1987). This type of analysis allows the plotting of accident on a Ordnance survey map by severity, cause code and map grid reference. This allows all motorcycle accidents where a passenger vehicle collides with a motorcycle at a junction to be plotted with an accuracy of 3 metres.

3.3.3 Method of Detailed Analysis

3.3.3.1 Treatment of data and scope of analysis

Information was gathered from geographic areas in Sussex where limited engineering changes had occurred, completed records were available and where there was the greatest diversity of speed limits and traffic flow. 23 factors were considered, together with a 25 word description of the accident written at the time of the accident.

[1] Serial number 63294 & 62391.

3.3.3.2 The need for re-coding

An initial investigation showed several problems with the database information. The database is not maintained for the convenience of psychological research. The main problem is that if an accident occurs within 25 metres of a junction it is coded by the police as having occurred 'at a junction'. All accident reports were manually recoded to reflect the nature of the accident's causality and the actual manoeuvres by both vehicles involved.

3.4 Results and Discussion

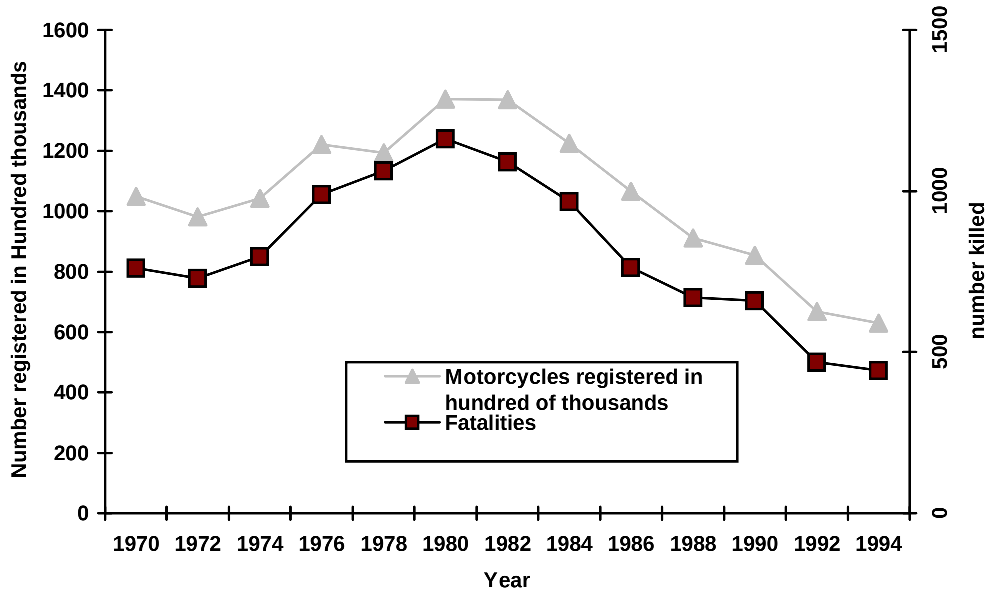
The results and discussion section take the issues raised by previous studies and examine each of them. Different sources of data are used which reflect the level of detail required to investigate the issues, for example, fatal accident files are used to discuss the use of conspicuity enhancers, because they are the only source that contain such data and UK national statistics are used to describe accidents according to junction type.

3.4.1 Do Motorcycle accidents still occur?

Accident rates for motorcycles have steadily decreased. The Accident Fact Sheet 10, (DOT 1996) indicates that the number of motorcyclists killed per year has decreased since 1980. It implies that accidents involving motorcyclists are falling and this may mean that L.B.F.S. error may not be occurring. Road safety organisations claim (e.g. ETSC 1997) that this has occurred since the introduction of CBT and the increased use of conspicuity enhancers. (70% of motorcycles in the UK use conspicuity enhancers, ETSC, 1997).

Figure 3-1 (source Casuality report 1996) shows that while motorcycle accidents have indeed decreased, the comparable number of accidents involving motorcycles has remained fairly constant. Figure 3-1 shows that the decrease in motorcyclist fatalities is paralleled by the decrease in the number of motorcycles legally used on the road. Similar findings have been reported by Peek-Asa and Kraus (1997).

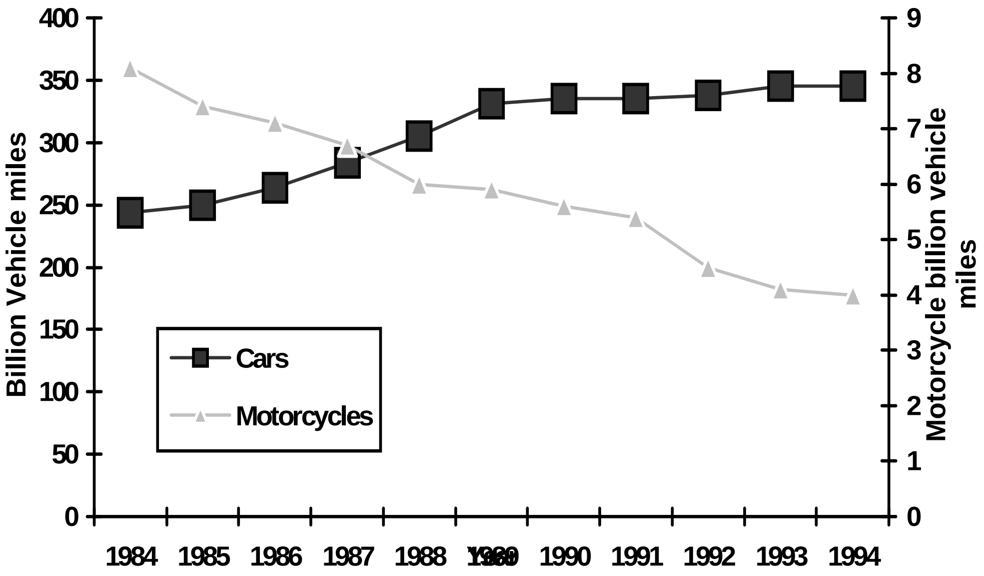
Figure 3-1 Number of motorcycles registered and number of fatal motorcycle accidents



3.4.2 Motorcycles are uncommon in traffic

How often does a motorist see a motorcyclist, and does the exposure rate suggested by Thomson in 1978 still apply? Figure 3-2 (Source Transport Statistics 1996) shows that while cars have become more common on the road, motorcycles are comparatively uncommon. This clearly has an implication for a laboratory study. Firstly, how many targets (motorcycles shown) should be displayed in laboratory experiments? If the laboratory experiment is to be ecologically valid the number of stimuli containing a motorcycle should reflect the actual exposure rate that a motorist would see when driving. Secondly, If the L.B.F.S. error is specifically a problem of expectancy (Cummings, 1974, Smith, 1974, Wulf *et al.* 1989) then the event rate of motorcyclists shown should be very low.

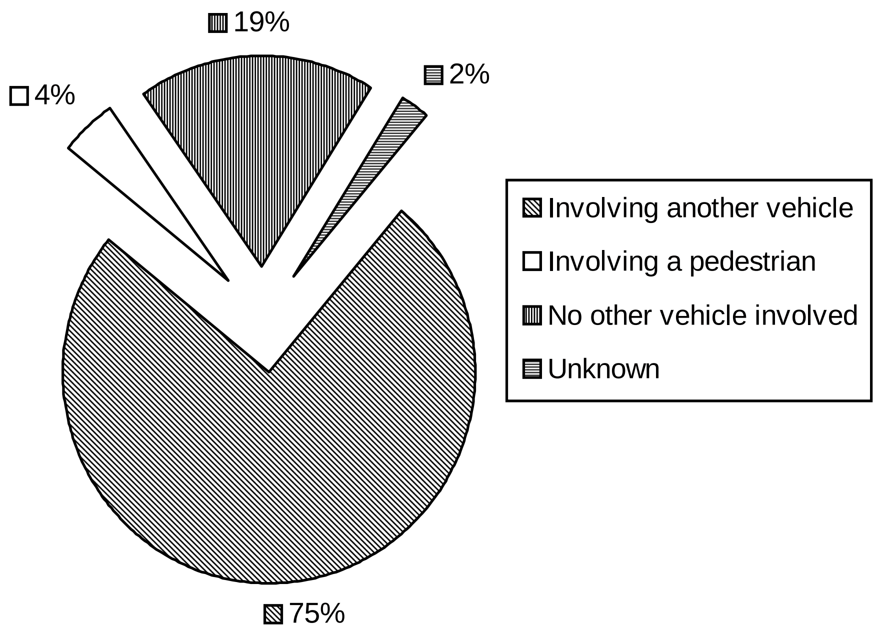
Figure 3-2 Road traffic by type of vehicle and distance travelled



3.4.3 Motorcycle accidents involve another road user

Many studies contain the statement 'motorcycle accidents tend to involve another road user' (e.g. Wulf *et al.* 1989). Is this true?

Figure 3-3 Involvement of other road users in motorcycle accidents involving injury in Sussex



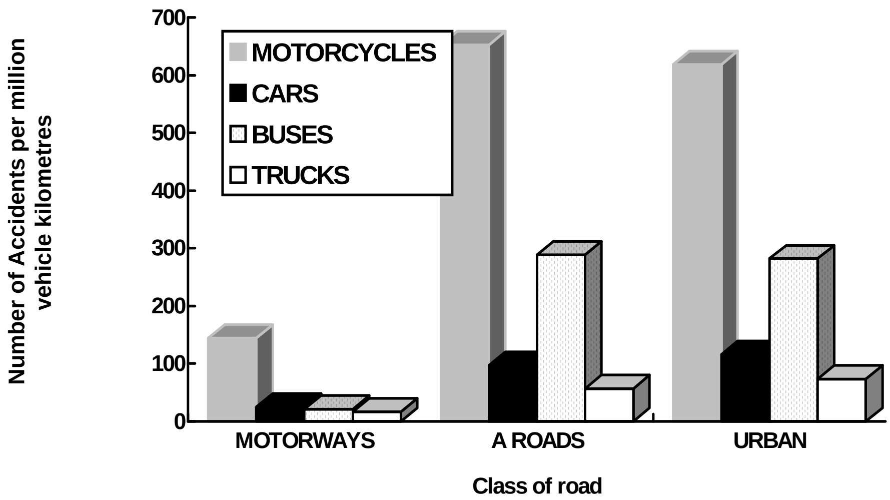
Williams and Hoffman (1977) have claimed that as many as 60% of motorcycle accidents involve another road user, for Sussex, the figure is 75% (Figure 3-3). This confirms Williams and Hoffman's suggestion that the majority of accidents for motorcyclists involve another road user.

3.4.4 Accidents happen at intersections

3.4.4.1 Urban rural or motorways

Figure 3-4 shows the relative frequency of accidents by vehicle type and road classification for distance travelled (Source Casuality Report 1996). Motorcycles have the highest accident rate. Motorcyclists have the greatest risk of an accident as a function of distance covered on all types of road as with other types of road user. Motorcycles appear most at risk on A class roads and in urban areas.

Figure 3-4 Accident involvement rates rate per 100 million vehicle kilometres Source Casuality report



3.4.4.2 Types of intersection

Table 3-1 and Table 3-2 shows the percentage of accidents occurring at different types of junction. For all vehicle types 'T' junctions appear to be the most problematical as they usually require a driver to make some form of visual search before emerging. However, whilst 'T' junctions are a problem for all vehicles it appears that these types of junction are particularly dangerous for motorcyclists. Table 3-2 shows a junction type where motorcyclists are comparatively 'safe'. Motorcycles are maginally less likely to be involved on a roundabout than any other road user. For all vehicle classes roundabouts are less represented in the data compared to 'T' junctions. However, there are more 'T' junctions than roundabouts.

Table 3-1 Percentage of accident involvement by junction type

	Round-about	T	Other junction	Cross Roads	Slip	Private Roads	Not at a junction
Cars	7	39.61	5	18	6	6	18.39
Cycles	9.98	41	3	13.02	0.9	6.1	27
Motorcycles	6.2	44	4	14	0.46	6.13	25.21
Trucks	7	20.87	1	1	2.96	5.1	62.07

Source The Casuality Report. 1996

A slightly different account is found in Sussex, where accident frequency for motorcycles is less at roundabout and slightly higher at 'T' junctions. These differences may reflect the types of junction in Sussex

Table 3-2 Percentage of accidents by vehicle and junction type in Sussex[2]

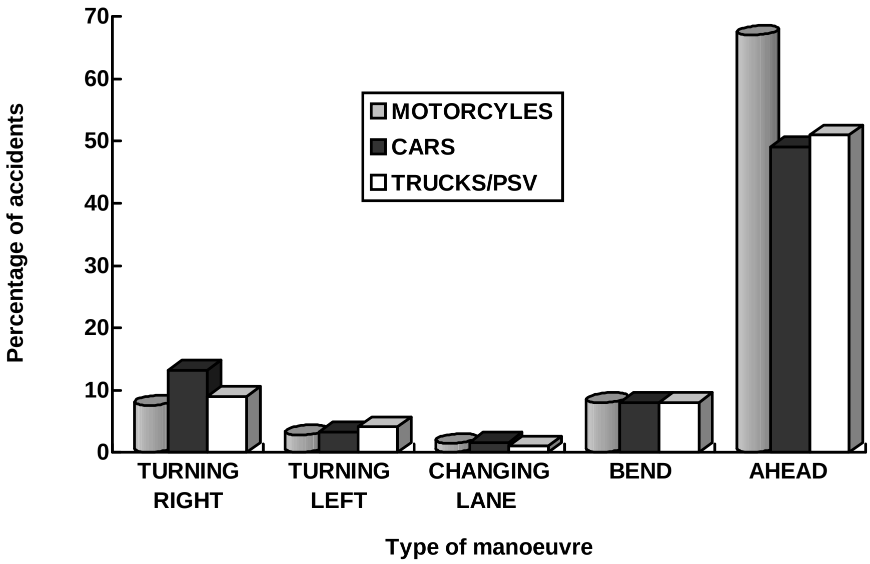
	Round-about	T	Other junction	Cross-roads	Slip	Private Roads	Not at a junction
Cars	8.76	39	2	20	2.1	8	20.14
Cycles	9.92	43	3	9	0.09	5.91	27
Motorcycles	5.56	49.1	4	16	0.02	7.2	18
Trucks	7	22	1	1	2.96	5.1	61

Source SPAD

3.4.4.3 The motorcyclist's right of way is violated

Previous research has shown that a major determinant of motorcycle accidents is the vehicle's manoeuvre (e.g. Hurt 1981, Williams and Hoffman, 1977, Cercarelli, *et al*. 1993). These studies found that 67% of the time the motorcycle is travelling ahead when another road user turns across their path. Figure 3-5 shows a comparison of different vehicle types and the manoeuvre when an accident occurs. Previous studies found similar results with, most often, the motorcycle travelling straight in 87% of the cases (Rieseer, Berger and Vallette, 1974).

Figure 3-5 UK accident causality by vehicle type and manoeuvre(Source Casuality Report 1996).



A detailed examination of 252 motorcycle accidents by cause codes and written description revealed a different story. This analysis was performed after recoding the accidents described above (3.3.3.2).

[2] Although expressed as a % missing values are when the accident occurred at a junction but the junction type was not specified in the accident report.

Table 3-3 A comparison of motorcycle manoeuvres with car manoeuvres for accidents in Sussex

	Motorcycle manoeuvre				
	Going ahead	Turning left	Turning right	Changing lane	Unknown
Car manoeuvre					
Going straight ahead	3 (0.1%)	12* (4%)	4 (0.25)	3 (0.1%)	1 (0.1%)
Turning Left	91 (36%)	16 (6%)	0	2 (0.1%)	0
Turning right	67 (26%)	0	2 (0.15)	***	1 (0.1%)
Changing lane	14 (5.5%)	0	0	34** (14%)	2 (0.1%)
Unknown or other	2 (0.1%)	2 (0.1%)	0	0	3 (0.1%)

* Includes motorcycles losing control at a junction
** Culpability is unclear because both vehicles tend to be changing lane
*** Counted as vehicle going ahead

After detailed analysis, the pattern in the Sussex accident data appear to echo that of the national sample. In Sussex however the left turn accident is the most common.
Cause code analysis (Table 3-3) also allows us to understand if the motorcyclist's right of way is violated.

Table 3-4 Primary cause of accidents by cause code analysis of intersection accidents in Sussex

Cause Codes	38	44	49	41	57	12	43
Type of Vehicle	Driver distracted	Junction entry error	Error of Judgement	Excessive speed	Pedestrian	Animal Impact	Manoeuvre error
All vehicle accidents excluding motorcycles	14.1%	13.3%	12.4%	10%	2%	0.017%	5.5%
Motorcycle accidents	10.3%	18.9%	14%	8%	8%	4%	9%

(Source SPAD)

Table 3-3 and Table 3-4 show motorcycle accidents also involve pedestrians and tend to be the pedestrians' fault. In accidents involving another vehicle, 70% of all accidents involving motorcycles refer to incidents at intersections or failing to take appropriate manoeuvres. A more appropriate comparison would be between cause coded motorcycle accidents and car/car crashes.
Table 3-4 shows accident cause codes for motorcycle accidents involving another road user and cause codes for accidents involving only cars. Differences are found in codes 41, 43 and 44. These codes refer to intersection violations where drivers enter a main road carelessly.

3.4.5 Accidents occur when the vehicle is close to home

The SPAD Strada analysis showed that the majority of motorcycle accidents are within 3 kilometres of the driver's starting point and for 'all vehicle' accidents within 5 kilometres. This finding is similar to the Hurt report, and like the Hurt report a tentative conclusion may be that the incidents that are occurring at intersections, which are close to the driver's home, this may mean the driver probably knows the intersection well. This may reflect the fact that drivers who are familiar with the junction are over-represented but there is a problem of exposure. Accidents will often occur near a driver's home because that is where they are most likely to drive.

3.4.6 The 'Offending' Driver

The Hurt report (1981) suggested that drivers over 55 who collide with a motorcycle may fail to recognise it as a motorised vehicle (See also Olson 1989,

Thomson 1980). German database studies (Allgemeiner \ Deutscher Automobil-club 1987) has shown that motorcyclists who drive cars are less likely to fail to see a motorcyclist when driving a car than a non-motorcyclist driving a car. Is this the case?

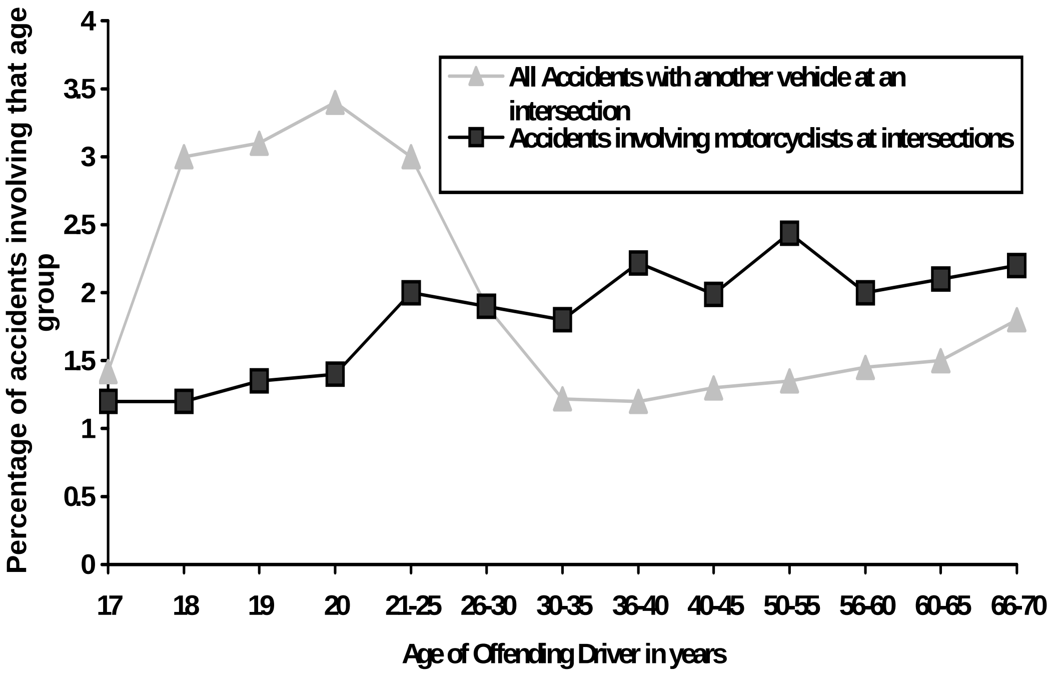
3.4.6.1 Strada analysis of the 'offending driver'

Personal details of the car driver are recorded by the police officer (Age, Gender, Driving licence number). Whilst driving licence numbers are recorded on the 'Stats 19', this does not unfortunately include the type of licence or the number of years that a licence has been held by the driver. To obtain this information each 'Stats 19' would need to be transcribed and requests made to the Driver and Vehicle Licensing Centre (D.V.L.A). Estimates of costing exceeded departmental budgets.

3.4.6.2 Age of the Offending driver

The Hurt report found drivers over 55 are over-represented in the accident data. Evans (1991) found that older drivers are over-represented in left turn accidents at intersections (turning across the path of vehicles in the UK). The casuality report (1996) suggests for all vehicle accidents that high accident rates are found for the 16 - 25 and over 65 age groups. Figure 3-6 was compiled using two separate Strada reports (source SPAD) for accidents by vehicle type. Figure 3-6 indicates that motorcycle accidents where a driver violates the right way at a junction have an unusual offending driver age distribution. This appears to suggest that the car driver under the age of 23 may be able to detect a motorcycle at an intersection as successfully as an older driver whom is possibly more experienced. The data imply that when it comes to motorcycle accidents the lower accident rate that is normally associated with increasing age of the driver may not occur. This may be relevant in the selection of experimental participants - this has not been considered by previous studies (e.g. Hole and Tyrrell 1995).

Figure 3-6 Percentage of all accidents by the age of the offending driver in Sussex for intersection accidents



Similar results have been found by Keskinen, Ota, and Katila (1998) who found by observational study at ‘T’ junctions that middle aged drivers (30 - 60) were more likely to emerge in front of a motorcycle with a smaller safety margins than young or older drivers. Chapter 4 returns to this issue (p 83).

3.4.7 Conspicuity enhancers

For the conspicuity hypothesis it is important to know how conspicuous in an accident a motorcyclist was. This type of information is not recorded by police officers at the accident scene. It is surprising then that claims are made that motorcycle accidents are caused because they are inconspicuous. Olson *et al.* (1979) states that very few data have been collected on the conspicuity of the motorcyclist at the time of an accident.

Details of conspicuity enhancers are however recorded in fatal accidents. Of the files examined (34) only four referred to conspicuity aids (lighting or fluorescent clothing).

The files portray accidents that would generally fit a description of an L.B.F.S. error. Witness statements contained the phrase “the driver did not see him” in 26 of the 34 files. Accidents tend to occur at uncontrolled ‘T’ junctions (32 of the 34). However these accidents tended not to be within urban environments but on either suburban or country roads. Fatal accidents tended to occur within five kilometres of the driver’s starting point (19 of the 34). The offending driver was usually over the age of 25 (31 of 34). The majority of accidents (18 of 34) were however caused by the 60+ age group.

3.4.7.1 Conspicuous Police Motorcycles

Until recently Sussex police motorcycles were a conspicuous lime - yellow (for a review see Solomon 1990)[3] The motorcyclists ride with their lights on in daylight and they wear fluorescent and reflective clothing. Total mileage for each vehicle per year is 4000 miles which represents the average for all motorcycles in the UK (Transport Statistics 1996). The motorcyclist is not young and inexperienced (mean age =26 sd 4 years).

Figure 3-7 Accidents involving Police Motorcyclists on General duties

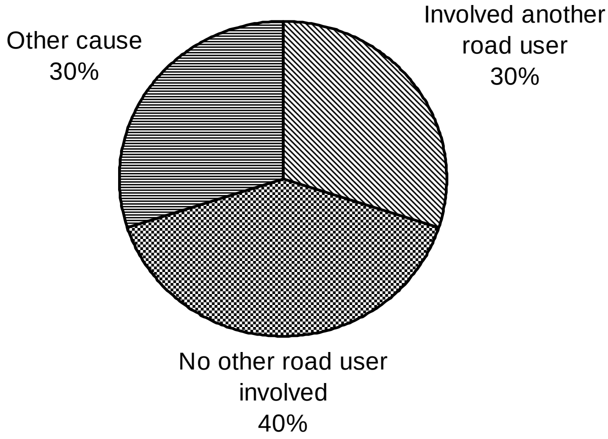


Figure 3-7 shows that the pattern of police motorcycle accidents is very different from the civilian pattern shown earlier. The difference is in the greater number of accidents where the police officer was not involved with another road user. On reviewing the accident description section all but one of the accidents, where no other vehicle was involved and the motorcyclist crashed, was caused by road surface conditions. In all but one case this was due to oil spillage on the road. Road defects (including surface contamination) normally accounts for less than 2 % of civilian motorcycle accident accidents (Hurt *et al.* 1981).

Accidents involving other road users

Police motorcycles were involved in accidents where their right of way was violated. All the accidents where a police motorcyclist is hit and their right of way violated occurred at ‘T‘ or staggered junctions. In these accidents the age of the offending driver tended to be similar to civilian motorcycle accident statistics. Again elderly drivers tended to be over-represented in the sample. Like Hurt’s study the over 55 age group tend to account for these incidents. However with a small sample size it is difficult to make further conclusions.

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[3] The original research documentation for this coloration performed by TRRL no longer exists. A summary account and press release is available only from TRL Leaflet number LF594. I acknowledge the services here of the TRL library

Further investigations show that there may be some report biases in these figures. Accidents involving police traffic officers are investigated by themselves. The 'Stats 19' is completed by the officer who has been involved in the accident unless there is a fatality involved. This appears to give a certain predictability to the accident reports. Accidents where the police motorcyclist is alone tend to be accounted for by claiming there was diesel spillage, and when another vehicle is involved, the other driver 'failed to see' them.

3.4.8 Pre-accident speed and Time to collision

Nagayama *et al.* (1980) and Hurt *et al.* (1981) made certain claims about the accident scenario - the pre-accident speed, angle of approach and the amount of time a motorcyclist has to avoid the collision. The Hurt study suggested the pre-accident speed was around 30 mph and the motorcyclist was less than two seconds away when the driver started their manoeuvre. This will be an important issue if video is used in the laboratory. These details are not recorded in accident summaries Written descriptions mention speed in only 13 of the 252 cases (SPAD). Fatal accident files however give forensic evaluations of impact speed. Here the issue is of the sample used. Fatal accidents where the data is recorded imply a mean impact speed of 50 mph. From photographic evidence in fatal accident files it appears that the driver fails to detect the motorcyclist when it is close to the viewer. Photographic reconstruction evidence suggests that the motorcyclist is impacted with the front of the car, suggesting that when the driver decided to emerge into road the motorcyclist was close to the viewer and within Hurt's claim of two seconds away. This suggest that speed estimation problems do not contribute to the understanding of the L.B.F.S. error.

3.5 Problems with accident statistics - quality, collection methods, biases, and sources

3.5.1.1 Reporting biases

Traffic officers appear to use almost formulaic responses to describe their own accidents especially when another road user is involved. Do police officers attending all accident scenes have a fairly predetermined idea of the accidents causality? Do police officers reporting accidents take the statement of the other driver - "I didn't see him"- at face value? This has caused some scepticism about the quality of information contained in the database as a whole. Problems with police databases are known (for a review see Marvel and Moody 1996). However, these procedures tend to be related to crime statistics rather than accident traffic statistics. More recently a DOT study concluded that there are widespread differences in the level of accuracy in accident statistics (Lapton, Jarrett and Wright 1997).

In all cases therefore the notion that the report is an accurate account of the accident must be questioned because there appears to be a filtering process involved. Missing values in 'Stats 19's are not rectified, also police officers tend to complete 'Stats 19's not at the accident scenes but during group discussion at the end of the shift in the police station. The account of the accident by the officer attending may be distorted by his or her colleagues back at the station. This may be particularly true if the reports are written with other officers. Edwards, (1991,1994) shows by discourse analysis that a reconstruction of events where

groups are involved tends to focus on the believable and prototypical aspects of the event. The report of the event may not have a high level of resemblance to the true chain of events. In short, in cases involving motorcycle accidents, police officers who attended the incident and are subsequently involved in a group discussion may tend towards a formulaic response to account for the incident.

3.5.2 Use of Fatal Accident Files

There appears to be little or no reporting bias in these reports. This may be because the reports are used in court and if a prosecution is started the defence lawyer has access to them. Lapidus *et al.* (1994) concluded in a comparison of differing sources of accident data for motorcycle accident causation that in the USA police reports of fatal accidents were superior in accuracy to those of hospital records and death certificates.

3.5.3 The accident scenario is dependent on the source of data

The above conclusions are based on different sources of data each containing different levels of detail. The issue is not the detail, but the type of accident scenario they each suggest and have for this thesis implications for later experimental manipulations. Reviewing just one source of data, for example, fatal accident reports such as those reviewed by Cercarelli *et al.* (1992) may give us an unusual accident scenario. Table 3-5 illustrates just four issues.

Table 3-5 Sources of accident data and the impression they give of the L.B.F.S. error

Source	Speed of approach	Primary cause	Where they happen	Offending driver
Previous studies e.g. The Hurt report	Under 30 mph	Violation of right of way	Intersection urban environmen t	Car driver Aged over 55
SPAD Summaries	Under 30 mph speeding not cited as a cause	Error of judgement by another road user	Intersection s	Car driver not aged under 25
Detailed analysis of a town centre	Under 20 or stationary	Pedestrian error and driver unfamiliar with their vehicle	Near a junctions	Elderly Pedestrian or visitor from abroad
Police accidents	Not recorded	Violation of the right of way by another road user or road surface failure	Country road with 60 mph speed limits	Not traced
Fatal accidents	Over 50	Violation of riders right of way. Driver changing lane	Dual carriage-ways	Car driver

This is an important issue if database evidence is used as a guide for constructing laboratory stimulus material. Some accident database studies have been very selective about the sources of their data (e.g. Wick, *et al.* 1998). Let's consider how these factors would affect the type of task the subject would perform in a laboratory, for example. Sources from the fatal accident files, where conspicuity is recorded, would imply that laboratory participants would search for a target against uncluttered rural backgrounds. If data were selected from the database as a whole they would suggest that the subject should search urban backgrounds. If

data from the detailed examination of Brighton town centre is used then again urban backgrounds would be used but the subject should be elderly non-drivers.

3.5.4 Snapshot of Social Trends

Accident databases are at best a snapshot of current social trends. Recently the number of accidents where another vehicle is involved has declined. The majority of accidents are now becoming single vehicle accidents attributed to 'born again bikers' (Beucanon 1998).

3.6 General Discussion

Local (Sussex) accident summaries broadly agreed with national summaries and previous research. The evidence suggests the L.B.F.S. error still exists, and that drivers of differing ages may be worth experimental investigation. Certain types of intersection, ‘T’ and ‘Y’ junctions, where the driver knows the junction tend to be over-represented in the data compared to other uncontrolled intersections like roundabouts however there are more T’ junctions than roundabouts‘. Generally the findings are similar to those of the Hurt study except that in the latter, roundabouts are under-represented as a location. The Hurt study would not have found this because in the USA no such intersections exist.

3.6.1 Use of accident statistics as evidence of the L.B.F.S. error

The use of such a database initially appears appealing. Previous studies, e.g. Williams and Hoffman (1977) claim that police files provide direct evidence that conspicuity is a factor in motorcycle accidents. The use of the database however shows that accidents which may appear to be L.B.F.S. errors may in fact have different causes. Even if the data do appear to suggest an L.B.F.S. accident has occurred this may be the interpretation of the facts about the accident by the researcher not necessarily the actual failure of the driver. For a scientific case to be made to say that the driver actually ‘looked’ and did not ‘see’, data are required which are not contained in accident databases. To make a conclusion about the failure in perception due to the target being inconspicuous, details of the target and its background are needed. These details are rarely recorded.

Hurt *et al.*’s (1981) claims about the motorcyclist’s pre-accident speed or viewing distance from the car driver are difficult to interpret. His claim that no peripheral vision problems are found in motorcycle accidents cannot be substantiated. The fatal accident files only give guidelines of speed based on forensic evidence alone. They do not record the driver’s head orientation or the motorcyclist’s position on the road. How then can it be claimed that the driver failed to see?

Although database studies are popular, the problem is not the level of detail that accident statistics can contain but the fact that the information needed is simply not recorded. What is needed by the psychologist is information about the type of conspicuity enhancer fitted - was it in use, at what distance did the motorist truly look and then ‘fail to see’? Fatal accident files may contain ***subjective*** witness statements using the expression that the ‘motorist looked but did not see the motorcyclist’ even when the accident may have been caused by a different failure than that reported.

3.6.1.1 Construction of Laboratory stimulus materials

This study suggests no formula of vehicle position, background complexity, speed of approach, or really anything that a basic conspicuity research paradigm would use (e.g. Engel 1971, 1976, 1977). Let us polarise the results and ask where is a motorcyclist likely or not to have had an accident. The accidents are occurring at intersections with the driver presumably performing some form of visual search. The visual search tends to fail more often in urban environments but not the very centre of the town. An urban cluttered background may be needed. The accident data do show that for the L.B.F.S. error, experience or age are issues. It will be worth investigating the search performance of drivers of differing ages as the database suggests that younger drivers are not over-represented in the sample. Older drivers (over 65) may have a specific problem detecting motorcycles at ‘T’ junctions.

The Hurt report concluded that the motorcycle may be close to the viewer when the driver makes a decision to emerge into traffic. The fatal accident files suggest that the motorcyclist is close to the junction when the driver emerges. Stimulus material in broad terms could include a nearby motorcycle.

A review of the literature (Chapter 1) suggests that explanations of L.B.F.S error in terms of speed mis-perception appear popular. No evidence by either cause codes, written descriptions or fatal accident files was found to suggest that either the motorcyclist was speeding or that the driver failed to appreciate the speed of the motorcyclist was found. The thesis will not consider speed or TTC. as an explanation of the L.B.F.S. error. Whilst acknowledging that they might play a part in some circumstances they are unlikely to be a major factor in its understanding. The close proximity of the motorcyclist to the car when the accident happens would suggest that speed mis-perception is not critical here.

3.7 Conclusion

The use of an accident database only partially helps in understanding the causes of the L.B.F.S. error. Claims from previous studies that indicate direct evidence to support the conspicuity hypothesis may not be valid. Hard evidence for the view that motorcycles are in some way difficult to see is not recorded in the accident statistics. Evidence that motorcycles present a specific problem to car drivers is not a valid conclusion from accident statistics alone. Accident statistics do not support the view that the accident was caused by a conspicuity failure simply because the data are rarely recorded. All accident statistics provides is a basic description of the accident. It is the researcher’s interpretation that because the driver emerges in front of the motorcyclist that firstly, a L.B.F.S. error occurred and that that error was due to a lack of conspicuity. Even if the basic facts of the accident are recorded the quality of the data is questionable.

What can be concluded, is that accidents appear to be a fairly intransigent problem through time. Accidents involving motorcycles tend to be in urban environments and involve another road user. Accidents may have many causes and often involve a string of unfortunate factors. The L.B.F.S. error accident may be over-represented in accident accounts because attending police officers may provide a basic formula to the accident. Accidents involving drivers colliding with motorcyclists tend to occur more often at uncontrolled ‘T’ junctions but are less common at roundabouts. The offending driver is not likely to be particularly young and inexperienced. The data suggests some characteristics that need to be taken

into account when designing laboratory stimulus material. Overall the local police accident database is not a particularly good measure of the L.B.F.S. error.

4. Reaction Time and Time to detect. How long do drivers search at a junction?

4.1 Introduction

How much resource time does a driver allocate for search at an intersection and what does this tell us about the claim that drivers 'look' but then fail to 'see' an approaching motorcycle? A simple and important question which has consequences for laboratory studies but which has received little previous research which has meant that laboratory practices have varied. This observational study aims to measure the amount of resource time that a driver allocates in the real world to searching for hazards at intersections and use these data to guide the construction of laboratory based stimulus materials- an important issue because detection of a target is often dependent on the amount of time spent searching for it.

Accident database evidence suggested that intersections are where motorcyclists are most likely to be involved in an accident (3.4.4). The accident tends to occur near the offending driver's home (within 3 km) and is not necessarily committed by young inexperienced drivers (3.4.6.2). The proximity of the accident to the driver's home may suggest two things. Firstly, that these are the roads the driver will most often use. Secondly, it may indicate that a driver who is familiar with the junction may be led to search in a different way or for less time at an intersection. Therefore, do drivers with a knowledge of a junction search for a lesser amount of time at an intersection because they are familiar with it?

4.1.1 Visual Search

Visual search is a common task both in naturalistic settings and in the laboratory. Outside the laboratory the individual controls the amount of time they spend searching. In the laboratory, search is simplified in several ways; commonly, the subject views a set of distinct objects and is asked to detect the presence of a particular object (the target) among a set of distracters. Search performance decreases as the number of items or set size decreases and as the difference between the distracter and target increases (review in Theeuwes 1993). In the laboratory the amount of time the experimenter allows the subject to search is limited, controlled and measured as a variable (review in Egeth and Yantis 1997).

Laboratory studies investigating comprehension of naturalistic scenes show that a glimpse of 100 milliseconds allows a person to gain a basic understanding of the scene (Biederman 1990). Rensink *et al.* (1997) found that 400 milliseconds are needed to process and understand an image in a scene. Generally, as display time increases, comprehension and detection also increase (Schyns and Oliva 1994). Potter (1976) showed a series of eight pictures with between 133 and 333 millisecond exposures for each picture. At 167 milliseconds participants detected 90% of all targets contained in the pictures. This was if the participants were primed to find a target in a detection task. In a subsequent memory test only 20% of targets could be recalled. This suggests that if participants know what they are looking for, and are only required to signal detection then very short display times are needed. Typically, simple detection tasks are evident in previous motorcycle research where participants provide a simple reaction time after instructions to

search for a motorcycle - however display times in this particular context have never been considered.

In many visual search tasks, reaction time (RT) for target detection is measured as a function of display size. The corresponding error rates are usually low but increase with increasing display size. Missed-target errors (false negatives) are more common than false alarms (Zenger and Fahle 1997). Zenger and Fahle (1997) ask if false negatives are caused as a result of imperfect rather than incomplete search. In recent models of visual search, the error rates are attributed to a premature termination of search. Termination and error rates increasing with display size are interpreted as indicating a speed-accuracy trade-off, (obtained from RT slopes), rather than incomplete search (i.e. it is assumed that there are task-specific probabilities of categorising a target or a distracter incorrectly). Therefore, in the laboratory, a failure by the subject to detect a target is accounted for by either a failure to recognise the target from its distractors (a failure to categorise) or, alternatively, it is caused by an incomplete search, the search being terminated before the subject has examined all possible distractors because of limited display time. Similar accounts of the failure to detect a motorcycle have been hypothesised. In a road environment with many 'distracters' or non targets is there a speed accuracy trade-off with participants not searching the whole environment? (e.g. Wulf *et al.* 1989), or is a false negative response evidence of a problem of categorisation of the target as a moving vehicle (e.g. Olson 1989)? Chapters 6, and 7 return to this issue.

The amount of time a driver searches a junction will depend on whether or not a target is located. Laboratory evidence suggests that a faster RT is found to detect a target than to signal that no target is present (Wolfe 1995). A driver who locates an oncoming vehicle in the real world will possibly observe the junction and continue to track until the vehicle is past. Data therefore would need only to be collected for clear roads with no approaching traffic.

4.1.2 How long do drivers search at a junction?

In the real world the driver approaching a junction will presumably search for the amount of time that training or experience has taught him is sufficient to locate hazards. The amount of time to allow a subject to search only becomes an issue in the laboratory. Engel (1976) stresses the importance of display time as he differentiates between visibility - the ability of a stimulus under a short display time to be detected with knowledge of its location - and conspicuity - the visibility of the target without knowledge of its location. Cole and Hughes (1984) claim that something is said to be conspicuous if the target is detected within a very short amount of time. How long is a short display time when the target's (motorcycle) location is relatively uncertain? Cole and Hughes (1984) recommend that a 100 millisecond display time appears appropriate in driver visual search experiments because this would prevent any eye-movements. However, drivers must do some form of search at a 'T' intersection, because the human field of view is limited, and it is necessary for the driver to move his eyes to sample different parts of the road environment (see also section 6.1 p.111).

4.1.3 Display time from previous motorcycle studies

Much research into the motorcyclist L.B.F.S error has been conducted in the laboratory and typically by slide presentation (e.g. Hole and Tyrrell 1995, Stroud and Kirby 1976). Previous motorcycle conspicuity research has not considered that display time is an issue. Table 4-1 shows typical display times.

Table 4-1 Display time of stimulus material in laboratory studies examining road safety issues.

Name of study	**Display time of stimuli.**
Avant *et al.* (1988)	24 milliseconds but tested 8 milliseconds
Donne and Fulton (1987)	50 - 200 milliseconds - Shuttered glimpses
Hughes and Cole, (1986)	250 milliseconds (exp. 1) 1500 milliseconds (exp. 2)
Williams and Hoffman (1979)	1.125 seconds
Robinson (1975)	4 seconds
Hole and Tyrrell (1995)	5 seconds
Freedman (1982) Laboratory experiment	Unlimited (paired comparison)

If there are no typical display times then perhaps understanding the typical reaction time will help.

4.1.4 Deriving display times from typical reaction times

If choice of an appropriate stimulus display time is not clear cut from previous research then reviewing the typical reaction times for drivers in previous detection tasks may be useful. Most studies that mention 'time to detect' or 'time to react' do so in the context of time to respond to unexpected hazards like brake lights on a vehicle in front, not the time taken to detect a hazard at an intersection (Reviews in Olson 1989b, Olson and Sivak 1986).
The reaction time a subject provides is made up of various individual elements. McGee, Hooper, Hughes and Benson (1983) claim that the perceptual elements of an RT are:

- The eyes moving (0.09)
- Fixation (0.20)
- Recognition (0.40)
- Total 0.69 seconds

What Olson (1989b) highlights is that an RT is a complex combination of time to search and time to react and is not a clear cut issue. An RT of 0.69 seconds is at best arbitrary for the perceptual aspects of a typical driver monitoring the road ahead. Therefore this tells very little about possible laboratory display times.

Early work (e.g. Desilva, 1938) suggested RT was 0.22 seconds for perception of a signal and 0.23 seconds to respond. He claimed however, that it all depends on the attentional state of the driver together with their age and sex. Typical RT to detect brake lights on the vehicle in front is between 0.44 seconds for 20 year olds and 0.52 seconds for 70 year olds (American Automobile Association 1952, also see Salthouse, 1985). However in most studies the driver is seen as a fairly passive perceiver merely monitoring the road environment, not conducting an active search for hazards as a driver does at an intersection.

4.1.4.1 Reaction times in previous motorcycle research

One way to consider display time for laboratory experiments is to review the mean detection time of motorcyclists in slide and video presentations. Previous research has reported typical RT to signal detection of a stimulus of between 600 milliseconds and 1.45 seconds (Hole *et al.* 1995, tables 1 and 2). Williams and Hoffman (1977, 1979) also report typical correct detection time for slide presentations containing a motorcycle of between 0.48 seconds and 1.88 seconds. Langham (1995) using video presentation and a 2 second display time found an a RT of between 0.38 and 1.55 seconds. These figures suggest a typical

display time of about 1 second for a single view of an intersection that a driver would come across. However, in Langham's study, standard deviations were large with a minimum correct response of 230 milliseconds and a maximum of 6.25 seconds.

4.1.5 Intersections and searching

Motorcycle accidents occur at 'T' junctions more often than other junction types (Casuality Report 1996). The question is, do drivers search from the earliest opportunity or do they wait until they arrive at the intersection? This is important in a laboratory simulation. If drivers search at one stage only, at the give-way line, then a simple video presentation is required. Conversely if the driver samples the environment prior to arrival at the intersection then the simulation needs to give a representations of self motion towards the junction and a display time allowing the subject to search several times the junction shown in the laboratory .

A further critique of previous motorcycle methodology is that only a single slide is displayed. The Highway Code (HMSO 1999) suggests that a driver emerging on a main road should make three separate searches, indicating that previous research should have displayed three separate scenes to replicate the activity of a driver. However how many searches is the driver undertaking?

Assuming drivers make three separate searches at intersections (i.e. left-right-left) there are three possibilities which could account for lack of detection of a hazard:
1) failure to pick up on the first search - simple failure to detect
2) failure to pick up on the third search - simple failure to detect
3) failure to notice the difference between the first and the third search - confusion because of number of searches - e.g. failure to appreciate the approaching vehicle's speed by its retinal size in scene 1 and scene 3.

If a driver makes three separate searches at an intersection, in which of the searches does the failure to detect the motorcycle occur? Is it when the driver makes the first search to the left or when they return to that scene to search it again? Failure to notice the changes between the first time they searched the intersection and when they searched it again could account for the L.B.F.S error. Alternatively the driver might have failed to detect the motorcycle on the initial search although it was already present - this is the traditional view.

Searching more than one version of an image or scene was addressed by Rensink *et al.* (1997), who developed a change blindness flicker paradigm to determine why drivers can 'look' but fail to 'see'. The flicker paradigm presents an original and a modified image continually alternating with a brief blank placed between these two. Under these conditions it becomes difficult to detect even large changes in the scenes. They describe this as change blindness and suggest that directed attention is needed to detect changes. The team found that poor visibility is not the problem but that objects which are unimportant are not noticed and vision is based on high level interest. Participants become blind to stimuli that have little interest. If this is the case other evidence suggests that minor changes to the scene (such as a small motorcycle approaching) which should be noticed during a visual search are most likely to be missed (Currie, McCookie, Carlson-Radavanski and Irvin 1995, Simmons 1996). Rensink's paradigm and explanation of the L.B.F.S error is worthy of research if the driver makes three separate searches.

4.1.6 Issues in Methodology

Assessing driver search behaviour is difficult in practice. Three separate attempts were made to obtain such data. These included the mounting of an interior mirror to monitor the driver's head orientation and eye movements; by a video camera mounted at the front of the vehicle to record the driver's reactions. In both cases drivers monitored the camera and the mirror rather than the junction. The next attempt reviewed Land's (1992) eye movement data which recorded driver eye movements in road scenes. However, Land's participants encountered too few intersections for useful data to be derived. The final attempt used a similar method to that used by Summala, Pasaen, Rasanen and Seivannes (1996).

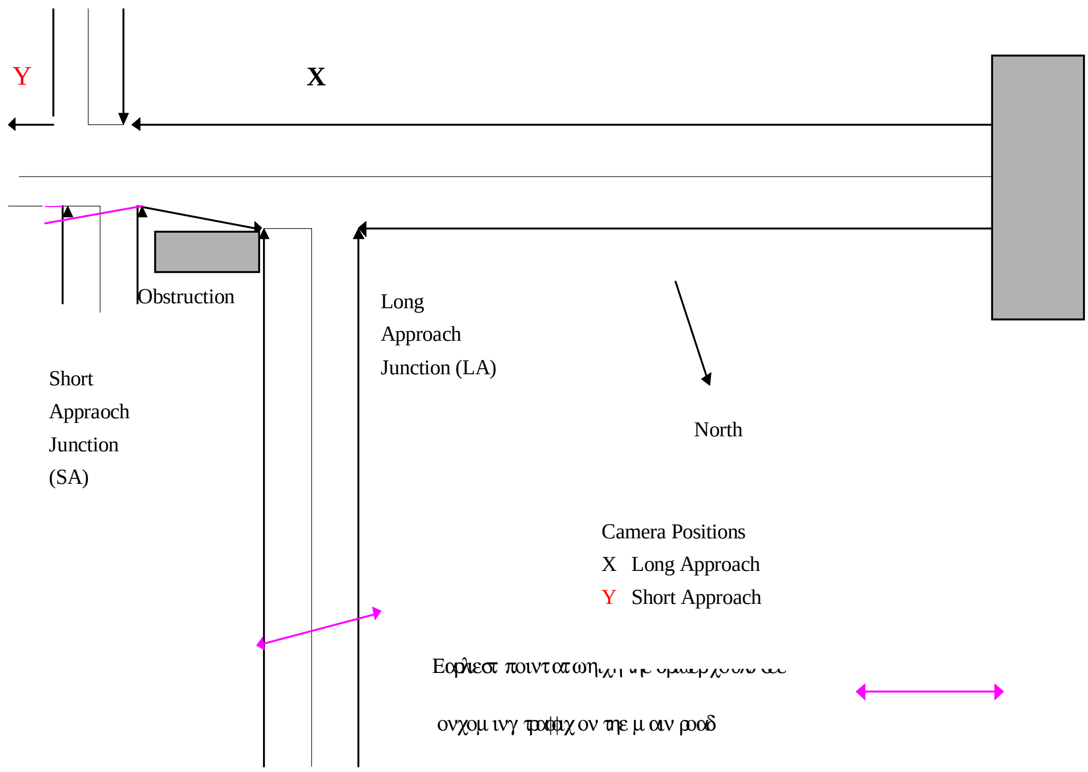
4.2 Method

4.2.1 Procedure

A hidden video camera was mounted at one of two junctions. The video camera (Panasonic SVHS) was fitted with a 12x zoom lens. Two junctions 20 metres apart were selected. They had different visibility properties but a similar background. The short approach junction (SA) had no view of the main road unless the driver's vehicle was on the giveway line. The long approach junction (LA) had an uninterrupted view of the main road for several hundred metres - see Figure 4-1

As it was thought that drivers' search times would be different if there were other vehicles present data were collected only if the main road was clear and the driver had to conduct a search of a clear road. Video recordings were made for one hour periods throughout different days of the week between 0900 hours to 1800 hours from a concealed camera. The video was shot over a period of five weeks during June and July 1996.

Figure 4-1 Plan of the site. Where the observational study took place



4.2.2 Selection of the site

The junctions selected were on the University of Sussex campus. The junctions were similar in nature to those where Chapter 3 suggests motorcycle accidents are likely to occur (Urban environments with 30 mph speed limits). The advantage of using these junctions was that vehicles who regularly used them are labelled. The university issues parking badges to vehicles who regularly use the campus. With such labels (a small badge on the windscreen) differences could be measured between those who regularly use this junction and those who do not. The filming was conducted during the Open University Summer school when students who were unfamiliar with the locations came to the university. Their vehicles did not display the university parking permit.

4.3 Results

4.3.1 Analysis and calibration

4.3.1.1 Analysis

Video tapes were analysed by ‘Vastec’ video analysis equipment. Video tape was displayed on a monitor and a mid-line was generated and superimposed over the video image of the driver approaching the junction. This provided a reference point representing when the driver’s head was pointing straight ahead. Mean search times were derived from a time counter used by the video analysis equipment and not by video frame rate.

4.3.1.2 Calibration

Video tapes from each junction (LA & SA) were analysed to assess the amount of time the driver's head was turned from the mid-line - the number of head movements to the left and right. Search time was defined as the amount of time from when the head of the driver left the mid-line and started to move until when the driver's head started to return to the front.

4.3.2 Inter-rater reliability

Written definition of behaviours was firstly agreed before coding began. 15% of the vehicle movements from both junctions were analysed by a second observer. The second observer independently selected a portion of video tapes for analysis and independently rated the driver's head turning behaviour and whether the vehicle was a university vehicle. Between observer reliability showed 100% agreement on whether or not the vehicle had a University label - Kappa coefficient $k = 1$ $p<0.001$. 98% agreement was found for the number of head turns of the driver - $k = 0.933$ $p < 0.01$, 88% agreement - $k = 0.799$ $p< 0.001$ - for the amount of time the head was orientated away from the midpoint. Accuracy was within one video frame, disagreement was typically one video frame (1/24 second).
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4.3.3 Treatment of data

Data were collected from 382 vehicles approaching both junctions and data were available for analysis from 221 drivers' searches of a clear road.

Data were disregarded if the drivers appeared to spot the video camera (in the opinion of either observer), or if another vehicle was approaching. Data were also ignored if the driver under observation had a second vehicle behind him at a relatively close distance because this may have meant that the driver's search behaviour would be affected.

Data comprised of 90 vehicles who either displayed university parking permit, were university vehicles or were delivery vehicles that had appeared in more than one analysis over the period of study. i.e. those who it was suspected knew the junction. 131 vehicles did not display university identification and were not delivery vehicles.

Number of head orientations.
Drivers looked only once and that was to the right when turning left. Only 27 of drivers of the 221 sample ever looked to the left. Only five of nine drivers of those whose vehicles displayed 'L' plates used the Highway code recommended 'Left - right - left' procedure. Some drivers on the long approach junction appeared not to move their head whatsoever towards the oncoming traffic. Table 4-2 shows the number of head turns at the intersections

Table 4-2 The number of head turns made by drivers at the observed intersections

Type of approach		
	SA	LA

Type of vehicle	Mode	Mean	SD	Mode	Mean	SD
University	1	1.1	0.2	1	1.08	0.04
Visitor	2	13	1.8	1	1.04	0.6

4.3.4 Search Time

Table 4-2 shows the amount of time the driver's head was orientated to the right. Large variations were found in search time. The maximum search time was 6 seconds. The minimum search was either not measurable by the equipment or a search was not made by the driver. However these can be considered as outliers. Drivers appear to turn their head in the direction of the oncoming traffic for a relatively short amount of time.

Table 4-3 The amount of time in seconds looking to the right.

Type of approach								
	SA				LA			
Driver	Mean	SD	Min	Max.	Mean	SD	Min	Max.
University	0.4	0.2	*	2	0.39	0.012	0.83	0.778
Visitor	0.44	0.08	0.4	1 5	0.36	0.03	*	6

*** indicates when drivers did not look.**

4.3.5 Distance from the junction at which drivers looked and searched for hazards

The LA junction approach road was divided into four distance zones using the white warning markers leading to the 'Give Way' line (The SA junction having only limited visibility). These were under 5 metres away, 5-10, 10-15 and over 15 metres away. Within-observer reliability for analysis suggests a good reliability (k = 0.944 p<0.001).

Table 4-4 Percentage of drivers who began searching at given distances from the junction

	Type of road user	
Distance from 'Give Way' in metres	University	Visitor
under 5	85%	94%
5-10	6%	5%
10-15	2%	0
over 15	3%	0

Table 4-4 shows that in the LA junction drivers appeared to wait until they were actually at the junction before they started to search. The benefit of an opportunity of early search of the main road afforded by the long approach junction appeared not to be used by drivers.

4.3.6 Age of the driver

Chapter 3 (p.65) shows an unusual age distribution of the offending driver in respect of motorcycle intersection accidents. The video was reviewed to assess if younger drivers searched for longer than older drivers. It was difficult to classify age exactly and it was difficult to assign age groups that both observers could agree. The majority of drivers were about 25 years of age.

4.4 Discussion

Drivers appear to search for a very limited amount of time at an intersection. Despite the potential risks of an incomplete visual search and a failure to detect a vehicle at a junction, the drivers observed spent less than 0.5 seconds searching for hazards. Drivers tend to search in one direction only. Drivers' behaviour is relatively constant across visibility conditions (i.e. SA and LA) and familiarity with the junction. Mean search times found imply that drivers may be conducting a rapid search of their environment and may not be attending to every detail.

Unlike Summala *et al.* (1996) only one camera was used. A pilot study found that using two cameras and following Summala's procedure of "mixing the resultant image" (Summala p149) was impractical. Summala claims that the images were later mixed and considered 'side by side'. This was not possible with the film studio equipment available. It was found that in displaying two images side by side on a single screen the resultant image compression in the vertical plane was considerable, distorting the image and making data analysis almost impossible. The video analysis system meant that the video had to be represented on a single screen.

The results, however, were broadly in line with the Summala *et al.* study. Drivers appeared to search to the right when turning left and ignore traffic coming from the other direction. Drivers also appeared not to search more than once to the right. Summala *et al.*'s study was at an accident 'blackspot' and they found that drivers' search was remarkably limited. In general they concluded that drivers' scanning behaviour:

"is in line with the general notion that, with experience drivers learn what is important in the traffic environment .... Thus drivers learn to scan the relevant characteristics at intersections to avoid motor vehicles but at the same time they may develop a scanning strategy which masks visual information about less frequent and less imminent danger such as cyclists coming from the right."(Summala *et al.* 1996 p152)

Has experience appeared to have taught the majority of drivers that at an intersection a glimpse to the right is enough? The statement 'I did not see it' may mean that the driver was simply not conducting a thorough enough search. Summala *et al.* comment that this may be the case with drivers who fail to detect cyclists. Summala *et al.* however consider only the direction of search and not the amount of time spent searching.

It was surprising that drivers irrespective of the apparent visibility of the junction either SA or LA, spent a similar amount of time looking to the right. The results from the junction observation also suggest that whether the driver was familiar with it or not they spent the same amount of time searching. However similar results of drivers only looking one way when joining traffic were also found by Berlinson, Kulmala and Leden (1992). They found that at some junctions only 21% of the drivers searched both ways.

4.4.1 Stimulus display in the laboratory

Tachistoscpically presented slides used in previous conspicuity research are possibly fairly realistic in terms of the display time used (e.g. Donne and Fulton

1987). It is not known whether the driver does the visual search/detection in the first 0.5 seconds and the cognitive processing and motor control in the rest of the time as the vehicle crosses the Give-Way line. Thus in the laboratory the driver may need a very short display time followed by a period of time while a decision is being made.

The results imply that for a laboratory investigation of driver search it is sufficient to show a single video clip or slide for only 12 video frames (half a second) firstly, for practicality[4], and secondly to reflect the driver's single search to the right when turning left. Moreover the junction needs to be only displayed for the right side view, provided the participant is requested to imagine they are turning left. Showing one view appears to be the only presentation style in previous laboratory studies (e.g. Hole and Tyrrell 1995) and there is possibly good justification for this.

The counter view of displaying three separate images - a view to the right, to the left, and then to the right would not represent the normal practice of a driver at an intersection. Therefore Rensink *et al.* (1997) view that the L.B.F.S error can be understood by his 'flicker paradigm' can not be justified as in practice the driver is usually looking in one direction whilst deciding whether or not to emerge from a junction.

Evidence to support the idea that accidents occur near a driver's home, implying that the driver was familiar with the junction, was not found. Previous studies suggesting that poor visibility may cause motorcycle accidents may be valid because irrespective of the visibility of the junction, drivers search for the same amount of time.

4.4.2 Rapid visual search - attention for objects or spatial locations

If drivers are searching intersections for a short amount of time this suggests that it is critical to know where they look and what they are looking for. What has experience taught drivers in terms of the allocation of the cognitive resources? Does the experienced driver search in different places in the road environment or for different categories of object compared to novice drivers? The fact that the junction type has little effect on search time implies that drivers who are familiar with the junction give a similar performance to those who are unfamiliar with the junction. Does this mean that we develop certain short hand codes about how to deal with all 'T' junctions as hypothesised by Hole and Tyrrell (1995)?

The 0.5 second search time may be an indication the drivers use their limited cognitive resources to search in either limited parts of the road environment or search only for certain categories of objects for identification. The fact that mean search time was under 0.5 seconds implies that the driver is only looking in limited parts of the road and may not be individually assessing each of its constituent parts. During a short search time how much detail is the driver extracting? Is the

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[4] An attempt was made to use two video screens placed next to each other showing the different views of an intersection to the left and to the right. The study was piloted to asses if Rensink *et al.* (1997) views about the L.B.F.S error could be applied to motorcycle accidents. Although it was possible to synchronise the video players displaying the images participants could not perform the task. Typically participants complained that either the screens were either two close together or too far apart.

driver reviewing every detail of the scene? Or is the driver looking for a description of what might be a hazard? In such a short viewing time what do previous psychological models of rapid scene comprehension tell us about what the drivers may be looking for? Do theories of rapid naturalistic scene interpretation (as proposed by researchers interested in how we recognise objects and models of object recognition) mean that the drivers at junctions are looking for either simple volumetric shape primitives or perhaps merely for objects defined in terms of their low spatial frequencies?

The literature review indicated that problems with object recognition and visual search may be an alternative explanation to the conspicuity hypothesis for the L.B.F.S error and worthy of investigation. Whether accounts of failing to see are explained in terms of a failure to allocate attention to locations or by problems of object recognition theories must attempt to understand scene interpretation and visual search in the context of a glimpse. Theories must also account for successful scene interpretation despite the uniqueness of each scene that a driver views.

Because visual search is so rapid are drivers learning to scan for more frequent classes of vehicle because of limited time spent searching? As ‘T’ junctions are sufficiently constant environments, do drivers develop efficient visual scanning strategies (Moray 1990) for the most common vehicle? Because these environments are so constant, drivers may know where to look and what is important in the traffic environment as they gain experience (Fuller 1984, Theeuwes and Hagenzeker 1993).

4.4.3 Problems

During video analysis observers could not agree the age of the driver at the intersection. A major improvement would be to follow the example of Sabey *et al.*(1977). After the driver had passed the junction the driver could have been stopped and questioned about his driving experience and age.

4.4.3.1 Generalisation

The major problem of this study is generalisation of these results to other junctions. This is complicated because of the many variables that may be interacting in the field. When many variables are considered together it is often difficult to generalise the results to different locations, lighting levels; times of day; subject variables and accident scenarios (Edworthy and Adams 1996). A major weakness of the study must be that the two junctions used, although with similar backgrounds, cannot be considered typical of all ‘T’ junctions. The problem of finding junctions where a camera can be hidden away from the road is particularly difficult. The advantages of using these two locations meant that because the junction was on campus it could be ascertained if the driver was familiar with the junction. It must be stressed that there were only two junctions which means that these results should be only tentatively be generalised to all ‘T’ junctions.

4.4.4 Improvements

The experiment was fairly limited. Several improvements can be suggested.

What if the driver was going to turn right?

A driver turning right at an intersection crossing both lanes appears to be over-represented in accident data in the UK. This would imply that the driver should have searched in more than one direction. Future research should turn to this issue but it was not investigated on this occasion because:

1. The types of scene the driver searches in laboratory study are usually just the view of the road to the right in a single scene. There is a good justification for this. If participants are asked to search different scenes which represent different views of the junction we do not know in which scene they detected or failed to detect the target vehicle. Moreover the failure may be because of the demand characteristics of the experiment.
2. Data from Fatal accident files suggest that although the emergence from a junction across both lanes of traffic is the most common form of accident in Sussex those involving a fatality are for left turn accidents only.

Although the video analysis was conducted independently it was not always clear when a driver began and finished searching. High inter-rater reliability was found in part because of a good definition of the behaviour and also because the second observer was highly practised in observation studies (See Martin and Bateson 1993). Measuring head movement does not necessarily measure the subject's gaze. This may mean that drivers are actually searching longer than was recorded. However Land (1992) concludes that eye-movements tend to be complemented by head movements. I shall return to these issues in Chapter 6.

4.5 Conclusion

There is some justification for using a single presentation of a video clip view of the road to the driver's right in laboratory studies. Little difference is found in drivers' search time according to junction type. The experimental design can be improved and more locations need to be studied. Many of the issues raised here are discussed in Chapter 8. An explanation of the L.B.F.S error suggested by Rensink *et al.*'s (1997) 'flicker paradigm' is therefore not to be investigated within this thesis.

5. Experimental design - instructions to participants. Expectancy and visual search.

5.1 Introduction

Chapter 2 (p 47) provides a critique of previous L.B.F.S. research methodology. This chapter focuses on two of those criticisms, in particular: the experimental design itself, and the specific search instructions given to participants. The critique is contextualised by research on visual search from laboratory based and applied studies. This examines whether guiding participants by instructions to search for a motorcycle will affect detection performance. This is an important issue because one explanation of the L.B.F.S. error is that the driver was 'looking' but not 'expecting to see' a motorcycle (Wulf *et al*. 1989). A comparison is made between participants who are asked to search specifically for a motorcycle and those who are asked to search for any potential hazard.

5.1.1 Theories of Search, based on Laboratory Research.

An important component of routine visual behaviour is the ability to find one item in a distracting world. This ability to perform visual search has been the subject of a large body of research in the past 15 years (Wolfe 1994) and post-dates the majority of motorcycle safety research. In a typical visual search experiment, observers look through a set of items for a designated target that may or may not be present. Most search experiments have a small number of participants performing a few hundred trials each, with RTs being measured as a function of the number of items in the display (set size), and inferences made about the underlying search processes are based on the slopes of the resulting RTs and set size functions (Wolfe *et al*. 1998).

What does laboratory research tell us about visual search failure in the real world? Rabbitt *et al*. (1989) claims this is very little. Many discussions of visual selective attention have been unhelpful because, claims Rabbitt, they have implied that people passively take in visual information to recognise any objects that may just happen to be there. Visual search is rather an active interpretation of the visual world during which people systematically direct their gaze to extract information relevant to their current task. They decide where to look first and in what sequence to seek for further information. People also actively look for some things rather than others. There is an active control of 'where' to look and control of 'what' to look for (Rabbitt 1989). The question considered here is 'what' are drivers looking for and 'where' and 'how' might this be affected by asking them to search just for motorcycles. However, a further distinction is needed to apply some of these laboratory conclusions of visual attention to the motorcycle detection failure.

A further distinction in selective attention mechanisms is made by those theorists who postulate that attention is directed to regions of space (Review in Watt 1992) or to preattentively defined perceptual objects (Egeth and Yantis 1997). Luck and Ford (1998) argue that it is necessary to differentiate between attentional mechanisms that influence the identification of a stimulus or target from non-targets and, having acknowledged its presence, recognise it for what it is. Neisser

(1967), Treisman (1986) and others distinguish between a pre-attentive, massively parallel stage that processes information about basic visual features (colour, motion, depth cues, etc.) across large portions of the visual field and a subsequent limited-capacity stage that performs other, more complex operations, such as identification of objects (Luck and Ford 1998). The L.B.F.S. error can be accounted for at many of these stages or by any of these theoretical perspectives.

If visual attention refers to the process of selecting a portion of the available sensory information for object identification and localisation, just what is selected in any given instance depends on two major factors: firstly, the properties of the scene and secondly, the expectations, beliefs, and goals of the observer. But Yantis (1996) says that in naturalistic scenes the two key questions are whether attention can ever be captured in a completely stimulus-driven fashion, or in a completely goal-driven fashion. Yantis claims that significant theoretical disagreement surrounds these and related questions and describes three 'degrees of attentional capture'. Yantis describes the first type of attentional capture as 'strongly involuntary' and it occurs when a perceptual event draws attention even when the observer is actively attempting to ignore it. An example would include abrupt visual onsets - a stimulus suddenly appearing in the visual field (e.g. Tichener 1908, Yantis and Hillstroom 1994). The second type 'weakly involuntary" attentional capture, occurs when an irrelevant attribute draws attention so long as the observer is not actively attempting to ignore it. The third category arises when observers adopt a deliberate state of attentional readiness for a basic feature that is known to define the target of search 'attentional readiness'. These important issues have not been considered by previous motorcycle research.

5.1.2 Search for motorcycles

Chapter 2 highlighted that motorcycle crash research has attempted to manipulate subjects' visual search in two ways. In terms of Yantis's (1996) view the experimenters have firstly only considered the properties of the stimulus, or relative conspicuity enhancers to capture attention without considering the goals and beliefs of the observer. Secondly they have guided their participants by cueing the spatial location by either having the motorcycle presented in slides in the same place each time or the target motorcycle being presented after a cue to its location (e.g. Williams and Hoffman 1977). Cue to location has been shown to be a powerful aid to detection and improves the ability to detect an object in a laboratory especially in discrimination tasks (Review in Graham 1985, 1989).

Previous research has attempted to measure attention in three ways in terms of Yantis's 'attentional capture'. By assessing conspicuity enhancers alone research has focused only on how the involuntary shift of attention would be driven by the stimulus. Guiding the subject to search for a basic target alters the 'goals and beliefs' of the observer away from how they might be encountered in the real world. Previous research therefore has not permitted the attentional capture properties of the target alone to elicit a fixation.

5.1.3 Cues to location by instructions to participants

In simple reaction time experiments (e.g. Posner *et al.* 1980), results from laboratory experiments suggest that cueing a location can speed up detection of a target and are thought to indicate that processing capacity is allocated to positions in space (Pashler 1998). Folk, Remington, and Johnston (1993) propose that

involuntary shifts of spatial attention, even those elicited by abrupt visual onsets, are contingent on variable internal control settings. They argue that the choice of ‘where’ to look, is dependent on where the subject believes the target is going to appear. Drivers know that motorcycles will generally appear on the road but may appear in a different place to that of a car and this may be particularly important here (Olson 1989).

In visual search experiments, observers search for a target among distracting items. The location of the target is generally random within the display as in motorcycle research (e.g. Williams and Hoffman. 1979). Previous research has shown that targets presented near fixation are found more efficiently than are targets presented at more peripheral locations (Review in Wolfe, O’Neill and Bennett 1998). Wolfe *et al.*(1998) however, also suggest that the primary cause of this ‘eccentricity effect’ (Carrasco, Mclean, Katz, and Frieder, 1998) is an attentional bias that allocates attention preferentially to central items.[5] However Moray (1978) claims that attention is not located to the centre of a scene and discusses how visual search strategies are developed after very little training. Visual search strategies are subtly developed to optimise the detection of targets which appear at the most frequent locations. If drivers develop an optimal searching strategy for dealing with junctions does the experimenter by asking the subject to search for a specific type of vehicle in an experimental setting, change this optimal search strategy?

Guiding participants to look in certain locations may not be important in all safety research but the 'where' and 'what' may be particularly important in accidents involving vulnerable vehicles such as motorcyclists (Olson 1989). Both Olson and Summala *et al.* (1996) comment that motorcyclists’ behaviour may mean that they appear in different places in the road environment compared with private motor cars. Specifically, location may be particularly important in motorcycle accidents as because motorcycles are more manoeuvrable than cars, their location within the road environment can vary greatly (Olson 1989).

5.1.4 Cues for the ‘what’ to look for

Theeuwes (1993) argues that there is a general consensus that visual scenes are encoded along a set of primitive feature dimensions such as orientation of edges, spatial frequencies, colour and brightness and that basic features are only combined into complex objects at later stages of processing. If the visual scene is first recognised along a framework of basic features, asking a subject to expect one particular vehicle class may have an effect. Knowing the type of vehicle to expect at an intersection is thought to affect accident potential (Theeuwes 1996). Blomberg, Hale and Preusser (1986) show that when evaluating bicycle and pedestrians’ conspicuity enhancers two separate measures are actually found: firstly the ability to detect the conspicuity enhancers and secondly the ability to identify what the target is (a theme returned to below). Findings indicate that significantly different detection and recognition distances were found according to the type of measurement used. This may be particularly important for the motorcycle accident because Olson (1989) and Wulf *et al.* (1989) both described the motorcycle L.B.F.S. accident as a failure of attention. If attention is for pre-attentively pre-defined objects than the subject will search for different shapes in

[5] They showed that the eccentricity effect cannot be accounted for by the peripheral reduction in visual sensitivity, peripheral crowding, or cortical magnification

the road environment (motorcycles present a vertical rather than the horizontal profile of a car). Therefore using the instruction to search for a motorcycle will affect 'what' participants are expecting to see.

5.1.5 Conceptions of Visual Search in Applied Research

What difference does it make to ask a subject to search for a vehicle rather than the usual laboratory based 'where is the motorcycle' question? Thomson (1980) suggests that when requiring participants to 'search for a motorcycle' all that is being measured is the relative merits of different conspicuity enhancers.

5.1.5.1 The role of conspicuity

Chapter 1 discussed Cole and Hughes's (1984,1986) definitions of search and attention conspicuity. They based their definitions on the examination of the effects of instruction given to participants and their success in detecting targets of different levels of conspicuity. 'Search conspicuity' was described as an object's ability to be readily located by visual search, and 'attention conspicuity' is the propensity of an unexpected object to attract attention. These definitions affect what is measured in the laboratory. If attention conspicuity is measured then the subjects' attention must be elicited without them having precise knowledge of the target for which they are looking. If search conspicuity is measured participants know what they are looking for and report its presence (Edworthy and Adams 1996). Previous research has, by asking participants to search specifically for a motorcycle, *measured* one type of conspicuity but *reported* the effectiveness of the other. Cole and Hughes (1984) also concluded that the detection of objects in the periphery is most benefited by the instruction to search for that particular category of object. It was found that both types of conspicuity was not strongly dependent on either object reflectance or size. An important determinant was the angle at which the object was displaced away from the line of sight.

5.1.6 Expectancy

Asking participants to search in one part of the visual field over another or to search for basic features, can affect what the subject is expecting to see. Evidence suggests that expectancy plays a major part in perception and successful detection (reviews in Hartley 1992, Kinchla, 1992). How does this relate to 'junction expectancy' on the part of a driver? To what extent does a ' T' junction cue the expected places at which other vehicles can appear, or the type of vehicle that is approaching? Is it the positioning of a target, its basic shape or colour which is the most important aspect for detection success, or a combination of all three? In contemporary theorising, there is a controversy about the role of spatial location in the selection of visual information; some theories postulate that position plays a unique role, whereas other theories hold that position is just one selection dimension that is not different from other dimensions, such as colour and shape (review in Humphreys 1992).

Does asking participants to expect to see one vehicle class or target affect the way in which they search the road environment or their subsequent detection success? If so asking participants to search for one vehicle class, a motorcycle, may affect the way they search in a laboratory. Hills (1980) and Olsen (1981) claim that driver expectancy is important in the detection of hazards. Groeger and Chapman (1996) suggest that the growth of driving expertise is frequently accompanied by an increase in expectancy and anticipatory behaviour and

attributed some accidents to driver expectancy. Rumar (1990) discusses the error of failing to see another road user as caused by a lapse of cognitive expectation, illustrated by the failure to scan for a particular class of road user, or to look in the appropriate direction. Importantly van Elslande and Faucher-Alberton (1997) claim that one cause of the L.B.F.S. error is when expectancies become, in the driver's opinion, certainties, although citing limited evidence, they claim that this is specifically a problem with experienced operators. For motorcycle L.B.F.S. accidents Chapter 3 reported that in contrast to other types of accidents experience does not seem to lead to a reduction in accident frequency. Does asking drivers to search specifically for a motorcycle affect their expectations and might this be the specific cause of the L.B.F.S. error? Shinar (1985) investigated drivers' judgement of night-time pedestrian visibility under various combinations of driver expectancy (to see a pedestrian on the road or not), and pedestrian conspicuity (wearing dark clothing, light clothing, or dark clothing with retro-reflective tags). The results indicated that visibility distance increased with expectancy, but the magnitude of the effect varied as a function of whether or not the pedestrian was wearing conspicuous clothes. Shinar (1985) claimed his findings demonstrate the relative importance of psychological variables such as expectancy on the subsequent detection of a target. Although expectancy is acknowledged to play a part in vehicle accidents this has not been suggested as a cause of the L.B.F.S. motorcycle accident

This chapter will focus on the deployment of visual attention based on the 'goals and beliefs' of the driver, because the bulk of previous research has focused on the properties of the stimulus alone to capture the driver's attention. Do L.B.F.S. motorcycle accidents involve a failure to deploy attention to a location (an interpretation favoured by Olson 1989 and Rumar 1990) or are they due to a failure in later attentional processes of recognition - an interpretation favoured by Theeuwes (1996)? This chapter examines the latter view and attempts to uncover what 'cognitive expectations' a driver has and how they are related to a particular class of road user - the motorcyclist.

5.1.7 Issues in Design.

Chapter 2 discussed if repeated measures or mixed designs (where the repeated measure was the display of a motorcycle as the stimulus material) were appropriate. If motorcycle accidents are caused in part because the driver is not expecting to see a motorcycle at an intersection, and previous laboratory motorcycle research has either not considered this important or deliberately affected the drivers' expectancies to see a motorcycle, does the experimental design compound the problem? If we accept that expectancy affects the success of detecting a stimulus, the previous designs have affected the subject's expectations by the inappropriate exposure rate of motorcycles shown in the series of film slides. The driver may after seeing the first motorcycle have adopted a strategy, or a set of expectations to search for the conspicuity enhancer alone - a point later confirmed by Hole, Tyrrell and Langham (1996). Using a repeated measures design may encourage the subject to deliberately adopt a different way of searching for a motorcyclist based on the conspicuity enhancer e.g. lights.

5.1.8 Implementation

This chapter therefore reports on two laboratory experiments: Experiment 1 reports on subjects' abilities to detect motorcycles in a mixed design where the repeated measures are the exposure of participants to motorcycles presented at different distances and the use or not of a conspicuity enhancer. The experiment

contrasts the effects of asking a subject to search specifically for a motorcycle with that of searching for any hazard. Experiment 2 again contrasts the effectiveness of conspicuity enhancers on successful detection at varying distances from the view with instructions to specifically search for a motorcycle or to search for any hazard. However Experiment 2 uses an independent measures design.

5.2 Experiment 1 - Repeated Measures

5.2.1 Method

5.2.1.1 Design

This experiment used a mixed design. Within participants variables were the simulated viewing distance (two levels - over and under 50 metres) and the presence or absence of a conspicuity enhancer (lights on or off) fitted to the motorcycle. The between participants variable was the type of instruction set given (‘specific search’ or ‘general search’)

5.2.1.2 Participants

Participants were recruited by advertisement and comprised 89 undergraduates who drove or were learning to drive. Average (modal) driving experience was 3 years. Mean age was 22 and the age range was 18 - 48 years although the majority of participants were in the 17 - 24 age range. 68% of the sample were female. All participants met current UK eyesight standards for driving.

5.2.1.3 Stimulus materials

The stimulus materials were 23 video clips of half a second duration, separated by gaps of 10 seconds. A pilot study showed that an abrupt onset of the video clip provided very high error rates. In the real world a driver is aware of the approach of a junction, so to avoid an abrupt onset a film time counter was placed before each video clip. The time counter started at 3 seconds and counted down one second at a time to the start of the video clip. The numbers were white on a black background. The BBC micro computer timer was started using a pulse on the video shown to the participants. These timer marks were accurate to one video frame.

The video was shot on grey overcast days in the summer to avoid excessive shadows in the scene. The video clips contained either no traffic, a motorcycle alone, or other traffic, either cars, buses or trucks. Video presentation simulated the driver’s view at a ‘T’ junction of a single view of the road to the right in urban environments. Motorcycles appeared in four of the 23 clips. Motorcycles, like all road traffic, appeared in different parts of the scene. Motorcycles were either lit or unlit and could appear close to or far from the viewing position. All other traffic could appear at any distance. No conspicuity aid was fitted to the other traffic. There were two different orders of video clip presentation. Half the participants saw one order, and the rest saw the reverse order.

5.2.1.4 Apparatus

Video images of vehicles approaching a junction were obtained by a professional film crew using near-broadcast quality U-matic video cameras and edit facilities. The images were taken from the perspective of a driver emerging into the main road. Video clips were displayed (Video clips were first generation from the original) on an SVHS 100 MHz National Panasonic 25 inch video display. Participants were seated 0.75 metres away so the resultant image was approximately 75% of the size of the actual image in the real world. This was a compromise, between image quality and subjects' comfort. Video tapes were played using a National Panasonic SVHS 4 head video player. A BBC micro computer
(model B) was used to record subjects' responses and reaction times. Participants indicated if they believed a video clip did or did not contain a vehicle by way of a two way button box.

5.2.1.5 Instructions

For participants in Condition 1 ('Search for a motorcycle'), the instructions were as follows:

"Please now watch this short video of traffic at a junction. Please imagine you are in your car waiting to turn left. Please press the yes (green) button on the box as quickly as possible if you see a motorcycle coming towards you. Press the no (red) button is the road is clear or there are vehicles going away from you. There are 23 clips. Each last for half a second and clips are separated by a ten second gap."

For participants in Condition 2 ('Search for a vehicle') the instructions were the same except the word 'vehicle' was used in place of 'motorcycle'.

5.2.1.6 Procedure

Participants were recruited by one of two campus advertisements displayed on different weeks. Different adverts were used that matched the instruction set given to participants. Participants were given the instruction sheet and this was also read to them. Participants provided details of age and driving experience and were seated in front of the video screen in a darkened room 0.75 metres away from the video screen. Participants were provided with a two button box and used one button to signal if they believed the clip contained a vehicle and the other button if they believed the clip contained no vehicle. The experiment lasted for less than 5 minutes. Participants were then debriefed.

5.2.2 Results

Participants provided 23 responses as to whether or not the clip contained a motorcycle and a reaction time for this decision. Data were discarded from participants who were not able to perform the task. (Some participants only ever pushed one of the buttons or appeared not to understand the instructions.)

5.2.2.1 Errors

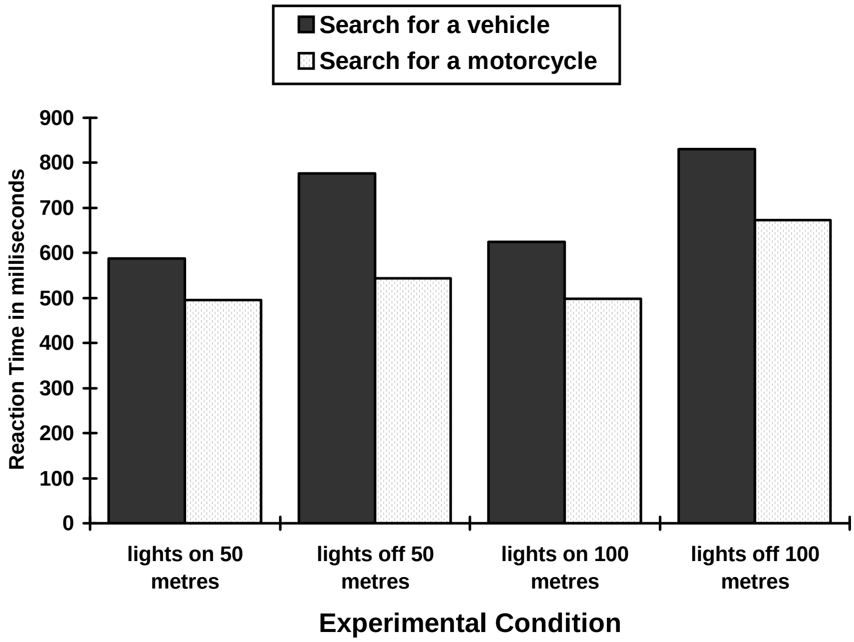
Very few errors were made. The total number of errors made for all participants in all conditions were two false negatives and four false positives.

5.2.2.2 Reaction time to detect

Data were analysed by a three way mixed design ANOVA. Independent measures were the type of question posed to the participants (2 levels: specific search or search for a motorcycle) and the repeated measures were the use of headlights (2 levels: on or off) and the distance the motorcycle appeared from the viewer (2 levels: <50 metres and >50 metres).

Reaction time to correctly detect a motorcyclist in each of the clips containing a motorcycle was analysed. No main effects were found for the question posed ($F (2, 260) = 1.56$ $p< 0.05$). No main effects were found for lighting ($F (1,260) = 2.12$ $p<0.05$). A main effect for distance approached significance ($F (2,260) = 2.69$ $p<0.05$). No significant interactions were found for Question and Lighting ($F (3,78) = 0.02$ $p.<0.05$) for question and distance ($F (3,78) = 0.89$) $p.<0.05$) or for lighting and distance($F (3,78) =.0.31$ $p<0.05$)
Mean reaction time to correctly detect suggested both lighting and the type of question had little effect on subjects' reaction times to correctly decide whether a vehicle was present. Figure 5-1 shows the results found.

Figure 5-1 Reaction time in milliseconds to detect a motorcycle at different distances from viewer, search instructions and lighting condition

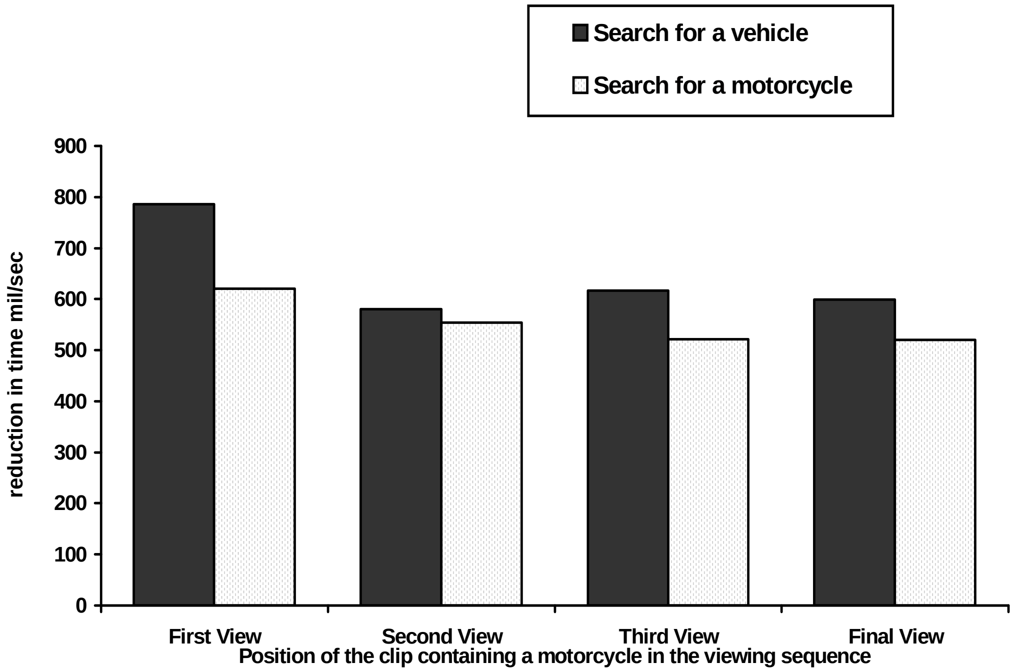


A more detailed analysis was made to consider subjects' reaction times to the first motorcycle they saw in the series of video clips. This was completed to examine whether the repeated exposure to seeing a motorcycle had affected the subject's performance.

To investigate the effect of the question set, the data were then analysed by a one way independent measures ANOVA in respect of the first motorcycle a subject saw. In the first clip in which the subject viewed a motorcycle and a correct response was made, a significant effect of question type was found ($F (1, 174) = 11.41$ $p < 0.01$). The instruction to search for a motorcycle significantly improved reaction time. Means suggested that participants took less time to detect a motorcycle when they were instructed to search for one than they did if they were instructed to search for a vehicle. Mean detection time for the first motorcycle seen was 620 msec (442 sd) if they were asked to search for a motorcycle and 766 msec (388 sd) if they searched for any vehicle.

Figure 5-2 shows that subjects' reaction times improved after viewing the first video clip which contained a motorcycle. It appears to suggest that there is a significant improvement in detection ($t (84) =2.58$ $p<0.05$) if the subject was instructed to search for a vehicle rather than a motorcycle at the second time of viewing Although only a small improvement was found it is thought that the results suggest that once a subject becomes aware that a motorcycle might be present they may adopt a search strategy to detect it. In contrast those participants instructed to search for a motorcycle showed only a small improvement in their ability to detect.

Figure 5-2 Reduction in reaction time comparing the first and subsequent times the subject saw a video clip containing a motorcycle for participants who searched specifically for a motorcycle or any hazard.



5.2.3 Discussion

The results suggest that using a repeated measures design may affect the subjects' detection of a motorcycle. Once a subject becomes aware that a motorcycle may be present in subsequent video clips they may adopt a strategy to specifically search for motorcycles as well as other vehicles. Hole and Tyrrell's (1995) suggestion that motorcycle lighting is only important when the motorcycle is at a distance was not supported although an effect of 'distance' approaching significance was found. No interactions were found in the initial data analysis possibly because of large standard deviations in the sample. Because participants viewed the clips in different orders it was possible to understand how participants reacted to the first motorcycle they saw regardless of lighting or distance effects. Here, in respect of the first motorcycle the subject saw significant improvements in the ability of the participants to detect a motorcycle was found provided participants were instructed to search for a vehicle. Subjects' reaction time data may be interpreted as indicating an improvement once they had seen a motorcycle if they had been instructed to search for a vehicle rather than a motorcycle.

5.3 Experiment 2 - Independent Measures

5.3.1 Method

5.3.1.1 Design

This experiment used an independent measures design. Participants viewed video clips that contained a motorcycle with or without a conspicuity enhancer (lights on or off), at a simulated distance that was either close to the viewer or far away (two levels: > 50 metres and < 50 metres). The participants were requested to either search for a 'vehicle' or a 'motorcycle'. Participants participated in only

one condition permutation of distance , lighting or instruction to search and only one.

5.3.1.2 Stimulus material.

Four video tape sequences were made. Video clips again lasted for half a second and were separated by a ten second gap. Video clips contained either cars, trucks, or a motorcycle or the video presentation contained no moving traffic. The video presentation again simulated the view of a driver at urban intersections searching for a hazard.

Participants either searched for a vehicle or a motorcycle and viewed only one permutation of vehicle distance and lighting. Each video consisted of eight clips with the target or motorcycle at clip number 4. Video clips lasted for half a second and were separated by a half a second gap. Participants were warned of the onset of each video clip by a time counter displayed three seconds before the clip commenced. Motorcycles were either lit or unlit, under 50 metres or over 50 metres. Participants were instructed to search for either a vehicle or a motorcycle. Therefore participants viewed one of the following video tapes:

Tape 1	Motorcycle with no lights close to the viewer
Tape 2	Motorcycle with lights close to the viewer
Tape 3	Motorcycle with no lights far from the viewer
Tape 4	Motorcycle with lights far from the viewer

5.3.1.3 Instructions

The instructions to participants were the same as in Experiment 1. Participants after reading an instruction sheet either searched for a motorcycle or for a vehicle.

5.3.1.4 Apparatus

The same apparatus was used as in Experiment 1 (p 100).

5.3.1.5 Participants

179 participants were recruited by campus advertisement during two Open University summer schools. They were all drivers or were learning to drive. Mean age was 23 with a range of 18-50, although drivers tended to be under 25 years of age. Mean driving experience was 5 years. Females represented 65% of the sample.

5.3.1.6 Procedure

The experiment was conducted over two years of Open University summer schools (1995 and 1996). Participants were recruited by campus wide advertisement. After reading a short subject instruction sheet participants provided their age and driving experience. The participants then viewed the short video which lasted for less than a minute, providing reaction times in milliseconds and their decisions whether each clip did or did not contain a vehicle.

5.3.2 Results

Participants provided eight responses and reaction times to the video clips

5.3.2.1 Errors.

Very few errors were made. A total of three false positives were made and two participants failed to detect the motorcycle - both claimed they had pushed the wrong button.

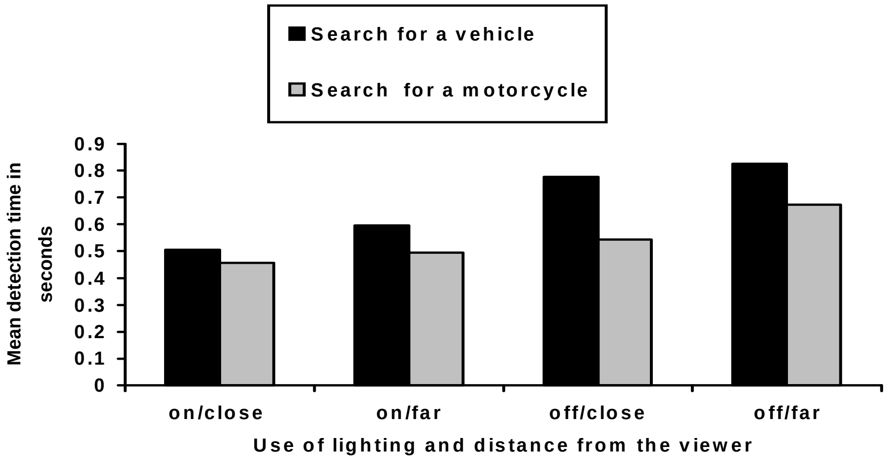
5.3.3 Treatment of data.

Data were collected from each experimental condition. (169 participants in all). Ten subjects' data were discarded either because they were not recorded by the equipment or because participants failed to perform the task properly. Data were analysed by a three way independent measures ANOVA. The Independent variables were the distance the vehicle was away (either <50 metres, > 50 metres) whether the motorcycle was displaying lights or not and the type of question posed (search for a vehicle or search for a motorcycle).

5.3.3.1 Effects of question, lighting and distance - correct positive responses .

Main effects were found for the type of question asked (F (1,159) = 24.84 p<0.01), for vehicle lighting F = (1,159) = 11.59 p<0.01) and for distance (F (1,159) =1.22 p<0.01) No two way interactions were found for any of the variables measured were found, question and lighting (F (1,159) =0.04 p>0.05 question and distance (F (1,159) =0.19 p>0.05) or for lighting and distance(F (1,159) = 0.58 p>0.05). No three way interactions were found. Figure 5-3 shows the mean reaction time in each condition. The time to detect a motorcycle was quicker if the subject was asked to search for a motorcycle than if they were told to search for a vehicle. Vehicle lighting improved subjects' detection time. The position of the motorcycle affected subjects' reaction time with motorcycles located under 50 metres being detected faster than those detected in the distance.

Figure 5-3 Effects of Lighting distance and question on reaction times



5.3.4 Discussion

The data suggest that independent measures are ecologically sound because the motorcycle is seen only once in the series of video clips and allows the effects of lighting and distance to be evident without the subject becoming practised in searching for a motorcycle. Although a small sample, significant differences were found in the type of instructions given to participants. Participants consistently detected the motorcycle in all conditions faster if they had been instructed to do so. Motorcycle lighting improved detection and the closer the motorcycle was to the junction the faster it was detected.

5.4 Overall Discussion

5.4.1 Issues in conspicuity.

Results were similar to Hole and Tyrrell (1995) and Langham (1995). In independent measures experiments participants detected the motorcycles that were closer to the viewer faster than those motorcycles displayed at a distance. This was the case whatever the instructions to search. However, there are two problems if this experiment is purporting to say something about the L.B.F.S. error.

Firstly the Hurt report (1981)and the fatal accident reports discussed in Chapter 3 concluded that when the driver makes the decision to emerge, the motorcycle is very close to the intersection prior to the accident. However the present results indicate that the nearby motorcycle is detected more rapidly than when it is simulated to appear at a distance. Why? Secondly the results and the laboratory manipulation may not have anything to do with the L.B.F.S. error. Laboratory experiments reporting visual attention performance by using a visual search paradigm, (e.g. Yantis and Egeth, 1996) report that objects appearing closer to the centre of the display tend to be detected more rapidly. The display of the image of the ‘T’ intersection means that vehicles appearing more closely are towards the centre of the visual field. This would also be the case in the real world. Here eccentricity may confound the effect of detection success when the motorcycle is at a distance away from the viewer. The use of lighting as a conspicuity enhancer appeared not to be effective after the first exposure of the motorcycle in the repeated measures design no main effects being found for

lighting. This supports the findings from other experiments where participants have been exposed to a repeated number of slides that contained a motorcycle. (Hole and Tyrrell 1995) showed that after prolonged exposure to motorcycles with their lights on, drivers adopt a strategy of searching for lights when instructed to search for a motorcycle. Results supported Cole and Hughes' (1984 1986) conclusions that the instructions to either specifically search for a target or report any hazards affects performance. This was shown in reaction time not in detection success as in Cole and Hughes' study.

5.4.2 Errors

Participants appeared to perform the task accurately. False positives in both experiments were rare although more were made in response to a clear road than false negatives when a vehicle was present. However, more clear road scenes were shown than clips that contained a hazard. The low number of errors reflect that capturing the L.B.F.S. error in the laboratory is impractical and that the use of such a measure as detection failure is inappropriate. The low number of errors may also suggest that the subject who is searching for a hazard merely needs to respond to anything that is present in the road, a theme returned to in Chapter 7. Measuring error is possibly an important tool for understanding the L.B.F.S. error but from these results it appears unlikely that it is possible to capture the rare real world L.B.F.S. error in the laboratory.

5.4.3 Reaction time - laboratory and real world.

Reaction times found in the laboratory reflected very poorly the amount of time a subject would spend searching in the real world. Chapter 4 concluded that drivers orientated their head towards where a hazard might be expected, for less than half a second). The detection of a motorcycle in the laboratory gave mean reaction time to decide if a hazard was present of about 0.700 milliseconds searching the clear road - actually the road described in the observation study in Chapter 4 - the mean search time in the laboratory was well over a second compared to a mean head orientation time of under 0.5 seconds. This may reflect the findings of Rabbitt and Vyas (1978) and Levy and Pashler (1995) who concluded that information about a particular stimulus is collected even after there is enough information to make a decision about its presence.

A tentative conclusion, is that the display time is appropriate for the laboratory, is made by the low number of errors found. Such results in speed classification tasks with limited display times are again similar to Rabbitt's (1979) conclusions. Participants appear to be able to perform the task with a half second search time provided there is no abrupt start to the video clip. The procedure of showing a time counter before the onset of the scene will be retained for future experiments.

5.4.4 Measures

Independent measures appear the most appropriate way to conduct this type of research. Once the subject becomes aware of a motorcycle their search time changes - or at least the time to make a decision changes. When a subject is required to search for a motorcycle they detect it faster than when they were told to search for a vehicle (Experiment 2). Previous research requiring participants to search for a motorcycle in a series of clips has used repeated measures designs. (e.g. Williams and Hoffman, 1977, 1979). This is not only ecologically unsound because of the higher event rate, but participants improved their reaction time through practice (Figure 5-2) and as Hole and Tyrrell.(1995) postulate,

participants may develop a detection strategy during the course of the experiment to detect a motorcycle if given enough exposure to motorcycles in the experiment possibly on the basis of lighting alone. This is a theme echoed by Bacon and Egeth (1994) who claim when reviewing research on visual search in the laboratory is that in tasks involving search for a known target, search may be successful because the subject may have been able to adopt a basic feature detection strategy. This is an issue returned to in Chapter 7(p 133).

Repeated exposure to the presence of a motorcycle in a series of video clips means that participants show improvements in detection ability to subsequent motorcycles irrespective of whether or not they instructed to search for a motorcycle or not. However the greater reduction in RT between the first and second views of a motorcycle occurred when they were instructed to search initially for a vehicle.

5.4.4.1 Selective visual attention

The reaction time measure found differences in 'time to detect' for those searching for a motorcycle and those searching for any vehicle. This may imply that participants when they expect to see a motorcycle search in a different way. Chapter 1 postulated that the L.B.F.S. error may be accounted for by a failure of either searching locations in the environment or searching for specific targets. However what mechanism accounts for the L.B.F.S. error? Differences were found in the detection time made by participants depending on the location of the potential hazard in the video clip. Is it therefore the 'where' in the environment which is important? Motorcycles presented at under 50 metres from the viewer were generally detected faster than those at a distance. This may tentatively suggest that drivers start searching for objects close to their own vehicle rather than far away and that attention is directed to certain locations. Alternatively the significant change in reaction time caused by the specific instructions to search, might have affected the 'what' in the environment the participants were searching for. Participants detected a motorcycle faster if they instructed to do so in the independent measures design implying that if as Theeuwes (1994) argues, we search for basic shape primitives, they were expecting to see a motorcycle because they were asked to search for one. This may reflect Hills' (1980) view that the motorcyclist shape does not trigger the correct 'neurological' response because generally drivers expect to see a car. There is little or no reason for them to suspect otherwise because motorcycles are fairly infrequent on the road (Thomson 1974).

If it is the 'what does a hazard look like' which is important in understanding the L.B.F.S. error, is it recognised at the basic feature detection stage thought to be driven by the stimulus (Yantis 1994), or a later stage of object recognition process thought to be a property of both the stimulus and of top down processes (Theuwees 1994)? Recognition of an object may involve two activities - firstly discrimination and secondly naming. Driving however, possibly only requires the first. We can recognise differing types of motor vehicle without being able to name them. As Wade and Swanston (1991) comment when discussing road crossing behaviour:
'Object recognition involves two aspects: discrimination and naming. The first is essential where the second is not. A guide dog will perform the first but not the second'. The issues remain unclear from the data reported here.

5.4.5 Expectancy

The above considers the L.B.F.S. error as a failure of the human selective attention mechanism in terms of limitations suggested by Egeth and Yantis (1997) and Theewues (1994). However what of expectancy? Does the driver have a set of expectancies at an intersection? Above all are they expecting to see the familiar passenger car? The results could be interpreted as showing that the driver when starting the experiment is expecting to see a *car* when s/he is instructed to search for a vehicle. Only when s/he is either instructed to search for a motorcycle or has seen other video clips that contain a motorcycle does s/he expect to see a motorcycle. Evidence for this first set of expectancies and a subsequent change may be reflected in the time to detect figures, illustrating that participants are faster to detect a motorcycle when they are instructed to do so. Does the expectation to 'see' a car mean that an unexpected motorcycle will not be seen. Studies such as Shinar (1985) shows improved detection in measures such as distance to detect and RT when the subject is expecting to see the hazard but is a measure such as change in RT, sensitive enough to reveal anything about the cognitive processes of the driver trying to detect a hazard at an intersection? However a weakness of this experiment may be that in the 'search for a vehicle' condition, perhaps participants consciously think 'the experimenter wants me to respond to vehicles - they are usually cars, trucks and buses'. So the 'search for a vehicle' condition may be priming the subject not to expect to see a motorcycle after all.

5.4.6 Improvements for Future Work

Database evidence reported in Chapter 3 found that experienced drivers may find searching for a motorcycle as much of a problem as do novice drivers, there being no reduction in accident potential with increasing driving experience. The participants were generally under 25 in this experiment and it may be suggested that these drivers do not have the problem in detecting the motorcyclist. In the next experiment a contrast will be made between participants who are under twenty-five and those over twenty-five in their motorcycle detection skills. If the L.B.F.S. error is to be explained in the context of driver expectation guiding their search to certain spatial locations or to search for certain objects, then novice drivers may have different expectations about the road environment than do experts.

5.4.6.1 Missing conditions

Participants searched either for a vehicle or a motorcycle. When participants searched for a 'motorcycle' but were shown a vehicle they needed to respond in the negative. When participants searched for a vehicle but saw a motorcycle they responded in the positive. A third condition needs to be introduced where the subject needs to signal the detection of a passenger car but is not instructed to search for a 'vehicle' but rather for a 'car'. Thereby the subject would be responding positively to the presence of a car when searching for a car. This was considered in the initial set up of this experiment. The third condition would make the experiment look thus:

	Search instruction		
	Vehicle	Motorcycle	Car
Stimulus present			

	Positive response required		
Car	Yes	No	Yes
Motorcycle	Yes	Yes	No
other vehicle	Yes	No	No

This would give a clearer idea what information a subject uses to classify in rapid search a passenger car or another vehicle. A comparison could then be made between positive responses for a motorcycle and positive response to a passenger car. However the pilot study found a major problem - what constitutes another vehicle. When piloting this study it was found to be difficult to define a ‘car’. Cars appear to be similar to vans - people carriers. The frontal views of many of this type of vehicle are the same.

5.4.6.2 Equipment

Video technology may aid detection by giving cues of movement but the reproduction is less than that of slides. A 25’’ SVHS monitor was used in this experiment. This was because of all the video equipment owned by the institution this gave the highest video production quality. The experiment originated as an investigation of conspicuity by an examination of lighting and distance effects. The problem is that participants are not willing to sit so close to the video screen as would make the retinal size the same as in the real world. Future experiments need to evaluate the use of video projection equipment although this would generate a lower quality image.

5.4.7 What Next

The question is therefore: in a short visual search at an intersection, is the L.B.F.S. error a failure to allocate attention to locations that contain a motorcycle, or is it that attentional resources are allocated to the expected object but the motorcycle/object does not then contain the expected triggers to elicit a fixation or further processing? If the problem of L.B.F.S. involves a failure to attend to the object then what is it about the object that fails to attract the attention (Egeth and Yantis 1997)? What is more important, shape and identity or location in target detection/ identification (Pashler 1998)? The next chapter therefore investigates whether the L.B.F.S. error is a failure of attention to spatial locations by examining driver eye-movement patterns in a laboratory simulated driving task.

5.5 Conclusion

The data are difficult to interpret clearly. However priming the subject to expect the presence of a motorcycle appears to aid its detection. The contrasting results provided by repeated measures and independent measures illustrate that laboratory experimentation should use an independent measures design. Throughout this thesis therefore a comparison needs to be made between the differences in driver behaviour between expecting to see a motorcycle and expecting to see any hazard. Theoretical evidence of human visual search and selective attention fails to answer these questions. In a dynamic complex environment to what extent does expectancy guide search for oncoming stimuli? If Theeuwes (1993) is correct in claiming that the only top down influence on visual search is the part of the visual field where the driver is going to look? Chapter 6 asks where do drivers look?

6. Where do drivers look at intersections?

6.1 Introduction.

One alternative explanation for the L.B.F.S. error is to suggest that drivers might be failing to direct their gaze towards parts of the road environment where the motorcyclist could be (Olson 1989). Olson suggests that another factor in L.B.F.S. is that the motorcyclist may have adopted a non-standard road position.

Rumar (1990) claims that because of driver expectancy, the driver fails to scan or look in the places where an uncommon vehicle may be present. Summala *et al.* (1996) found that a cause of bicycle accidents is that drivers developed a visual search strategy which ignores visual information about less frequent dangers. Drivers may develop through experience a visual scanning pattern that is well suited to detect commonly-occurring vehicle types (cars, lorries and buses) but inappropriate for the efficient detection of relatively rarely-seen vehicles such as motorcycles.

Chapter 4 showed that drivers look for very short periods of time before emerging from a junction. Given that most drivers do not routinely crash at junctions, they must be operating quite efficiently in terms of extracting relevant information about the presence or absence of other road users and their speed of approach (Cairney *et al.* 1995). However, what all of these workers have failed to examine is the fundamental issue of where drivers actually look at junctions, when they are deciding whether it is safe to emerge. Do drivers look in the 'right' places to detect motorcycles? If drivers are using peripheral vision to detect oncoming vehicles, they might be missing motorcyclists because they are too small to be detected or because peripheral vision is poor at recognising form (Olson *et al.* 1979).

The potential field of view for the entire retina is 200° horizontally and 130° vertically. The active binocular visual field extends to 180° horizontally and 130° vertically (Burg 1968). The view when a driver approaches a junction is at least 180° horizontally (Noon 1992). A small 2° region of the visual field projecting onto the fovea represents the region of greatest acuity and receives the greatest amount of processing (Cohen 1981). Mackworth (1974) claims that an appropriate way of understanding the potentially available field of view is the 'useful field of view', defined as the area around the fixation point from which information is being processed in the sense of being stored or acted upon during a given visual task. Mackworth (1965) found in a laboratory investigation that the useful field of view (FOV) may be as little as 2°-6°. Mackworth, Kaplan and Metley (1964) claim that the main limitation on the useful FOV is the time taken to do the task. As the periphery represents the majority of the retina it is likely that the motorcyclist will be first 'detected' in the periphery, which is comparatively poor at identification of form. Miura (1992) claims that regarding L.B.F.S. accidents the FOV may be narrowed by time pressures or cognitive load. Under cognitive pressures (review in Crundell, Underwood 1998) there may be a form of cognitive tunnel vision limiting the performance of the driver.

Peripheral vision will play an important part in the detection of a hazard if drivers are not making a foveal fixation of the motorcyclist. Hills (1980) claims that something is said to be conspicuous if it is firstly detected in the periphery and then subsequently fixated. Do car drivers detect motorcyclists firstly in the

periphery and then a make a fixation towards them. If this is so what is the normal range of vision in the peripheral field? From Edwards and Goolkassian's (1974) early research it appears that participants are able to detect targets quite easily in peripheral vision between 50°-90° from the fixation point. However Edwards and Goolkassian provide the caveat 'providing adequate time is given'. Results from Chapter 4 show that search may be very rapid. Mackworth (1974) claims that the useful peripheral FOV is quite different when a participant is "searching for a needle in a haystack" (p308). Mackworth describes how in a peripheral discrimination task, as the number of targets increased, (that is the complexity of a scene increased), the smaller the field of view became. Given this laboratory evidence one must ask how much of a FOV the driver can use away from the fixation point.

As a result Wulf *et al.* (1989) point out:

"Driving in urban traffic requires a greater effort to extract relevant information. As a result the average eye fixation time is prolonged and therefore the total number of fixations per time intervals is reduced ."
(Wulf *et al.* 1989, p171)

Cohen (1980) points out that longer fixations and less 'searching' may mean that there is an increased probability of smaller targets being overlooked. Importantly the increased load on the fovea vision will mean that there is effectively a decrease in the performance of peripheral vision. Wulf (1989) refers to this as a form of Mackworth's tunnel vision where in an information overload situation only fixated targets will be processed further. As Cohen (1980) points out, foveal vision has priority over peripheral vision in a competition for limited cognitive resources. Miura (1995) found that in increased situational demands, drivers' response times to detect targets located in the periphery took longer, indicating a narrowing of the FOV.

Thus it may be that motorcycle accidents can explained in the terms of a narrowing of the functional field of view so that objects likely to appear in the periphery are not detected. If this is the case a failure to 'point the eyes at' certain locations in the road environment may also mean that highly conspicuous objects would be missed, because the driver is not looking in the right place.

6.1.1 Eye-movements

We sample from our environment in a series of relatively brief fixations which move from one point to another via a series of rapid jerks known as saccades. We can look at whatever we choose. Consequently this control over saccadic movements has been seen as an overt indicator of hidden cognitive processes (Chekaluk, *et al.* 1992). Sequences of fixations are a popular way of emphasising the link between overt behaviour and higher mental activities namely the presence of a temporal structure for planned fixation sequences (See Zingale and Kowler, 1987). It is believed that eye-movements determine the position and the velocity of the retinal image and thereby the interpretation of performance on any visual search task requires us to understand what the eye is doing or at least make some assumptions about it (Kowler 1990).

6.1.2 Driver scanning patterns

Lashley (1951) argues that eye-movements are organised into structured sequences whose main feature is the spatial and temporal integration of distinctive elements into an effective purposeful activity. He claims that saccadic movements have a ‘syntax of movement’.

It has been hypothesised that ‘visual scanpaths’ exist (Noton and Stark, 1971) and that people can rapidly learn to inspect spatial locations on a display in an optimal order to detect targets (Rabbitt, 1984) and that sequenced patterns of fixations are evident in eye-movement recordings. However others (e.g. Jacobs 1986, Viviani 1990) believe that regularities in the scanpath are based on the nature of the stimulus and not related to higher order oculomotor planning.

Venger (1971) has shown that efficiency in visual scanning is a function of task demands for stimulus recognition or discrimination. The most exhaustive scanning may not necessarily be the most effective. Venger (1971) claims a developmental sequence is detectable and that eye-movement patterns have three separate stages which develop with experience, proceeding from 'partial' to 'exhaustive' to 'efficient'. The difference between the two forms of incomplete scanning behaviour, ‘partial’ and ‘efficient’, is that efficient scanning is to ‘task relevant features of the display’. Do drivers with increased experience change their scanpath at a junction?

Levy-Schoen (1984) claims “that before beginning to scan a field and as a function of the task and the expected properties of the material to be explored, a participant prepares a basic scanning routine around which oculomotor behaviour will be organised. For instance while opening a book a reader is setting up an ocular reading routine which involves scanning the successive lines of text from left to right with certain basic organisational constraints related to the text form, content and to the aims of a particular reading task adopted.” (p 301). In another case, Levy-Schoen (1984) claims “while searching for an object among many others a ‘perceptual set ‘ (i.e. some kind of mental image of the object) is established together with an oculomotor routine “ (p 301.)

If laboratory evidence can be applied to driver search behaviour then a driver’s search may be dependent on a series of pre-programmed saccades. These pre-programmed movements may be elicited at the approach to a junction. If for example, a driver develops a series of saccades that experience has taught them provide the most efficient search, it may mean that common vehicles will be detected rather than relatively rare vehicles.

Despite the plausibility of a link between selective attention and saccades it is still not clear that such a link actually exists (Kowler 1990). There is some dispute that eye-movements are the ‘window of cognition’ (Viviani 1990). Are eye-movements or saccadic sequences planned as a unit as with other forms of motor behaviour or on a basically stimulus driven step by step basis (Viviani 1990)? Saccades may not be a good measure of attention as they are often inaccurate and often overshoot or undershoot the target (Frost and Poppel, 1976). Tracking constantly viewed moving targets is more accurate (Lemij and Collewijn 1989). Participants can also decide to make saccades that fall short of the target, exceed the target's position or track in the opposite direction to that of the target (Steinman *et al* 1973). In ‘natural’ scenes there is a problem of background. There appears to be ‘a centre of gravity’ tendency for saccades (Totes 1985). Studies in the laboratory show that backgrounds in which targets appear have little effect on smooth eye-

tracking but can affect saccadic movement. Totes reported that when there was complex background involved participants tended to centre on the entire scene. Importantly selective attention can be moved about without saccades (Reeves and Sperling 1986) but this is thought to demonstrate that shifts of attention do not require saccades (Erisen, and Murphy 1987) and leaves open the question of whether saccades need involve corresponding attentional shifts (Klien 1980, Kowler 1990).

6.1.3 Driving and eye-movements.

Where drivers look at intersections can be influenced by many factors. Kito, Haraguchi, Funatsu and Sato (1989) found that gaze movements were significantly greater in participants who drove large vehicles rather than small vehicles. Fixations showed a peak at the point 50°-60° to the right and left of the median plane of the driver. They found that few gaze movements were directed towards the regions 0° - 20° from the median plane (Kito *et al.* 1989, figure 3, p 23). This finding may have an important influence on motorcycle detection if the motorcyclist is within 20° of the junction (Hurt et al. 1981) when the driver claims s/he 'looked' but did not 'see' it.

The type of junction being approached also affects fixation patterns. Rahimi, Briggs and Thom, (1990) found that eye-movements are 'highly dependent' on the type of turn configuration. They examined subjects' fixation and detection performance for when participants repetitively made left-turns alternately at busy and then quiet intersections in traffic. Results suggest that the eye and head movements are highly dependent upon the type of turn configuration, type and frequency of distractors (other vehicles). Laya (1987) examined the fixation patterns of drivers entering roundabouts. Laya found mean dwell time (length of fixation) for drivers at roundabouts was higher than at other junction types. He also found that driver search times were significantly higher when traffic volumes were high.

Differences in fixation patterns have been found between experts and novices. Looking patterns when driving on straight roads are different between experts and novices in the horizontal and vertical fixation planes (Evans (1991). Land (1992, 1994) focused on a novice and experienced driver's ability to negotiate bends and found that experienced and novice drivers fixate in different parts of the road environment to elicit the information about the angle of the bend. Mourant and Rockwell (1970,1972) concluded that inexperienced drivers searched the road environment closer to their vehicle than did experienced drivers. Differences in mean fixation times were found between novices and experts by Cohen (1981), Henderson *et al.* (1989) and discussed by Underwood and Everett (1992). Increased fixation duration found in these studies implies extra cognitive processing by the novice driver - and that novices perform the driving process with less automation (Crundall and Underwood 1997). Different fixation patterns were also found between novices and experts in visual search tasks by Tole, Stephens, Harris, and Ephrath (1982) who reviewed pilot search strategies. Cole and Hughes (1993) who investigated the areas of the road that participants examined when driving found that experienced drivers only searched for objects "located within +/- 8° of the direction of travel" (p 415). They found that guiding participants to search for certain targets or under conditions of free search had little effect on participant' eye-movement.

6.1.4 Implementation

In this experiment therefore subjects' eye-movements will be recorded as they view a series of video clips where their task is either to detect a vehicle or specifically a motorcycle. Chapter 5 found that motorcycles were detected faster if participants were instructed to search for them. Are these differences reflected in the spatial locations where participants search? Two types of subject will be tested - novices and experts (both participating in each experimental condition) to investigate if experienced drivers search in different locations than novices.

Relevant questions to be addressed in respect of the motorcycle L.B.F.S. error.

1. *Do drivers search the entire field of view?*

2. *Do experienced drivers search the FOV in a different way to inexperienced drivers?*

3. *Do different types of junction elicit different types of search?*

4. *Does experience teach the driver where to look?*

5. *Does the experienced driver start looking in one location rather than another?*

6. *Are there areas of the road environment where drivers do not look? If this is the case might those areas contain a motorcyclist?*

7. *Are eye-movements reduced and fixations changed by the nature of the search task?*

6.2 Method

6.2.1 Pilot Study

To test feasibility and equipment a pilot study was conducted. Chapter 4 showed that on average, despite large individual differences, drivers searched for about 0.5 seconds and subsequent experiments used this as a basis for the display time of video clips. However initially the pilot study for the experiment reported in this chapter showed that at a 0.5 second display no eye-movements were found and participants maintained their fixation in the centre of the screen. A series of increasing display times were therefore evaluated - increasing by intervals of 0.5 seconds. The discussion section returns to this issue.

6.2.2 Design:

There were four conditions, representing the four permutations of experience level ('experienced' ('E') versus 'inexperienced' ('I')) and search-task ('search for any vehicle' ('V') versus 'search for a motorcycle' ('M')). Each participant performed only one of these four conditions (EV, EM, IV or IM) but all participants viewed the same eight video clips of different road scenes. Participants were asked to decide as quickly as possible whether or not a vehicle (or motorcycle, depending on condition) was present in each of these scenes by pressing one of two buttons on a button-box. Participants were therefore under the impression that the dependent

variable was their reaction time to detect the relevant stimulus, whereas in fact only their pattern of fixations and saccades were being recorded.

6.2.3 Participants:

Participants were recruited by advertisement at the University of Sussex. Potential participants were excluded if they were motorcyclists (as their search behaviour might well be different to that of other drivers); if they had been involved in a major accident in the past year; if they wore spectacles or contact lenses; if they took medication such as anti-depressants that might affect eye-movements; or if they were prone to epilepsy (as the flicker rate of the equipment was similar to that likely to induce seizures). They were also required to have a well-defined contrast between the iris and sclera (the equipment being only sensitive to a well defined iris) which meant that participants generally had brown eyes. The data from two participants were discarded after testing was completed, due to an previously undiagnosed cataract in one case, and equipment calibration problems in the other.

12 participants were finally selected: six experienced drivers (four males and two females) and six inexperienced drivers (three males and three females). The mean age of both groups was 25 overall (range: 24 to 27 years for the experienced drivers; 23 to 30 for the inexperienced drivers). Experienced drivers had all had full licenses for over two years. Inexperienced drivers were taking driving lessons but had not yet booked their driving test. Four experienced and three inexperienced drivers were allocated to the ‘search for any vehicle’ condition, and two experienced and three inexperienced drivers were allocated to the ‘search for a motorcycle’ condition.

6.2.4 Stimuli

Film recording and editing were performed by a professional film crew. The stimuli consisted of eight two-second video clips (each lasting for 48 video frames), displayed onto a white screen 1.1 metres away. Clips were first generation copies. Clips were separated by ten second gaps. Participants were informed of a clip's onset by a three second counter (black digits on a white background)[6] similar in nature to a film start timer code, which appeared in the centre of the screen.
The video clips showed several different types of junctions, including six scenes of a ‘T’ junction and one scene of a roundabout. The eight clips used contained either traffic coming towards the driver, going away from the driver or contained no moving vehicles. Clips 1-6 and clip 8 were shown to participants in the experiments reported in Chapter 5. All scenes showed roads either on the University of Sussex campus or on the main approaches to the university. All road scenes therefore should have been highly familiar to the participants in this study.

6.2.4.1 Summary of stimulus material

[6] This is an inverse image when compared with Chapters 5 and 7. Using a black background caused the eye-tracker camera to fail in a darkened room.

Clip 1 showed the approach road to the University. A large yellow tanker was approaching the viewer. This clip was intended as a practice clip, to familiarise participants with the equipment and procedure.

Clip 2 was a complex road scene (Arts Road, on the University campus) with parked vehicles on one side of the road. The same view appeared in three other clips (clips 4, 6 and 8). In this version, there were no moving vehicles present.

Clip 3 was a rural road, the approach road to the University's sports pavilion. There were no moving vehicles present.

Clip 4 showed the same scene as in clip 2, except that a motorcycle was approaching the viewer. The motorcycle was a blue 1976 Honda CG125, ridden by a motorcyclist wearing a red and blue leather jacket, blue jeans and a white helmet. The headlight was unlit. The motorcycle's position was close to the centre line of the road.

Clip 5 Showed a roundabout located on the approach road to the University.

Clip 6 Was a repeat of clip 2 (i.e., there were no moving vehicles present).
Clip 7 Showed the same scene as clip one, with no traffic approaching. There were vehicles moving away from the viewer. This clip was selected to investigate if participants were looking for approaching vehicles or merely responding to movement in the scene.

Clip 8 showed the same scene as in clips 2, 4 and 6. The clip contained the same motorcycle as in clip 4, but located in a different position. Instead of appearing 55 metres away from the junction, it was 13 metres away. It took the same trajectory on the road as the motorcycle appearing in clip 4 and was therefore close to the centre line of the road (See Figure 6-4p 121).

6.2.5 Apparatus

Video clips were played on a Panasonic SVHS video recorder, and projected onto a 2m x 2m white screen by a Bell and Howell SVHS L.C.D projector (model number LCD10e). The resultant image was 31° horizontal and 22° vertical. Participants wore the 'Sussex Eyemark' eye-tracking equipment developed by Mike Land
(See Figure 6-1) (for a full description see Land 1992). This consists of a head-mounted Panasonic penlight camera which records both the scene in front of the wearer and an image of the wearer's eye (via a small half-silvered mirror mounted beneath the eye). The resultant images were recorded by a Sony Hi-8 Palm video recorder onto Hi 8 computer grade videotape. Land (1992, 1994) claims that this equipment can measure the position of fixations within a scene with an accuracy of within 0.5° degrees.
Participants signified the detection of a vehicle by way of a button box, which - unknown to the participant - was a 'dummy', not actually connected to any recording machine.

Figure 6-1 Sussex Mk3 Eye-Track equipment

6.2.6 Procedure

Each participant was tested individually, in a single session which lasted approximately 45 minutes (although much of this was spent in calibrating the equipment). At the beginning of the experiment, participants completed a disclaimer regarding medical conditions and were asked if they had consumed any substance (e.g. alcohol) that would preclude them from driving. A simple acuity test was then performed, to check that the participant's eyesight was sufficiently good for driving. During the experiment the participant was seated facing the projector screen, with the video projector above and behind their head. Before the experiment began, the eye-tracking equipment needed to be calibrated individually for each participant. Participants were asked to fixate on each of a sequence of letters and numbers within an alphanumeric display grid projected in front of them by the video-projector. Half of the participants were asked to perform one sequence of fixations, and half were given another, in order to minimise any effect of these search instructions on performance during the experiment itself. In each case, the final fixation points were not at the point where the first clip would reveal an oncoming vehicle.

The participant then viewed the eight two-second video clips described previously. Participants either searched for a vehicle or searched for a motorcycle. Instructions to participants are described in Chapter 5 (p.94).

6.3 Results

6.3.1 Method of Initial analysis

Analysis of the eye-movement data was conducted using programs developed by Land (see Land 1992).

6.3.2 Errors in detection

No errors were made: all participants successfully detected all vehicles in all clips that contained a vehicle. No participant indicated that a vehicle was present when no such vehicle existed.

6.3.3 Treatment of results

The analysis of the eye-movement data was performed using the following measures.

6.3.3.1 Interpretation of overall saccadic movements for all participants

The number of saccades made by all participants were considered.

Figure 6-2 Mean number of saccades to each video clip for experienced drivers.

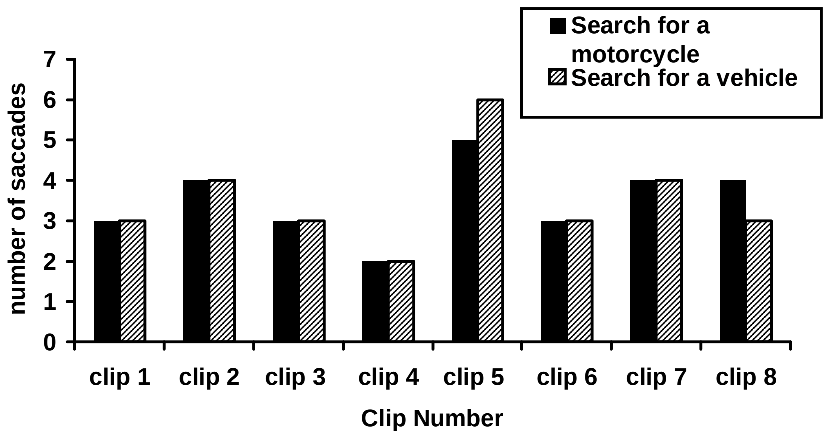


Figure 6-3 Mean number of saccades to each video clip for inexperienced drivers.

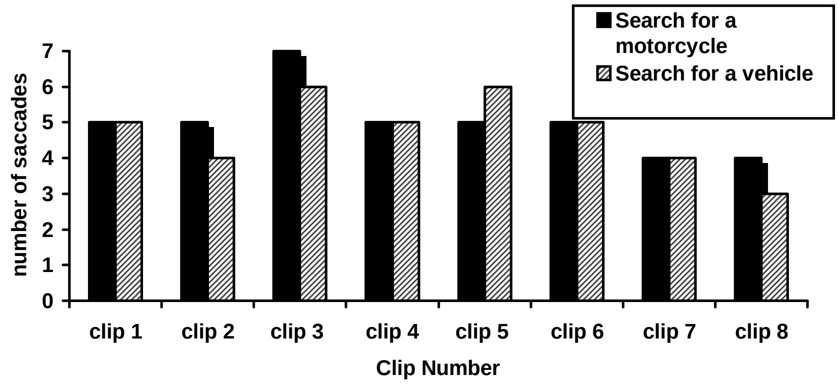


Figure 6-2 and Figure 6-3 show that novice drivers make significantly more saccades at 'T' junctions than experienced drivers (z =5 p<0.001) However a similar number of saccades are made by both groups to the clip that displays a roundabout.

6.3.4 Analysis of Search Patterns

6.3.4.1 Treatment of Results.

The number of saccades, direction, start and end points and dwell time were calibrated and measured and encoded by the writer.

6.3.4.2 Analysis of eye-movements by the number of degrees of arc

Table 6-1 shows that EV and EM drivers searched at 'T' junctions less than IV and IM participants. At 'T' junctions with no traffic present novices searched more than did experienced drivers (t (11) = 9.84 p< 0.01) When there is a motorcycle present in the scene at a distance again novices perform a wider search (t(10) = 9.11 p< 0.01). At the roundabout this was not the case (t(11) = 0.22 p< 0.05). Generally novice drivers search more (in degrees) compared with experienced drivers. Details of the stimulus material for each clip is on page 116. Table 6-1 shows the mean total degrees of arc for all participants in response to video clips that did or did not contain a hazard both roundabouts and 'T' junctions.

Table 6-1 Summary of all subjects' mean total degrees of arc from the initial fixation point when searching (figures in brackets are the standard deviation found for that group)

	Experienced		Inexperienced	
Type of junction	EV(Sd)	EM(Sd)	IV(Sd)	IM(Sd)
T Junction clear (clip 2)	7 (4)	8 (5)	24 (9)	22(9)
With motorcycle at a distance (clip 4)	8 (1)	11(4)	22 (17))	17(12)
Mini roundabout (clip 5)	28(2)	23(12)	29 (12)	31(6)
Close by motorcycle (clip 8)	14(2)	15(6)	14 (14)	17(13)

Table 6-2 shows a similar picture to the summary above, The search of four drivers' visual scanpath at the different intersection types again shows only experienced drivers have a limited saccadic movement a 'T' junctions. The differing instructions to search produced little difference in the number of saccades made.

Table 6-2 Comparison of four drivers' (two from each condition) mean total degrees of arc from fixation point when searching different junction types.

	Mean total degrees of arc Experienced driver		Mean total degrees of arc Inexperienced driver	
Type of junction	EV	EM	IV	IM
T Junction clear (clip 2)	4	5	29	42
With motorcycle at a distance (clip 4)	7	7	19	22
Mini roundabout (clip 5)	31	28	27	22
Close by motorcycle (clip 8)	17	17	10	12

6.3.5 Where do participants look?

6.3.5.1 Treatment of data.

One problem in examining eye-movements is to represent a dynamic series of fixations exploring a 3D world in a static 2D picture. The important issue for the L.B.F.S. error is to understand the location of the fixations and where the first fixation is elicited. Therefore for ease of understanding the look-point data, the displayed screen image was divided equally into a 10 x 10 box grid[7]. The grid had 100 boxes which can represent by shading, the location of a fixation made by each subject. The position of each fixation was coded into one box. A fixation was defined as a stationary eye fixation for more than two video frames. The total horizontal FOV is 31° therefore each horizontal box on the grid represents approximately 3 degrees. The boxes were chosen to reflect the accuracy of the equipment. The section below discusses either fixation patterns for individual participants (selected on the basis of the quality of recordings) to illustrate a point or summarises fixations for all participants in that condition. When summary data are discussed the box contains the fixation points of where two or more participants fixated in that location for more than two video frames.

The following figures code experienced drivers in red whilst novice drivers are in blue.

6.3.6 Effects of experience EM and EV compared with IM and IV

6.3.6.1 'T' Junctions

Figure 6-4 shows eye-movement fixation patterns for an experienced driver and Figure 6-5 shows eye-movement patterns for a novice driver. The EM driver searches only at the distant area away from the intersection whereas the IM subject searches more of the road environment than the EM driver. The IM driver also fixates on areas of the scene which are not part of the road environment. This is also shown in the summaries of eye-movements.

Figure 6-4 An example of one EM subject's visual search pattern at an intersection. The shaded boxes represent all points where this subject fixated for more than two video frames during the entire two second display.

[7] For a review of 'simple' techniques for understanding lookpoint data see Harris Glover and Spady (1986) especially Appendix A

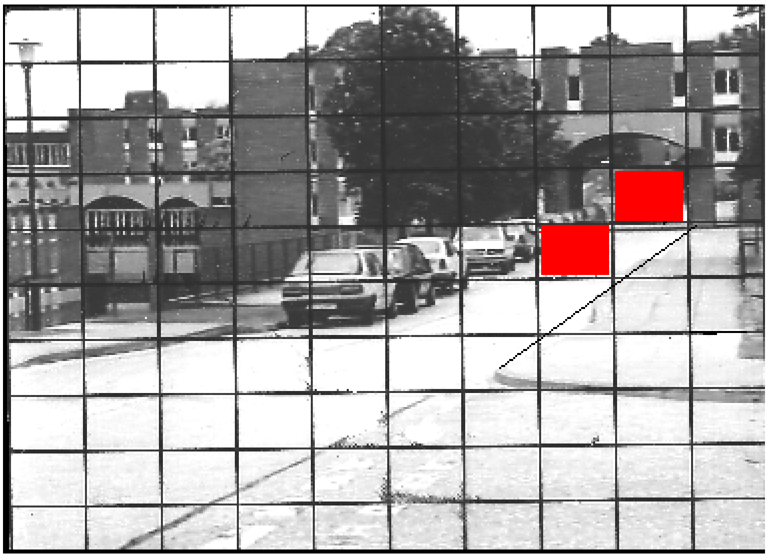
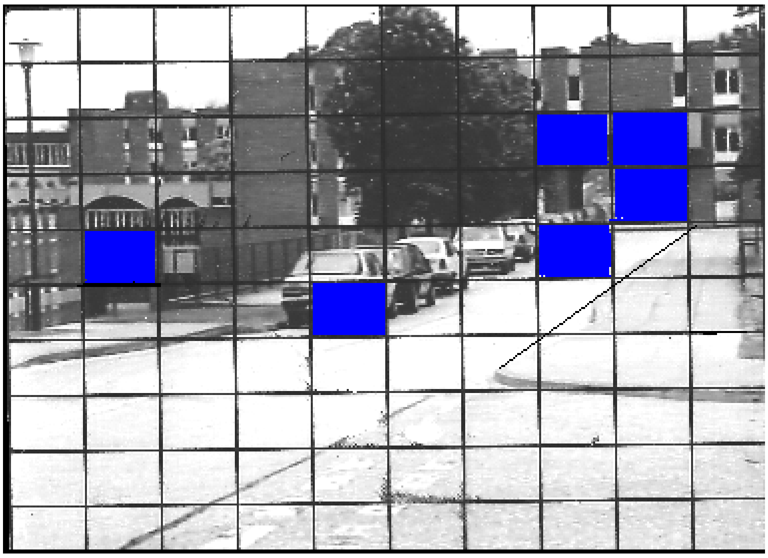


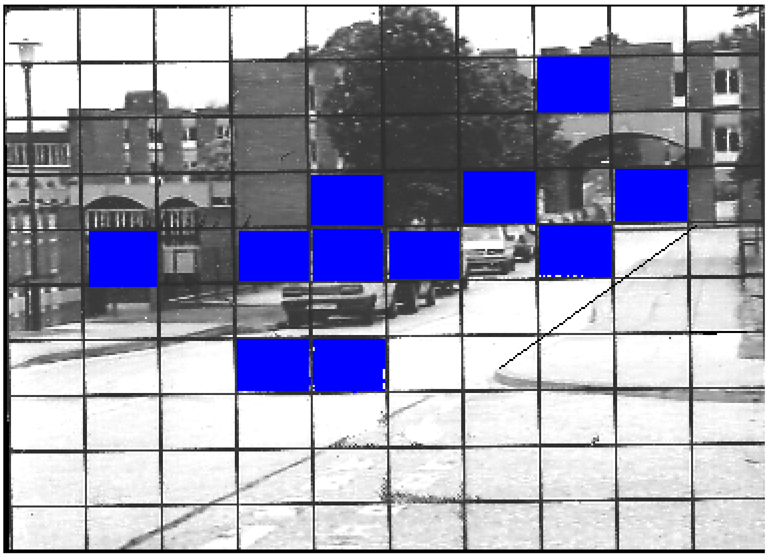
Figure 6-5 An example of on IM subject visual search pattern at an intersection. The shaded boxes represent all points where this subject fixated for more than two video frames during the entire two second display.



A summary of all subjects' search behaviour was completed. A summary represents a location where two or more participants fixated for more than two video frames in that location, represented by one box in the grid. Figure 6-6 and Figure 6-7 show a summary of where at a 'T' junction all EV/IV participants searched.

Figure 6-6 A Summary of EV search patterns at a 'T' junction. Shaded areas show where two or more participants maintained their fixation for more than two video frames.

Figure 6-7 Summary of IV search patterns at a ‘T’ junction. Shaded areas show where two or more participants maintained their fixation for more than two video frames



Novice and experienced participants appear to have had rather different fixation patterns. Experienced drivers were found to have a much more narrow search field. Inexperienced drivers appear to observe the scene and then fixate in more locations of the scene than did experienced drivers. Experienced drivers tended when searching ‘T’ junctions to search more limited parts of the scene and these tended to be located in the distance. Inexperienced drivers tend to fixate in more parts of the environment and these can include locations away from the road.

One way to interpret these data is that experienced drivers are tending to focus on areas of the road which they may believe through their experience to be informationally rich. Inexperienced drivers tend to search more locations for a hazard when viewing clear road scenes.

6.3.6.2 Roundabouts.

Clip 5 illustrated a mini roundabout. Figure 6-8 shows a summary of where EM, EV participants searched and Figure 6-9 shows a summary of where IV and IM drivers searched. Both groups search in remarkably similar locations with little difference in the amount of eye-movements in degrees arc.

Figure 6-8 -Shows a summary of all experienced drivers' fixation patterns in response to a mini roundabout. The shaded areas represent where two or more drivers maintained a fixation for two or more video frames.

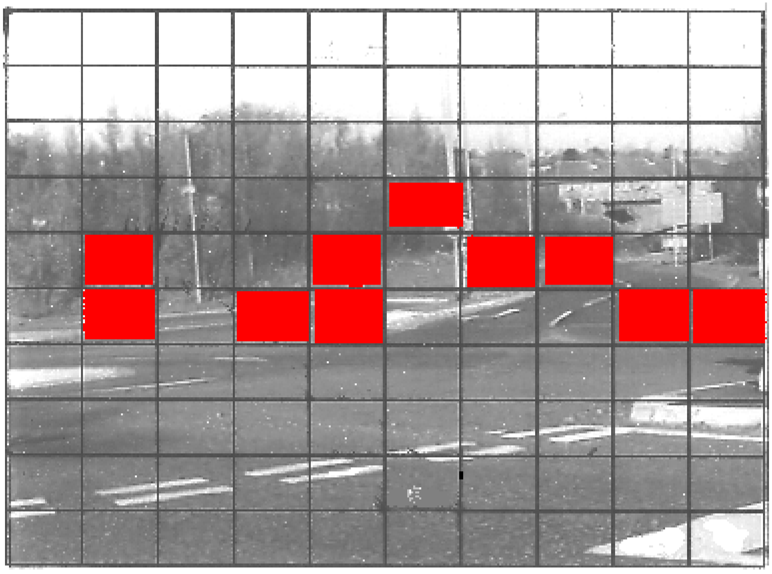
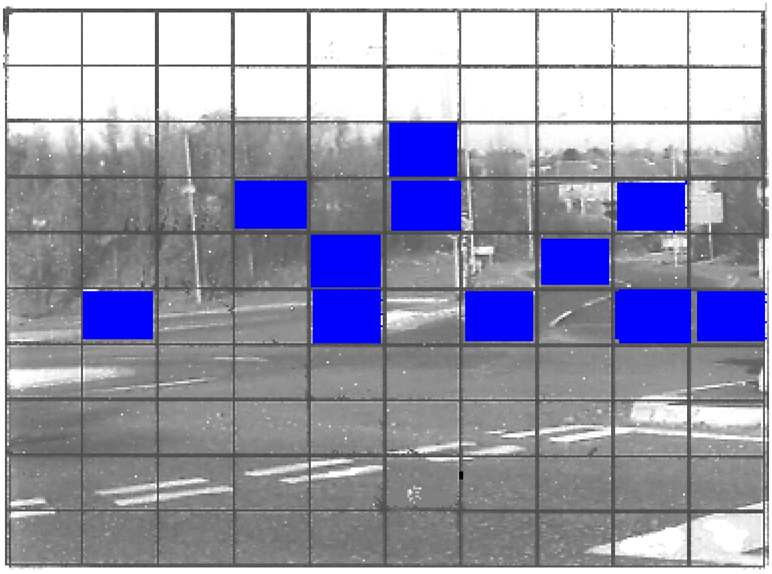


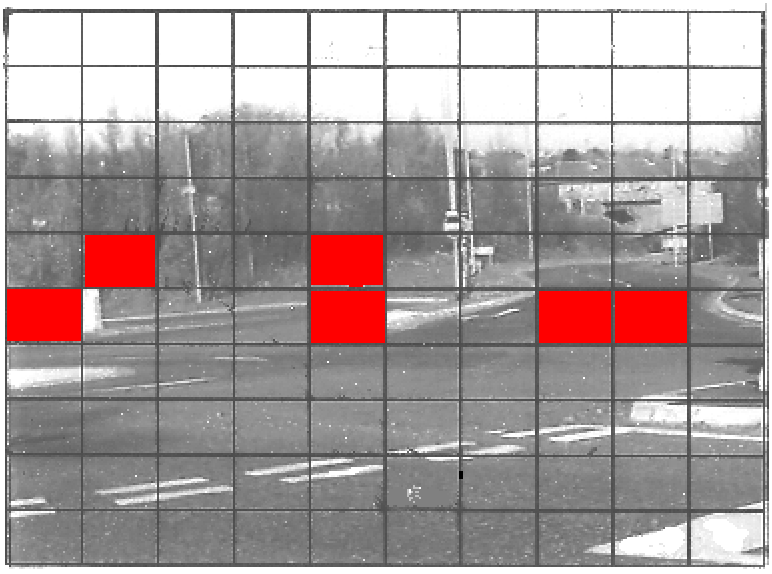
Figure 6-9 Shows a summary of all novice drivers' fixation patterns in response to a mini roundabout. The shaded areas represent where two or more drivers maintained a fixation for tow or more video frames.



In summary accounts of both novice and experienced drivers the fixation patterns are fairly similar. Both novices and experienced drivers search widely with few areas of the road environment unfixated. Because however there are many fixations the pattern of fixation is considered for two drivers. Figure 6-10

represents the fixation patterns of two participants selected on the quality of video image recorded

Figure 6-10 Shows the fixation pattern of two representatives, one of each condition, at a roundabout. The shaded areas represent where that subject maintained a fixation for a minimum of two video frames.



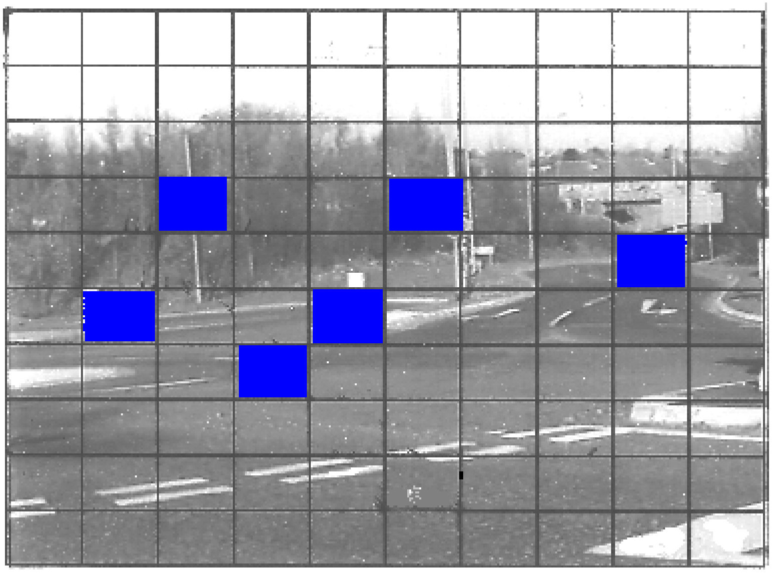


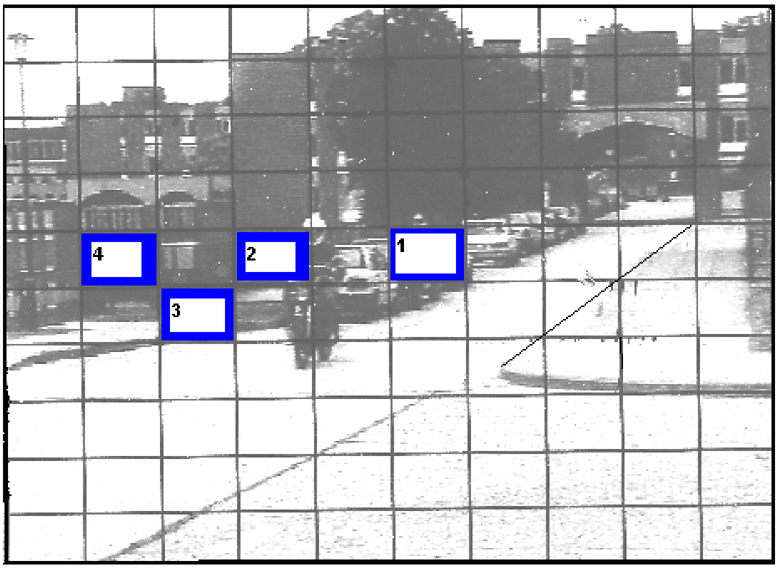
Figure 6-10 shows that at roundabouts both groups appeared to have made a more extensive search of the entire road scene compared to how they performed in response to the ‘T’ junction. Both novices and experienced drivers search at the entry point of the roundabout where traffic may appear but also search other parts of the scene. Novice drivers as with ‘T’ junctions tend to search outside the area that may contain a vehicle.

6.3.6.3 Eye movements when the motorcycle is close (Clip 8)

The Hurt report (1981) found that the motorcyclist is likely to be very close to the junction when the car driver makes the decision to emerge. Clip 8 showed a motorcycle close to the junction and had the driver decided to emerge the motorcyclist would have been hit. Therefore what is of interest here is where the driver first fixates and then where subsequent fixations occur. Figure 6-11 and Figure 6-12 shows the eye-movements of two participants again selected on the basis of the quality of images recorded. These are labelled with the order of fixation. Fixation point 1 shows where the driver was fixating when the video clip appeared. The first fixation during search is labelled number 2.

Figure 6-11 Shows the fixation pattern of an experienced driver who has been instructed to search for a motorcycle. The shaded areas are numbered to reflect the order in which the driver fixated the scene. The box labelled number 1 represents the location of where the driver was looking when the video clip appeared. This shows that for the experienced driver the second fixation of the scene is not to the target motorcycle but towards the distance.

Figure 6-12 Shows the fixation pattern of an novice driver who has been instructed to search for a motorcycle. The shaded areas are numbered to reflect the order in which the driver fixated the scene. The box labelled number 1 represents the location of where the driver was looking when the video clip appeared.



The above figures show that these particular novice and experienced drivers selected for review fixated in different parts of the road environment. The first fixation for the novice driver after the image appeared was to the motorcycle. The novice then fixated on the moving motorcycle during fixations 3 and 4. The experienced driver however fixated away from the motorcycle in their first fixation after the clip appeared towards the area in the distance. Only their third fixation was on the motorcyclist. However unlike the novice driver the experienced driver continued to search the scene making further fixations into the distance. Summary accounts of all drivers in each condition are difficult to represent.

6.3.6.4 Effects of the instructions

Search instructions do not appear to have as much effect as hypothesised. Table 6-1 shows little difference in visual search in terms of the number of saccades as a consequence of the type of instruction type given. Eye-movement fixation patterns are very similar for drivers irrespective of the type of instruction to search in location - within one fixation grid box.

*6.4 **Discussion***

6.4.1 Patterns and eye-movement

Venger (1971) claims that with experience eye-movement patterns move between three distinct stages continuing from 'partial' to 'exhaustive' and finally 'efficient' (see 6.1.2). Examination of drivers' fixation patterns in the present experiment suggests that two distinct patterns are observed. The inexperienced driver's search pattern of a clear road could be described as exhaustive. The patterns are wide ranging and show large search movements. Venger's word 'exhaustive' certainly describes the inexperienced driver's eye-movements but is all this movement efficient? It is not efficient in the sense that it takes longer to search the whole scene rather than the parts but it is efficient in the sense that it is a comprehensive search strategy. The experienced driver's search strategy is efficient but the experienced driver only searches the part of the road environment that is rich in potential hazards. Is this partial search efficient? It is for the amount of time taken but it may lead to sections of the road not being searched (even though they might be unlikely to contain a vehicle).

Is there evidence of Lashley's 'syntax of movement' or of Levy-Schoen's (1984) claims of a perceptual set or a motor routine around which oculomotor behaviour will be organised ? Figure 6-5 and Figure 6-6 shows that experienced drivers fixate in different locations to novice drivers. One interpretation of the data is that experienced drivers develop a motor routine to fixate only in limited parts of the road environment at 'T' junctions. Novice drivers have not yet developed a motor routine to efficiently search at an intersection thus a wider search pattern that includes fixations away from the road environment is evident. The prepared motor routine is indicated by why firstly the experienced driver searches the parts of the road that may contain a hazard and is unlikely to fixate elsewhere. Figure 6-11 and Figure 6-12 show that the experienced subject unlike the novice, searches away from the target after the first fixation. This may be interpreted that because the novice who may have no motor routine developed for dealing with junctions, fixates only on the target.

Klien (1980) concludes that saccades could be made without shifts in attention. This experiment measures only where the gaze is directed. There is no measure if the driver is actually attending to the point at which s/he is fixating.

6.4.2 Informationally Rich or Contour Complex?

Antes (1984) suggests that eye-movements are firstly to locations which are informationally rich. In this study the data shows that the experienced driver tended to look first at the point in the scene where it is most likely a car would appear. However there are difficulties in interpreting the data. Totes (1985) reported that background complexity can also affect saccadic movement, and that with complex backgrounds participants tended to centre on the entire stimulus or scene. Experienced drivers did not appear to focus on areas of greatest contour density but on the road where there may be vehicles. This was also true of the novice driver. However once inexperienced drivers had located the target they tended then to direct their gaze away from the road to other features in the scene. These features tended to be trees, the most contour complex objects in the scene. Similar results for novice drivers were found by Dishart (1997).

6.4.3 Implications for the L.B.F.S. error

The data do not concur with all previous eye-movement studies. Mean fixation time differences between novices and experts as found by Cohen (1981), Henderson *et al.* (1989) and discussed by Underwood and Everett (1992) were not found. Increased fixation duration by novices attributed by these studies to indicate extra cognitive processing by the novice driver implies that the inexperienced driver is undertaking a less automated process (Crundall and Underwood 1997. In line with Antes (1974) and Antes *et al.* (1978) findings in the visual scanning of naturalistic scenes showed that first fixations for experienced drivers were to parts of the road environment that were potentially informationally rich. The results support Ellis and Stark's (1986) claim that eye-movements are not random but indicate an active seeking of potential information based on knowledge, training or experience.

6.4.4 Do drivers search the entire field of view?

In general terms experienced drivers do not search in all parts of the road environment. The useful field of view is the important aspect here. The video screen contains all the information that a driver needs in order to make a decision

to emerge into a main road. Given this as the total FOV do drivers search the whole of the screen?

On reviewing Figure 6-4 - Figure 6-12 it would appear that the participants did not examine the entire scene but instead tended to examine a relatively small area of the video screen in front of them, with differences being found between inexperienced and experienced drivers.

The screen contained the entire view that a driver would see. If we examine the part of the scene where vehicles might appear, do drivers search that useful field of view? Even if this more limited field of view is used drivers still did not actively search the entire scene. This was particularly true of experienced drivers who appeared to have the most limited search of all.

6.4.5 Do different types of junction elicit different types of search?

Rahimi *et al.* (1990) found where drivers looked was affected by the type of turn configuration. In the study reported here differences are found in eye-movements between ‘T’ junctions and roundabouts. The number of fixations agrees with Laya’s (1987) study that examined roundabouts. The typical number of saccades in response to a ‘T’ Junction was between 2-4 but to roundabouts was 5-7. Results are similar to those proposed by Liu (1997) who claims that drivers develop eye-movement fixation patterns for different driving tasks which are superimposed on each other rather than the driver formulating new patterns each time they search a particular type of road environment. Liu (1997) claims that distinct differences in fixation patterns can be detected according to the driver’s task.

Can the differences in eye movements found between different junction types be related to accident involvement. Chapter 3 (p.71) found that more motorcycle accidents occurred at ‘T’ junctions than at roundabouts. Do these differences in search patterns between ‘T’ junctions and roundabouts contribute to any understanding of why this may be so? This depends on whether we accept that eye movements reveal anything about cognition. Does less pointing of the eyes mean that less of the road is being searched?

6.4.5.1 Other evidence of limited visual search

Morant and Rockwell (1972) report that novice drivers search close to their vehicles when driving on highways - an unsafe strategy. Similar results are reported here where novice drivers search the road environment directly in front of the junction compared with experiences drivers who fixate only in the distance from the intersection. Chapter 3 illustrated differences in accident involvement between young and old drivers, with young drivers not being over-represented in the data. Does the wider search pattern with the inexperienced driver fixating close to the vehicle mean they are less likely to hit a motorcyclist? Kito *et al.*’s (1989) results indicate that experienced truck drivers’ fixation patterns showed a peak at the point 50-60 degrees to the right and left of the median plane of the driver. They comment that a region of 20 degrees either side of the median plane of the driver (i.e. directly in front of them) is left relatively unfixated. This may be particularly important in motorcycle accidents where, because of its small size, the motorcycle is often within this 20° angle from the centre of the driver when it is hit (Hurt *et al.* 1981). The results reported here suggest that experienced drivers do not fixate within this region.

Wierda and Maring (1992) showed that young cyclists fixate more often on irrelevant areas of the environment and are less able than adults to detect hazards such as cars. They fixate more often on irrelevant moving stimuli (e.g. joggers) than adults. In this case Figure 6-8 - reveals that novice drivers search in areas that, in terms of Antes (1974), are informationally poor as far as the driving task is concerned.

6.4.6 Effects of Instruction

Chapter 5 (p 105) reports differences in detection success according to the instructions given to the participants but this was not found here. However the fact that no difference in eye-movements were found here between the groups is consistent with Cole and Hughes (1993) who found that instruction type (search for certain types of road sign) did not affect driver's eye-movements but did affect detection success.

6.4.7 Later replication

An attempt was made to replicate these results using expert police drivers (the study is not reported in this thesis). Langham, Hole, O'Neil, Cook and Land (1998) investigated how police traffic patrol officers searched at different types of junctions examining driver reaction time and visual search strategies by recording eye-movements. In their study fifteen police officers viewed 23 video clips which did or did not contain traffic. Police traffic officers were selected because it was thought that under conditions of free scanning the more salient parts of the stimuli would be inspected first (see Nodine 1992) and for longer periods of time (e.g. Antes 1974). Whilst experience is normally associated with expertise (Duncan *et al.* 1981) it was speculated that because of their training the macro-structure of their 'visual scan-path' (Levy-Schoen 1981) would mean that only certain parts of the road environment would be selected because police drivers need to emerge rapidly at intersections. It was hypothesised that experts again would support Laya's (1980) view that drivers would perform a wide search at a roundabout like the experienced drivers reported here. However, police pursuit drivers only fixated at the entry point of the roundabout making on average 2-3 saccades.

The short visual search expected at 'T' junctions with fixation supporting Mourant and Rockwell's (1970,1972) conclusion that experienced drivers only sample in the distance when driving (as police driver training insists they do) was not found. Police drivers fixate in many parts of the road environment at 'T' junctions. In many ways their fixation patterns resembled those of novice drivers leaving little of the road environment unfixated although they did not fixate on buildings or trees. One video clip shown to the police officers displayed a conspicuous motorcycle close to the viewer. The combination of background and target location was hypothesised to result in the failure of an experienced driver to detect it. Using bright conspicuous target will in Engles' (1971, 1977) view attract attention to a conspicuous object. i.e. the object exerts control over the visual selection system. In Engles' view the top-down processes should orientate the attention system into certain spatial locations within the scene but when fixation is close to 'the conspicuous lobe' then eye-movements will firstly be towards the target. If eye-movements are however driven by a pre-determined scan-path routine then where a driver looks will not necessarily be to the most conspicuous target in the scene. The results were mixed but some drivers (5 out of 15) did not fixate first on the conspicuous target but searched other areas of the road.

However, the major problem with this experiment was that of the 298 responses recorded 19 of them (6.4%) were incorrect. Police officers appeared to trade speed for accuracy. The experiment had many problems one of which was the unusual way police officers moved their heads when wearing the equipment. Unlike the participants reported in this study police officers searched beyond the visible view of the video screen and made head movements that dislodged the equipment.

The study was replicated in the field driving a route that the 23 video clips they had seen represented. However, because of the atypical head moving strategy of police officers and the video equipment used to record their eye-movements little data was obtained.

6.4.8 Problems

6.4.8.1 Participants

The sample is not truly representative of the population of drivers. Participants tended to be young and fit. Although Chapter 2 (p 60) stresses the importance of a representational sample this was not possible as older participants did not meet the medical requirements for taking part in this experiment because they tended to wear glasses or were on medication.

6.4.8.2 Display Time

The display time used poorly reflected the actual amount of time a driver would search at the junction as observed in Chapter 4 (p.83). Schyns and Oliva (1994) contend that when participants look at naturalistic scenes, that before eye-movements take place (under 300 milliseconds) the global details of the scene are extracted. This may show that the driver at a junction takes the broad global description of the scene first then moves their eyes to locate that area which may or may not contain a vehicle. Later experiments will return to this issue.

6.5 Conclusion

In interpreting the data only general conclusions can be drawn. The data may be considered generally in line with the hypothesis that driving becomes an automated task and that drivers fixate firstly on some parts of the road environment over others. This strategy in fixating on limited parts of the road environment may lead to the failure of detection of a motorcycle. This chapter suggests that experienced drivers may adopt an efficient search strategy that is perhaps programmed by previous encounters with similar junctions. The pre-programmed ‘T’ junction search allows the experienced driver to look in the areas where the majority of vehicles would be detected. However, there is a possibility of a small gap in the driver’s search pattern that most of the time is irrelevant because the majority of road vehicles are too big to fit into the gap. Most of the time motorcycles would also be too big. However, in environments making high task demands of the driver’s visual search, such as driving in urban traffic, this gap may in effect grow as the cognitive system concentrates on a smaller (foveal) area. This concentration on the foveal vision may be at the cost of the peripheral visual system processing. This contrasts with the inexperienced driver’s extensive

search pattern. Novice driver's search is more extensive and is more likely to detect targets appearing in unusual places. In contrast, at roundabouts where a limited fixation pattern was not apparent with the experienced drivers. A wide extensive search appears to occur at such junctions with no apparent gap that might contain a vehicle. Whether these eye fixation patterns can be used as evidence of why L.B.F.S. error occurs at particular types of junction is debatable. Evidence that eye-movements directly reveal something cognitive or that detection is always related to fixation is open to discussion. These results should be used to support further investigation.

7. Can object recognition theories explain the L.B.F.S. error?

7.1 Introduction

An alternative explanation for why drivers may 'look' but fail to 'see' the motorcyclist is that the motorcycle may not be recognised as a motorised vehicle. This chapter returns to the theme that the selective attention mechanisms which account for human skill in extracting information from a complex environment, may fail in recognising the target as a hazard (the 'what'). Some researchers have contended that attention is allocated to objects rather than locations (e.g. Duncan 1984, Vecera and Farah 1994). The concept of an 'object' implies spatial continuity or connectiveness because two objects cannot occupy a single space. Pashler (1998) shows that visual attention is not necessarily allocated to gross spatially convex areas of space as popular metaphors of a spotlight imply (Chapter 1). This is particular true, claims Pashler, when discussing the use of laboratory studies of selective visual attention to understand the real world because there are objects in naturalistic scenes rather than the blank space prior to the arrival of a stimulus.

The identification of objects in the visual environment plays an important role in every day activities (Theeuwes 1992). Olson (1989) and Wulf *et al*, (1989) give an explanation of the motorcycle L.B.F.S. error as a failure by the car driver to identify the motorcycle as a hazard. They describe the L.B.F.S. error as being caused by the motorcycle presenting a shape that is similar to a non-motorised vehicle, or alternatively a shape which is so different from the expected car, that the car driver fails to identify the motorcyclist's presence. As Olson (1989) points out the shape of a motorcycle is predominantly a vertical profile whereas the car driver is expecting to see the horizontal profile of a car. This experiment investigates if drivers 'look' but then fail to 'see' a motorcyclist because the driver is searching for one 'shape' over another. Therefore the problem of failure to detect a motorcyclist is considered from the perspective of object recognition and scene interpretation.

7.1.1 Scene and object recognition.

How does the driver rapidly understand a scene, and detect a target, all in a dynamic environment, where targets (vehicles) may occlude each other and each scene is essentially novel? This experiment measures what experienced and novice drivers are looking for at a junction using a theoretical framework of rapid scene interpretation. The 'what' a driver is looking for, claim Theeuwes *et al.* (1997), is important in understanding late detection accidents where the driver may be searching for prototypical shapes that represent a hazard.

Many views exist that purport to account for how humans so successfully recognise objects and interpret scenes (reviews in Humphreys 1992, Schyns and Oliva, 1994, Ullman 1984). Theories are essentially complementary, however as Humphreys describes, the implementation of these theories fails catastrophically when 'wheeled out into the real-world of noisy images'. The fact that we recognise objects within a scene implies that humans have some kind of internal

representations to store and manipulate information about the shape of objects (Kirby and Kosslyn 1992). Dennett (1991) points out that our own sense that we have a richly detailed representation of a scene may be illusory. Rather, argues Dennett, this illustrates that we have an inner representation of the scene and that we merely have the ability to accrue extra information of the scene by moving our eyes.

7.1.1.1 Feature Primitives

There is general agreement that visual scenes are encoded along a basic set of feature primitives e.g. orientation of edge, colour, luminance etc. in the early stages of perception (Theeuwes 1992). Pre-attentive parallel search for basic shapes or primitives is demonstrated by 'present/absent' visual search tasks where participants are asked to make speeded decisions about whether a target which is defined by a specific feature is present or not (e.g. Treisman and Gelade 1980). Treisman and Sato (1990) propose a 'feature integration theory' of pre-attentive and attentive processing. In this theory, parallel search occurs over the whole of the visual field, when the target item is defined by a distinctive pre-attentively available feature which the non-targets do not share. Might the motorcycle L.B.F.S. error be caused by the motorcycle having a perceptual feature that is common to non-targets?

How are thousands of objects recognised from stored representations that are triggered by widely different retinal images? Modern approaches to vision often conceive scene recognition as the penultimate result of a gradual bottom-up extraction of information of the scene with multiple systems for recognition (Logothetis and Sheinberg, 1996). Each theory emphases certain aspects of the scene to be important (e.g. motion or edge extraction) .

7.1.1.2 The importance of motion

Motion may be particularly important to separate objects from their surroundings and to recognise them (Kahnerman *et al*. 1992, Yantis 1992). Horn (1986) claims that there is little evidence to suggest how local motion signals might be used to extract the 3D shape of objects by analysis of the motion flow field. Others (review in Parker *et al.* 1992) believe there are suggestions how some higher order processing of motion together with local motion signals might give information about the trajectory of moving objects. Gibson (e.g. 1950, 1979) emphasised that the smooth change of the image on the retina provides a great deal of information about the observer's movement and about the 3D structure of the world (Harris, Freeman and Williams 1992). Gibson pointed out that as we approach an object its image gradually expands so that each point moves away from a unique 'locus of expansion'. Gibson believed that movement relative to a fixed rigid surface will produce a smooth gradient of speed in the image and this gradient can tell us about the 3D layout of the surfaces. There are many studies which show how an observer can extract from retinal flow patterns (optic flow on the retina) expanding motion to understand 'time to collision' (TTC) (e.g. Schiff 1965, Schiff and Oldak 1990, also Chapter 2). More recent work has considered the role of retinal motion in recovering 3D object form (Braunstien and Anderson 1984, review in Harris, Freeman and Williams 1992).

Detecting objects or particular shapes by identifying their edges has been particularly popular in computational accounts of object recognition. The logic is simple claims Watt (1992). The viewed scene is made up of a number of individual items which when viewed from one particular place have different characteristics of occluding edges with different surface reflections and illuminations. Therefore edges between different objects project a change in image intensity identifying different objects from their surroundings. Edge maps - the differences in values of brightness and reflectivity of parts of a scene - have a certain appeal because these maps provide a summary of the objects contained in the scene. It has been supposed, more intuitively than by empirical means, that human low level visual systems may produce an edge map.

Previous motorcycle L.B.F.S. research has focused on low level vision accounts of accident causality concentrating on the properties of the stimulus input. In simple terms, research has concentrated on the driver's ability to detect the edges of the stimulus by the use of brighter colours to discriminate the target from its background. However, if an account of high-level vision is used to describe the L.B.F.S. error (See Chapter 1) we need to understand how the driver is using stored information about the possible target, and specifically, how this is utilised in the later processes of object recognition and identification. Understanding how drivers recognise objects may help us to account for rapid image processing by the driver at the intersection and may provide insight into why failures may occur.

7.1.1.3 Computational Approaches

Computational approaches (e.g. Marr 1982) postulate that early visual processing is handled by modules dedicated to simple tasks (motion perception, and edge detection) whose outputs are integrated into more complicated modules (e.g. object and scene recognition). The importance of 3D shape primitives was recognised by Marr and Nishihara (1978) who proposed that 3D objects can be represented in object centred co-ordinates by hierarchical descriptions called generalised cylinders at various levels of resolution. Object centred co-ordinates are defined as the shape of the object being described relative to the intrinsic properties of the object itself such as its axis of elongation. Because each generalised cylinder has its own intrinsic axis, this axis is used to define the reference orientation relative to which the object's shape can be represented thus providing an orientation invariant description that be used to identify the object (Palmer 1992).

7.1.1.4 Scene Schema hypotheses

Some theories relate rapid scene interpretation to the recognition of specific objects within the scene. A scene is recognised after a few diagnostic objects are recognised from local information such as object contours. In general 'scene schema hypotheses' theories (e.g. Antes and Penland 1981, Biederman 1982, de Graef 1992, Friedman 1979) suggest that fast scene interpretation depends on an early activation of a few scene representations in memory to drive a top down extraction of information.

Schyns and Oliva (1994) applied scene schema theories to understand how humans rapidly interpret scenes of cities and found at the first stage (before eye-movements) in the extraction process only coarse descriptions of the scene were used (under 300 milliseconds). The subject can classify only the type of scene they are looking at. Participants then search for particular objects in the scene

(e.g. vehicles or buildings). This may imply that with typical search times found in Chapter 4 82 participants may be extracting only global descriptions of the scene. Therefore this chapter focuses on how drivers might interpret a road scene in terms of such coarse descriptions or simple volumetric shapes. The aim is to understand 'what' the driver is expecting to see and as Olson (1989) suggests, whether the L.B.F.S. error is a failure to recognise the motorcycle as an hazard.

7.1.2 Low spatial frequencies and coarse descriptors

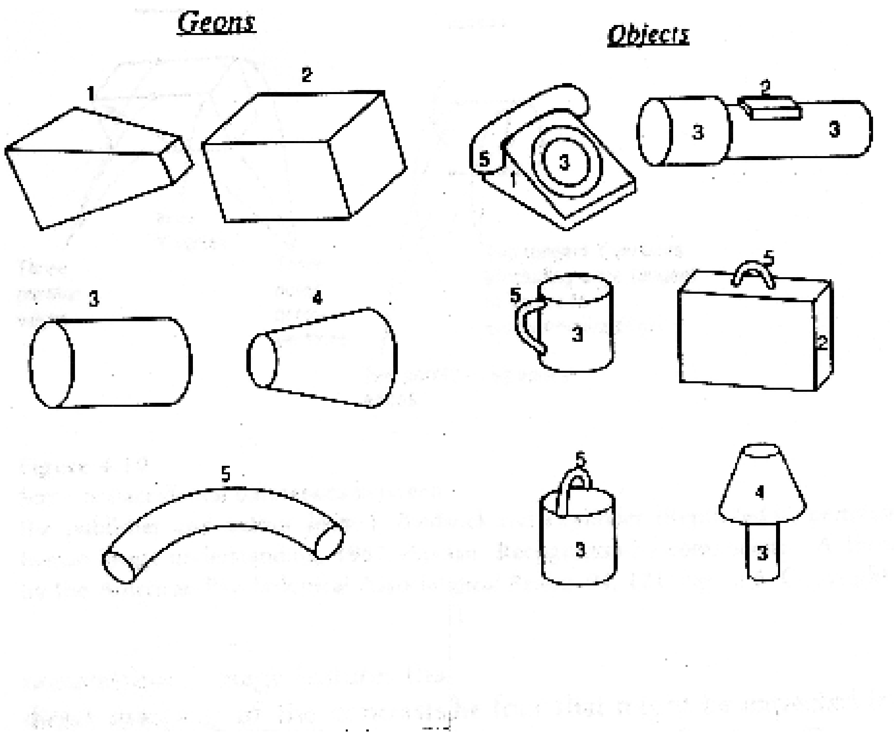
Originally suggested by Campbell and Robson (e.g. 1968) visual spatial frequency refers to the frequency of change in a periodic pattern within a given distance on the retina. The unit used to express spatial frequency is the number of cycles that fall within 1° of visual angle (each cycle being a light and a dark bar). Broadbent (1977) claims that low frequency attributes of objects define global structures and high frequency provides the detail. Navon and Norman (1983) found that people respond more quickly to low spatial frequency information than to higher spatial frequencies. Davis, Kramer and Graham (1983) and Peterssik (1978) found that when stimuli are presented very briefly, only the low frequency components find their way into our perceptual experience. Lambert and Fleury (1994) found that older drivers may use low spatial frequencies to detect road signs. Do drivers search for certain spatial frequencies at intersections? Moreover, does this low frequency extraction mean that drivers fail to recognise the motorcyclist because the motorcyclists' spatial frequency components differ to those of cars?

7.1.3 Recognition By Components

Recognition by components (RBC) offers an account of how humans can rapidly and accurately classify images of objects at a base level (Biederman 1995). The base level being the most general level of a class that specifies shape information. RBC assumes that complex visual objects can be decomposed into simple components typically as regions of matched concavities. Biederman (1987) argues that complex visual shapes can be decomposed into 24 volumetric shapes or primitives. These primitives can be described as a family of 'generalised cones' or Geons (for geometric icons). Geon shapes are therefore; bricks, cylinders, cones and wedges. The image properties from which Geons are activated are viewpoint invariant and are resistant to degradation. Geon determination requires only categorical classification of edge characteristic to activate a recognition in memory. No precise details of the object are needed. Such general recognition therefore accounts for rapid recognition of objects without precise detailed knowledge.

Biederman (1987) claims that Geon theory accounts for our ability to recognise a pattern or object in a single glance. Much debate exists about how representations are encoded and stored in memory but general agreement exists that some comparison is made between our memory for an object and the image that is appearing on the retina. (See Kosslyn 1981, Kirby and Kosslyn 1992). Figure 7-1 shows how objects may be made up of generalised icons. While the present experiment cannot directly assess whether participants are using 'Geons' to recognise vehicles (as opposed to other forms of shape primitive) the following discussion will use Biederman's theory as a theoretical framework.

Figure 7-1 Recognition by Components (from Biederman 1987)



7.1.4 Implementation

To investigate if drivers search for low spatial frequencies (or Geons) this experiment was conducted in the following way. Manipulated images of a motorcycle approaching a junction were replaced with a vertical rectangle low spatial frequency 'blob' or Geon depending on ones theoretical stance. The vertical bar shown was the same size as the actual motorcycle expanding to the same size and tracked along the road in the same way. By replacing the motorcycle with the geon (or low spatial frequency shape) I was interested in whether drivers respond that a motorcycle is present in the scene and do not notice the deception. If Hole and Tyrrell (1996) (see also Chapter 5, van Elslande and Faucher-Alberton 1997) is correct that drivers use relatively impoverished visual cues (i.e. short hand codes) about their environment when driving, participants who are experienced drivers (i.e. have developed short hand codes) will respond to the presence of the geon **as if** it was the real motorcycle. Novice drivers whose driving has not yet become an automated process (e.g. Duncan *et al,* 1991) should readily notice that a motorcycle is not present in the scene and detect that only a simple volumetric shape exists. If experienced drivers respond as if a real motorcycle is present then this suggests something about how we rapidly interpret scenes when driving. Olson (1989) claims that drivers are expecting to see a generally horizontal profile of a car. Therefore a car was be replaced by a horizontal blob or bar. It was hypothesised that experienced drivers should respond to the presence of a horizontal geon **as if** it was a car. Novice drivers should notice that a car is not present because novices extract more information from the scene to enable them to make a decision which does not rely on any short hand codes.

Chapter 1 & Section 7.1.1.2 show the importance of movement as a cue to the presence of a vehicle as part of the object recognition process. Video presentation presented a complication in the understanding of the results. Do drivers search for simple volumetric shapes or for shapes that are moving, or

movement alone? The aim was to create an invisible moving ‘shape’ that would not actually have immediate obvious form but would cause a distortion in the optic flow. This would be a control condition to understand if it is the manipulated shape that the subject views or the fact that it is moving that is important in detection by the driver. This distortion would appear that an object was present and moving towards the viewer. A Mosaic distortion was used that moved across the screen in the same way as the real motorcycle (See 7.2.4).

7.1.4.1 Importance of instructions

Chapter 5 showed the importance of the instructions given to participants. Will instructions affect whether or not the drivers will specifically search for one shape over another? Drivers need to search either for ‘Vehicles’ or specifically for ‘Motorcycles’. However, in this case the driver is actually searching for either a vertical Geon representing a motorcycle (inspired by Olson 1989) or both a vertical Geon and a horizontal Geon representing a vehicle (motorcycles are a subset of vehicles). Participants will be given either of two separate search instructions (See Chapter 5 (p100). The detection of low spatial frequencies describing a motorcycle should be superior when the instruction to search for a motorcycle is given because the a vertical Geon is a close match to the participant’s own mental representation of a motorcycle and the subject will respond **as if** a motorcycle was present. As this experiment is essentially a subterfuge, an independent measures design was again chosen. Each participant therefore only viewed one type of Geon (‘Vertical’ ‘Horizontal’ or ‘Mosaic distortion’) and was provided with either set of instructions.

7.1.4.2 The use of Reaction Time as a measure

A further problem is the measurement of false negatives here. Does the pushing of a button equate with something which occurs in the real world? Is a difference in RT between conditions going to allow this to be shown? In previous motorcycle research RT is the only measure usually used (review in Wulf *et al*. 1989) but has been criticised as being an inappropriate measure (review in Thomson 1978 and Chapter 2). If drivers are using movement or shape to detect a motorcycle in a complex road scene why should the RT be different to detect a shape rather than a real motorcycle?

Clearly asking the participant outright “did you see a shape” would not be an appropriate measure. What is needed is a subtle interrogation of the participant. The subject was asked firstly what they thought the experiment was about, secondly how many motorcycles they saw and if they noticed anything unusual (See 7.2.6.2). When participants are shown a Geon that is concordant with the search instruction (e.g. a vertical Geon/a motorcycle), then the likelihood of the participant noticing the illusion should be less likely than a discordant Geon and instruction to search (e.g. a vertical geon/all vehicles). Experienced drivers should report less often that a subterfuge had occurred than novice drivers. This will be because experienced drivers are typically searching for low spatial frequencies that represent a vehicle.

Therefore RBC will be used to investigate if:

- Drivers are using limited visual cues when rapidly searching at an intersection to detect a target.

- These limited cues can be understood as consisting of low spatial frequencies which are enough for drivers to rapidly make a decision.
- Motorcycles are represented differently to cars.
- Drivers expect to see one shape over another.
- Differences will be found between experienced drivers and novices. Because novices do not rely on short hand codes develop by experience novice drivers will readily detect that no vehicle is actually present However experienced drivers will respond as if the video contain a vehicle

7.2 Method

7.2.1 Design

An independent measures was used with each subject viewing only one experimental condition.

7.2.2 Participants

Participants were recruited by advertisement located on the University of Sussex campus. Participants were staff and students of the Open University attending a Summer school. Initially 198 participants were tested (viewing manipulated images) with a mean age of 32 (Sd 9.32 years), participant ages ranged from 16 - 63 years in the inexperienced group and 19 - 58 in the experienced group. In both groups 60% were female and 40 % male. Driving experience ranged from to 0 to 45 years (mean number of years holding a full licence was 11). Drivers were asked if they met eyesight standards to drive. Experienced drivers were those with more than 2 years driving experience. Novices were those who did not drive or who had recently passed their driving test (within one month).

7.2.3 Stimuli

7.2.4 Geon generation

A section of video tape was selected on the basis of the quality of the image. The video was of a 1977 Honda CG125 motorcycle approaching a junction filmed from a car driver’s perspective who was waiting to emerge from the junction onto the main road. A section of video tape was selected that showed the motorcycle approaching the viewer from a distance of 50 metres until it reached 25 metres away. This represented 75 video frames. When the motorcycle was at 75 metres from the viewer the video tape was stopped and six co-ordinates of its position in the scene were measured. The co-ordinates were four locations that represented the four corners of the motorcycle and the relative position to centre of the video display. The co-ordinates were measured by Director 4 animation software. Therefore position co-ordinates for each corner of the motorcyclist together with relative expansion rate co-ordinates were derived. A grey rectangle was generated using Adobe Paintbox 2 and was superimposed on the original co-ordinates of where the motorcycle had been. The animation software using the digitising images superimposed a grey rectangle in the same co-ordinates for the all 75 video frames thus directly replacing the motorcyclist. A new video sequence was created showing only the motorcycle. A background was generated by digitising the SVHS video to form a consistent static image. The image of an animated shape moving and expanding towards the viewer was combined with the static image of the background. The same calculations were performed on the

new modified tape to ensure that the animated shape moved, tracked and expanded at the same rate as the motorcyclist. The process faithfully reproduced dips and bumps in the road surface that affected the movement of the original motorcycle. Figure 7-2 shows the 'motorcycle geon'.

The car geon was the same grey rectangle used to show the motorcyclist, rotated by 90° it tracked towards the viewer in the same way.

7.2.4.1 Examples of stimuli

Figure 7-2 Shows the vertical Geon close to the junction and represent its position in the final video frame 13 metres away from the viewer

Figure 7-3 Shows the horizontal Geon at the first video frame approximately 75 metres away from the viewer

The movement cue
The final 'illusion' was the Mosaic distortion. This was generated by copying a 32 grid 'pixel mosaic' from a Panasonic mixing desk. The effect is similar to the distortion used in quantised degrading of a stimulus used in face recognition experiments (e.g. Bachmann 1991). The image was digitised using non-linear editing facilities and then given the same treatment as other illusions. The quantised distortion comprised of a 32 grid pattern that reduced the background behind it to 32 squares reducing the image to 16 levels of colour and 3 levels of grey.[8]. Therefore in practice the illusion looked like a moving ripple in the background conveying a sense of motion yet without the impression of a coherent 'object'

Each of the three stimulus tapes contained only one of the modified stimuli

7.2.4.2 Summary of Stimulus Material

Tape: 1 Contained a vertical rectangle (to represent a motorcycle)
2 Geon rotated through 90° (i.e. Horizontal to represent a 'car')
3 A vertical Mosaic distortion (conveying a sense of motion without form)
4 Control condition real motorcycle (from Chapter 5 (p103)

Each clip lasted 0.5 of a second (Chapter 4). There were six clips shown to each participant and the tapes were identical to those described in the preceding chapters except for clip number 4. This contained one of the manipulated stimuli described above. Video clips were of three locations and contained images of cars, trucks and clear road. The target (and subsequent digitised Geon) was a 1977 Honda 125cc motorcycle. Video editing was performed on SVHS edit desk. Four tapes were made each consisting of 6 clips.

[8] Before this experiment is replicated National Panasonic should be contacted to obtain a full description of how this system works. Although software packages such as Adobe Photoshop can be used giving a more precise account of the quantisation process this package could not used with director 4 software or animated to video.

Clip order was:
1) Clear urban road.
2) Rural road with vehicles approaching.
3) Clear rural road .
4) Effect clip.(i.e. either a vertical, horizontal, mosaic image(ripple effect) or a control (manipulated) image)
5) Clear urban road.
6) A real motorcycle approaching the viewer

7.2.5 Apparatus

The video was shot using U-Matic broadcast tape by a professional film crew. Video editing was by a SVHS linear editor and subsequent copies were first generation copies. Geons and backgrounds were generated by an Apple Macintosh running Adobe Photoshop professional version 1 and Director 4 software. Image presentation and additional equipment are described in Chapter 5 (p.104).

7.2.6 Procedure

7.2.6.1 Instructions to participants

For each series of clips participants were asked to make either a specific 'search for a motorcycle' or general 'search for a vehicle'. The instructions were the same as in preceding experiments - described in Chapter 5.

The experiment was an independent measures design with each subject viewing only one effect clip in either of the search conditions. Participants viewed video clips on a SVHS video monitor in a darkened room (see Chapter 5). Participants were given a two way button box and allowed sufficient time to practice with it. Participants were asked questions about their driving experience and given either of two written instruction sheets. These instructions were also read to the subject.

Each subject therefore participated in only one of the following conditions.

'General Search' viewing a Vertical Geon	At clip position 4
'General Search' viewing a Horizontal Geon	"
'General Search' viewing a Mosaic distortion	"
'Specific Search' viewing a Vertical Geon	"
'Specific Search' viewing a Horizontal Geon	"
'Specific Search' viewing a Mosaic distortion	"

7.2.6.2 Interrogation of participants

After participants viewed all the clips they were asked the following questions:

What did you think this experiment is about?
and then
How many motorcycles did you see?
and then
Did you notice anything unusual about any of the clips?

Questions two and three were not asked if the participant reported noticing the deception in response to questions 1 or 2 .
The video lasted less than 60 seconds and the whole procedure less than 4 minutes.

7.3 Results.

7.3.1 Treatment of Results.

The following data were collected:
A) Subjects' reaction time in milliseconds to decide if each of the video clips contained a motorcycle or a vehicle and the decision if a vehicle was or was not present.
B) A 'noticed the deception' score rated by how easily the participant noticed the deception, if at all.

1 Commented before the end of the video
2 Commented after question 1 or 2
0 Did not notice the deception.

Data was disregarded in the following circumstances.

1) When the participant made more than one button depression error (one error in the entire sequence of clips)
2) When the subject failed to detect the actual motorcycle in clip 6.
3) If the reaction time exceeded two standard deviations from the mean in that condition.

7.3.2 Reaction time

Data reported below is for correct positive responses[9] and was initially analysed from 117 participants.

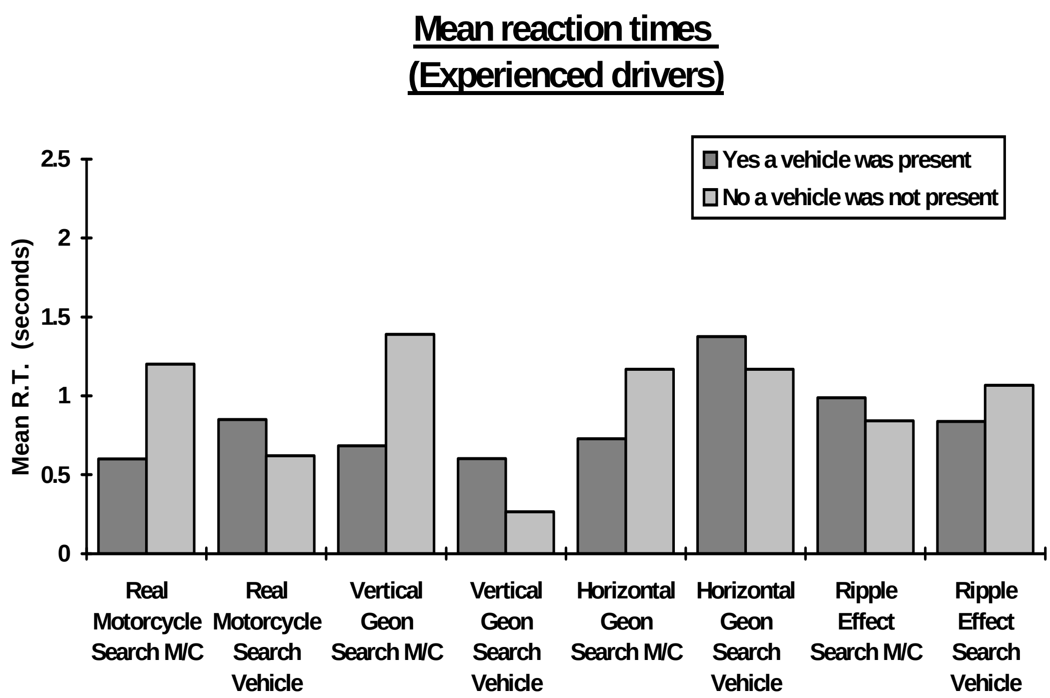
Data analysis was by a three way independent analysis of variance (ANOVA). The dependent variable being reaction times in milliseconds. Independent variables were Stimulus type, Search Instruction and Experience Level of the participant. Stimulus type therefore had three levels (Vertical, Horizontal and 'Mosaic distortion ') Search instructions had two levels (Specific Search and General search) Experience had two levels (Novice and Experienced driver).

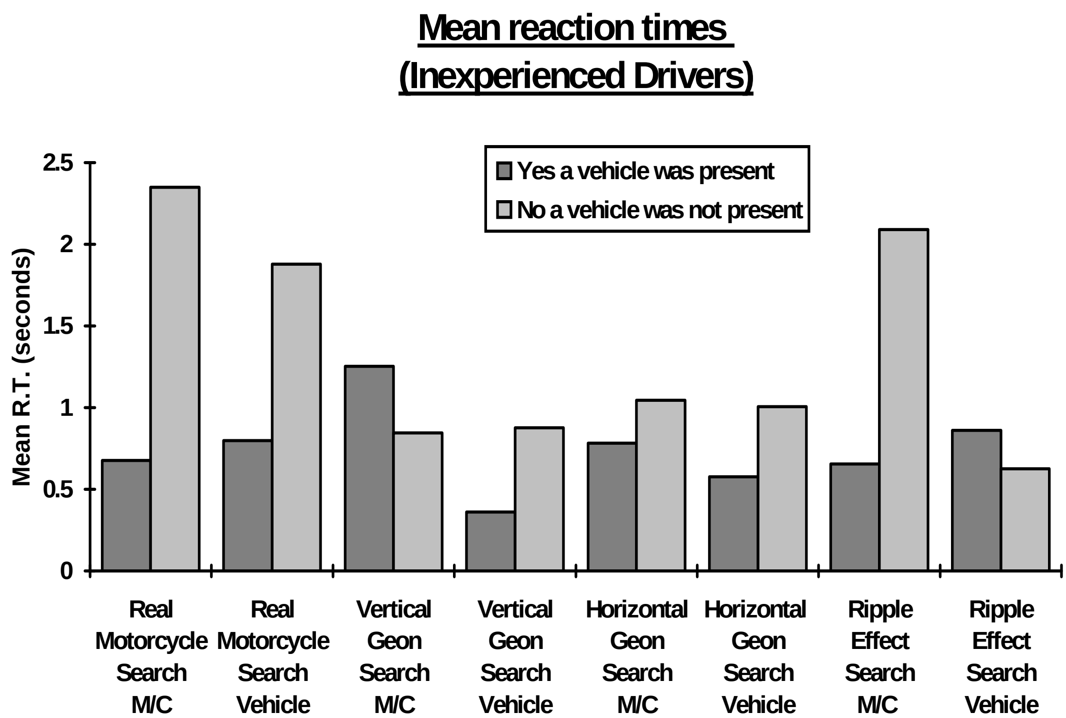
A main effect of instruction ($F(1,113) = 6.48$ $p<0.01$) was found. The means suggest that participants detected the manipulations image faster in the search for a motorcycle condition than they did in the search for vehicle condition. A main effect was also found for the stimulus type ($F(2,113) = 5.42$ $p< 0.05$). Generally reaction times were longer for participants viewing the Geon orientated in the

[9] One argument could be that for clip 4, all responses are valid, not just correct positive responses. One issue is that what does a 'yes' or a 'no' response actually mean because the subject is not viewing a 'real' motorcycle. The data from the 'yes' responses contain data from subject who either thought a real motorcycle was present or believed that they were required to push the yes button because the shape looked like a real vehicle and they might be expected to. Participants who responded 'no' either failed to detect the target, or thought that the vehicle was a Geon and not a vehicle. It is difficult if all the data were analysed to understand what a change in RT would mean. Because in some conditions many inexperienced drivers found it easy to tell that a vehicle was not present sample size in respect of inexperienced drivers is lower than power statistics would suggest is required. However I shall return to this issue in the discussion section.

horizontal plane. No main effect was found for experience (F (1,113 = .0.27 p<0.05.) An interaction was found between the orientation of the stimulus and the experience level of the driver. (F (2,112) 2.89 = p<0.05). No interactions were found for the type of instruction and level of experience (F (2,112 = .0.27 p<0.05) or for orientation and instruction (F (1,113 = .0.03 p<0.05). A three way interaction was found between orientation, the type of search instructions given to the participant and the experience level of the subject. (F= (2,113) = 0.01 p<0.05) was found. This suggests that drivers of certain experience levels tend to react differently to the stimuli in certain orientations based on the question they are posed. Figure 7-4 shows the means found.

Figure 7-4 Experienced and inexperienced drivers' mean reaction times to detect the manipulated image





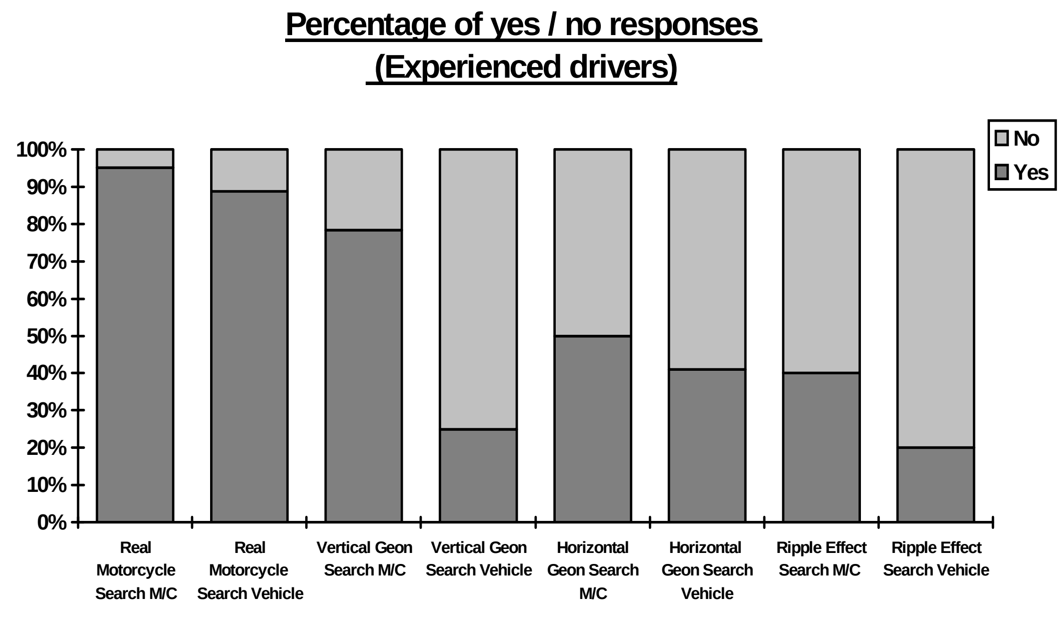
Reaction time data are difficult to interpret. The sample sizes are in some cases very small. Although significant main effects are found these results should be treated with caution. Post hoc analysis revealed that for the participants who

affirmed the presence of a vehicle, differences approaching significance are found between experienced and novice drivers' reaction times to detect the vertical geon when they were asked to search for a motorcycle (t (18) = 2.42 $p<0.01$). The means suggest that novice drivers process the image longer than do experienced drivers who appear to rapidly affirm the presence of the motorcycle. Considering the reaction times for novice drivers and experienced drivers who considered the horizontal geon to be a vehicle when they were instructed to search for all vehicles differences approaching significance are found (t (13) = 2.12 $p<0.01$). The means suggest that experienced drivers declare that a vehicle is present faster than novice drivers who may realise the illusion by spending extra time in processing the image.

7.3.3 Detection success

Figure 7-5 shows the number of participants who in each condition either decided by pushing the appropriate button that a motorcycle or a car was present. Significant differences were found between participants according to the instruction given and the orientation of the stimulus material. Experienced drivers were more likely to think that a vehicle was present than a novice if the instruction to search matched the orientation of the stimulus material for the vertical and horizontal images (x^2 = 5.89 df =1 $p<0.05$)

Figure 7-5 Percentage of yes and no responses for experienced and inexperienced drivers on seeing the manipulated image



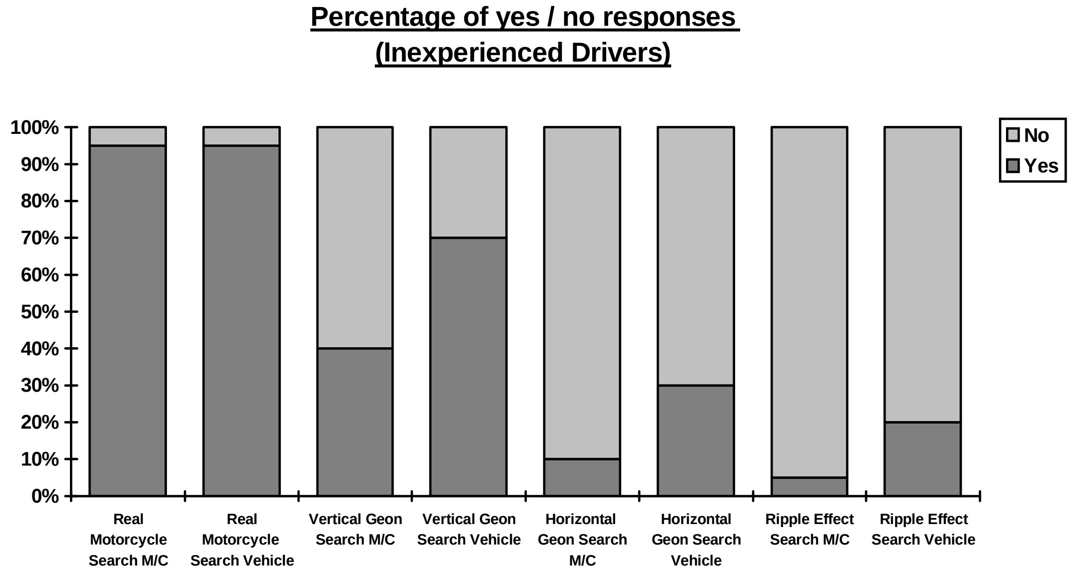
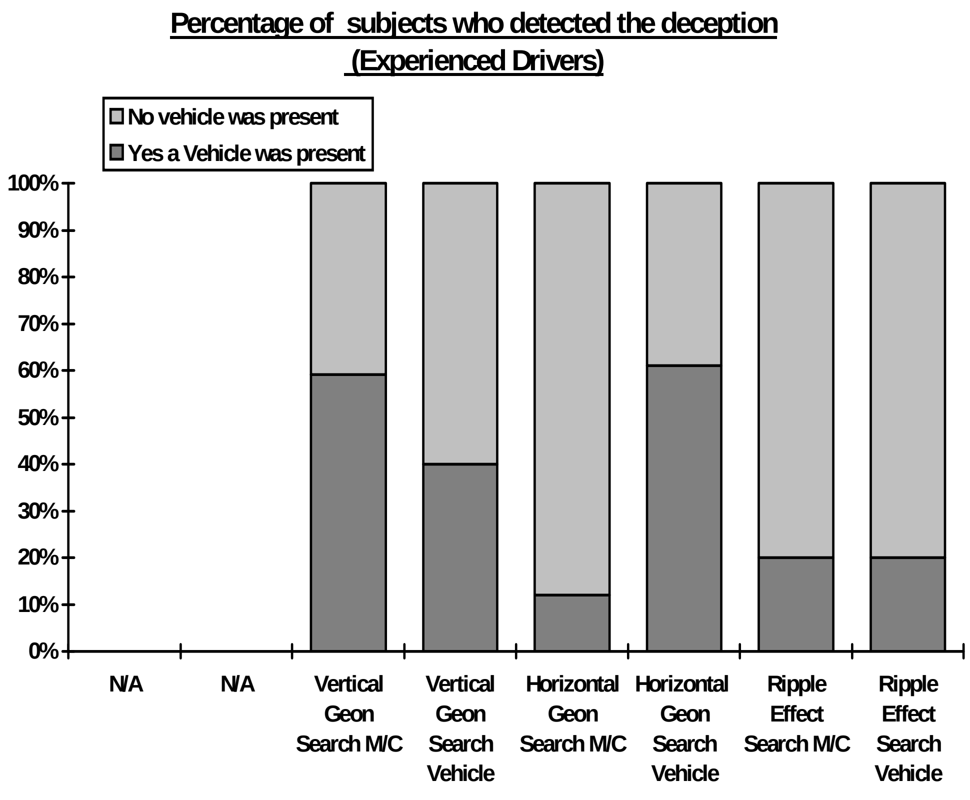


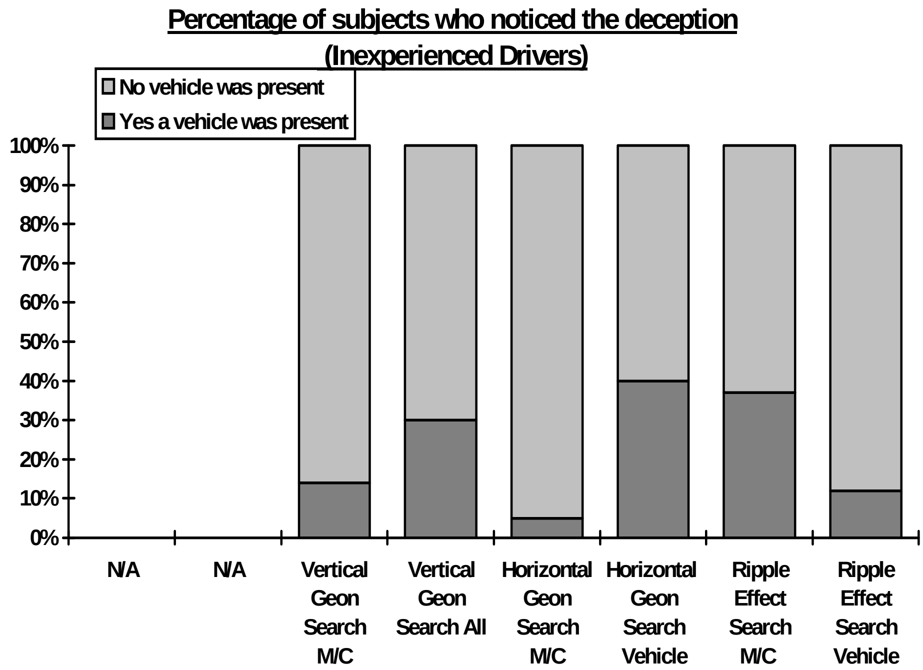
Figure 7-5 shows that inexperienced drivers tend to detect the illusion and consider it was not a vehicle whilst experienced drivers tended not to notice the deception except when they were instructed to search for a vehicle and were shown the vertical geon,. These effects are mediated by the instructions given to the subject and the orientation of the stimulus material.

7.3.4 Detection of Deception

Whether or not the subject noticed the illusion this was recorded after the viewing of the tape. There were two categories (either they realised the deception or failed to notice the deception). Significant differences were found between experienced and inexperienced participants. Of the solid effects, significant differences (x^2 = 39.573 df 1 $p<0.01$) were found for orientation of the animated shape. Figure 7-6 shows the percentage of participants who noticed if the video clip contained an illusion.

Figure 7-6 Shows the percentage of those who detected the deception in both experience and inexperienced drivers





The percentage of drivers who noticed the deception implies that inexperienced drivers tended to report more often that they noticed the deception than did experienced drivers. Experienced drivers noticed the deception more often if the instruction to search did not match the primitive shape that was thought most likely to represent that class of vehicle. Only a few experienced drivers considered the movement cues alone to represent a vehicle. Few inexperienced drivers considered the horizontal Geon to be a vehicle. All the drivers who considered the Mosaic distortion effect to be a vehicle were subsequently found to be police drivers.

7.4 Discussion

7.4.1 Key findings

Inexperienced drivers appeared not to perceive a simple shape as a vehicle and most noticed the deception immediately, often during the actual clip itself. Generally inexperienced drivers reported seeing the deception very rapidly in all conditions. Although the 'search motorcycle condition' when a motorcycle Geon was shown resulted in a longer reaction time - it is difficult to interpret these data. However in interpreting these data it should be noted that relatively small samples are used.

In either measure of performance (noticing the deception or reaction time) as in Chapter 5 the instructions to search affected the detection performance. There appears to be a relationship between the type of instruction given to the subject and their ability to respond as if a motorcycle was present. In all conditions mean RT suggests participants appear to take longer when searching specifically for a motorcycle. The orientation of the stimuli appear to be important during certain search instructions. When the orientation of the stimulus matched the shape primitive orientation, then participants were more likely to respond that a real vehicle was present than when the shape orientation was discordant to that suggested by the search instructions.

Interactions were found in the analysis of the RT for the response to the effect clip and for the ability to declare they had noticed the deception. Experienced drivers appeared to need just a shape to confirm that they believed there was a vehicle present. The amount of information required to declare that a vehicle was present may be represented adequately by a single Geon.
However in interpreting the data the effect could simply be due to different demand characteristics in the 'search for a vehicle' condition. In the 'search for a motorcycle' condition the participants are shown something that vaguely like looks like a motorcycle and they think 'the object I have just seen is not a motorcycle but obviously the experimenter wants me to respond to it as if it is'.

The data may be interpreted as showing that experienced drivers appeared to search for simple shapes. Highly experienced drivers appeared to regard the motion and shape information as a vehicle, because they responded to the Mosaic distortion effect as being a vehicle and did not report this deception after the clip had finished. Very experienced drivers were police pursuit drivers and driving test examiners. This group appeared only to need 'movement'. In interpreting the data in terms of the L.B.F.S. error it should be noted only eleven police officers took part and the sample is too small for firm conclusions to be drawn [10].

7.4.2 RBC, low spatial frequencies and rapid search

Was this an implementation of RBC? Conceptualising the task as a search for a single Geon underestimates the complexity of the task. Using the term Geon only reflects a way of describing the effects observed and the stimulus generated. The driver may not be looking for Geons but for low spatial frequencies.

This experiment may be considered as an implementation of Biederman's theoretical stance of using RBC as a theoretical framework. RBC does not for example directly postulate the importance of experience or expectancy especially in any pre-attentive process (although the simple diagnostic tools must develop somehow). Perhaps what is more plausible in terms of Broadbent's (1977) view is that the driver is searching for low spatial frequencies or coarse descriptions. The label 'Geon' possible only reflects my own preferences. This may be particularly important here because RBC has been thought of as a static paradigm used to understand simple images but this application has a naturalistic background with the subject expecting to see real objects or targets. O'Kane, Biederman, Cooper and Nystrom (1997) used degraded images of military vehicles under infrared lighting conditions. Although these scenes can be argued as naturalistic to the soldier the image definition was still comparably limited. Whether the application of movement was the important factor has only been speculated with a simulation of movement to a few participants. Relating these findings to Schyns and Oliva (1994) the display times of 500 milliseconds would suggest that only an analysis of the coarse description of the scene was undertaken. Low spatial frequencies may trigger from memory that a vehicle was present although the effects observed may be an artefact of the experimental manipulation.

[10] Police officers appear to use a heuristic of " movement means approaching vehicle" all the police officers form the traffic division who were tested in the condition were convinced that a vehicle was present. The effects have been demonstrated at several police conferences and it appears robust. Chapter 8 returns to this particular effect clip using longer display times and different backgrounds to examine if the effect can be generalised to other locations, because it is suspected that the background complexity of the scene may affect performance.

7.4.3 Problems and improvements

7.4.3.1 Effects of age.

One of the problems with this and previous experiments is that experience and age are inextricably linked. A problem when using RT as a measure is understanding what improvements or degradation in performance are due to age and which are due to experience. Using an independent measures design meant that participants were difficult to get in certain conditions. Older drivers are more experienced. There are no young experienced drivers - this is a theme returned to in Chapter 9.

7.4.4 Ecological Validity and the L.B.F.S. error

What was actually being measured? Is this task really the same as a driver searching at a junction? Do drivers really search for what are essentially moving low spatial frequency blobs? Chapter 1 and 7.1.2 show that low frequency signals may be important to the driver. Poor eyesight is not a significant contributory factor in accident involvement (Burg, 1975, Hills and Burg 1977) and it has been described as a paradox (Hills 1980) that drivers with poor acuity are not involved in more accidents. Perhaps then drivers are not involved in more accidents because the ability to resolve fine detail is not needed by the driver at the most common accident site - the intersection. Poor acuity may be reflected in the inability to read road information signs but not the detection of a hazard.

Although there are several problems here, the data may show that experience may affect ‘what’ experienced drivers are looking for and perceiving. If the attentional mechanisms postulated by Theeuwes (1994) are set for certain targets or hazards located somewhere in space then drivers’ expectancies ‘set’ for certain orientations or shapes (Hills 1980) may cause the driver to be searching for one shape over another, this may mean that the motorcycle will not trigger the response that a hazard is present. The main problem is designing a measure that can record these subtle but possibly important hypothesised differences.

7.4.5 Is the L.B.F.S. error a cost of experience?

We traditionally think of experience meaning an increase in skill or in performance (Duncan *et al*. 1991). In this case as in. Chapter 6 there appears to be some ‘cost’. The costs of experience may be illustrated in the interaction between the question asked and the orientation of the Geon. When experienced drivers are shown a Geon that is concordant with the search instructions given, the likelihood of them detecting the deception is reduced. When the search instructions do not match the Geon presented participants are more likely to detect the subterfuge. What is interesting is that experience may be making the driver search for the Geon format s/he will most often encounter unless s/he is reminded that a motorcycle is present.

7.4.6 Later replication

Police officers provided unusual data suggesting that movement cues were sufficient for them to respond **as if** a vehicle had been present. To investigate this the study was replicated using fifteen police officers (the study is not reported

here). Langham Hole, O'Neil, Cooke and Land (1998) displayed both illusions (ripple effect or mosaic distortion and the vertical rectangle) against a different backgrounds to those reported here. The final video clip (of 23) the participants viewed which was displayed for 2 seconds was a low spatial frequency representation of a motorcycle and clip 18 displayed the mosaic distortion. Differences were found in the time taken to respond to the illusion - those who responded under 0.5 seconds generally believed a vehicle was present (7 of 9). Those who responded after 0.5 seconds (2 of 6) tended to notice that an illusion had occurred. This implies that drivers who search rapidly at a junction may use low spatial frequencies to guide their search.

7.5 Conclusion

This study should be considered only as a preliminary investigation of drivers' visual search failure at intersections. Results are broadly in line with the idea that drivers are searching for expected prototypical shapes (e.g. Theeuwes 1997, Olson 1989) at an intersection. In interpreting the data only tentative conclusions can be made to suggest that a contributory cause of the L.B.F.S. error may be that the motorcycle 'shape primitive' is not that which is expected by the car driver. While the data may well suggest that experienced drivers are looking for shape primitives the problem is to design a measure that is sensitive enough to measure these findings in the context of the L.B.F.S error.

The major obstacle in the application of a laboratory based theory to the understanding of the problem is one of methodology. The implementation of RBC described here may be considered novel but whether this reveals the precise cause of the L.B.F.S. error is debatable. This experiment has firstly indicated that differences which exist between drivers of different experience level appear to exert a top down influence on the driver's behaviour, meaning that the driver may have certain expectancies about the road environment. This experiment has again shown that what is being searched for by the participant does influence the driver's search time. The experiment may show that experienced drivers use in some way low spatial frequencies when searching at a junction. The results may indicate that selective attention mechanisms may be driven to search for 'what' is expected in the visual field.

In reviewing the data from this and the preceding chapter both the spatial locations of 'where' in the environment and 'what ' the driver is searching for may contribute to the drivers statement "I did not see it". Although the driver reports a subjective experience of failing to detect a motorcycle, this might be in reality one of three possibilities:

- a failure to recognise the motorcycle as a hazard or
- to direct attention to the location where it is positioned on the road or
- a failure to see the motorcycle's shape as one that should be included in the general category 'approaching vehicle'.

These findings again suggest only that the L.B.F.S error may have many causal factors in addition to physical conspicuity.

8. Can the L.B.F.S. error involve highly conspicuous police vehicles? The possible role of conspicuity, vigilance and the false hypothesis.

8.1 Introduction

Chapter 1 highlights two distinct forms of the L.B.F.S. error (p 20). *Type 1* error was typified by a driver searching at a junction and was described as a failure of rapid visual search or selective attention. The *Type 11* error was associated with air accidents where pilots claim not to have seen a hazard although it had been visible for some time (e.g. Hurst and Hurst 1982). In pilot error the failure to detect was associated with a failure of sustained attention or vigilance (Chapter 1). This chapter examines vigilance failures where a driver on a motorway claims s/he did not see a highly conspicuous vehicle and reviews the possible psychological explanations for the *Type 11* error.

8.1.1 Visual size and the L.B.F.S. error

If we now account for why drivers apparently ‘look’ but fail to ‘see’ a motorcyclist at an intersection because of a failure in the human attention system rather than physical conspicuity, one issue still remains unaddressed. Wulf *et al.* (1989) and Olson (1989) suggest that the L.B.F.S. error may simply be caused by the small visual size of the motorcyclist. However Rensink (1997) and Lieberwitz (1983) contend that visual size is not important because large objects (e.g. railway trains) are hit by drivers who claim they did not see them. This chapter reports an investigation with police cars that are fitted with conspicuity enhancers and are believed to be conspicuous who are hit by drivers but who nevertheless claim they did not see them.

As in the case of motorcycles, failures to detect emergency service vehicles have been assumed to be physical conspicuity failures. The driver’s statement of failing to see them have been taken at face value and the solution to the problem has been thought to be to make the police car as physically conspicuous as possible. Figure 8-1 shows the view a driver will see when approaching a police vehicle. The vehicle is fitted with many conspicuity enhancers.

Figure 8-1 The rear of a police motorway patrol car,

8.1.2 The Problem

Prior to 1996 police vehicles were parked across the carriageway in the lane that contained the hazard so that the side of the vehicle was visible to oncoming drivers (hereafter referred to as ‘echelon’ parking). From 1996 ACPO guidelines (ACPO 1996, see also Cook 1996 and Thomas 1998) required the vehicle to park ‘in line’(hereafter referred to as 'in line') so that the rear of the police vehicle was visible to the oncoming traffic (i.e. the vehicle’s long axis was parallel to the lanes line marking). Their rationale was that ‘in-line’ parking would make the light bar on top of the vehicle and parallel to the rear of the car (see Figure 8-1) highly visible to the traffic. However the accidents involving police patrol cars that had been hit on carriageways by drivers who claimed not to have seen them appeared to increase

8.1.3 What does vigilance research tell us about this?

Why use a vigilance paradigm rather than a selective attention paradigm to explain these accidents? Posner and Boies (1971) suggest that the idea of attention generally encompasses three subdivisions. Firstly, it involves the alertness or the ability of an operator to maintain optimal sensitivity to external stimuli. Secondly, it requires the ability to concentrate awareness upon one source of information rather than another. Thirdly there are issues to do with the amount of limited processing that people show when trying to do two tasks. In essence the study of vigilance according to Davies and Parasurman (1982), is concerned with the first two areas. Warm (1984) claims that what is of interest in the study of vigilance is the ability of observers to maintain their focus of attention and remain alert to stimuli over prolonged periods of time. Monk (1984) describes the difference between vigilance and visual search as being: “vigilance is where non-signal temporal variability is often comparatively low and there is neither signal nor non signal variation”(p 88). Vigilance studies have usually a high level of signal temporal variability and a low level of forcing the subject to attend. Non signal temporal variability is usually low and typically neither signal nor non-signal

spatial variability exists. In visual search tasks the characteristic property is a high signal spatial variability, other variables being relatively low. Therefore we can think of vigilance as search that has been transferred from the spatial to the temporal domain and search as a vigilance task that has been transferred to the spatial domain. It could be argued the act of driving on a motorway mirrors most closely a vigilance task rather than a visual search task A driver on a motorway is often performing the task for several hours (Transport statistics 1996) so is not being forced to 'attend', hazards (accidents) are relatively rare (Chapter 3) and they appear in limited spatial locations.

Sustained attention is important in many practical situations including sonar and radar monitoring (e.g. Mackworth 1957) as well as vehicle guidance (Matthews, Davies and Holley 1993). Vigilance studies tend to focus on tasks where the participant needs to monitor and report possible minor changes to either a display screen or report if a target is present in a changing scene. Vigilance theories have attempted to understand the overall level of performance and what determines the decline in vigilance performance over time (Warm 1984). Vigilance research therefore measures detection rates, false alarms and detection latencies.
One measure of efficiency in vigilance tasks is the number of occasions on which a signal is reported when none in fact has been presented. To account for the decline in vigilance performance several theories (in general terms) have been postulated. Inhibition theory (review in Parasuraman and Davies 1977) envisages vigilance decrement as being analogous to the extinction of a conditioned response when that response is no longer reinforced. Filter theory (Broadbent 1977) accounts for vigilance failures because participants observing the same information for long periods of time are liable to intermittent interruption or 'internal blinks' which increase with time. The mechanism controlling the selection of information from the environment, processes more non relevant information through time. Arousal or activation theory (Mackworth 1968) relates the detection success and the decrement in performance to the level of arousal of the central nervous system which decreases with the length of the task. Habituation theory suggests that behavioural responses may be said to be habituated as a results of repeated stimulation. Motivation theory (Smith 1966) emphasises the role of interest and individual differences. Expectancy theory suggests that observers formulate expectancies about the future probability of signal occurrence on the basis of previous experience of the task and that detection rate is determined by the expectancy level. Expectancy models of vigilance have been postulated since the 1940's. Baker (1959) suggested that if participants expect temporal patterns very different to those they encounter it is the discrepancy between the subject's expectations and the stimulus actually encountered which is the principal cause of the results found in vigilance experiments. Loeb and Alluisi (1984) also suggest that performance is determined by uncertainties and expectancies based partially on previous experiences. The observer's level of expectancy is affected by the probability of signal occurrence. Therefore low signal probability equates to low expectancy. Participants develop a expectancy hypothesis about the likelihood of a stimulus appearing at a given rate of presentation. Detection failure is therefore explained in terms of the subject developing an expectancy of likely target rate from experience which is then changed by the experimenter and the decline in vigilance performance through time is because the subject has developed an idea when a target is likely or not to appear.

When driving on a motorway the driver is performing a monitoring task where hazards are being presented very rarely. Whilst spatial uncertainty is potentially great, in practice the 'where' a hazard may be on the road is relatively limited and predictable. Driving on a carriageway typically means the driver is monitoring for

hazards in his lane over a period of time. In this case therefore does the driver of a car on a motorway develop a hypothesis about the likelihood of seeing a hazard on a motorway and toward the end of his journey have a low expectancy about the likelihood of a hazard being present?

Therefore from laboratory studies on vigilance it can be seen that changes in signal detection with spatial temporal and signal strength affect the vigilance task. Measures tend not to be reaction times but focus on the success of detection. Most research although not all, finds a performance decrement throughout the time spent on the task. (Matthews, Davies and Holley 1993).

8.1.4 What do vigilance failures by other transport operators tell us about this?

Recent studies in which a failure of sustained attention has been suspected to account for an accident have tended to focus on activities where the task has been fairly automated or has lasted for a long time (e.g. train drivers or aircraft pilots). For example Edkins and Pollock's (1997) analysis of rail accidents and near misses found that vigilance failure was the most salient contributing human factor across all incident types. Cabon, Coblentz, Mollard and Fouillot (1993) examined both long haul pilots and train drivers and found that during times of low workload or inactivity, vigilance performance falls dramatically. Lewis (1973) investigated failures in pilots and found response rates were influenced by the frequency of traffic warnings and found that vigilance declined when traffic density and traffic warnings were low.
Of interest to vigilance researchers is the failure of an operator to notice a signal or potential hazard. Although the phrase looked but failed to see is not always used in vigilance research some accidents scenarios are very similar because the operator fails to detect a signal that was there to be seen. The failures of air crew and train operators are generally perceived as vigilance failures not as errors of visual search. The task is not conceptualised as a series of actions or visual searches but a continuous vigilance task. For example, when train drivers fail to detect a red signal it is considered as a failure of vigilance not a failure to search for the signal, e.g. Edkins *et al.* (1997). When one plane hits another in a mid air collision it is not considered as a failure of the pilot searching appropriately for other aircraft but as a failure during the whole flight to monitor the area outside the cockpit.

8.1.4.1 False hypotheses

The idea of hypothesis testing in visual perception is of course is not a new idea (e.g. Rock and Mitchener, Rock 1981, Gregory 1980, review in Parks 1995). Parks postulates that an initial hypothesis is made from initial stimulus inputs that drive the perception process. The hypothesis about the object that is being viewed is generated which colours the later success of identification. Could drivers develop a expectancy hypothesis based on previous experience?

8.1.4.2 Drivers 'see' it but develop a 'false hypothesis'

The driver who claims not to have seen a police car may be 'seeing' the object but believe the stationary police vehicle is in fact moving because of the expectation that police cars displaying lights are moving (see also Shinar and Stiebel 1986). Therefore a driver might create an erroneous hypothesis about the state of the

road, based on his experiences of seeing police vehicles previously. The car driver falsely hypothesises that flashing blue lights equate to a fast moving police car only to hit it claiming they did not see it. The original notion of the false hypothesis was referred to by Davis (1958) to describe aspects of train driver error. Davis' ideas also apply well to pilot error (Hurst & Hurst 1982). Davis cites failures of vigilance or attention in train drivers as being where the driver 'sees' the red signal but continues to claim that in fact the signal was not red. Davis discusses conditions where false hypotheses may occur. These times are when expectancy is very high because of repeated exposure to the situation regardless of the precise nature of the stimulus. When attention is 'elsewhere' (i.e. the operator is distracted by another task) s/he will be less likely to be critical in accepting hypotheses over all tasks. Thus Hurst *et al.* claim that when a pilot is devoting a lot of effort in spotting runway lights in bad weather s/he is more likely to develop a false hypothesis about other critical information. Finally after a period of high concentration Hurst *et al.* claims that pilots are all aware that after a stressful flight on landing they 'over-relax' and appear to be unable to maintain their attention. The false hypothesis in this case is that the flight is over and that nothing else could go wrong. This is thought to explain why pilots successfully land their aircraft only to collide with the terminal building or vehicles on the apron claiming they did not see them (e.g. Borowsky, and Wall 1983). Therefore once an operator forms a hypothesis about the given situation (no matter how wrong) s/he is unlikely to change the hypothesis or assumption despite all information to the contrary. A driver who sees a police vehicle displaying lights might construct a hypothesis that it is moving. Despite all the cues to the contrary (e.g. looming, changes in optic array, etc.) they may still believe that the vehicle ahead is moving, until a collision occurs.

8.1.5 Experimental Design

This laboratory study has many differences to those in preceding chapters. The investigation is of a sustained attention task rather than one of a short visual search. Earlier chapters discussed display time of video stimuli with a maximum of two seconds and typically 0.5 of a second exposure. This vigilance task requires far longer display times and consequently more video footage. A recurring theme of this thesis is the amount of time a driver should be allowed to view the scene in the laboratory. In the present study, it is difficult to give an ecologically sound justification for the amount of time required to display the scene. Little guidance can be obtained by reviewing the limited number of accident files.

One of the problems with the design of this experiment was to prevent the participant believing that the experiment was short as this would mean that they would be in a high state of arousal. Equally the experiment should not be of a length that would induce them into total boredom. Previous vigilance experiments have shown that with Participants who are expecting to complete a long task but then do a short experiment instead (see Sawin and Scerbo 1995) performance significantly declines. The importance of the wording in instructions, for example using the words 'difficult or monotonous' will also affect performance (Lucaccini, Freedy and Lyman 1968). Participants must also not feel that extra effort to do the task is needed. For example, using the simple change of instructions to emphasise 'attention' can again change subject's expectations (Sawin and Scerbo 1995). Three types of instruction were tried. Results indicated that the subject should not know exactly the length of time the experiment would take nor be provided with any description of the type of vehicle for which they were searching.

(Chapter 5 shows the effects of search performance of looking for a particular class of vehicle).

8.2 Study 1 - Accident data

8.2.1.1 Stage 1 - Soliciting expert opinions

Other police forces were contacted together with other universities and motoring organisations regarding their experience with similar accidents. The survey had 31 respondents. Differing thoughts were evident by the type of organisation reporting. Psychologists favoured the 'echelon' parking methods as a solution and forensic engineers favoured the 'in-line' method, and all reported that carriageway accidents were a serious problem. The motoring organisations[11] confirmed such accidents did occur to their vehicles and had issued specific training instruction to park 'in-line' but it was thought not to be a problem[12].

8.2.2 Method

The Institute of Traffic Accident Investigators (ITAI) were requested to organise a nation-wide campaign to solicit information from other police forces. Further requests for detailed data were made by advertising at police conferences. Advertisements were also placed in the journal Impact. The requests were made with the assurance that the information could be reported by telephone or facsimile in total confidentiality.

8.2.2.1 Sources of data

Police Vehicle Accidents in the UK

With the co-operation of the ITAI, information was collated about 47 vehicle accidents from twelve UK police forces. The information was to the level at least of a 'Stats 19'. together with details of the police vehicles' parking orientation and lighting. Reports were generally for only the preceding two years. Of the 47 incidents reported, only 29 were provided that met the criteria for consideration[13].

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[11] The RAC and Green Flag reported directly to Sussex Police

[12] A subsequent meeting with the Automobile association suggests that in fact these accidents are a major problem.

[13] The criteria for consideration was:

1) The police vehicle was conspicuous

Conspicuous vehicles were defined as:

''vehicles fitted with conspicuity enhancers such as reflective and retro-reflective materials, with the vehicle having a Westman light bar or pulse beacon'.

2) The accident needed to involve the actual collision with the police vehicle, police officer, or nearby equipment

3) The accident report must refer to the driver either failing to see or claiming that he did not see the police vehicle in time

4) Accidents must be caused by someone with a valid driving licence.

5) No plausible explanation for the accident must be evident other than a late detection error.

6) The accident must be attended by a police officer other than those involved in the incident

Of the remainder the accidents were attributable to bad weather (often fog), driver fatigue or the influence of alcohol on the driver (although still under the legal limit) incomplete reporting or vehicle defects (e.g. scratched windscreens). Individual police forces reported between one and eight incidents.

Accident data from Sussex police accident database
Sussex police provide accident data in respect of::

A) Conspicuous vehicles in urban environments

A survey of all marked police vehicles accidents in urban environments in Sussex for the period 1983 to 1997 in two reports[14]. The combined reports detailed some 214 incidents. Incidents where police vehicles were deliberately rammed or accidents caused by other police officers were disregarded.

B) Accidents on carriageways involving vehicles without conspicuity enhancements:

Incidents were considered where stationary vehicles (i.e. not just emergency vehicles) were hit on carriageways. Only daylight accidents where there was good visibility were examined. The report[15] highlighted 8, 294 incidents.

8.2.3 Results

8.2.3.1 National sample

Police forces reported between one and eight incidents but suggested many other cases had occurred. If this is the case with forces having 8 and 10 incidents for a two year period, there being 42 forces in the UK, an estimate of circa 150 cases in the UK per year[16] is envisaged. Table 8-1 summarises the data found

[14] Serial numbers 76294 & 76293.

[15] Serial numbers 76424 & 76429.

[16] These results have been presented to Police Scientific Development Branch who consider that these finding "substantially underestimate the problem. This figure may only represent 2 or 3 forces annual reports".

Table 8-1Summary of accident data from the national sample of motorway L.B.F.S. error accidents

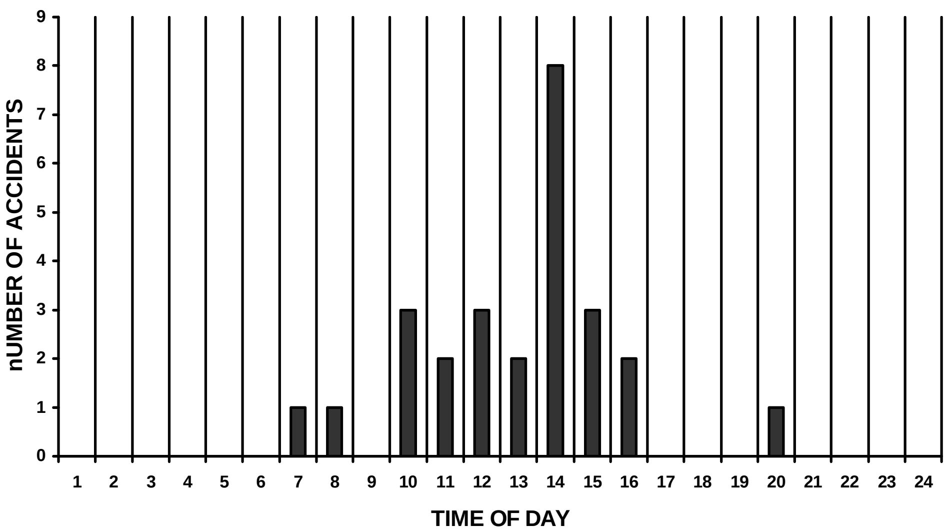
	Age & Gender of offending Driver M (Male) F (Female	Time of day	Lighting	Orientation	Class of road Motorway(M) A class road (A) A class road used as a motorway (a)M	Number of emergency service providers present	Offending drivers distance from home (in Kms)	Cause code Secondary cause ()	Other warning devices in Use
1	45 m	11.00	blue	In-line	A	1	20	38	Cones
2	41 male	12.00	unknown	Echelon	A	1	15	38	None
3	31 female	11.00	blue	unknown	A	1	3	38	Cones and signs
4	28 female	15.00	blue/red	Echelon	A	1	21	49	None
5	44 male	08.30	blue	unknown	A	1	15	49	unknown
6	56 male	11.00	blue/red	In-line	A	1	11	38	unknown
7	55 female	14.00	blue	Echelon	A(m)	1	12	38	Cones
8	6 1 male	15.30	blue/red	In-line	A	1	280	49	Cones
9	42 female	19.00	none	Echelon	A	unknown	29	45	Warning signs
10	51 female	10.00	Blue	In-line	A	1	12	38	none
11	29 male	14.00	Blue/red	In-line	A	1	8	49	none
12	27 male	12.30	Blue	In-line	A	1	12	49	Vehicle equipment
13	32 male	11.30	Blue/red	unknown	A	1	11	38	none
14	45 female	13.00	Blue/red	In-line but facing on coming traffic	Urban carriageway	Many	3	11	Cones warning signs Police motorcyclist
15	34 female	14.30	None	In-line	M	1	11	49	none
16	70 female	20.00	Blue/red	In-line	M	1	23	38	unknown
17	44 female	16.00	Blue	unknown	M	1	unknown	38	none
18	48 female	12.00	Blue/red	unknown	M	1	19	38	none
19	28 male	13.00	Blue/red	In-line	M	1	15	49	warning signs
20	43 not recorded	16.00	blue	In-line	M	1	14	38	none
21	39 female	14.00	blue	Echelon	A	2	6	38	none
22	45f	07.30	blue	In-line	M	1	23	49	taper cones
23	61 female	14.30	blue/red	In-line	M	1	59	38	cones
24	58 male	14.20	blue/red	unknown	M	1	7	49	none
25	55 male	.12.30	blue	unknown	M	unknown	7	38/42	none
26	31 male	14.30	blue/red	In-line	M	2	12	49	Cones from road works placed across carriageway
27	26 female	14.30	blue	In-line	M	1	80	38	none
28	22 female	10.30	blue/red/white	In-line	A(m)	1	2	38	none
29	58 female	16.30	blue/red/white	In-line	A	1	4	38	unknown

Table 8-2 Definition of cause codes

Cause Codes	Meaning	Cause Codes	Meaning
11	Object in Carriageway	46	Following too closely
42	Overtaking	38	Driver inattentive or distracted
49	Error of Judgement	45	Failed to conform to signs

The data from the national sample suggest:
(a) Accidents involving police vehicles tended to occur between the hours of 11.00 am and 3.00 p.m. Figure 8-2 shows the distribution by time of day

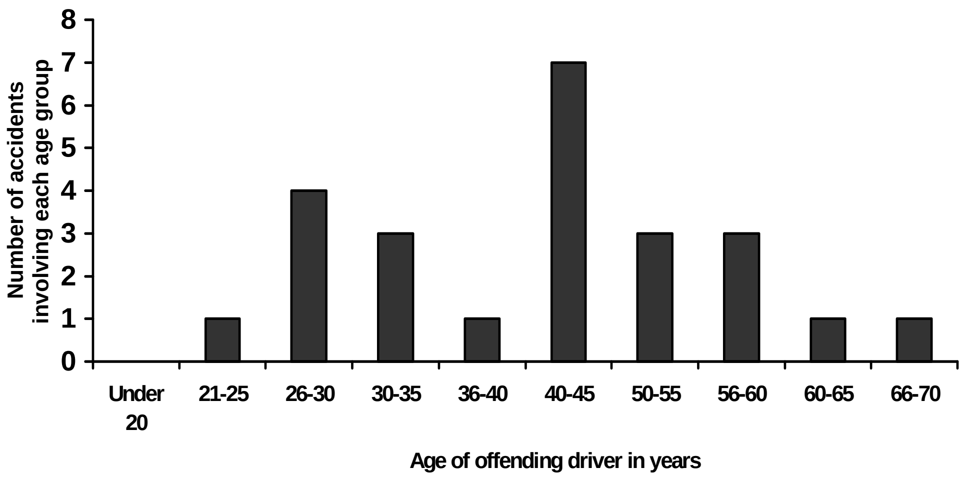
Figure 8-2 Motorway accidents involving police cars by time of day



(b) Not all forces recorded vehicle parking or orientation, although accidents when the vehicle was 'in-line' (17 of 29 incidents (59%) did tend to be over-represented in the sample.
(c) Accidents tended to occur when there was only one emergency service provider at the scene. This was either if the police vehicle was the first at the scene or the last at the scene. Only one incident was reported where there were two or more stationary emergency vehicles.
(d) Vehicle lighting was not usually recorded, but officers assumed that vehicles were using every light they had. Some forces thought that the red lights fitted to the bar were not in use at the time, and some light-bars do not have red lights.
(e) The early deployment of warning signs and traffic cones did not guarantee detection.

The offending driver
(a) Females tended to be over-represented in the data.
(b) Although accidents occur on motorways and dual carriageways, in many cases accidents appear to be within 15 kms of the offender's home address(18 of 29 incidents 62 %).
(c) The offending drivers were over the age of 25 except in one case. Figure 8-4 shows the distribution of accidents by age. The accident profile for the age of the offending driver appears therefore very similar to the age profile of accidents involving other highly conspicuous vehicles such as police motorcyclists (3.4.7.1). (However accidents with police motorcyclists tend to occur in towns rather than on carriageways).

Figure 8-3 Frequency of accidents by the age of the offending driver for collision with stationary police vehicles on motorways



Skidding and avoidance
Evidence from these reports suggests that in this type of accident the driver is not detecting the hazard too late, but is failing to detect the vehicle *at all*. This conclusion can be drawn as many of the accident reports -11 of 29 (39%) contain no evidence that the driver braked before the collision. Driver statements often contained the phrase ”I did not see it “(70%).(20 of 29) incidents.

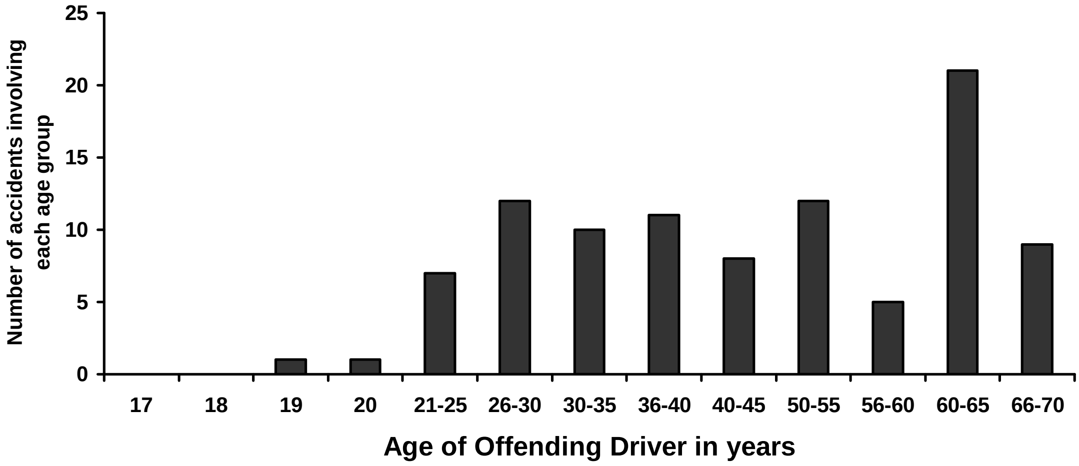
Although a limited sample, accidents with conspicuous police vehicles on carriageways appears to be a problem for the possibly experienced older driver. The prevalence of accidents at certain times of day may reflect the exposure of the number of vehicles on patrol at any time.

8.2.3.2 Sussex Police accident database

A) Conspicuous vehicles in urban environments
If conspicuous vehicles are hit on carriageways are they also hit while stationary in urban environments? This is important because when in urban environments the driver should not develop a false hypothesis about the police vehicle as stationary since police vehicles are often seen stationary in urban environments whilst attending accidents. 214 incidents, during a 15-year period, were considered in which a stationary marked police vehicle was hit. Incidents which occurred in darkness or had plausible explanations were disregarded. 87 accidents were therefore considered).

Accidents that occurred in urban environments tended to be between the hours of 1100 and 1600 hours. Incidents were close to the offender's home (under 3 kms) and if occurring in 30 mph speed limits, tended to be fairly minor. Unlike carriageway accidents, the majority of urban accidents showed that the vehicle braked before impact. Younger drivers again tended not to be over-represented in daylight accidents. However the age group that was significantly over-represented in these urban failures were elderly drivers (60+). Figure 8-4 shows the age distribution found

Figure 8-4 The age of the offending driver for conspicuous vehicle accidents in the urban environment



Many of these incidents were not used for analysis because it was unclear if the driver failed to detect the police vehicle in time or was unable to steer around the vehicle. Most of the incidents were not of a straight line impact as shown on carriageways, but consisted of a glancing blow to the offside of the vehicle hit.

B) Accidents on carriageways involving vehicles without conspicuity enhancements
If drivers develop a false hypothesis about the state of the road triggered by seeing a conspicuous vehicle on the motorway displaying lights, what of vehicles broken down on carriageways that do not display blue/red warning lights?
(a) As was found with the data on conspicuous vehicles, offending drivers tended to be aged over 25.
(b) In contrast to the accidents where a conspicuous vehicle was involved, at some point drivers appeared to notice the vehicles into which they crashed, as the majority of accident reports showed that skidding had occurred (72%).
(c) Accidents appeared outside the normal peak times of the rush hour most frequently between 1500 and 1600 hours.

8.2.4 Discussion

Firstly all the caveats from Chapter 3 concerning the use of accident data apply here. The problem of vehicles being hit while stationary on motorways and dual carriageways is not a problem confined to Sussex police. Accidents are reported from all over the UK. Despite being physically conspicuous, police vehicles were still crashed into by drivers who claimed not to have seen them. Accidents on dual carriageways for both conspicuous and standard vehicles occur outside the rush hour and younger drivers are not over-represented in the data (in contrast to how they are over-represented in accident statistics generally). The accident data collected are consistent with the hypothesis that there has been a failure in vigilance. Motorway and dual-carriageway driving is relatively undemanding and unarousing most of the time: since Mackworth's studies in the 1950's, it has been appreciated that there is a pronounced deterioration in vigilance performance after as little as 20 minutes (depending on the task, and the frequency with which the to-be-detected event occurs). Motorway driving conditions would promote a decline in vigilance: traffic is always travelling in the same direction, and more importantly, perhaps, any traffic in front of the driver is almost always moving. Drivers very rarely encounter stationary vehicles on such roads (at least, not immediately in front of them), and so may fail to look for them. The cues that signal to a driver that the vehicle in front is in fact stationary are not obvious, and may be detected (and responded to) too late for effective avoiding action to be taken.

This is a very small sample. The prevalence of accidents where braking did not occur may be questioned here because there needs to be physical evidence at the accident scene before 'skidding' is recorded. Accident investigation specialists tell me that evidence of skidding on the road surface may sometimes not be apparent.

8.3 Study 2 - Laboratory Investigation

A laboratory study was performed although the investigation was firstly attempted in the field. The accident data may be interpreted to mean that older drivers are possibly colliding with police cars that are parked 'in-line' as they are relying on certain expectancies about the road ahead. Experience may have taught the driver that the 'in-line' parked vehicle displaying blue lights is possibly a moving vehicle rather than stationary. The novice driver is under-represented in the accident data because they have not developed these expectancies about the road environment and believe accurately that the police car is stationary. This laboratory experiment therefore displays the scene of a dual carriageway filmed from the normal driver's perspective. The subject who is either an experienced or a novice driver views the video and is asked to report any hazards they see. Towards the end of the video unknown to the subject they will encounter a stationary police car parked 'in-line' or 'echelon'. It is hypothesised that experienced drivers will take longer to detect a stationary police car when it is parked 'in-line' than 'echelon' and that novice drivers will detect either orientation equally well.

8.3.1 Method

8.3.1.1 Collecting the stimulus material

Selection of the site.
Great care was taken in the selection of the site. The site where the stimulus materials were collected had a well-defined point at which an approaching driver could see the parked police vehicle. The site was on the A27 dual carriageway west of Chichester, Sussex, UK where two L.B.F.S. errors had previously occurred.

Three marked and three unmarked police vehicles were supplied by Sussex police and were fitted with 'Provid' motorised cameras which recorded the stimulus material used for the laboratory investigation. The video recording were made during September 1997 in fine weather between 0600 and 0915 hours. This prevented shadows being cast in the scene from the driver's view.

Figure 8-5 Plan of rolling road block system used to collect video stimulus material

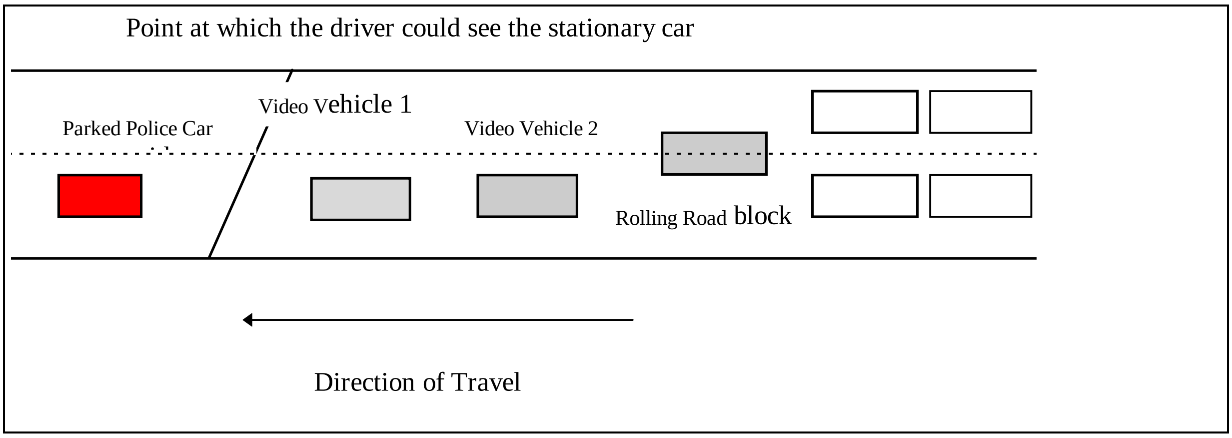
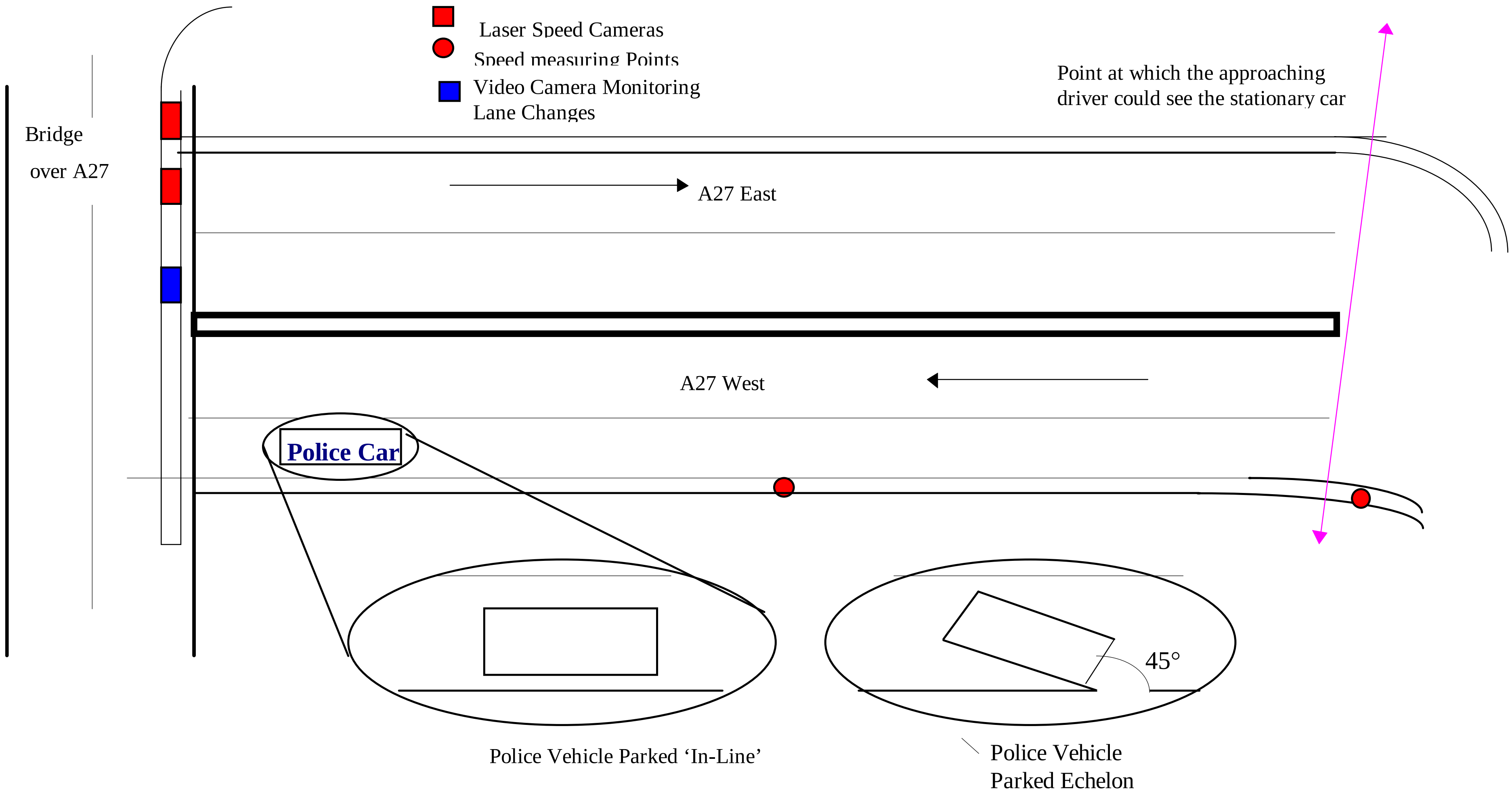

Point at which the driver could see the stationary car
Video Vehicle 1
Parked Police Car
Video Vehicle 2
Rolling Road block
Direction of Travel

Figure 8-6 Plan of site where laboratory stimulus material was obtained



Marked police vehicles were parked on the dual carriageway in either an 'in-line' position or an 'echelon' position. Two police video vehicles preceded a rolling road block, a marked police Range Rover (Figure 8-5) reducing traffic flow towards the parked police car. Traffic was stopped on the carriageway 4 kilometres away from the site. When the road past the parked police vehicle had cleared, the first police video vehicle drove towards the parked police car travelling in the lane in which the hazard lay. After the first video vehicle completed its run a second video vehicle passed the scene the orientation of the vehicle at the experimental site having changed. (Figure 8-6). In both cases the hazard vehicle faced the direction of traffic flow. After both video vehicles had passed the scene a marked police vehicle escorted the traffic past the experimental site.

In the 'in-line' condition the vehicle was parked 0.9 metres from the kerb. In the 'echelon' condition the vehicle was parked facing the central reservation at an angle of 45° from the near-side of the road. In each condition the vehicle used displayed blue and red lights.

8.3.1.2 Design

The experiment used an independent measures design. Experienced drivers or novices viewed either a police vehicle parked 'in-line' or parked 'echelon' in one video clip amongst a series of video clips that were otherwise identical. Participants therefore participated in one of four conditions
'Experienced in-line'(EI)
'Experienced echelon'(EE)
'Novice in-line'(NI)
'Novice echelon' (NE)

Subjects' reaction times and their decision about whether the clip contained a 'hazard' were recorded.

8.3.1.3 Stimulus Material

The display time for each of the video clips was two minutes. Participants were shown six video clips representing twelve minutes of driving. Only the final clip contained the hazard of a marked police vehicle in either an 'in-line' or 'echelon' position. The preceding five clips were the same for all participants.

Only the most noticeable 'Battenberg' pattern (Thomas 1998) was used. Figure 8-7 shows the view of an 'echelon' vehicle as shown to participants.

Figure 8-7 Example of stimulus material- an 'echelon' parked vehicle

Video clips were all of stretches of dual carriageway. In all cases the view of the camera was from the driver's perspective when travelling in the near-side lane. Clips 1, 3 and 6 contained hazards. All clips, except clip 4, showed the subject's vehicle travelling at 70 mph. Clip 4 showed the subject travelling at either 34 mph or 84 mph. These speeds were the minimum and maximum speeds observed by the laser speed cameras before testing commenced on this road. The speed of approach was displayed in the lower section of the video screen. Participants were made aware of this before the experiment commenced.

Summary of Clips
Clip 1 Hazard of a slow moving motorcycle which appeared after 30 seconds.
Clip 2 Clear carriageway.
Clip 3 Two hazards at 1.00 and 1.30 minute intervals both in the near-side lane (slow traffic).
Clip 4 Clear carriageway varying in speed between 36 and 84 mph.
Clip 5 Clear carriageway.
Clip 6 Either a police vehicle parked 'in-line' or parked 'echelon' displayed after 1 minute 30 seconds.

8.3.1.4 Participants

Sixty participants were recruited by campus advertisement at the University of Sussex. There were 20 males and 39 females. Mean age was 27 (range 17 - 49 years). Experienced drivers were defined as drivers with more than two years' driving experience. Novice drivers were either learning to drive or had recently passed their test (within one month). Experienced drivers had a mean of 13 years driving experience.

8.3.1.5 Apparatus

Video display characteristics were the same as in Chapter 6 (p.117). Participants viewed the video in a darkened laboratory seated in front of a screen. Participants indicated when a 'hazard' was present by pressing one of two buttons on a two way button box.

8.3.1.6 Procedure

Participants read a short instruction sheet and completed details about accident involvement and driving experience before the commencement of the experiment. The time of day that the experiment was conducted was also recorded. Participants had a two-way button box and pressed the left button if they believed a hazard was in the near-side (left) lane and the right button if they believed a hazard was in the outside lane. Participants were allowed a short time to practise. Video tape took 12 minutes to view. Each subject was tested individually.

8.3.1.7 Instructions to Participants

Written instructions were firstly piloted. Participants were instructed to look for possible hazards with the determination of 'hazard' left to the discretion of the participant. When participants took part in this experiment they were not aware how long it would last - this to minimise the possibility of an increase in vigilance near the end of the task.

8.3.2 Results

Data was collected from 60 participants. Data were analysed from 59 of the 60 participants. One subject's data were disregarded because the subject stated they could not use the button box at the same time as viewing the video. Data were collected from participants for:

- Time to detect the police vehicle as a hazard
- Decision about which lane the hazard was in (inside or offside lane)
- Total number of responses for all clips.

Reaction time data were analysed by a two way ANOVA with independent measures on both variables. The independent variables were the orientation of the vehicle ('echelon'/'in-line') and the experience of the driver (experienced/novice).
Main effects were found for vehicle orientation (F (1,56) = 10.49 p<0.01 and experience level of the driver (F(1.56) = 6.67 p<0.05. An significant interaction effect between the experience level of the driver and the vehicle's orientation of F(1.56) = 6.39 p<0.05) was found. Table 8-3 shows the mean time to respond by participants in each of the four experimental conditions.

Table 8-3Mean time to detect the stationary police-car in the final video-clip:

Condition	Mean time to detect	SD
Echelon/ Experienced	3.118 sec's.	0.566
Echelon/ Inexperienced	4.558	0.422
In-line/ Experienced	4.764	0.994
In-line/ Inexperienced	4.501	0.455

All participants detected the hazard successfully, regardless of whether it was parked 'in-line' or 'echelon' Novice drivers detected the 'in-line' vehicle slightly faster than did the experienced driver. Vehicle orientation significantly affected reaction-times only in the case of experienced drivers, who were faster to detect 'echelon'-parked vehicles than they were to detect vehicles parked 'in-line'(t (28) = .4,22 p<0.001).

Response criteria
The number of hazards participants believed the video clip contain a hazard was recorded for all clips. Table 8-3 shows the results. Experienced drivers considered that the video clips contained fewer hazards than did the inexperienced drivers.

Table 8-4 Mean total number of key depression for participants for all six clips

	Mean	SD
Experienced	5	2
Inexperienced	16	17

The number of false positives fell after video clip 4 for both experienced drivers and inexperienced drivers. Table 8-5 shows that generally, inexperienced drivers were more willing to report that a hazard exists or are more willing to consider changes in the road environment to be a hazard.

Table 8-5 Mean number of false positive responses to each video clip (all participants)

	Clip 1	Clip 2	Clip 3	Clip 4	Clip 5	Clip 6
Novice	6	4	7	5	5	2
Experienced	2	1	0	0	1	0

This implies that the inexperienced driver may consider a dual carriageway to be more hazardous than does an experienced driver. The experienced driver appears to monitor the road ahead and considers very little of the environment to be hazardous.

8.3.3 Discussion.

The experiment suggests that during a simulated driving task, experienced drivers were faster to detect an 'echelon' parked vehicle and slower to detect an 'in-line' parked vehicle. None of the participants failed to detect the hazard altogether, but it must be kept in mind that these participants were in an alert state in which they were actively looking for hazards for a comparatively short period of time. Table 8-4 and Table 8-5 show that participants changed their response criteria as the experiment progressed. This is in line with Warm's (1984) review. This change in performance may be explained as either a decrement in vigilance performance or a change in response criteria.
However video technology is limited: video reproduction is very far from the conditions found in the real world, and does not allow for the evaluation of the fluorescent properties of the materials fitted to police vehicles. For example, the physical characteristics of the vehicle and its surroundings (ambient lighting, vehicle lighting, fluorescence and reflectivity of materials) are all poorly replicated by video technology.

8.4 General Discussion

Accident data and laboratory results are consistent with the hypothesis that during tasks of sustained attention, expectation about the task may affect performance. Significant differences were found between novice and experienced drivers in response to the orientation of the vehicle in the laboratory study. Experienced drivers detected the 'echelon' vehicle faster than when it was parked 'in line'. Results from accident statistics may be interpreted as suggesting that experienced drivers may have developed a set of expectancies about the road environment as they did not detect the police vehicle as being stationary.

Davies and Parasuraman (1981) show that an important measure in vigilance tasks is the decline in responses throughout time and the decrease in false alarm rates. Decline in the number of false negatives as the task progresses is well documented (Broadbent and Gregory 1965, Egan *et al.* 1961, Murrell 1975). Fewer responses by the participants may show a more conservative response criterion rather than a decline in observer's vigilance. The number of false positives was also significantly higher among the novice drivers. Novices appeared to signify that a hazard was present a lot more readily than did

experienced drivers. However little work has been conducted on the relationship between vigilance decrement and operator's levels of experience. The results suggest that inexperienced may monitor the road environment more closely. The experienced driver appeared to benefit by the recording of quicker reaction times if the police vehicle was parked 'echelon' across the road.

8.4.1 Later Replication

Data reported are similar to a later replication. Langham, Hole, Edwards and O'Neil (1998) used the same video presentation and instructions. To further encourage drivers to adopt a low state of vigilance perhaps more similar to that experienced during driving, participants performed a secondary task at the same time as watching the video and looking for hazards. The secondary task - a logical reasoning task, which involved deciding whether verbal statements are true or nonsensical - has some of the attributes of conversation on a mobile phone. There was a highly statistically significant effect of attention-state reaction times in both of the divided-attention conditions: Participants were significantly slower in these conditions than in the undivided attention conditions. There was also a highly statistically significant effect of orientation of vehicle: people were slowest to detect the police car when it was parked 'in-line' than when it was parked in 'echelon' fashion. No participants in either of the 'echelon' parking conditions failed to detect the police car; however, four participants in the In-line/Divided Attention condition, and one subject in the In-line/Undivided Attention condition, failed to detect the police car altogether. These numbers are too small to perform any statistics on, but are suggestive - especially given that the conditions of the experiment would tend to militate against the occurrence of vigilance failure on any large scale. (In the real world, collisions with stationary vehicles are extremely rare when one considers how many vehicles are on the road at one time).

The experienced driver may be relying on a set of expectancies about the road environment. The first police vehicle on the scene may be hit because even if the car driver **does** detect the police car its conspicuity enhancers give him the wrong signal. The driver on seeing the blue flashing lights may hypothesise that the police vehicle is moving and subsequently collide with it. Such expectancies are not reinforced if the vehicle is parked 'echelon' across the road. This is because the vehicle profile is discordant with the expectation of the experienced driver.

8.4.2 Expectancies and the false hypothesis

Older drivers appear to be over-represented in the accident data and differences were found between experienced drivers and novices in the laboratory. Therefore it may be argued that experienced drivers have, through exposure to motorway driving, developed expectancies about the environment. One such expectancy could be that a police vehicle is assumed to be moving when displaying lights generating a false hypothesis which is difficult to overcome. Drivers may be expecting to see a moving police car thus a 'moving-police-car-hypothesis' is formed and despite all the information that is available that it is not moving, (e.g. optic flow and looming (see Stoffregen and Riccio 1990), this hypothesis does not change.

Therefore, the false hypothesis may mean that either the driver is not expecting to see a parked vehicle on the carriageway or furthermore that a certain signal observed - the flashing lights, - is associated with a moving police vehicle. Where false hypotheses or dips in vigilance performance are possibly most likely to occur when the driver believes that he is 'as good as home'(Davis 1958) or after a period of intense concentration. These factors may be detectable in the accident data concerning police vehicles, because many of these accidents are occurring close to the offending driver's home.

8.4.3 The wrong type of conspicuity enhancer?

The police car may be highly conspicuous but camouflaged. Generally speaking, we detect objects because of their shape (review in Chapter 7). Information about shape is provided in two main ways. The first is by the object's outline demarcating it from its surroundings. The second is by shading information. If the shape of an object is broken up by coloration and markings, the object can become difficult to distinguish from its surroundings. This can happen even when the markings are, in isolation, very bright. The checkerboard pattern of a police vehicle and its curved shape tend to break up the contour lines of the vehicle at a distance. With up to 90 % of the vehicle covered with patterning of four colours (Thomas 1998) the driver may not recognise it as a vehicle.

The police car may not be conspicuous enough. Humans cannot perceive all wavelengths of light equally well. Spectral sensitivity for humans is less for blue than for orange (Abramov and Gordon 1994, Boynton 1988). The use of blue lighting on the police vehicle may also cause a problem. Berkhout (1979) reports that blue/red light combinations on police vehicles create an illusion of receding motion[17] when actually at rest. This is an issue for further research.

8.4.4 Alternative explanations

8.4.4.1 Exposure

A simple explanation of the difference found in the accident data survey was that the results were due to differential exposure.

Vehicles
Some times of day have fewer number of road traffic accidents than others.(Casualty Report 1996). By implication fewer attending police vehicles, thus reducing the possibility of exposure of a police vehicle to a collision.

Further data were sought. Sussex police supplied information on the number of police vehicles on patrol at any one time. It appears that in Sussex between 0900 and 1800 hours the number of traffic patrol vehicles on the road is between 42 and 50 with peaks between 1100 and 1345 and 1415 and 1600 hours. Perhaps therefore the number of accidents found in the survey during these hours reflects only the number of police cars on the road.

8.4.4.2 Sleep.

Dips in vigilance performance have been noted before a rest period and during low workload demands (Cabon, Coblentz, Molar, and Fillet. 1993). The accident data suggest that the driver is close to home when the accident occurs and accidents tend to occur at certain times of the day. The driver of the vehicle may claim that s/he did not ‘see’ the hazard, which could imply that the driver was gazing in the right direction without being aware s/he was in fact asleep. Mavje and Horne (1994) claim that in the usual waking day there is a propensity for sleepiness in the early afternoon. Horne claims this is between 1200 -1600. - a post lunch dip. The propensity to sleep is however masked by what Horne describes as various exogenous factors. The most important of these is ‘interest’. Mavje and Horne (1994) claim that if a task lacks interest then the effects of the post lunch dip is more noticeable. It is often in the early afternoon when the majority of these accidents occur (See also Hole and Langham 1997). Driving on a motorway or dual carriageway may be described as boring.

[17] Of the 29 incidents reviewed drivers believed in two cases that the vehicle was reversing when they hit it.

However the accident data suggest that it is only mature drivers that are involved in this type of accident not the younger inexperienced driver. Horne and Reyner (1995) however also in respect of driving found older adults may be more vulnerable to accidents in the early afternoon.

8.4.4.3 Optic flow sampling.

Chapter 7 discussed how optic flow sampling may aid the detection of a target. Draper (Personal Correspondence) suggests that these accidents are really caused by an optic flow processing error. He assumes that when driving, most processing is done by optic flow. This is not done after object recognition, but before and/or without it. Studies suggests TTC (See Chapter 2) can be computed directly from optic flow. Although there will be ‘noise’ in the optic flow data as elsewhere, experienced drivers probably learn to process only large patches in the flow field. In fact on motorways, drivers probably look ahead and extract the speed of whole flows of traffic. A single stationary police car may not stand out, especially if moving traffic can be seen ahead of it. In terms of optic flow changes, a stationary vehicle may effectively be the same as the roadway between the vehicles.

8.4.5 Further improvements, recommendations for further study

This type of study is possibly not best suited to laboratory investigation. A better procedure would be a real world study. Although this was attempted here the quality of the data obtained were questionable. A significant improvement would be to stop all the vehicles that passed the stationary vehicle and obtain further details about the driver e.g. their age and experience, in the context of the database evidence (e.g. Sabey *et al.* 1975).

8.5 Overall Conclusion

On the basis of the data reported here, one can conclude that one possible contributory factor in the *Type 11* L.B.F.S. error in that there may have been a failure of vigilance possibly exacerbated by the practice of ‘in-line’ parking. The data **tentatively** suggest that a police vehicle parked in an ‘echelon’ fashion may be more readily identified by other road-users as a stationary vehicle on a motorway than is an ‘in-line’ vehicle.
Laboratory studies do not adequately simulate all of the properties of the real-world conditions under which this type of accident takes place. In drawing attention to a possible role for expectation failures, one cannot rule out other possible explanations, for example, driver fatigue. The need is for further research in real-world conditions, testing drivers who do not expect to see a police vehicle, during the hours of the day when these accidents seem most likely to occur. However this study does suggest that the visual size of a target and its high physical conspicuity value do not guarantee detection[18].

[18] On this basis of these studies ACPO have agreed to allow the parking of police vehicles at accident scene to be under the control of the police officer attending. The officer now parks the vehicle in the orientation that he believes is the most visible. In respect of the Metropolitan and Sussex forces vehicles are now parked ‘echelon’ and display only red lights when stationary.

9. Conclusion

9.1 The aim of this research

The aim of this thesis was to investigate the L.B.F.S. error more closely, given the preoccupation in previous research with sensory detectability. It also evaluated whether models of selective attention derived from laboratory investigations of attention could be applied to the L.B.F.S. error. Chapter 1 has described how previous work overemphasises the conspicuity hypothesis as an explanation for motorcycle L.B.F.S. accidents. Previous research has been widely criticised in respect of the methodology (e.g. Thomson 1980). The aim of this thesis was to improve the methods of investigation. In line with review articles (e.g. Wulf *et al.* 1989, Brooks 1989) this research has attempted to investigate if the failures in detection are caused by the driver looking in the inappropriate place or a failing to recognise a motorcycle as a hazard. The relatively small visual size of the motorcyclist has also been offered as an explanation of the L.B.F.S. error (e.g. Wulf *et al.* 1989). This issue was addressed by examining accidents involving larger objectively 'conspicuous' police vehicles. The consistent themes of this thesis have been measurement, methodology generalisation and ecological validity.

9.2 Key Findings

This thesis has investigated whether poor physical conspicuity alone is the only explanation for the L.B.F.S. error. It began by reviewing the possible contribution to these accidents of the limitations of human attention which have seldom previously been given serious attention. Chapter 1 showed that two distinct forms of the L.B.F.S. error occur and each one was associated with a failure of selective visual attention (*Type 1*) and the other a failure of vigilance (*Type 2*). Both forms of error were subsequently investigated. Whilst the *Type 1* L.B.F.S. error has been accounted for previously by a single explanation Chapter 2 when reviewing previous methodology found that practices, particularly laboratory experiments, varied greatly and concurred with Thomson's (1980) assertion that previous research did not in fact measure the L.B.F.S. error at all.
Chapter 3 (p65) concluded that an over-reliance by previous research on accident statistics may be flawed. Accident statistics provide only a basic framework about the circumstances of the accident and provide little for the scientific inquiry of the L.B.F.S. error. The problem with accident statistics for the psychologist is that the data needed to make a case that the driver 'looked' but then did not 'see' are simply not recorded at the accident scene. However the limited findings agreed with previous research such as Hurt *et al.* (1981) and added that certain types of junction may affect accident potential for vulnerable vehicles. In Sussex an unusual age distribution was found for the offending driver in motorcycle intersection accidents with younger drivers not being over-represented as they are in all other types of accident statistics. General details about the accident scenarios were used to construct stimulus material for the laboratory (Chapter 3) and guide the selection of participants for experiments (Chapters 5-8).
Accident data from conspicuous police vehicles demonstrated that physical conspicuity alone does not guarantee detection because police motorcyclists even when displaying warning lights are hit by drivers who claimed that they 'did not see' them.

Chapters 2-5 show that methodological issues are important in trying to apply laboratory research to the 'real world'. The important issue of stimulus display times in a laboratory for this area of research had not been considered previously. Practices had varied greatly, with display times of the stimulus material shown to subjects varying from 8 milliseconds to 5 seconds (Chapter 4). The observational study of drivers' search behaviour at 'T' junctions

showed that drivers tend to search in one direction only for a very limited amount of time. The mean search time found (0.5 seconds) and the single scene display were used in subsequent experiments. The view that the L.B.F.S. error could be accounted for as a failure to notice the change between two scenes (the view of the road to the left and then to the right) discussed by Rensink (1997) was thought to be inappropriate because drivers at the intersections observed looked only in one direction.

Chapter 5 (p 94))continued the theme of improving the methodology. This chapter addressed two issues. Firstly it considered the appropriateness of asking a subject to specifically search for one vehicle type - a motorcyclist - as opposed to all hazards. The common practice of asking a subject to 'search for the motorcycle' was thought to be ecologically unsound for a number of reasons. Firstly, motorcyclists are infrequent in traffic and drivers do not just look for motorbikes. Secondly because their rarity has been speculated as a cause of the L.B.F.S. error, drivers may not be expecting to see them. This rarity should ideally be simulated in laboratory studies of the L.B.F.S. error. Previous studies had typically used a repeated measures design with subjects viewing a series of slides (e.g. Hole and Tyrrell 1995) with different conspicuity treatment conditions. In a short experiment subjects would therefore view more motorcycles than they would see in the real world.

The results indicated that subjects' detection times significantly improved if they searched for one vehicle type over another. The instructions to search and the resulting differences in performance were thought to indicate that drivers may have certain expectancies about the junction. Experiment 1 therefore recommended that later laboratory work contrasted the specific instructions to search for one type of vehicle with a general instruction to search for hazards. This became a recurring theme throughout the thesis. Experiment 2 (p 103) illustrated that an independent measures design was the only ecologically sound way of conducting L.B.F.S. research. After repeated exposure to a rare vehicle class subjects improved their detection times for the motorcycle. Later experiments, although costly in time, then used an independent measures design.

Chapters 3-5 provides evidence that some of the alternative explanations of the L.B.F.S. error (other than physical conspicuity) appeared to be inappropriate. For example understanding the L.B.F.S. error as a failure to appreciate the speed of the motorcyclist was inappropriate because no evidence was found in the accident data to support this. Accident data suggested that the motorcycle may be in the centre of the driver's field of view and the assumed lack of speed cues from the optic expansion in the course of the driver's brief glance at the road before emerging, tends to suggest the L.B.F.S. error was not a speed perception problem.

In terms of the information processing model discussed in Chapter 1 (p 42) the data imply that Stage 1 -Search - at intersections is very rapid. In respect of Stage 2 - Detection - evidence from the police accident database suggests that physical conspicuity does not guarantee detection. For Stage 3 - Recognition- Chapter 5 shows that subjects would detect the target motorcycle more rapidly if they were instructed to do so. For Stage 4 - Evaluation - little evidence can be found in the accident data that the problem is in speed perception and the results in Chapter 4 indicate that in search times under half a second the driver is unlikely to make any assessment of speed. In respect of Chapters 4 and 5 the 'Decision' to emerge from the junction again appears rapid but it is uncertain if the driver assesses the risks of assuming that the vulnerable road user does not pose a threat. In respect of Stage 6- Action - limited evidence is found in the database that the L.B.F.S. error can be conceptualised by Reasons *et al.*'s (1990) error modelling.

Chapters 6-8 focused on two possible explanations of the L.B.F.S. error in terms of attentional failure. Firstly that the *Type 1* L.B.F.S. error may stem from failure by the

experienced drivers to selectively attend to regions of space (discussed in Chapter 6). Secondly, it was suggested that it was may be caused by a failure to allocate attentional mechanisms to detect certain objects in the road environment. Chapter 6 reported on two eye-movement studies that investigated where novices, experienced and expert drivers 'looked', and one experiment that investigated what type of object drivers were searching for. Investigations of 'what' drivers were looking for were modelled on previous investigations of human object recognition.

Chapter 6 found differences between novices and experienced drivers' visual search patterns at different types of junction. Results from the laboratory experiment were broadly in line with previous findings that novices search closer to their vehicle (e.g. Mourant and Rockwell 1972) and had a wider search pattern at 'T' junctions, whereas experienced drivers had a more limited search pattern that appeared optimised for detecting the most frequently observed road users. A wide search pattern was found for both groups at roundabouts. The results were tentatively interpreted as demonstrating the development of optimum scanning patterns honed by experience. The motorcycle L.B.F.S. error accident might therefore involve a failure to scan appropriately. This was because the accident data suggested the intersection L.B.F.S. accident was not caused as with all accidents by the inexperienced driver. Different search patterns were associated with lower accident rates with motorcycles at roundabouts as compared to 'T' junctions. However later replication with expert police drivers whose training and experience requires them to emerge at 'T' junctions at high speed failed to substantiate these findings.

Chapter 7 (p 133) replicates the effects of Chapter 5 by asking subjects to either search for a specific hazard - motorcycle- or to make a general search for any hazard. It was considered that the L.B.F.S. error might be a failure to recognise the motorcyclist as a motorised vehicle because its shape was similar to that of cyclists, street furniture and the like. Consequently models of human object recognition were reviewed. Chapter 7 reported therefore on an implementation of Biederman's (1982) theory of Recognition by Components. Subjects viewed manipulated video clips where the vehicle had been replaced by a shape primitive representing that vehicle. Novice and experienced drivers' responses were recorded to evaluate who did or did not realise that an illusion had occurred. The data can be interpreted as being consistent with the hypothesis that in rapid scene interpretation only the low spatial frequencies of the target are used to decide if a vehicle is present. It was found that provided the instructions to search were concordant with the low spatial frequencies displayed, experienced drivers affirmed the presence of a vehicle or a hazard. This was not the case with novice drivers who readily detected that no actual vehicle was present but merely a 'blob' or shape.

The final experimental chapter (p.153) addressed the issues of visual size and physical conspicuity. Whilst it may be appealing to consider the L.B.F.S. error as a combination of failures to recognise the motorcycle as a vehicle or to orientate the eyes to certain locations in space, the driver might not see the motorcyclist merely because of his small visual size. To show that visual size is not also the sole determiner of accident potential, accidents involving larger conspicuous objects (police motorway patrol vehicles) were reviewed (Chapter 9). In these cases, despite a vehicle being highly visible, drivers collided with it whilst it was stationary claiming they 'did not see it'. Whilst the *Type 1* error was associated with selective visual attention, this error - *Type 2* - seems to be associated with a vigilance failure. Accident data indicated that accidents occurred near the driver's home, with experienced drivers being over-represented in the sample and that in some cases the error was not in late detection but a failure to detect at all. Failures in vigilance in other transport fields together with current thinking about human attention performance were reviewed. Stimulus materials were collected in the field where accident data suggested the L.B.F.S. error had previously occurred. Although designed as a field study, problems in safety became paramount and this

chapter therefore only reported a laboratory investigation. From the accident data and advice from collaborating agencies the laboratory experiment investigated the effectiveness of parking orientation styles on driver detection skills. The laboratory study and subsequent independent replication found that vehicles parked at an angle to the approaching driver were detected more readily by the experienced driver whereas vehicles parked in-line were detected more slowly. Parking orientation did not appear to affect novice or inexperienced drivers' performance. The results from the laboratory and database studies were interpreted as showing that the experienced driver develops a hypothesis about the road environment when performing the undemanding task of motorway driving. It is possible that a vehicle parked in-line with the carriage way displaying blue lights is detected by the driver but experience has taught them that seeing blue lights and the rear of a police vehicle only means that there is a probably a *moving* police car ahead. In contrast the echelon parked vehicle was discordant with the driver's expectations resulting in its detection by the driver. Alternative explanations for this type of accident e.g. tiredness and exposure were also considered.

In conclusion the results suggest that physical conspicuity alone may not be the only reason why drivers 'look' but 'fail to see'. The conceptualisation of the failure to detect as an experienced-related failure to either orientate attention to gross areas of space or a failure to detect certain objects is considered worthy of further research. Although the data should be treated with caution (see below) the data **may** suggest that at intersections the experienced drivers develop a time-efficient search strategy and search for prototypical expected shapes. The under representation of novices in accident data may reflect their wide search pattern, and more meticulous inspection of the scene.

In terms of the information processing model described in Chapter 1 the data suggest that in respect of Stage 1 - Search the eyes are directed by experienced drivers to some locations over others at a intersection. These movements are unlikely to be limited by physiology. For Stage 2 - Detection evidence from police motorway accidents suggests that highly conspicuous vehicles are not necessarily detected and that physical conspicuity does not guarantee detection. Therefore detection and physical conspicuity although attracting the majority of the previous research efforts is still worthy of further investigation. Physical conspicuity by the use of bright blocks or patterns on police vehicles may even act as camouflage. An object that is readily detected in one environment may be easily lost in another. Stage 3 Recognition prompts a more complex response. Chapter 7 shows that detection may not require recognition of a specific vehicle. Although acknowledging many limitations, the results can be interpreted as showing that the driver at an intersection uses low spatial frequency representation to trigger awareness that a hazard is present. Recognition and/or detection may consequently occur without precise naming of that hazard. It is difficult to comment on Stage 4 - Evaluate as evaluation data e.g. TTC were not investigated because of perceived problems in implementation and in measurement. In respect of Decision - Stage 5 risk homeostasis theory (Simonet and Wilde 1997) would appear to be inappropriate in L.B.F.S. error accidents. Whilst the driver may emerge in front of the motorcyclist, the notion that a driver considers a stationary police vehicle to be less threatening or worth consciously ignoring appears implausible.
Overall, the data found can be described at best as mixed, implying that the L.B.F.S. error is a complex issue which is not open to 'simple' methods of measurement. The previous research has been theoretically impoverished and has taken a folk psychological explanation of the driver's statement 'I did not see it' literally. The dubious methods previously used have been used to support only the conspicuity hypothesis. However the implementation described in this thesis whilst novel, shows that the use of different methodologies only highlights the complexity of the problem. The difficulty is in understanding and designing a measure that encapsulates and measures the error.

9.3 Limitations

9.3.1 The problem of generalisation

Generalisation is as Edworthy and Adams (1996) point out, a major problem in applied research. The number of variables as McKnight (1972) describes means the data obtained should be treated with caution. The studies reported here should be considered as a small scale implementation of theories on how we selectively attend to our environment. For example in generalising the results from Chapter 4 where data is reported from two junctions, care should be taken that in assuming that the average search times found could therefore be applied to any junction in the UK. Similarly generalising the results from the Sussex police accident database to the UK it must be remembered that Sussex may have an atypical population of drivers.

9.3.1.1 From laboratory to the real world

In interpreting the data obtained from the laboratory one must question how well these results reflect the real world. One concern is the quality of the video image presented to the driver. The best video reproduction at the time of this thesis (SVHS) poorly represents it. Conspicuity enhancers (colour, luminosity and reflectivity) are poorly replicated by video. In interpreting the data especially from Chapter 9 (p.164) these issues should be of paramount importance.

One may argue that the laboratory task poorly represents the task of the driver at either an intersection or when driving on a motorway. The subject in a laboratory is in a heightened state of awareness and his task is merely to respond via a button box that a hazard is or is not present in the scene. This compares poorly with the number of activities that the driver is likely to be engaged in when driving. The experimental manipulations described here could be reproduced in future in a driving simulator. Ideally these results should be replicated in the real world on a close-circuit track.

9.3.2 Age and experience

For this thesis age and/or experience were major issues. The findings have assumed that age equates to experience. This requires further investigation. It has been assumed that because a driver is over the age of twenty-five that s/he is 'experienced'. Whilst it is likely that this may be the case, further confirmation should be sought. In isolating the effects of age and experience, future research should note the difficulties found during this thesis in obtaining older inexperienced drivers and young relatively experienced drivers.

9.3.3 Eye-movements

Two experiments were reported. The assumption that eye-movements are a 'window on cognition' should be treated with caution. Whilst the data in Chapter 6 may appear to provide evidence that the L.B.F.S. error is a problem of the allocation of spatial attention replication shows that this hypothesis must be treated with care. The problem with generalising the results from measuring driver eye-movements and RT data is that as Hills (1980) points out L.B.F.S. errors are a complex interaction of many factors that may not be reflected in these sources of data.

9.4 Laboratory based Psychology

What do these results tell us about laboratory based psychological investigation? The data presents a mixed and complex picture. This thesis has attempted to understand why drivers have 'looked' but have not 'seen' using models of human attention that have been used in previous research. The *Type I* error was seen as a failure to selectively attend to certain locations or as a failure to recognise certain objects. The *Type II* error was conceptualised as a failure of vigilance.

9.4.1 Visual Selective Attention - the *Type 1* error

Are attentional mechanisms directed to regions of space as suggested by Watt (1992) or to preattentively defined perceptual objects as Egeth and Yantis (1997) would contend? The results from Chapter 7 suggest that attention is directed to detect objects, because experienced drivers tended to respond that a vehicle was present when it was represented by a simple shape. In addition results from Chapter 5 suggest that when participants are primed to look for one object over another, the target that they see affects their performance. Luck and Ford (1998) argue that different attentional mechanisms deal with the separation of targets from non- targets and other mechanisms recognise and identify them. However the data suggest that detection does not require identification or categorisation to a high level of detail because low spatial frequencies representing a vehicle appear enough often for an experienced driver to declare that a vehicle is present.

There is general agreement that visual scenes are encoded along a basic set of feature primitives e.g. orientation of edge, colour, brightness etc. in the early stages of perception (Theeuwes 1992). The data do not exclusively suggest which of the object recognition models discussed is the most appropriate for understanding how we rapidly interpret novel scenes(e.g. Scene Schema hypotheses: Biederman 1982, Schyns and Oliva, 1994). The data may be considered in line with Broadbent's (1977) claims that low frequency attributes of objects define global structures and high frequency provides the detail. Drivers of cars may sample their environment in the way Davis, *et al.* (1983) and Peterssik (1978) suggest when stimuli are presented very briefly, only the low frequency components may find their way into perceptual experience and stimuli appear therefore like blobs or blotches. The results suggest further research and the problem of understanding the L.B.F.S. error. Drivers who only viewed a primitive shape yet believed it was a vehicle may support Dennett's (1991) view that in our sense hat we have a richly detailed representation of a scene may be illusory.

Are eye-movements directed to informationally rich areas as Antes (1974) suggests? The experienced driver searches areas where a hazard might be. The novice driver searches areas away from the road (often trees) which may contain just contour information. Antes and Penland's (1991) view that the first fixation tells something about where the subject is expecting to find information suggests that the experienced driver searches into the distance at 'T' junctions first but if a motorcycle is located close by, the distance may not be the most informationally rich area.

From Edwards and Goolkassian's (1974) early research it appears that participants are able to detect targets quite easily in peripheral vision between 50°-90° the present research supports this view, as fixation was not needed to detect a target. A popular view is that sequences of fixations are planned (Kowler 19990) emphasising the link between overt behaviour and higher mental activities. (Zingale and Kowler, 1987).There is limited evidence for this but Viviani (1990) claims the idea that long strings of planned inspections is possibly false because drivers appear to only plan one fixation at a time based on the type of junction displayed. Levy-Schoen (1984) claims that a participant prepares a basic scanning routine

around which oculomotor behaviour will be organised. This may be true, but the recording of eye-movements does not allow us to infer attentional direction. The stimulus-driven step-by-step oculomotor performance suggested by Viviani (1990) is not supported by the current studies, because first fixations made by participants were not always towards the most conspicuous object in the scene.
Folk, Remington, and Johnston (1993) propose that involuntary shifts of spatial attention, even those elicited by abrupt visual onsets, are contingent on variable internal control settings. The 'where' to look, they argue is dependent on where the subject believes the target is going to appear. Drivers know that motorcycles will generally appear on the road but may appear in a different place to that of a car and this may be particularly important here (Olson 1989). Eye-movement studies showed differences between novices and experienced drivers, with experienced drivers fixating only in limited parts of the road environment. Experience may modify these 'internal settings' reflecting where the driver will look.

The improved reaction times found when participants were asked to search for a specific class of target could be considered to be consistent with Posner *et al.* (1980) whose results from laboratory experiments suggested that cueing a location can speed up detection of a target and are thought to indicate that processing capacity is allocated to positions in space (Pashler 1998).

9.4.2 Vigilance and the *Type 11* error

Vigilance theories have attempted to understand what determines the decline in vigilance performance over time and the overall level of performance (Warm 1984). The experiment reported here measured detection rates, false alarms and detection latencies. The results from Chapter 8 tended to agree with previous research that a vigilance decrement occurred through time and this was thought not to reflect a change in vigilance, (especially as this was a short experiment) but a change in report criteria. The data does not suggest which of the theories outlined in Chapter 8. (e.g. Smith 1966)) is the most appropriate to understand why drivers collide with conspicuous stationary police vehicles, but Loeb and Alluisi's (1984) view that performance is determined by uncertainties and expectancies based partially on previous experiences may be supported. However as discussed, the data found may be interpreted in other ways. The idea of hypothesis testing (review in Parks 1995) and the false hypothesis were investigated. From the measures used and the data collected Davis' (1958) theory of the false hypothesis may be worthy of further research.

9.4.3 Methodology

In the application of laboratory based findings to the real world the challenge is converting the methodology to test real world phenomena. For example in understanding if attention is directed to gross regions of space and if this is reflected in eye-movements, the challenge is to make the stimulus material as realistic as possible. In understanding the allocation of attention to objects the challenge is not just to conceptualise if drivers search for primitive shapes, Geons or low spatial frequencies but to conceptualise the environment where this might happen. For example Biederman's theory previously had been a static paradigm yet object recognition particularly when driving may yet rely on only movement cues. Therefore what initially appears to be an answer contained within the laboratory psychology needs to be mediated in terms of ecological validity, measurement and practicality.

9.5 Further Research

The studies contained in this thesis should be used to recommend further study only. In interpreting the results further research should aim to replicate these results in the field and with larger samples.

9.5.1 Methods, machines and larger samples

Chapter 4 reported on only two junctions and it was noted that a problem existed to generalising these results to all other junctions. Further observational studies at junctions with different characteristics should be considered particularly if drivers search in the way they are recommended to by the highway code (HMSO 1999).

Since Chapter 2 urged the use of a video to allow movement cues, the advent of digital standard video display means that these studies could be replicated using better quality stimuli. Computer technology having dramatically improved could also enable the generation of 3D stimulus materials to re-test Biederman’s RBC theory.

In some cases the sample size used was just adequate for statistical analysis but participants often showed wide performance differences. Some experiments particularly those reported in Chapter 7 should be replicated with larger samples.

9.5.2 Folk Psychology - the need for communication

On reviewing the literature and the data reported and after experiencing the responses at conferences to the findings of this thesis, there still appears to be a strong belief in the face validity that conspicuous objects are more detectable. When a person is asked for example how conspicuous they think a motorway police patrol car is, (as Cook 1996 did) their response that it is ‘highly conspicuous’ is taken to mean that it would be readily detectable by a tired driver who is not actively searching for hazards on a motorway, and who for the majority of his driving experience has assumed that the view of the rear of a police car with flashing lights represented a moving vehicle. This thesis acknowledges the persistence of the idea, despite the evidence, that physical conspicuity is the sole determiner of the detection of vulnerable vehicles. Whilst police officers, accident investigators and parts of the academic community independently agree this is not the case, the conclusion must be that communication between these groups is established with the aim of further research.

Issues in methodology measurement together with ecological validity have perhaps become the major issues in this thesis. In using one measure over another or one source of data over others a different understanding of the L.B.F.S. error has become evident. For example, accident data suggests different accident scenarios depending on the source reviewed. Experiments investigating object recognition theories are influenced by whether reaction time or the subject’s decision is measured.

Although several of these studies were attempted in the field the achievement of ecological validity is questionable. How the activities of a subject who is sampling a video screen reflects his performance in the field is debatable. Whilst the subject in the laboratory may fixate on certain parts of the scene over others, whether s/he does this in the real world is worthy of more research. One problem is that testing outside the laboratory is hazardous. For example exposing unsuspecting drivers to a stationary police vehicle on the motorway as they return home after a long shift is impracticable. I note however the limitations of using laboratory findings to make claims about the real world.

9.6 Final Remarks

Is there a scientific case to claim the following:

- Do drivers truly look but fail to see?
- Are vulnerable vehicles such as motorcycles particularly difficult to detect?
- Are motorcyclists difficult to detect because they are inconspicuous?

It is difficult to make a scientific case that the driver 'looked' but did not 'see' the motorcyclist. The data from accident files after interpretation merely imply that this is the case. Trying to isolate the L.B.F.S. error is almost impossible in the laboratory because of its rarity. Of the four hundred participants tested during this thesis only a few times did a subject fail to detect the hazard. In conclusion the statement 'I looked but I did not see it' may mean any of the following:

- I looked but I could not see because of physical restrictions in the road environment.
- I looked but could not see, because of my poor acuity.
- I looked but disregarded the motorcycle because it was not a threat.
- I looked but deliberately emerged into its path.
- I was looking in the wrong location.
- I was looking but did not expect to see a motorcyclist.
- I looked but the motorcyclist was inconspicuous.

In respect of drivers who claimed they did not see a stationary police vehicle their statement may mean any of the following:

- they may look but fail to appreciate that the conspicuity enhancements did not warn of a stationary police vehicle.
- they believed they were looking but may have been asleep
- they looked but the target was not conspicuous enough in the environment to be detected.

The thesis shows that it is not just motorcycles that are involved in accidents where the driver claimed they did not see them. Police motorway patrol vehicles are also hit by drivers who claim they did not see them. Operators of other conspicuous vehicles report that physical conspicuity alone does not guarantee detection. The Police Riders Handbook advises police motorcyclists that just because they are conspicuous they should not think they are safe. A view that is supported in the light of the data reported here.

The final conclusion must be that the 'folk psychological' explanation for the L.B.F.S. error is almost obsessive in attempting to consider only one explanation to the exclusion of all others. One may consider previous work to be relatively naive in thinking that the L.B.F.S. error has a single cause. The results reported in this thesis suggest the possibility that there are a number of factors working together that lead the driver to claim that they 'looked' but they are sure they did not 'see'.

10. References

62391 Accident Report Strada Analysis, November 1995, Sussex Police Authority, Accident Statistics Section, Lewes, Sussex.

63294 Accident Report Strada Analysis, November 1995, Sussex Police Authority, Accident Statistics Section, Lewes, Sussex.

76293 Accident Report Strada Analysis, November 1997, Sussex Police Authority, Accident Statistics Section, Lewes, Sussex.

76294 Accident Report Strada Analysis, November 1997, Sussex Police Authority, Accident Statistics Section, Lewes, Sussex.

76424 Accident Report Strada Analysis, December 1997, Sussex Police Authority, Accident Statistics Section, Lewes, Sussex.

76429 Accident Report Strada Analysis, December 1997, Sussex Police Authority, Accident Statistics Section, Lewes, Sussex.

Abrams, B. S. 1990, Night Vision, Visual Perception and Motorcycle Conspicuity, *Accident Investigation Quarterly,* 5, 26-30.

Accident Fact Sheet, 10 1995, Motorcycle Injury Road Accidents: Great Britain 1994, The Facts Series **3,** No. **2,** The Department of Transport, London.

ACPO 1996, The Motorway Manual, The Home Office, London.

Allgemeiner/Deutscher Automobil-club, 1987, Mitteilungen der Hauptabteilung Verkehr No 03, 15/228.

American Automobile Association 1952, Traffic Engineering and Safety Department - *Age and complex reaction time*, Report No*.* **4***.*

Antes, J. R. 1974, The time course of picture viewing, *Journal of Experimental Psychology,* **103**(1), 62-70.

Antes, J. R. and Penland, J. G. 1981, Picture context effect on eye-movement patterns, in Fisher, D. F., Monty, R. A. and Sanders (eds.) *Eye-movements, Cognition and Visual Perception* (Erlbaum, Hillsdale).

Antes, J. R., Singsasa, P. A. and Metager, R. L. 1978, Components of pictorial informativeness, *Perceptual and Motor Skills,* **47,** 459-464.

Arthur, W. J., Strong, M. H. and Williamson, J. 1994, Validation of a visual attention task as a predictor of driving accident involvement, *Journal of Occupational and Organisational Psychology,* **67**, 175-182.

Atkinson, J. and Braddick, O. J. 1989, 'Where' and 'What' in visual search, *Perception,* **18,** 181 -189.

Aulhorn, E. and Harms, H. 1972, Visual Perimetry, in D. Jameson and C. M. Hurvich (eds.) *Handbook of Sensory Physiology,* **7**, *Visual Psychophysics*, (Springer – Verlag, Berlin).

Avant, L., Nelson, N., Short, N., Connerly, M. and Bowes, M. 1988, Prerecognition, sensory and cognitive processing of traffic signs, *Vision in Vehicles* **II**, A.G. Gale *et al.* (eds.) (Elsevier Science Publishers B.V., North Holland).

Bachmann, T. 1991, Identification of spatially quantised tachistosocpic images of faces: How many pixels does it take to carry identity? *European Journal of Cognitive Psychology*, **3**(1), 87-103.

Baker, H. 1959, Attention To Visual Displays During A Vigilance Task: Maintaining The Level Of Vigilance, *British Journal of Psychology,* **50,** 30-36.

Berkhout, J. 1979, Information transfer characteristics of moving light signals, *Human Factors*, **21**(4), 445-455.

Berlinson, L., Kulmala, R. and Leden, L. 1992, Test of new arrangements at cycle cross-roads, *Technical Report*, **121**, Research Centre of Finland.

Beucanon, R. 1998, Born Agains, Paper presented at the Institute of Road Safety Officers. Brooklands, September.

Biederman, I. 1989, Real-time human image understanding in Pilot performance models in Elkind, J. J., Card, S. K., Hochberg, J. and Huey, B. M. (eds), *Human performance models for computer-aided engineering* (Academic Press, London)

Biederman, I. 1990, Higher Level Vision, in Osherson, D. N., Kosslyn, S. M. and Hollerbach, J. M. (eds.) *Visual Cognition and action: An invitation to Cognitive Science,* **2**, 41-73.

Biederman, I. 1995, Visual object recognition, in Kosslyn, S.M., Osherson, Daniel N. (eds.), *Visual cognition: An invitation to cognitive science,* **2** (2nd ed.) 121-165 (MIT Press, Cambridge, Mass, USA).

Biederman, I., Glass, A. L. and Stacey, W. E., Jr, 1974, On the information extracted at a glance from a scene, *Journal of Experimental Psychology*, **103,** 587-600.

Blaustein, M. 1977, Army traffic fatalities in Hawaii: 1975. Military-Medicine, Sep. **142**(9), 689-692.

Blomberg, R. D., Hale, A., Preusser, D. F. 1986, Experimental evaluation of alternative conspicuity-enhancement techniques for pedestrians and bicyclists*. Journal-of-Safety-Research*, Spring, **17**(1), 1-12.

Boersema, T. and Zwaga, H.J. 1996, Pop out in visual search requires practice, *Perceptual and Motor Skills*, **82** (2), 355-365.

Boersema, T., Zwaga, H.J., Adams, A.S. 1989, Conspicuity in realistic scenes and eye-movement measure, *Applied-Ergonomics*, Dec. **20**(4), 267-273.

Borowsky, S. and Wall, R. 1983, Flight experience and naval aircraft mishaps, *Aviation-Space- and- Environmental- Medicine*, **54**(5), 440-446.

Bottom, C. G. and Ashworth, R. 1978, Factors affecting the variability of the driver gap acceptance behavior, *Ergonomics*, **21**, 721-734.

Braunstien, M. L. and Anderson, G. J. 1984, Shape and depth perception for parallel projections of three dimensional motion*, Journal of Experimental Psychology Human Perception and Performance*, **14,** 582-590.

Broadbent, D. E. and Gregory, M. 1965, Effects Of Noise And Signal Rate Upon Vigilance Analysed By Means Of Decision Theory, *Human Factors,* **7**, 155-162.

Broadbent, D. E. 1977, The hidden preattentive process, *American Psychologist,* **32,** 109-118.

Broadbent, D. E. 1982, Task combination and the selective intake, *Acta Psychologica,* **50,** 253-290.

Brooks, P. 1989, The Importance Of Driver Decision Making And Interaction In Accidents Involving Motorcycles: in T. Rothengatter, R. De Bruin (Eds.) *Road User Theory And Research*, (Van Gorcum, Maastricht, Netherlands).

Brown, I. D. 1990, Drivers' margins of safety considered as a focus for research on error, *Ergonomics*, Oct-Nov, **33**(10-11), 1307-1314.

Burg, A. 1968, Lateral visual field as related to age and sex, *Journal of Applied Psychology*, **52**, (3)10-15.

Burg, A. 1975, The relationship between visual ability and road accidents: Proceedings of the 1st International congress on Vision and Road Safety Prevention, Routiere' International Linas-motbury France, 3-12.

Cabon, P., Coblentz, A., Mollard, R. and Fouillot, J. P. 1993, Human Vigilance In Railway And Long-Haul Flight Operation, *Ergonomics,* .**36**, No. 9, 1019-1033.

Caird, J. and Hancock, P. 1994, The perception of arrival time for different oncoming vehicles at an intersection, *Ecological Psychology*, **6**(2), 83-109.

Cairney, P. 1995, Real-Life night time performance of lights and reflective devices for cyclists, Proceedings of the **VI** Vision in Vehicles conference, Derby UK,. (Elsevier Science, Amersterdam).

Cairney, P. and Catchpole, J. 1995, Patterns of perceptual failure at intersections of arterial roads and local streets, in Gale, A. G. (ed.), *Vision in Vehicles,* **VI**, (Elsevier Science, Amersterdam).

Campbell, F. W. and Robson, J. G. 1968, Application of Fourier Analysis to the visibility of gratings, *Journal of Physiology,* **197**, 551-566.

Carrano, B. 1979, Update: Motorcycle accidents in 1977, *Traffic Safety*, **79**, No 2, 8-11.

Carrasco, M., Mclean, T. L., Katz, S. M. and Frieder, K.S. 1998, Feature Symmetries in visual search: Effects of display duration, target eccentricity, orientation and spatial frequency, *Vision Research*, **38**, No. 3, 347-374.

Carter and Laya, O. (in Press), Drivers' visual search in a field and in a driving simulator, in A. G. Gale, M. H. Freeman, C. M. Haslegrave, P. Smith, S. P. Taylor, (eds), *Vision in Vehicles* - **VI**, 221-230, (North-Holland, Amsterdam, Netherlands).

Casuality Report 1996 *Road Accidents Great Britain: 1996 The Casualty Report* Government Statistical Service London

Cavilo, V. and Laurent, M. 1986, Visual information and skill level in time-to-collision estimation, *Perception*, **17**, 623 632.

Cercarelli, L.R., Arnold, P.C., Rosman, D.L. Sleet, D. And Thornett, M. L., 1992, Travel exposure and choice of comparison for examining motorcycle conspicuity by analysis of crash data, *Accident Analysis and Prevention*, 24 (4), 363- 368.

Chekaluk, E. and Llewellyn, K. R. 1992, From the preface *The Role of eye-movements in perceptual processes* (North Holland, Netherlands).

Chesham, D. J., Rutter, D. R., Quine, L. 1993, Motorcycle safety research: A review of the social and behavioural literature, *Social Science and Medicine*, Aug. **37**(3), 419-429.

Cohen, A. S. 1981, Car drivers' patterns of eye fixations on the road and in the laboratory, *Perceptual and Motor Skills,* **52,** 515-522.

Cohen, A. S., Hirsig, R., 1979, Causality between drivers' successive eye fixations, *Perceptual-and-Motor-Skills*, Jun.: **48** (3,Pt 1), 974.

Cohen, K. M. 1981, The development of strategies of visual search, in Fisher, D. F., Monty, R. A., Senders, J. W. (eds) *Eyemovements: Cognition and Visual Perception* (Lawrence Erlbaum Associates, Hillsdale, NJ).

Cole, B. L. and Jenkins, S. E. 1980, The nature and measurement of conspicuity, in proceedings of the 10th biannual conference of the Australian Road Research Board, Melbourne, ARRP, 99-107.

Cole, B. L., and Hughes, P. K. 1984, A field trial of attention and search conspicuity, *Human-Factors,* Jun. . **26**(3), 299-313.

Cole, B. L., Hughes, P. K. 1993, Drivers don't search, they just notice, in Brogan, D.(ed.) *Visual Search* (Taylor and Francis, London).

Connors, M. M. 1975, The conspicuity of lights, the influence of color. *Technical report N.A.S.A TN-D 7960*, Ammes Research Centre, CA.

Cooffe, C. and O'Reagan, J. K. 1987, Reducing the influence of non-target stimuli on saccadic accuracy predictability and latency effects, *Vision Research,* **27,** 227-240.

Cook, S. 1996, *Police vehicle motorway patrol vehicle markings - Rationale for their design,* (ICE Ergonomics Home Office/Police Scientific Development Research, Hertfordshire).

Coyne. P. 1996, Motorcycle Roadcraft - The Police Rider Handbook, The Police Foundation, HMSO.

Crundell, D. E. and Underwood, G. 1998, Effects of experience and processing demands on visual information acquisition in drivers, *Ergonomics*, **41**, No. 4, 448-458.

Cummings, J. E. 1986, *Perception with an eye for motion* (MIT Press, Cambridge, MA).

Cummings, R.W.1964, The analysis of skills in driving. *Australian Road Research,* **1** (9) 4-14.

Currie, C., McCookie, GW., Carlson-Radavanski, L. A. and Irvin, D. E. 1995, Maintaining visual stability across saccades. Role of the saccade target object *Human perception and performance Technical report UTUc-81 HPP-95-01,* University of Illinois.

Currie, L. 1975, Habit as the source of an Inappropriate Response, *Ergonomics*, **18**, No 4, 435-442.

Dahlstedt, S. 1986, *A comparison of some daylight motorcycle visibility treatments*, VAG Trafik Institute, Linksping, Sweden.

Damon, A., Stoudt, H. W., McFarland, R. A. 1966*, The human body in equipment design* (Harvard University Press, Cambridge, MA).

Davidson, P. and Irving, A. 1980, *Survey of Visual Acuity of Drivers*, TRRL Report **945**, Crowthorne, Berkshire.

Davies, D. R. and Parasuraman, R. 1982, *The Psychology Of Vigilance* (Academic Press London).

Davis, E. T., Kramer, P. and Graham, N. 1983, Uncertainty about spatial frequency, spatial position or control of visual patterns, *Perception and Psychophysics,* **33,** 20-28.

Davis, R. D. 1958, Human engineering in transport accidents, *Ergonomics,* **2,** 24-33.

de Graef, P. 1992, Scene-context effects and models of realworld perception, in Rare, K. (ed.) *Eye-movements and visual cognition - scene perception and reading* (Springer-Verlag, New York).

DeLucia, P R, 1992, Even during active control of self motion collision avoidance for small objects can occur later than for large objects of equal distance and speed, *Investigative Ophthalmology and Visual Science*, **33**, 1144.

DeLucia, P. R. 1991, Small objects can appear further than large far objects during object motion and self motion. Judgments of object-self and object-object collisions, in Beek, P.J., Bootsma, R.J. and van Wieringen (eds) *Studies in perception and action, Proceedings from the 5th International conference on event perception and action* (Rodopi, Amsterdam).

Dennett, D. 1991, *Consciousness explained* (Little Brown, Boston).

Desilva, H. R. 1938, Time to React, *Brake -Service*, **8**, 9-12.

Deutch, J. A., Deutch, D. 1963, Attention - Some theoretical considerations. *Psychological Review*, **70**, 80-90.

Dishart, D. 1997, The development of Eye Movement Strategies of learner drivers, Poster presentation, *Vision in Vehicles Conference VII*, Marseilles, France, September.

Donk, M. 1993, On the comparison of conspicuity with visibility, in *Proceedings of the second Conference of Visual Search* (North Holland, London).

Donne, G. L., Fulton, E. J. 1985, The evaluation of aids to the daytime conspicuity of motorcycles. *TRRL Report number LB1137 TRL*, Crowthorne, Berkshire, UK.

Draskoczy, M. 1989, Bus driver behaviour at rail-highway grade crossings, in T. Rothengatter, R. De Bruin (eds.) *Road User Theory And Research* (Van Gorcum, Maastricht, Netherlands).

Duncan, J. 1981, Directing attention in the visual field, *Perception-and-Psychophysics,* **30**(1), 90-93.

Duncan, J., Williams, P., Brown, I. 1991, Components of driving skill: Experience does not mean expertise, *Ergonomics*, Jul. **34**(7), 919-937.

Duncan. J. 1984, Selective attention and the organisation of visual information, *Journal of Experimental Psychology- General,* **113**, 501-517.

Edkins, G. D. and Pollock, C. M. 1997, The Influence Of Sustained Attention On Railway Accidents, *Accident Analysis And Prevention,* July, **29**, No. 4, 533-539.

Edwards, A. and Goolkassian, A, S. 1974, Peripheral vision location and kinds of complex processing, *Bulletin-of-the-Psychononic-Society,* **9**(2), 139-141.

Edwards, D. 1991 Categories are for talking - On the cognitive and discourse bases of categorisation, Special Issue Cognitivism and its discontents, *Theory-and-Psychology*, **1** (4), 515-542.

Edwards, D. 1994, Script formulations - An analysis of event descriptions in conversation, *Journal of Language and Social Psychology*, **13** (3), 211-247.

Edworthy, J. and Adams, A. 1996, *Warning Design: A Research Prospective* (Taylor and Francis, London).

Egan, J. P., Greenberg, G. Z. and Sclman, A. I. 1961, Operating Characteristics, Signal Detectability and the Method of Free Response, *Journal of Acoustical Society of America,* **33**, 993-1007.

Egeth, H. E. and Yantis, S. 1997, Visual attention: Control, Representation, and Time Course, *Annual Review of Psychology*, **48**, 269-297.

Ellis, S. 1986, Statistical Dependency in Visual Scanning, *Human Factors* ,**28** (4), 421- 438.

Engel, F. L. 1971, Visual conspicuity directed attention and the retinal locus. *Vision Research,* **11,** 261- 270.

Engel, F. L. 1974, Visual conspicuity and selective background interference in eccentric vision, *Vision research*, **14**, 459.

Engel, F. L. 1976, *Visual conspicuity as an external determiner of eye movements and selective attention* (Technische Hogeschool, Einhoven).

Engel, F. L. 1977, Visual Conspicuity - visual search and fixation tendencies of the eye. *Vision Research*, **17**, 95-108.

Enns, J. T. 1990, Three dimensional features that pop out in visual search, in Brogan, D. (ed.), *Visual Search* (Taylor and Francis, London).

Erisen, C. W. and Murphy, T. D. 1987, Movement of attentional focus across the visual field - a critical look at the evidence, *Perception and Psychophysics,* **42,** 299-305.

ETSC 1997, *European Transport Safety Council. A Strategic Road Safety Plan For The European Union*, February 1997, (European Safety Council, Brussels).

Evans, L. 1991, *Traffic safety and the driver*, (Van Nostrand, Reinhold, New York)

Finlay, D. 1982, Motion perception in the peripheral visual field, *Perception*, **11**, (4), 457-462.

Fiser, J., Subramaniam, S, and Biederman, I. 1996, The effect of changing size and spatial frequency content of grey scale images in RSVP identification tasks, *Poster presented April 1996* at the Association for research in Vision and Ophthalmology, Ft Lauderdale, Florida.

Flach, J, 1990, Control with an eye for perception - Precursors to and active psychophysics. *Ecological Psychology*, **2**, 83 -111.

Foldvary, L. A. 1967, A method of analysing collision accidents. Tested on Victoria Road Accidents which occurred in 1961 and 1962, *Australian Road Research,* (1), 25-38.

Folk, C. L., Remington, R. W., Johnston, J. C. 1993. Contingent attentional capture: A reply to Yantis, *Journal-of-Experimental-Psychology:-Human-Perception-and-Performance*, Jun. **19**(3), 682-685.

Freedman, M. 1982, Effectiveness of techniques to improve side and rear conspicuity of motorcycles and mopeds. *Proceedings of the American Association for Automotive Medicine*, October, Ottawa, Ontario, Canada.

Friedman, A. 1979, Framing Pictures: The role of knowledge in automatized and memory for gist, *Journal of Experimental Psychology, General,* **108,** 316-333.

Frost, D. and Poppel, E. 1976, Different programming modes of human saccadic eyemovements as a function of stimulus eccentricity - Indicators of a functional subdivision of the visual field, *Biological Cybernetics,* **23,** 39-40.

Fulton, E. J., Kirby, C. and Stroud, P. G. 1980, Daytime motorcycle conspicuity. *Supplementary report 625,* TRRL, Crowthorne, Berkshire.

Galinat, W. H. and Borg, I. 1987, On symbolic temporal information: Beliefs about the experience of duration, *Memory-and-Cognition*, **15**(4), 308-317.

Gibson, J. J. 1950, *The perception of the visual world* (Houghton-Mifflin, Boston).

Gibson, J. J. 1966, *The senses considered as perceptual systems* (Houghton Miller, Boston).

Gibson, J. J. 1979, *The ecological approach to visual perception* (Houghton Miller, Boston).

Graham, N. 1985, Detection and identification of near-threshold visual patterns, *Journal of the Optical Society of America,* A 2, 1468-1482.

Graham, N. 1989, *Visual pattern analyzers* (OUP, Oxford).

Green, D. M. and Swets, J. A. 1966, *Signal detection theory and psycho-physics* (Wiley, New York).

Gregory, R. L. 1972, Seeing is thinking, *Times Library Supplement*, June 23.

Gregory, R. L. 1980, Perceptions as hypotheses. *Philosophical Transactions of the Royal Society of London*, Series b **290**, 181-197.

Groeger, J. A. and Chapman, P. R. 1996, Judgement of traffic scenes: The role of danger and difficulty, *Applied-Cognitive-Psychology*, Aug. **10**(4), 349-364.

Hale, A. R., Stoop, J., Hommels, J. G., 1990, Human error models as predictors of accident scenarios for designers in road transport systems. Commission of the European Communities Workshop: Errors in the operation of transport systems (1989, Cambridge, England), *Ergonomics*, Oct.- Nov. **33**(10-11), 1377-1387.

Hallstead-Nussloch, R., Sivak, M., Olson, P. and Sturgis, R.1986 Development and field testing of techniques for increasing the conspicuity of motorcycles and motorcycle riders. *Interim Report*, The University of Michigan, Highway Safety Research Institute.

Hancock, P. A. and Mansier, M. P. 1995, Endogenous and exogenous factors influencing estimates of time-to-contact, in A.G. Gale (ed.), *Proceedings of the VI Vision in Vehicles conference*, Derby, *UK - in press.*

Hancock, P. A., and Hurt, H. H. 1985, Motorcycle conspicuity, *Technical report 85-01*, Los Angles Motorcycle Accident Research Laboratory, Department of Safety Sciences, USC.

Harfield, A, 1998, Attention in early scientific psychology, in R. D. Wright, (ed.) *Visual Attention* (Oxford University Press, New York).

Harris, M., Freeman, T. and William, G. 1992, Surface layout from retinal flow, in Humphreys, G. (ed.), *Understanding Vision Readings in Mind and Language* (Blackwell, Cambridge, MA).

Harris, R. L., Glover, B. J. and Spady, A. A. 1986, Analytical techniques of pilot scanning behaviour and their application, *NASA Technical Paper,* **2525**.

Hartley, A. 1992, Attention, in Craik, Fergus I. M. (ed.), Salthouse, Timothy A., *The Handbook of Ageing and Cognition,* 3-49, (Lawrence Erlbaum Associates, Inc. Hillsdale, NJ).

Hartmann, E. 1970, Driver vision requirements, *SAE Technical Paper Series 700392*.

Haworth, N., Schulze, M. 1997, Motorcycle crash countermeasures: Literature review and implementation workshop. *Report 87*, Monash University Accident Research Centre.

Henderson, J. M., Pollatses, A. and Rayner, K. 1989, Covert visual attention and extra foveal information use during object identification, *Perception and Psychophysics,* **45**, 196-208.

Henderson, R. L. 1983, Motor Vehicle Conspicuity, *SAE crash avoidance SP-544*, 145-187.

Henderson, R. L., and Burg, A. 1974, Vision and audition in driving, *Final report,* System Development Corp. Santa Monica.

Herstein, A. and Walker, M. L. 1993, Perception of vehicle speed as a function of vehicle size, *Bulletin of the Psychonomic Society*, **31**(6), 566-568.
Hills, B. L. 1980, Vision visibility and perception in driving, *Perception*, **3**, 434-467.
Hills, B. L. and Burg, A. 1977, A re-analysis of Californian Driver vision data. General Findings, *TRRL Report 768*, Crowthorne, Berks.

Hoffman, E. R. 1968, Detection of vehicle velocity changes in car following. *Proceedings Australian Road Research Board*, **4**, 821-837.
Hoffman, E. R. and Mortimer, R. G. 1994, Drivers' estimation of time to collision. *Accident Analyses and Prevention*, **26**(4), 511-529.
Hole, G. and Langham, M. 1997, Reaction Time, Paper presented at the Biannual Conference of the Institute of Traffic Accident Investigators, Telford, November 1997.
Hole, G. and Tyrrell, L. 1995, The influence of perceptual set on the detection of motorcyclists using daytime headlights, *Ergonomics*, **38**, No. 7, 1326-1341.
Hole, G., Tyrrell, L., and Langham, M. 1996, Some factors affecting motorcyclists' conspicuity, *Ergonomics*, **39**,(7), 946-965.
Horn, B. K. P. 1986, *Robot Vision,* (MIT, Cambridge, Mass,).
Horne, J. A. and Gibbons, H. 1991, Effects on Vigilance Performance and Sleepiness Of Alcohol given in the Early Afternoon (Post Lunch) Vs Early Evening, *Ergonomics,* **34**, No. 1, 67-77.
Horne, J. A. and Reyner, L. A. 1995, Driver sleepiness, *Journal of Sleep Research*, **4**, No. 2, 23-29.
Howell, D. C. 1992, *Statistical Methods For Psychology* (Duxbury Press, Belmont, California).
Howells, R. A., Buck, J. R., Knight, J. L., Jr., Weiss, S. M. and MacMillian, A. G. 1980 Decision making in intersection entry accidents. *Proceedings International Motorcycle Safety Council*, Washington, DC. May, 1585-1611.
Hughes, P. K. and Cole, B. L. 1984, A field trail of attention and search conspicuity, *Human Factors*, **26,** 299 –313.
Hughes, P. K. and Cole, B. L. 1986, Can the conspicuity of objects be predicted from laboratory experiments? *Ergonomics*, Sep. **29**(9), 1097-1111.
Hughes, P. K. and Cole, B. L. 1986, What attracts attention when driving? *Ergonomics*, **29** (3), 377- 391.
Hughes, P. K. and Cole, B. L. 1988, The effect of attentional demand on eye movement behaviour when driving, in A. G. Gale, M. H. Freeman, C. M. Haslegrave, P. Smith, S. P. Taylor, (eds), *Vision in Vehicles* - **II**, 221-230, (North-Holland, Amsterdam, Netherlands).
Humphreys, G. 1992, *Understanding Vision Readings in Mind and Language* (Blackwell, Cambridge, MA).
Hurst, R. and Hurst, L. 1982, *Pilot Error – The Human Facto*r, (2nd Ed), Granada, London.
Hurt, H. H., Jr Oulett, J. V., and Thom, D. R. 1981 Motorcycle accident cause factors and identification of countermeasures *Vol. 1 Technical Report* Los Angles Traffic Safety Centre University of Southern California.
Hurvich, C. M. 1981, *Color Vision*, (Sinauer Associates, Sunderland, Mass).
Ikeda, M. and Takeeuchi, T. 1975, Influence of foveal load on the functional visual field, *Perception and Psychophysics*, **18**, 225-260.
Isler, R., Kirk, P., Bradford, S. J. and Parker, R. J. 1997, Testing the relative conspicuity of safety garments for New Zealand forestry workers, *Applied Ergonomics*, .**28**, No. 5-6, 323-329.
Jacobs, A. M. 1986, Eye-movement control in visual search - how direct is visual span control? *Perception and Psychophysics,* **39,** 47-58.

Jagaicinski, R. J., Johnson, W. W. and Miller, R. A. 1983, Quantifying the cognitive trajectories of extrapolated movements, *Journal of Experimental Psychology, Human Perception and Performance*, **9**, 43-57.

James, W. 1890, *The Principles of Psychology*, (Holt, New York).

Janoff, M. S. 1973, Motorcycle noticeability and safety during daytime. *Paper No. 73034*. Paper presented at the second international congress on automotive safety, San Francisco, California.

Janoff, M. S. and Cassel, A. 1971, Effect of daytime motorcycle headlight law on motorcycle accidents, *Research Record No. 377*, 56-63.

Janoff, M. S. and Cassel, A. 1971, Effect of distance motorcycle headlight conditions on motorcycle noticeability. *Highway research, Record 377*, 33-43.

Janoff, M. S., Cassel, A., Fertner, K. S. and Simierciak, E. S. 1970, Daytime motorcycle headlight and taillight operation. *Technical report f-c 2588*, Philadelphia. Franklin Institute Research Laboratories.

Jenkins, S. E. and Cole, B. L. 1982, The effect of density of background elements on the conspicuity of objects, *Vision Research*, **22**, 1241-1252.

Jerrison, H. J. 1958, Experiments In Vigilance v The Empirical Model For Human Vigilance, Wright Air Development Technical Report, In Warm, J. S (ed.) *Sustained Attention In Human Performance Studies In Human Performance* (John Wiley And Sons, Chichester, UK) 293–321

Johnson, J. C. and Pashler, H. E. 1991, Close binding of identity and location - visual feature perception, *Journal of Experimental Psychology Human Perception and Performance,* **16**, 843-856.

Kahnemen, D., Ben-Ishal, R. and Lotan, M. 1973, Relation of a test of attention of attention to road accidents, *Journal of Applied Psychology*, **58**, 113-115.

Keskinen, W. Ota, H. and Katila, A. 1998, Older Drivers Fail in Intersections: Speed discrepancies between older and younger male drivers, *Accident, Analysis and Prevention*, **30**, 323-330.

Kinchla, R. A. 1992, Attention, *Annual-Review-of-Psychology,* **43,** 711-742.

Kirby, C. and Fulton, E. J. 1978, *The daytime use of headlights on low powered motorcycles*, Loughborough Leicestershire Institute for Consumer Ergonomics.

Kirby, K. N. and Kosslyn, S. M. 1992, Thinking visually, in Humphreys, G. (ed.) *Understanding Vision Readings in Mind and Language* (Blackwell, Cambridge, MA).

Kirkpatrick, M., Baker, C. C. and Heasily, C. 1987, *A study of daytime running lights design factors*, (DOT 165807-193, Fairfax, VA).

Kito, T., Haraguchi, M., Funatso, H., Sato, T. and Kondo, M. 1989, Measurements of gaze movements while driving, *Perceptual- and –Motor-Skills*, **68**(1), 19-25.

Klien, R. 1980, Does oculomotor readiness mediate cognitive control of visual attention? In Nickerson, R. S. (ed.), *Attention and performance,* 259-275, (13 Hillsdale, New Jersey).

Kowler, E. 1990, The role of visual and cognitive process in the control of eyemovements, in Kowler, E. (ed.) *Reviews of Oculomotor Research*, **l4***,* Eye movements and their role in visual and cognitive process, 353-393, (Elsevier, Amsterdam).

Krus, D. J., Fletcher, S. H. 1986, Time: A speeding train or wind-driven sand? The estimation of fixed temporal intervals as related to images of time, *Perceptual-and-Motor-Skills*, . **62**(3), 936-938.

Kundel, H. L., and Nodine, C. F. 1983, A visual concept shapes image perception, *Radiology*, **28**, 356-361.

Lambert, L. D., Fleury, M. E. 1994, Age, cognitive style, and traffic signs, *Perceptual-and-Motor-Skills*, **78**(2), 611-624.

Land, M. F. 1992, Predictable eye-head co-ordination during driving, *Nature*, **359**, September, 318-320.

Land, M. F. and Horwood, J. 1995, Which parts of the road guide steering? *Nature*, **377**, 339-340.

Land, M. F. and Lee, D. N. 1994, Where we look when we steer, *Nature*, **369**, 742-744.
Langham, M. P. 1995, A laboratory investigation of the effects of cognitive style and motorcycle conspicuity, *Vision in Vehicles* **VI**, A.G. Gale *et al.* (eds) (Elsevier Science Publishers B.V., North Holland).
Langham, M. P., Hole, G., Edwards, J. and O'Neil, C. 1998, Can the 'looked but failed to see' error involve highly conspicuous police patrol cars? Evidence from accident reports and laboratory studies, Paper presented at the First Engineering Psychology Conference, British Psychological Society Special Interest Group, University of Southampton, March.
Langham, M. P., Hole, G., O'Neil, C., Cooke, M. and Land, M. F. 1998, Where do police officers look? The effects of training and experience on visual search at intersections, Paper presented at the Annual Conference of the Association of Industrial Road Safety Officers, and the Metropolitan Police Driving School, Metropolitan Police Headquarters, Hendon, November.
Langley, J. 1995, Sorry mate I did not see you, *The Electronic Telegraph,* June 20 1995.
Lapidus, G., Braddock, M., Schwartz, R., Banco, L. and Jacobs, L. 1994, Accuracy of Fatal motorcycle injury reporting on death certificates*, Accident Analysis and Prevention*, **26**,(4), 535-542.
Lapton, K., Jarrett, D. and Wright, C. 1997, *The consistency of road accident variables in Great Britain 1995*, Middlesex Business School.
Lashly, K. S. 1951, The problem of serial order in behaviour, in Jeffress (ed.) Cerebral mechanisms in behaviour - The Hixon Symposium, 112-136 (Wiley, New York).
Laya, O. 1987, Visual perception at roundabouts - Multiple Levels of Task complexity, in A. G. Gale, M. Freeman, C. M. Haslegrove, P. Smith and S. P. Taylor (eds) *Vision in Vehicles* **II**, Amsterdam, North Holland.
Lee, D. 1980, The optic flow field- The foundation of vision. *Philosophical transactions of the Royal Society of London*, b**290,** 169-179.
Lee, D. N. 1976, A theory of visual control of braking based on information about time to collision, *Perception*, **5**, 437-459.
Leibowitz, H. W. 1983, A behavioural and perceptual analysis of grade crossing accidents. *Operation Life Saver, National Symposium 1982*, Chicago, National Safety Council.
Leibowitz, H. W. 1996, The symbiosis between basic and applied research, *American-Psychologist*, Apr. **51**(4), 366-370.
Leibowitz, H. W., Appllee, S. 1989, The effect of a central task on luminance thresholds for peripherally presented stimuli, *Human Factors*, **4**, 387-392.
Leibowitz, H., Post, R.B., Brandt, T., Dichgans, J. 1982, Implications of recent developments in dynamic spatial orientation and visual resolution for vehicle guidance, in A. Westheim, Waganaur and Leibowitz, H. (eds). *Tutorials in Motion Perception*, 231-260, (Pleneum Press, New York).
Lesley, G. 1995, Enhancing the daytime conspicuity of pedestrians through the usage of fluorescent materials. ISCC Conference: Colorimetry of fluorescent materials 1994, Williamsburg, Virginia, *Color-Research-and-Application,* Apr. **20**(2) 117-123.
Levy, J. and Pashler, H. 1995, Does perceptual analysis continue during selection and production of a speeded response? *Acta Psychologica,* **90,** 245-260.
Levy-Scheon, A. 1981, Flexible and /or rigid control of occulmotor scanning behavior, in Fisher, D. F., Monty, R. A. and Sanders, J. W. (eds.) *Eye-movements, Cognition and Visual Perception,* (North Holland,Amsterdam).
Lewis, M.F. 1973, Frequency of anti-collision observing responses by solo pilots as a function of traffic density, ATC traffic warnings, and competing behaviour, *Aerospace-Medicine* . **44**(9), 1048-1050.

Liu, A. 1997, Towards predicting driver intentions from patterns of eye-fixations, Paper presented at the 7th Vision in Vehicles Conference, November 1997, Marseilles, France.

Lock, A. and Beger, A. 1993 Influence of sex, presentation order and trail blocks on young adults' simple and type c reaction times, *Perceptual and Motor Skills*, **76**, 1199-1210.

Loeb, M. and Alluisi, E A. 1984, Theories Of Vigilance, in Warm, J.S. (ed.) *Sustained Attention In Human Performance Studies In Human Performance*, 293–321, (John Wiley And Sons, Chichester, UK).

Logothetis, N. and Sheinberg, D. L. 1996, Visual object recognition, *Annual-Review-of-Neuroscience*, **19**, 577-621.

Lovegrove, A. S. 1978, Approach speeds at uncontrolled intersections with restricted sight distances, *Journal-of-Applied-Psychology*, Oct, **63**(5), 635-643.

Lucaccini, L., Freedy, A. and Lyman, J. 1968, Motivational Factors In Vigilance Effects Of Instruction On Performance In A Complex Vigilance Task, *Perceptual And Motor Skills,* **26**, 783–786.

Luck, S. J. and Ford, M. A. 1998, *Proceedings of the National Academy of Sciences of the United States of America,* **95**, 825-830.

MacDonald, W. A. and Cole, B. L. 1988, Evaluating the role of color in a flight information cockpit display, *Ergonomics*, **31**, pp 13 -37.

Mackie, R. R. 1977*, Vigilance theory operational performance and physiological correlates*, (Plenum, New York).

Mackworth, J. H. and Morandi, A. J. 1967, The gaze select information details within pictures, *Perception and Psychophysics*, **2**, 547-552.

Mackworth, N. H. 1957, Some Factors affecting Vigilance, *Advancement Of Science,* **53**, 389-195.

Mackworth, N. H. 1965, Visual noise cause tunnel vision, *Psychometric Science*, **3**, 67-68.

Mackworth, N. H. 1974, Stimulus density limits and the useful field of view, in Monty, R. A. and Senders, J.W. (eds) *Eyemovements and psychological processes,* (Lawerence Erlbaum Associates, Hilsdale, NJ).

Mackworth, N. H., Kaplan, I. T. and Metley, W. 1964, Eye movements during vigilance, *Perceptual and Motor Skills,* **18,** 397-402.

Marr, D. .1982 *Vision* W.H. Freeman, New York.

Marr, D. and Nishihara, H. K. 1979, Representation and recognition of the spatial organisation of three dimensional shapes, Proceedings of the Royal Society 8 (20), 269- 291.

Martin, P. and Bateson, P. 1993, *Measuring behaviour - An introductory guide*. Cambridge University Press, Cambridge

Marvel, T. B., Moody, C. E. 1996, Specification problems - Police levels and crime rates, *Criminology*, **34** (4) 609-646.

Matthews, G., Davies, D. R. and Holley, P. J. 1993, Cognitive predictors of vigilance, *Human Factors.* **35** (1), 3–24.

Mavjee, V. and Horne, J. A. 1994, Boredom effects on sleepiness alertness in the early afternoon Vs early evening and interactions with warm ambient-temperature, *British Journal of Psychology*, **85**, (3), 317-333.

May, J. Cooper, C. and Kline, P. 1986, The reliability of reaction times in some elementary cognitive tasks: A brief research note, *Personality-and-Individual-Differences.* **7**(6): 893-895.

McGee, H. W. Hooper, K. G., and Hughes, W. E. and Benson, W. 1983, Highway design and operation standards affected by driver characteristics. 2 Technical Report Fhwa-rd 83 015, Vienna, Virginia.

McKenna, F, .P., Duncan, J. and Brown, I. D. 1986, Cognitive abilities and safety on the road - a re-examination of individual differences in dichotic listening and search for embedded figures, *Ergonomics*, **28**(5), 649-663.

McKnight, A. J. 1972, "*The application of system/Task analysis the identification of driver perception and decision making processes*" paper presented to the OECD Symposium on road user, perception and decision making, 13-15 November, Rome.

Meiszies, N. 1984, Voriahrt mufachtet (right of way violated) *Motorad Ressen and Sport* **17**, 60-61.

Miller, J. D. 1976, Encoding Processes in Memory scanning tasks, *Memory and Cognition*, **4**, 501-506.

Miru, T. 1987, Behaviour orientated vision, Functional field of view and processing resources, in O'Reagan, K. and Levey Schoen, A. (eds.) *Eye movements from physiology to cognition* (Elsever, North Holland).

Monk, T. H. 1984, Search, in Warm, J. S. (ed.), *Sustained Attention In Human Performance Studies In Human Performance*, 293-321, (John Wiley And Sons, Chichester, UK).

Moore, R. L. 1969, Some human factors affecting the design of vehicles and roads. *Journal of the Institute of Highway Engineers*, **16**, 13-22.

Moray, M. 1990, Designing for transport safety in the light of perception, attention and metal models, *Ergonomics*, **33**, 1201-1212.

Moray, N. 1978, The strategic control of information processing, in Underwood, G. (ed.) *Strategies of information processing*, (Academic Press, New York).

Moreland, J. D. 1972, Peripheral color vision. In Jameson and Hurvich's (eds) *Handbook of Sensory Physiology*, . **7** (1), (Springer–Verlag, Berlin).

Mortimer, R. G. and Schuldt, R. C. 1980, Field test evaluation of gap acceptance of drivers as a function of motorcycle front lighting. Proceedings of the International Motorcycle Safety Conference, *Motorcycle Safety Foundation*, **2**, 945-954.

Mortimer, R. G., Hoffman, E. R., Poskicil, A., Jorgeson, C. M., Moore, C. D. and Olson, P. L. 1974, Studies of automobile and truck rear lighting and signalling systems. *Report HF,* 74-25, University of Michigan Safety Research Institute.

Mourant, R. R. and Rockwell, T. H. 1970, Mapping eye movement patterns to the visual scene in driving - an explanatory study, *Human Factors,* **12,** 81-87.

Mourant, R. R. and Rockwell, T. H. 1972, Strategies of visual search by novice and experienced drivers, *Human Factors,* **14,** 325-335.

Muller, A. 1982, An evaluation of the effectiveness of motorcycle daytime headlight laws, *American Journal of Public Health*, **72**, 1136-1145.

Muller, A. 1983, How Effective Are Daytime Motorcycle Headlight Laws? A Response To Zador's Criticisms, *American Journal Of Public Health*, .**73**, 809.

Muller, A. 1984, Daytime headlight operation and motorcyclist fatalities, *Accident Analysis and Prevention*, **16**, 1- 8.

Mulligan, R. and Shaw, M. L. 1981, Attending to simple auditory and visual signals, *Perception and Psychophysics,* **30,** 447-454.

Murrell, G. A. 1975, A Reappraisal Of Artificial Signal as an Aid to a Visual Monitoring Task, *Ergonomics,* **18,** 693-700.

Nagayama, Y., Morita, T., Miura, T., Watanabe, J. and Murakami, M. 1979, Motorcyclist Visual scanning pattern in comparison with automobile drivers, *SAE technical paper*, Society of automotive engineers congress, Detroit, February- March 1979.

Nagayama, Y., Morita, T., Miura, T., Watanabe, J. and Murakami, M. 1980, Speed Judgement Of Oncoming Motorcycles, *Proceedings Of The International Motorcycle Safety Conference*, 955-971.

Navon, D. and Norman, J. 1983, Does global precedence really depend on visual angle? *Journal of Experimental Psychology Human perception and Performance*, **9**, 955-965.
Neisser, U. 1967, *Cognitive Psychology*. (Appleton Century-Crofts, New York).
Noon, R. 1992, *Introduction to Forensic engineering*, (CRC Press, Boca Ratan).
Noton, D. and Stark, L. 1971, Scanpaths in eye-movements during pattern perception, *Science*, **171**, 308-311.
O'Kane, B. L., Biederman, I., Cooper, E. C. and Nystrom, B. 1997, An account of object identification confusions, *Journal of Experimental Psychology-Applied*, **3** (1) 1-21.
O'Hare, D., Roscoe, S., Vette, G., Young, M. 1990, *Flightdeck performance: The human factor*, (Iowa State University Press, Ames, IA, USA).
Olsen, P. L., Halstead-Nussloch, R. and Sivak, M. 1981, The effect of Improvements in Motorcycle/ Motorcyclist Conspicuity on Driver Behaviour, *Human Factors*, **23**(2), 237-248.
Olsen, R. A. 1981, Human factors engineering and psychology in highway safety, *Human-Behavior-and-Environment:-Advances-in-Theory-and-Research,* **5,** 131-167.
Olson, P. L. 1989, Motorcycle Conspicuity Revisited, *Human Factors*, **31**(2), 141-146.
Olson, P. L. 1989b, Driver perception Response time*, SAE Technical Paper series no. 890731,* International congress and exposition, Detroit, Michigan, Feb/March.
Olson, P. L., Halstead-Nussloch, R. and Sivak, M. 1979, Development and testing of techniques for increasing the conspicuity of motorcycles and motorcycle drivers. *Technical Report, Department Of Transport, HS 805.242*, Washington, DC.
Olson, P. L., Sivak, M., 1986, Perception-response time for unexpected roadway hazards, *Human Factors*, **28**, 91-96.
Palmer, S. E. 1992, Modern theories of Gestalt perception. In Humphreys, G. (ed.) *Understanding Vision Readings in Mind and Language* (Blackwell, Cambridge, MA).
Parasuraman, R. and Davies, D. R. 1977, *Vigilance theory,* 559 (Academic Press London).
Parker, A. J., Christou, C., Cumming, B. C., Johnson, E. B., Hawken, M. J. and Zisserman, A. 1992, The analysis of 3D shape, Psychophysical principles and neural mechanisms, in Humphreys, G. (ed.), *Understanding Vision Readings in Mind and Language* (Blackwell, Cambridge, MA).
Parker, D., Reason, J. T., Manstead, A. S. R. and Stradling, S.G. 1995, Driving errors driving violations and accident involvement, *Ergonomics*, **38**(5), 1036-1046.
Parks, T. E. 1995, The microgenesis of illusory figures: Evidence for visual hypothesis testing, *Perception*, **24**(6) 681-684
Pavel, M. 1990, Predictive control of eye-movement, In E Kowler (ed.) *Eye-movements and their role in visual and cognitive process*, (Elsevier, Amsterdam).
Peek-Asa, C., Kraus, J. F. 1996, Injuries Sustained By Motorcycle Riders In The Approaching Turn Crash Configuration, *Accident Analysis And Prevention*, **28**(5), 561-568.
Peterssik, J. T. 1978, Possible role of transient and sustained visual mechanisms in the determination of similarity judgements, *Perceptual and Motor Skills,* **47**, 663- 698.
Polanis, S. F. 1979 Motorcycle accident patterns, *Pennsylvania Traffic Quarterly*, **33**, 139-155.
Polyak, S. L. 1941, *The Retina*. (University of Chicago Press, Chicago).
Posner, M. L. and Boies, S J. 1971, Components Of Attention, *Psychological Review,* **78**, 391-408.
Posner, M. L., Snyder, C. R. R. and Davidson, B. J. 1980, Attention and the detection of signals, *Journal of Experimental Psychology General,* **109,** 160-174.
Potter, M. C. 1976, Short term conceptual memory for pictures, *Journal of Experimental Human Learning and Memory*, **2**, 509-522.

Prower, S. M. 1985, Daytime light-on laws for motorcars motorcycles. London British Motorcyclist Federation (personal correspondence, Graham Hole, Oct. 1997)

Rabbitt, P. M. 1979, How young and old subjects monitor and control responses for accuracy and speed, *British Journal of Psychology*, **70**, 305-311.

Rabbitt, P. M. and Vyas, S. 1978, Processing a display even after you make a response to it - How perceptual errors can be corrected, *Quarterly Journal of Experimental Psychology - Human Experimental Psychology*, **33**, 223-239.

Rabbitt, P. 1979, Some experiments and a model for change in attentional selectivity with old age, in Hoffmeister, F. and Muller, C. (Eds.) *Brain function in old age* (Springer Veriag, Berlin).

Rabbitt, P. and Mueller, H. J,. 1989 Spatial cueing and the relation between the accuracy of 'where' and 'what' decisions in visual search, *Quarterly-Journal-of-Experimental-Psychology,* 41(4-A) 747-773.

Radin, U. R. S., Mackay, M. G. and Hills, B. L. 1996, Modelling of conspicuity related motorcycle accidents. In Seremban and Shah Alam Malaysia *Accident Analysis and Prevention* **28** (3) 325-332

Radins, U. R. S. 1992, Detailed analysis on road accidents in pilot areas, *Research Report 4 jk3p,* Kuala Lumpur, National Road Safety Council, Malaysia.

Rahimi, M., Briggs, R. P. and Thom, D. R. 1990, A field evaluation of driver eye-movements strategies towards environmental targets and distracters, *Applied Ergonomics*, **21** (4), 267-274.

Ramsey, J D. and Brinkley, W A. 1977, Enhanced Motorcycle notability through daytime use of visual signal warning devices, *Journal of Safety Research*, **9** (2), 77-84.

Rayner, K. 1978, Eye-movements in reading and information processing, *Psychological Bulletin,* **85,** 618-660.

Reason, J. 1979, Actions not as planned. The price of automatisation, in G. Underwood and R. Stevens (Eds.) *Aspects of Consciousness*, (Academic Press, London).

Reason, J. T., Manstead, A. S. R., Stradling, S. G., Baxter, J., Campbell, K. 1990, Errors and violations on the road - a real distinction? *Ergonomics*, **33**(10/11),1315-1332.

Reeves, A. and Sperling, G. (1986) Attention gazing in short term visual memory. *Psychological Review,* **93,** 180- 206

Reiess, H. L. and Haley, J. A. 1968, *Motorcycle Safety Final Report*, Cutler Hammar Inc., Airborne Instruments Laboratory, New York.

Remmington, R. W. 1980, Attention and saccadic eye-movements, *Journal of Experimental Psychology Human Perception and Performance,* **6,** 726-794.

Rensink, R. A., Oreagan, K., Clark, J. J. 1997, To see or not to see: The need for attention to perceive changes in scene, *Psychological Science*, **8**, 368-372.

Robinson, G. H. 1972, Visual search by automobile drivers, *Human Factors*, **14**, 314-323.

Rock, I. 1981, An Orthoscopic Perception. *Scientific-American,* **244** (3), 145-153.

Rock, I. and Mitchener, K,. 1992 Further evidence of failure of reversal of ambiguous figures by uninformed subjects, *Perception*, **21** 39-45.

Rosenbaum, D. A., Ishoff, A. W. and Gordon, A. M. 1984, Choosing between movement sequences - a hierarchical editor model, *Journal of Experimental Psychology-General,* **113**, 372-393.

Rumar, K. 1990, The basic driver error: Late detection. Commission of the European Communities Workshop: Errors in the operation of transport systems (1989, Cambridge, England), *Ergonomics*, **33** (10-11), 1281-1290.

Sabey, B., Staughton, G. C. 1975, Interacting Roles Of Road Environment, Vehicle And Road User, in Accidents Paper Presented To The 5th International Conference Of The International Association For Accident Traffic Medicine, 1975, London, TRRL, Crowthorne, Berkshire.

Salthouse, T 1985, *A Theory of Cognitive Ageing*, (Amsterdam, North Holland).

Sanders, A. F. 1980, *Stage analysis of reaction processes. Tutorial in motor behaviour*, 331-338. (Amsterdam, North Holland).

Sawin, D. A. and Scerbo, M. W. 1995, Effects Of Instruction Type And Boredom Proneness In Vigilance - Implications For Boredom And Workload, *Human Factors,* .**37**, No. 4, 752-765.

Scheider, W. and Shiffrin, R. M. 1977, Controlled and automatic human information processing in detection search and attention, *Psychological Review*, **84**, 1-66.

Schiff, W. 1965, Perception of impending collision. A study of visually directed avoidance behaviour, *Psychological Monographs General and Applied,* **79**, 604.

Schiff, W. and Derwiler, M. 1979, Information used in judging impeding collision, *Perception*, **8**, 647-658.

Schiff, W. and Oldak, R. 1990, Accuracy in judging time to arrival. Effects of modularity trajectory and gender*, Journal of Experimental Psychology, Human perception and performance*, **16**, 303-316.

Schiff, W., Oldak, R. and Shah, V. 1992, Ageing persons' estimates of vehicular motion, *Psychology and Ageing*, **2**, 647-656.

Schmidt, R. A. 1989, Unintended Acceleration: A review of Human Factors Contributions, *Human Factors,* **31** (3), 345 - 364.

Schmidt, R. A. and Gordon, G. B. 1977, Errors in motor responding 'rapid' corrections and false anticipations, *Journal of Motor Behaviour,* **4**, 101-111.

Schyns, PG and Oliva, A 1994, From blobs to boundary edges Evidence for time - and spatial-scale-dependent scene recognition, *Psychological Science*, **5** (4), 195 200.

Se Je, Howe, Sr, Warm, J. S., Dember, W.N (1995): Meta-analysis Of The Sensitivity Decrement In Vigilance, *Psychological Bulletin,* .**117,** (2), 230-249.

Sekuler, R. and Blake, R. 1994, *Perception*, (McGraw-Hill inc., New York).

Shaw, M. 1983, Division of attention among spatial locations - a fundamental difference between detection of letters and detection of luminance increments, in Posnor, M. (ed.), *Attention and Performance,* 109-121, (Lawrence Erlbaum Associates, Hilsdale)

Sheridain, T. and Johnson, G. 1976, Monitoring behaviour and supervisory control, (Plenum Press, New York).

Shinar, D. 1978, Field dependence and driver visual search behaviour, *Human Factors*, **20**(5), 553-559.

Shinar, D. 1985, The effects of expectancy, clothing reflectance, and detection criterion on night-time pedestrian visibility, *Human-Factors,* Jun. **27**(3), 327-333.

Shinar, D. 1993, Traffic safety and individual differences in driver attention and information processing capacity, *Alcohol Drugs and Driving*, (**4**), 219-237.

Shinar, D., McDowell, E. D., Rockwell, T. H. 1977, Eye movements in curve negotiation, *Human-Factors*, Feb, **19**(1), 63-71.

Shinar, D., Stiebel, J. 1986, The effectiveness of stationary versus moving police vehicles on compliance with speed limit, *Human-Factors*, Jun., **28**(3):365-371.

Siegal, A. I. and Federman, F. 1965, Development of a paint system for increasing aircraft detectability and visibility, *Journal of Applied Psychology*, **49**, 93-105.

Simmons, D. J. 1996, In sight out of mind - when object representations fail, *Psychological Science*, **7**, 301-305.

Simonets, A. J., Wilde, G. S. 1997, Risk: perception, acceptance and homeostasis. *Applied Psychology*-An-International review-psychology appliquee-revue internationale, **46,** 235-252.

Sivak, M. 1987 Human factors and road safety, *Applied-Ergonomics*, Dec, .**18**(4), 289-296.

Sivak, M. 1996, The information that drivers use: Is it indeed 90% visual? *Perception*, **25**(9) 1081-1090.

Sivak, M. 1997, Recent psychological literature on driving behaviour: what, where, and by whom? *Applied psychology*-an international review-psychologie appliquee-revue internationale, . **46**, no.3, 303-310.

Smets, G. J. F. and Stappers, P. J. 1990, Do invariants or features determine the conspicuity of forms? in D. Brogan (ed.) (1990). *Visual Search,* 29-35, (Taylor & Francis, London).

Smith, R. L. 1966, Monotony and Motivation, *A Theory of Vigilance,* (Dunlop Associates, Los Angeles).

Solomon, S. 1990, Lime-yellow color as related to reduction of serious fire apparatus accidents: The case for visibility in emergency vehicle accident avoidance, *Journal-of-the-American-Optometric-Association*, Nov, **61**(11), 827-831.

Sparks, G. A., Neudorf, R. D., Smith, A. E., Wapman, K. R, and Zador, P. L. 1993, The effect of daytime running lights on crashes between two vehicles in Saskatchewan. A study of a Government Fleet, *Accident Analysis and Prevention*, **25** (5), 619 – 625.

Staughton, G. C. and Storie, V. J. 1977, Methodology of an in-depth accident investigation, *Survey Report no* **672**, TRRL, Crowthorne, Berks.

Stoffregen, T. E. and Riccio, G. E. 1990, Response to optical looming in the retinal centre and periphery, *Ecological Psychology*, **2**, 251-274.

Summala, H. 1996, Accident Risk And Driver Behaviour, *Safety Science*, 22, 103-117.

Summala, H., Pasanen, E., Rasanen, M., Sievanen, J. 1996, Bicycle Accidents and Drivers' Visual search at left and right turns, *Accident Analysis and Prevention*, 147-153.

The Highway Code, (HMSO 1999) London

Theeuwes J. 1994, Endogenous and exogenous control of visual selection, *Perception*, **23**, 429-440.

Theeuwes J. 1996, Perceptual selectivity for color and form: On the nature of the interference effect, in Kramer, A. F., Coles, M.G.H., Logan, G.D. *Converging operations in the study of visual selective attention*, (APA, Washington, DC.)

Theeuwes, J. 1991, Visual selection exogenous and endogenous control, in Gale, A.G. (ed.), *Vision in Vehicles, **111***, 53-62, (North Holland, Amsterdam).

Theeuwes, J. 1993, Visual attention and driving behaviour, in Santos, J.A. (ed.), *Human factors in road traffic*, (Esher, Lisbon).

Theeuwes, J. 1993, Visual search at intersection - an eye movement analysis, in *Vision in Vehicles,* **V,** Gale, A. G. 125-134, (Elsever Sciences, Amsterdam).

Theeuwes, J. 1993, Visual selective attention - A theoretical analysis, *Acta Psychologica,* . **83**(2), 93-154.

Theeuwes, J. 1994, Endogenous and exogenous control of visual selection, *Perception*, **23**(4), 429-440.

Theeuwes, J., Alfferdenck, J. W. A. M. 1997, The effectiveness of side marker lamps - an experimental study, *Accident Analysis and Prevention*, **29**, 2, 235-245.

Theeuwes, J., Hagenzieker, W A M. (1993).Visual search of traffic scenes, on the effect of location expectations, in Gale, A.G. (ed.) *Vision in Vehicles,* **V**, 149-156, (Elsevier, Amsterdam).

Thomas, A. 1998, Specification for the Livery on Police Patrol Cars, *Home Office Police Policy Directorate, Police Scientific Development Branch* PSDB 298.

Thomas, E. L. 1974 Advice to the searcher or what do we tell them, in Monty, R.A and Senders, J. W. (Eds.) *Eyemovements and Psychological Processes*, (Lawrence Erlbaum Associates, Hilsdale, NJ).

Thomson, G. A. 1979, The role frontal motorcycle conspicuity has in road accidents, *Proceedings New Zealand Reading Symposium*, August, Wellington.
Thomson, G. A. 1980, The role frontal motorcycle conspicuity has in road accidents. *Accident Analysis and Prevention*, **12**, 165-178.
Thomson, G. A. 1982, Do Measurements Of Motorcycle Conspicuity Really Measure Conspicuity Effects? *Ergonomics*, **25**, 771-782.
Tichener, E. B. 1908, *Lectures on the elementary psychology of feeling and attention*, (MacMillan, New York).
Tole, J. R., Stephens, A. T., Harris, R.L. and Ephrath, A.R. 1982, Visual scanning behavior and mental workload in aircraft pilots. *Aviation-Space-and-Environmental-Medicine*, Jan, . **53**(1), 54-61.
Treisman, A. M. 1986, Properties parts and objects, in K. Boff, L. Kaufman and J Thomas (eds) *Handbook of perception and human performance, Vol 2, Cognitive Processes and Performance,* 1-70 (Wiley, New York).
Treisman, A. M. 1988, Feature and objects- The fourteenth Bartlet Memorial Lecture, *The Quarterly Journal of Experimental Psychology,* **40,** 201–237.
Treisman, A. M. and Gelade, G. 1980, A feature integration theory of attention, *Cognitive Psychology*, **12**, 97-136.
Treisman, A. and Sato, S. 1990, Conjunctive search revisited*, Journal of Experimental Psychology Human Perception and Performance,* **16,** 459-478.
Ullman, S. 1984, Visual routines, *Cognition*, **16**, 97-159.
Underwood, G. and Everatt, J, 1992, The role of eye movements in reading - some limitations of the eye-mind assumptions, in Chekaluk and Llewellyn, K. R., *The Role of Eye Movements in Perception,* 111-169, (Amsterdam, North Holland).
Unema, P. and Rotting, M. 1993, Differences in eye movements and mental workload between experienced and inexperienced drivers, *Vision in Vehicles,* **111**, (Taylor and Francis, London).
Van der Hejden, A. H. C. 1992, *Selective attention in vision* (Routledge, London).
van Elslande, P. and Faucher-Alberton, L. 1997, When expectancies become certainties, in Rothengatter, T., Vaya, Enrique-Carbonell (eds), *Traffic and transport psychology: Theory and application* (Pergamon/Elsevier Science Inc., Oxford).
Vecera, S. and Farah, M. J. 1994, Does visual attention select objects or locations? *Journal of Experimental Psychology –General*, **123**, 146-160.
Venger, L. A. 1971, Selection from perception and learning, *Soviet Psychology,* **10,** 5-108.
Viviani, P. 1990, Eye movements in visual search: cognitive, perceptual and motor control aspects, in Kowler, E. (ed.) *Reviews of Oculomotor Research* Vol. **l4**, Eye movements and their role in visual and cognitive process, 353-393, (Elsevier, Amsterdam).
Wade, N. J. and Swanston, M. 1991, *Visual perception: An introduction* (Routledge, London, England, UK).
Waller, P. F. 1972, An analysis of motorcycle accidents with recommendations for licensing and operation. Highway Safety Research Centre, University of North Carolina.
Waller, P. F., Griffin, L. I. 1977, *The impact of motorcycle light-on laws, an update*, Chapel Hill, University of North Carolina Highway Safety Research Centre.
Warm, J. S. 1984, *Sustained Attention In Human Performance Studies In Human Performance*, 293–321. (John Wiley And Sons, Chichester, UK).
Watson, P. M. F., Lander, F. T. W. 1973, “Motorcycle accidents and injuries” paper presented at symposium of vehicle safety legislation - In Engineering and Social Implication, London Institute of Mechanical Engineers.
Watt, R. J. 1992, Visual analysis and representation of Spatial relations, in Humphreys, G. (ed.), *Understanding Vision Readings in Mind and Language* (Blackwell, Cambridge MA).

Watts. G. R. 1980, The evaluation of conspicuity aids for cyclists and motorcyclists, in Osbourne, D. J. and Levis, A. J. (eds.), *Human Factors in Transport Research*, Vol.**1**, London Academic Press, 203-211.

White, W. T., Toomath, J. B. 1980, Motorcycle exposure to risk of accident, *Proceedings international conference on motorcycle safety*, Washington. DC, May Vol. **4**, 1613-1638.

Wick, M., Muller, E. J., Ekkernkamp, A., Muhr, G. 1998, The motorcyclist: Easy rider or easy victim? An analysis of motorcycle accidents in Germany. *American Journal Of Emergency Medicine*, **7** 234-242.

Williams, M. J. 1976, The importance of motorcycle visibility in accident causation. *Motorcycle and Safety Symposium* (ARRB) 54-99.

Williams, M. J. and Hoffman, E. R. 1977, *The influence of motorcycle visibility on traffic accidents*, Melbourne, Australia, Department of Engineering, University of Melbourne.

Williams, M. J. and Hoffman, E. R. 1979 Conspicuity of motorcycles. *Human Factors*, **21**, 619-626

Witkin, H. A. 1950, Individual differences in ease of perception of embedded figures. *Journal of Personality*, **19**, 1-15.

Wolfe, J. M. 1996, Extending Guided Search - Why Guided search needs a preattentive Map, in Kramer, Arthur F., Coles, M. G. H. (eds), *Converging operations in the study of visual selective attention*, 45-76. (American Psychological Association*. XXV,* Washington, DC, USA).

Wolfe, J. M. 1998, What can 1 million trials tell us about visual search? *Psychological Science*, **9**, No.1, 33-39.

Wolfe, J. M., O'Neill, P., Bennett, S. C. 1998, Why are there eccentricity effects in visual search? Visual and attentional hypotheses, *Perception & Psychophysics,* **60**, No. 1, 140-156.

Woltman, H. L. and Austen, R. L. 1974, Some day and night time visual aspects of motorcycle safety, *Paper No. 73036 Transport road research record* **502**, 1-5.

Worthman, R. H. and Matthias, J. S. 1983, An evaluation of driver behavior at signalized intersections, *Final Report*, Arizona Transportation and Traffic Institute.

Wulf, G., Hancock P. A., Rahimi, M. 1989, Motorcycle Conspicuity - An Evaluation And Synthesis of Influential Factors, *Journal Of Safety Research*, 20, 153-176.

Yantis, S. 1992, Multi-element visual tracking: Attention and perceptual organization. *Cognitive-Psychology,* Jul. **24**(3), 295-340.

Yantis, S. 1996, Attentional capture in vision, in Kramer, Arthur F. (ed.), Coles, Michael G. H. *Converging operations in the study of visual selective attention*, 45-76, American Psychological Association, Washington, DC, USA.

Yantis, S. and Jonides, J. 1990, Abrupt visual onsets and selective attention: Voluntary versus automatic allocation*, Journal-of-Experimental-Psychology:-Human-Perception-and-performance*. Feb, **16**(1), 121-134.

Yantis, S., Hillstrom, A. P. 1994, Stimulus-driven attentional capture: Evidence from equiluminant visual objects, *Journal-of-Experimental-Psychology-Human-Perception-and-Performance*, Feb, **20**(1), 95-107.

Zenger, B. and Fahle, M. 1997, Missed targets are more frequent than false alarms: A model for error rates in visual search, *Journal of Experimental Psychology-Human Perception and Performance*, . **23**, 1783-1791.

Zingale, C. M. and Kowler, E. 1987, Planning sequences of saccades, *Vision Research,* **27,** 1327-1341.