The comparative Situation Awareness performance of older (to younger) drivers

by

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Abstract

The overall aim of this thesis is to corroborate whether the Situation Awareness (SA) of older drivers is deficient to that of younger driving groups, due to the onset of age-related cognitive decrements. This is important to ascertain due to a presumed linkage between the concept and accident causation. In addition, the research undertaken to date to investigate this linkage has exclusively utilised rather artificial driving simulators and simulations. Thus there is a need for data from more ecologically valid methods.

The research studies reported here have sought to preference on-road assessments (of different complexity), and to capture what information was selectively perceived, comprehended and reacted to; rather than, as in previous work, what was recalled.

To achieve this, a 'Think aloud' methodology was chosen to produce narratives of a driver's thoughts. This method was advantageously unobtrusiveness, but also flexible - it could additionally be used to compare an individual's SA to a driving performance measure, Hazard Perception.

The driving-based studies undertaken found that for a relatively non-taxing route, an older driver group could produce cohesive awareness in parity with a younger driver group. However, the concepts from which that awareness was based upon drew more on general, direction based, concepts, in contrast to the younger group's focus on more specific, action based, concepts, and rearward and safety-related cues. For a more cognitively taxing route, the younger group produced significantly higher ($p<0.024$) individual SA-related scores than their older counterparts. But the concepts/cues both groups relied upon remained similar - particularly in regards to the ratio of those indicative of a rearward and/or a safety-related focus.

In a video-based study, however, and in contrast, the older driver group's SA scores improved sufficient to outperform a younger group, but, despite this, not for video-based scores indicative of Hazard Perception (HP). In this latter regard, age-related decrements appeared to be more influential, as the older group felt they were under time pressure during a HP test. However, the difficulty this presented appeared to

advantageously bring more attention and effort to the task, which were argued as important factors for the uplift in their SA scoring.

The thesis also showed that older groups' judgement of the *actual* complexity of a driving task could potentially be deficient to that of younger driver groups. This could cause problems as incorrect perceptions could deflate the relevance and cohesiveness of information being processing. In contrast, the *perceived* complexity of a task could bring a rise or fall in SA score for both groups.

Such results raised questions as to the impact of cognitive decrements, relative to task difficulty and related effort whilst driving. It also provided evidence that Situation Awareness, rather than being uniformly good or bad, could, like any other psychological construct, be prone to change. These aspects were drawn together in a proposed model of driving SA.

Keywords
Situation Awareness; Hazard Perception; Older drivers; 'Think aloud' method.

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Chapter 1: Introduction

1.1. Preamble

This thesis centres on the exploration of a driver's Situation Awareness (SA). A term first used by United States Air Force fighter aircrew after conflicts in Korea and Vietnam (see Watts, 2004). They identified having good SA as the decisive factor in air combat engagements (Spick, 1988).

Given these roots, it is perhaps not surprising that the study of Situation Awareness has traditionally been carried out within aviation contexts (see Stanton et al., 2001). However, it can be a vital component of human performance across a range of socio-technical domains, and became of interest to human factors expertise in the 1990's. Today, it is prevalent in, for example: power plant operations; military command and control (across all services); emergency services - such as surgery teams; and transport - including more individually focussed tasks such as cycling, or driving a motor vehicle.

1.2. What factors assist good SA

We tend to intrinsically know what factors might assist or prevent us having good Situation Awareness in a particular environment, though perhaps not all. To begin with, some brief, often interrelated, examples are given below that give a flavour for the range involved.

a) To be able to identify crucial or critical information cues.
Bellet et al. (2009) have proposed that our identification of crucial cues, that inform good Situation Awareness, are dependent upon our goals, past experiences, and the level of attention that we have available for processing information. The identification of such cues would be of particular importance in, for example, safety systems, such as Air Traffic Control.

b) To accurately extract relevant information during times of information overload.
Related to (1.2.a) above, an individual can often be confronted with excessive amounts of information, and may not be able to accurately process, or might simply miss, its

important aspects. Thus, if an individual cannot rapidly and accurately extract the information s/he needs, then errors may occur which may cause “lower alertness and situation awareness” (Yung-Tsan et al., 2011, p.236).

c) Being aware of fixation errors.

Brooker (2008) highlights the role of fixation errors, which he defines as “fixation on some precise detail or aspect that prevents an objective consideration of the ‘total situation’” (p.1484) - akin to the expression of ‘not being able to see the wood for the trees’ (Heywood, 1546/1874). Thus if we fixate, we have poorer Situation Awareness.

d) Being able to effectively allocate limited attention to different tasks

Woods et al. (2010) argue that limited attention is “especially critical when examining human performance in dynamic, evolving situations where practitioners are required to shift attention in order to manage work over time” (pp.114/5). Our limited attention denies us an opportunity to process all of the information presented to us, therefore how we allocate it will determine how effectively we retain Situation Awareness. An example might be landing an aircraft, and needing to observe the approaching runway whilst checking relevant instrumentation.

e) Having good mental representations.

Stanton et al. (2009) (amongst others) have argued that Situation Awareness is about the mapping of relevant information in a situation onto a mental representation of that information. These representations have been argued as equating to networks that are said to have a structure (e.g. Anderson, 1983), with their proficiency dependent on the interconnection between the elements that comprise them. These networks are said to also inform both the cues that we take from an environment and how quickly we can process and comprehend them, both of which impacting on our Situation Awareness.

f) Relevant communication

Fulton et al. (2011) suggest that communication with others impacts on what people observe in the environment around them, which again will impact on the quality of their Situation Awareness.

These examples highlight that an important aspect of Situation Awareness is our proficiency in processing information, as we cannot process all that is available to us (as suggested by e.g. Bellet et al., 2009). As a result, it seems that sometimes we can process too little information (e.g. Brooker, 2008) or conversely attempt to process excessively large amounts of information (e.g. Yung-Tsan et al., 2011) with both impacting on our quality of Situation Awareness.

1.3. Definitions

Although we seem to know the kinds of factors, highlighted above, that might assist or reduce our Situation Awareness, the concept itself nevertheless continues to defy a single definition. The most cited is that given by its most influential researcher, Mica Endsley: “the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future” (Endsley, 1988, p.97).

However, many other definitions have been suggested, some examples of which are given below that are indicative of the concept’s relevance for a wide range of domains:

- "accessibility of a comprehensive and coherent situation representation which is continuously being updated in accordance with the results of recurrent situation assessments" (Sarter & Woods, 1991, p.52).
- “The knowledge that results when attention is allocated to a zone of interest at a level of abstraction” (Fracker, 1988b, p.102).
- "adaptive, externally-directed consciousness that has as its products knowledge about a dynamic task environment and directed action within that environment" (Smith & Hancock, 1995, p.145).
- The "aim of efficient situation awareness is to keep the operator tightly coupled to the dynamics of the environment" (Moray, 2004, p.4).
- "the ability to maintain a constant, clear mental picture of relevant information and the tactical situation including friendly and threat situations as well as terrain" (Dostal, 2007, p.1).

- “an intermediate state in the decision-making process of dynamic systems where one should be able to comprehend the situation in order to make an appropriate decision for future development” (Artman & Garbis, 1998, p.1).

These definitions can perhaps be encapsulated by simply suggesting that Situation Awareness is an individual’s ability to know what is going on around him/her, sufficient to allow effective operation within an environment. However, not having a single definition, or even a poorly defined one, is not uncommon or necessarily a detriment for psychological concepts. Pew (2000) gives, intelligence, vigilance, attention, fatigue, stress, and workload, as related examples, and argues that despite them being poorly defined, they each have brought beneficial attention to critical processes or mental states that were previously unknown.

1.4. Situation Awareness and driving

Situation Awareness has relevance for driving as it enables us to explain how drivers can combine long-term goals (such as reaching a destination) with short-term goals (such as slowing down for a junction) as they drive (e.g. Sukthankar, 1997). It also explains how we employ a range of cognitive processes in driving contexts, to recognise and comprehend meaningful events (e.g., a roundabout is approaching, so traffic may appear from the right), and that as the number of these events increase, that this could bring about an overload of information. As was mentioned above (in 1.2.b.), how we deal with such excesses of information will impact on the quality of our Situation Awareness, and as Woods et al. (2010) (1.2.d.) have argued, this is particularly crucial in regards to how our attention is distributed. In driving this relates to both individual tasks (e.g., what to concentrate on whilst driving); and across tasks (e.g., when driving and interacting with in-car technologies).

SA in driving also involves both temporal and spatial components. The tempo of an individual’s driving will be dependent on his/her actions, the task characteristics, and the environment. As new inputs enter the system, s/he will incorporate them into their relevant mental representations that might then require changes in plans and actions to achieve a desired goal. For example, slowing down to avoid a collision. The spatial component relates to knowledge of locations and events, such as the vehicle’s current position in relation to its destination, the relative positions and behaviour of other vehicles and hazards, and also how these critical variables are likely to change in the near future (Sukthankar, 1997).

Perhaps unsurprisingly, a lack of, or inadequate levels, of Situation Awareness are said to constitute a primary factor in accidents attributed to human error (Hartel, Smith, & Prince, 1991; Merket, Bergondy, & Cuevas-Mesa, 1997; Nullmeyer et al., 2005). Indeed, Gugerty (1998) points out that “errors in maintaining situation awareness are the most frequent cause of errors in real-time tasks such as driving” (p.498) and that poor SA can be attributed to more accidents than improper speed or technique.

As will be seen in the following chapters, there can be much debate on the internal processes underlying the acquisition of SA, and the ways drivers utilise it. However, there is agreement that the major source of SA errors alluded to above appear to reside at the information ‘content’ level of analysis (e.g. Jones & Endsley, 1996). This is also the level at which SA is most amenable to measurement, and it provides a precursor in this thesis for finding a method to measure the concept in a range of driving environments.

1.5. Situation Awareness and driver age

The measurement of an individual’s or a group’s Situation Awareness is of value, as if it is in some way deficient and the basis of that deficiency can be found, then we may be able to suggest improvements. At this time, the performance of older drivers, for example, has become increasingly scrutinised due to the rapid expansion of this driver group, and our awareness of age-related cognitive, perceptual and physical declines. Research suggests that these could impinge on an older driver’s performance and therefore road safety, examples include slower motor responses (Rinalducci, Smither, & Bowers, 1993) and poorer judgement of gaps (Darzentas, McDowell, & Cooper, 1980).

In fact, relevant research in the literature is generally rather negative in regards to older drivers. For example: Albert & Kaplan (1980), have demonstrated inabilities in focussing on more than one source of information at one time; Ponds, Brouwer, & Van Wolffelaar (1988), a neglect, or insufficient attention to, relevant information from road signs and from other cars and pedestrians; and Rabbitt (1965), a greater susceptibility to distraction by irrelevant information.

Situation Awareness is of relevance to these perceived declinations, as most relate to an individual's proficiency in processing information. Therefore, an evaluation based around the concepts that are informative to older drivers could provide some important evidence as to whether this driver group does indeed present a potential danger to other road users, as the studies reported above suggest.

1.6. Aims and scope

The overall aim of this thesis is to provide a view as to the performance of older drivers' Situation Awareness, and to compare it to drivers within far younger age groupings. What threshold is taken for a driver to be classed as 'older' appears to depend on what point the researcher feels a driver might experience the onset of age-related cognitive declines (and perhaps the number of age-group s/he is assessing). So the age chosen can be as low as 56 (Ho et al., 2001); more usually 65 (Kaber et al., 2012/Zhang et al., 2009; Bolstad, 2001), or even sub-divided to include groups over 75 (Horswill et al., 2009). Each of the thresholds have been found to demonstrate age-related deficiencies. For example, hazard perception response latencies have been found amongst drivers over 55 (Quimby & Watts, 1981); a worsening of an awareness of hazards has been found for over 65's (e.g. Renge et al., 2005), and that this declines further after 75 (Horswill et al., 2009).

It was decided, when looking to recruit participants for this series of studies, to take a pragmatic approach and to set the age threshold for the older groups at 60 years, but to always give a preference to the oldest of those who volunteered. This would advantageously maximise the scope to recruit sufficient numbers, be at an age that also had justification in the literature (e.g. Underwood et al., 2005; Bolstad, 1996), and align with that which many organisations first considered a person to be 'old': such as the Royal Society for the Protection of Accidents (ROSPA), Age UK, and the United Nations.

The Situation Awareness of such participants would be assessed, both quantitatively and qualitatively, through a methodology capable of providing in-depth age-group comparisons. As most Situation Awareness research in the driving domain, and all in regards to older drivers, has been undertaken with the assistance of simulators - from rudimentary p.c.'s with no kinetic element, to more sophisticated car mock-ups – an aim was to collect data through more ecologically valid methods. To achieve a comprehensive assessment of both an individual's and a group's Situation Awareness, a 'Think aloud' methodology would be used for all three studies. This was an advantageously safe, simple, and unobtrusive approach for capturing the thoughts of the participants as they encountered differing driving environments.

The scope of the work was anchored around the principal aim of assessing the Situation Awareness of older participants. It began by considering cognitively non-taxing driving environments: firstly, when driven (Study 1); and then, secondly, when viewed on video (Study 2). The emphasis then shifted towards more cognitively taxing environments: with a measure now firstly being taken from video footage (Study 2); and then from a final return to actual roadways (Study 3). The thesis did not and could not (on epistemological grounds) extend to any quantification of age-related cognitive decrements amongst the older groups that it evaluated. Neither did it seek or make judgements as to an individual's driving capability when on actual roadways. This was, for reassurance, always made clear to a participant prior to driving a route. The only measure, related to driving proficiency, that was sought, was an exploration of Hazard Perception in Study 2. This was an opportunistic assessment to see whether better Situation Awareness could assist Hazard Perception. Such an assessment was considered of value, as, if any correlation was found, this could indicate a potential for improving proficiency in the latter through SA training.

The following Aspects (labelled AP1 & AP2) and Research Questions (labelled RQ1, RQ2, & RQ3) were addressed within the thesis:

AP1: What theoretical perspective and method would be the most useful for evaluating Situation Awareness in driving contexts?

- Research methods (Chapter 3)

RQ1: Is Situation Awareness worse amongst older (than younger) drivers in cognitively non-taxing driving conditions?

- Study 1 (Chapter 4)
- Study 2 (Chapter 6)

RQ2: Does Situation Awareness proficiency assist in the detection of roadway hazards?

- Study 2 (Chapter 6)

RQ3: Is Situation Awareness worse amongst older (than younger) drivers in more cognitively taxing driving conditions?

- Study 2 (Chapter 6)
- Study 3 (Chapter 7)

AP2: What conclusions can be made in regards to older driver SA? Could it be improved and how?

- Overview and synthesis (Chapter 8)

1.7. Chapter summaries and the structure of the thesis

This chapter, **Chapter 1,** introduced Situation Awareness as a topic. It highlighted that although we may instinctively know the kinds of information that might inform it, a single, encapsulating, definition has proved hard to achieve. The concept was then considered in relation to driving and driver age, and proposed as a lens through which older driver information processing proficiency could be revealed. The chapter concluded by outlining the scope of the thesis, its aims and objectives, the Aspects and Research Questions that were tackled, and its structure.

Chapter 2 is a literature review that has two parts. The first of which looks at the general concerns that an increasing older driver population raise, but also how any related risks might be mitigated. The second part looks at the relevance of Situation Awareness for driving, and how age-related cognitive declines might impact upon its proficiency: again mediating facts are discussed. Finally, consideration is given to older driver Situation Awareness and driving performance, where, as yet, no negative correlation has been found.

Chapter 3 (Aspect 1) focuses on research methods. It outlines the two main and competing approaches for explaining SA: one based on the individual, the other taking a wider environmental, or systematic, view. Various methods are then discussed that, in general, are related to either of these two approaches (though mainly to the former). The merits of both approaches are then compared and discussed, with a justification then made for a systematic-based evaluation for the studies that are to be undertaken. The 'Think aloud' method, that is utilised for all three studies in the series, is then introduced and explained. The chapter concludes by outlining how captured narratives would be assessed through computer software that is capable of displaying their main concepts visually as networks, and able to quantify both their overall cohesiveness and the strength of the concept interrelations within them.

Chapter 4 (Research Question 1) reports the first empirical study that considers the Situation Awareness proficiency of two driver groups based on age. This is assessed fom having participants drive their own cars around a cognitively non-taxing route, whilst contemporaneously, they provide a commentary on what they feel is of driving relevance. It was later found that when assessed at the group level that the younger driver's commentaries, or narratives, were more cohesive, and thereby demonstrated better Situation Awareness. However, when they were scored individually, and then averaged for each group, that these SA 'scores' were then remarkably similar. There were, though, indications of more depth in information processing by the younger participants: these included the enunciation of more safety-related cues, and words indicative of a rearward awareness.

Chapter 5 is a brief literature review chapter that introduces the concept of Hazard Perception (HP), how it relates to SA and older drivers, and the usefulness of the method presently used to measure it in the UK Driving Test. The detection of hazards was to be measured in the following chapter (Study 2).

Chapter 6 (Research Questions 1, 2, & 3). This chapter reports the second empirical study in the series that assesses an older and a younger participant group's Situation Awareness and Hazard Perception through the commentaries they gave for segments of, or longer, journeys, that were shown on video footage. The Situation Awareness scores subsequently calculated were found to be better for the older participants; whereas those indicative of Hazard Perception ability, better for the younger participants. Although no general SA to HP relationship was found when all the participant scores were considered together, a strong statistically significant relationship was revealed for the younger driver group. It was also evident that there were differences between the two groups in regards to the perceived difficulty of undertaking the study's video tasks, in comparison to the actual driving task undertaken for Study 1.

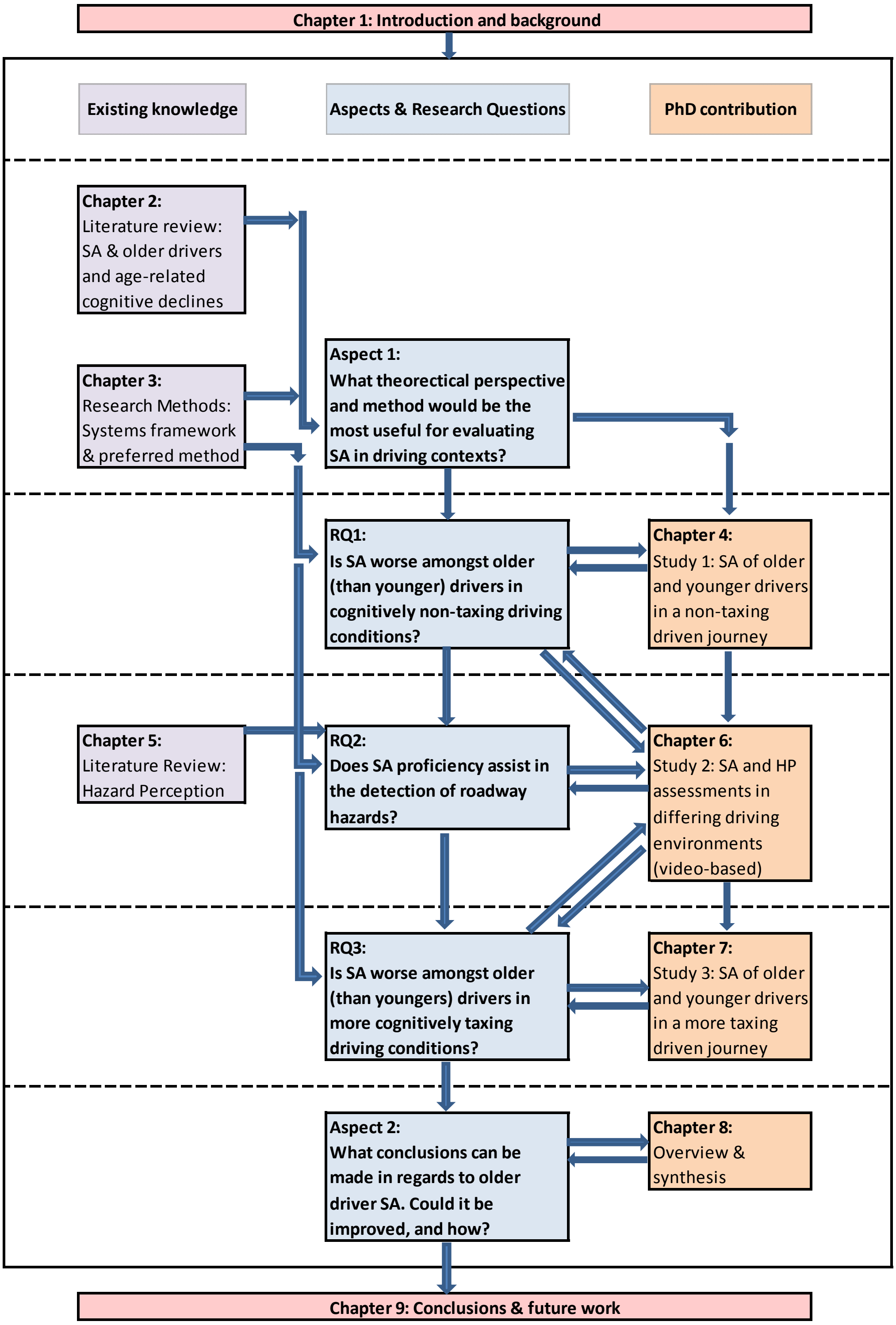
Chapter 7 (Research Question 3) reports the third empirical study that once again considered the Situation Awareness proficiency of an older and a younger participant group. This was again assessed by having participants drive their own cars, though on this occasion they would traverse a quantifiably more cognitively taxing route. It later was found that when assessed at both the group and individual levels that the younger drivers demonstrated the better Situation Awareness. There were, though, again indications of more depth in information processing by the younger participants: these included similar ratios to Study 1 in regards to the detection of safety-related cues, and of what was occurring behind their vehicles.

Chapter 8 (Aspect 2) summarises and brings together the main findings from the thesis structured around its Aspects and Research Questions, and considers how the Situation Awareness of older drivers might be improved.

The thesis concludes in **Chapter 9**. This states what were felt to be its most important contributions to the literature, its notable limitations, and the potential future work that has emerged.

The structure of the thesis is shown in a graphic below (Figure 1.1). This indicates the relationship between the Aspects and Research Questions posed, the existing knowledge, and that contributed by the thesis.

Figure 1.1. The structure of the thesis



Chapter 2: Situation Awareness literature review

2.1. Issues relating to older driver performance, and the contribution of Situation Awareness

2.1.1. Why is the Situation Awareness of older drivers worthy of measurement?

In today's UK society, increasingly larger towns have often made amenities more distant and less accessible through public transport – impacting on older people. Additionally, families have become more dispersed, and less able to provide immediate help for older relatives than in previous generations. Older citizens are therefore reluctant to give up driving (Eby et al., 2003; Burkhardt & McGavock, 1999), and when they do, it has been found that this can lead to a variety of negative psychological outcomes: such as regret; a lower sense of self-worth; and feelings of social isolation (Rudman et al., 2006; Johnson, 1995). In fact, it is said that even the prospect of giving up driving can lead to considerable depression and depressive feelings (Marottoli et al., 1997). It therefore must be beneficial to try to keep older people driving for as long as possible, and increasing their Situation Awareness could assist in that aim.

A related issue, that would help to facilitate this aspiration, is the need to assess whether, for example, mandatory re-testing schemes that are used in many countries for drivers above a specified 'risk-related' age, are, in fact, necessary. We know there is research that, using actual crash involvement rates, suggests these "*have no demonstrable road safety benefits overall*" (Langford et al., 2004, p.326). Also, that there is a bias in the accident data that informs this testing. For example, the exaggeration of the risk for low mileage (mainly older) drivers (Staplin, Gish, & Joyce, 2008), when in fact an increasing number of licensed older drivers (>60 years) relates more to significant *negative* effects on crash fatality rates (e.g. Tay, 2006).

Much of the debate as to the proficiency, or otherwise, of older drivers is due to the fact that there is not, as yet, an assessment method capable of accurately identifying accident risk. The relatively new measures of Situation Awareness that are employed in this thesis also cannot provide a full picture in this regard, but they certainly can make a contribution as to whether an individual shows information processing deficiencies likely to increase accident risk.

Additionally, the Situation Awareness assessments of the kind undertaken in this work potentially may improve the cognition of older adults, as they provide a framework to highlight where their awareness may have, for example, been negatively affected by new technology or particular driving environments. They could also, in turn, inform training programs that could, for example, focus on expanding an older adult's view of his/her surroundings, and/or alert him/her to a narrowing of attention. Aspects that could be very beneficial both to the older driver him/herself, and for the safety of others.

Indeed, training interventions that have focussed on informational cues have significantly improved an older drivers' cognitive abilities - such as processing speed, reasoning, and memory (e.g. Ball et al., 2002; Salthouse, 1985). Additionally, training programmes that have facilitated the development of anticipatory schema in regard to other road users, have been found to enhance road user Situation Awareness and to increase driving performance (Walker et al., 2009). Finally, training strategies that aim to enhance Situation Awareness by improving an older driver's perception, may also improve, as a result, his/her comprehension of an environment. This is because it could facilitate a change in situational processing from a conscious to an unconscious, automatic state, enabling the driver to better project appropriate actions. In this regard we have seen, for example, that Hazard Perception ability can be improved by learner-generated and/or expert commentaries while viewing driving scenarios, or from the identification of high risk locations (Pollatsek et al., 2006).

2.1.2. The relevance of Situation Awareness for driving

As was seen in the previous Chapter, the most widely used definition of Situation Awareness (SA) is "the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1988, p.97). This was encapsulated as an ability to know what is going on around you, and to be able to provide an understanding of the environment that you operate within.

Although the assessment of Situation Awareness has had a traditional focus within the aviation domain, it is a relevant component of human performance in any socio-technical environment, including driving. It has been argued that it enables us to explain how drivers can combine long-term goals (such as reaching a destination) with short-term goals (such as avoiding collisions with other vehicles) as they drive (e.g. Sukthankar, 1997). These goals are undertaken within continuously and often rapidly changing environments where a driver must keep track of a number of critical variables: such as the route; his/her own and another's position and speed; and the road and weather conditions. This information then being used to anticipate and react to changes and events in an environment, to avoid conflicts with objects and other road users (Gugerty, 2011).

To achieve this, the driver will employ a range of cognitive processes demonstrative of Situation Awareness, including: perception and pattern recognition (Kass et al., 1991); attention allocation (within and across tasks) and comprehension (Kass et al., 2007; Wickens & Hollands, 2000); and decision-making (Endsley, 1995b; Ma & Kaber, 2005). As such, Gugerty (1998) argues that "errors in maintaining situation awareness are the most frequent cause of errors in real-time tasks such as driving" (p.498), and that poor SA can be attributed to more accidents than improper speed or technique.

The review that follows will consider the Situation Awareness of a particular group of drivers, those over 60 years of age, who are classed by the UK Royal Society for the Prevention of Accidents (ROSPA) as 'older drivers'. This group has been chosen as the principle one to assess, as due to the relevance of cognitive deficits for driving, alluded to above, much research has been undertaken into this group's driving proficiency.

This review will begin by outlining the evidence in relation to older driver performance and risk, and then consider the mediating factors to the concerns that were raised. In its second part, the discussion will then turn to Situation Awareness based investigations of driving and age, how age-related cognitive declines might affect it, and how these too might again be mediated. Consideration will then be given to the evidence for older drivers actually having poorer SA, and how that might relate to driving performance. Finally, a reasoning and an approach will be given for the work that follows.

2.2. The evidence in relation to older driver performance and risk

2.2.1 The basis of a potential problem

2.2.1.1. A rising older driver population

With continuing advances in health and medicine, people are generally living longer. The Organisation for Economic and Co-operation Development (OECD) forecast that by 2030 one quarter of the population of their member nations will be over 65 years old (Organisation for Economic Co-operation and Development, 2001). The World Health Organisation (WHO) further expect the number of people aged 65 or older to grow, from an estimated 524 million in 2010 to nearly 1.5 billion by 2050, with most of the increase in developing countries (National Institute on Aging Report for the World Health Organization, 2011). In the UK it is estimated that by the year 2031 almost 23% of our population will be over 60 (Office for National Statistics, 2010).

As the population in the developed world is aging, so the number of older drivers is rapidly expanding. In the UK it has been estimated that today some 4.5 million people aged over 70 hold a current driving licence (Noble, 2000). The Driver and Vehicle Licensing Agency (DVLA) has estimated that whereas amongst 80-89 year olds in 1993, 44% of men and 11% of women held a current driving licence, by 2020 the figures for this age group will rise to around 65% and 35% respectively (Department for Transport, 2004). In fact, older drivers represent the fastest growing group in the UK driving population (e.g. Burkhardt & McGavock, 1999; Lyman et al., 2002). This is principally because older drivers are continuing to drive into later years, and with an increasing number of females entering the older driver population, this trend is expected to rise (Department for Transport, 2004).

2.2.1.2. Lifestyle

Much of the reason behind this increase lies in the fact that many elderly people view driving as an important social and 'self-care' facility (Chipman et al., 1998; Department for Transport, 2004; Oxley & Whelan, 2008). As alluded to above (2.1.1.), as communities have become more dispersed and regional infrastructures have increasingly made transport use a necessity, older drivers are becoming increasingly reliant on driving to compensate for physical frailties and disabilities that impede their mobility (Bendixen, Mann, & Tomita, 2005; Cannon, Hendrickson, & Mann, 2005).

2.2.2. What are the concerns related to this increase in older drivers?

It has been predicted that road traffic accidents will be the sixth most prevalent cause of global deaths by the year 2020 (Jacobs, Aeron-Thomas, & Astrop, 2000). As the proportion of older people in society and their propensity to continue driving increases, this demographic change has been a cause of concern due to established age-related declines in perceptual and cognitive abilities (e.g. Birren & Schaie, 2006; Salthouse, 2010).

There are three main arguments here, that:

a) There are a range of age-related physiological changes that may negatively affect driving ability, namely: declines in vision; hearing; reaction time; and the musculoskeletal system.

b) Police reports and insurance data show older drivers are more likely to be considered responsible for the accidents in which they are involved (Langford et al., 2006), and that they tend to involve multiple vehicles and more serious injuries (Department for Transport, 2004).

c) Older individuals are more likely to suffer serious injury and are at more frequent risk of being a fatality as a result of an accident - in the region of 2-5 times more than that of a younger person - due to their physical frailty (Department for Transport, 2004). They are also likely to take far longer to recover from their injuries, in comparison to younger accident victims (see Platts-Mills et al., 2015).

These arguments are now considered in further detail, but at this point it might be useful to reiterate that the age used in this research as a threshold for being considered as an older driver will be 60 years. The UK Royal Society for the Prevention of Accidents (ROSPA) states that "older drivers are defined as drivers over the age of 60 years. Although they "do not form a homogenous group as wide variations in their characteristics and driving abilities exist within this general category". (ROSPA policy paper, 2010, p.7)

2.2.2.1. Age-related physiological changes

As people age, they tend to have to cope with decrements to a number of physiological functions. The examples of visual, auditory, and cognitive declines are discussed below. Such decrements have been found to affect basic driving skills and manoeuvres: such as speed control, tracking, positioning, and reversing (Brendemuhl, Schmidt, & Schenk, 1988; Brainin, 1980); turning to look out of the rear window (Herriots, 2005); and coping with visual displays and technological functions (Shaheen & Niemeier, 2001), which are likely to contribute to an increased risk of accident involvement.

<u>Visual</u>

It appears that visual attention and search efficiency declines with age in regard to what is termed 'bottom-up' processing (Madden, 2007). This relates to our more micro scanning activities, such as finding our vehicle's actual speed on a display (as opposed to more macro, 'top-down' processing, such as looking briefly at the position of an indicator).

In addition, it has been suggested that for every decade after the age of 25, a driver may need twice the brightness at night to receive visual information. On this basis, drivers reaching 75 years may require 32 times the brightness that they did when they were 25 years old (Department for Transport, 2004). This may equate, at night, to older drivers needing to be as much as 23 to 35% closer to road signs in order to accurately interpret them (Sivak, Olson, & Pastalan, 1981; Sivak & Olson, 1982).

The loss of visual field – defined as "the extent of visual space over which vision is possible with the eyes held in a fixed position" (Sekuler & Blake, 1985, p.499) is also most severe amongst older drivers (over 65), and relates to a far higher risk of collision when compared to normally sighted people (e.g. Johnson & Keltner, 1983; Szlyk et al., 1992).

Research on the 'useful field of view' (UFOV) – defined as "the total visual field area from which target characteristics can be acquired when eye and head movements are precluded" (Kline & Scialfa, 1997, p.37) has also found age-related decrements (e.g. Ball et al., 1988) and has been able to show an association with poor driving performance (Clay et al., 2005) and actual crash frequency (Ball & Owsley, 1991).

Age also often leads to decrements in contrast sensitivity - the visual ability to see objects that may not be outlined clearly or that do not stand out from their background. This makes the older driver more sensitive to glare, and more vulnerable to its disabling effects (Mortimer, 1989; Schieber, 1994). This is particularly evident on roads where there is no distinct separation from oncoming vehicles (e.g. Staplin et al., 1988).

<u>Auditory</u>

Although research has not, as yet, directly associated injury-related crashes with impaired hearing, driving while using hearing aids does appear to increase this risk by about two times due to them giving feedback and distracting reaction noise (McCloskey et al., 1994).

<u>Cognitive</u>

In relation to crash involvement, studies of older drivers have found a pattern of cognitive deficits relating to visual, perceptual, and motor functioning (e.g. Lundberg et al., 1998). These are often related to age-related declines in, for example, fluid abilities (Horn & Cattell, 1967) that bring reductions in: processing resource capacity and processing speed (Salthouse, 1991); deficiencies in inhibitory processing (Hasher & Zacks, 1988); and increases in neural noise (Welford, 1981). These, in turn, negatively impacting on problem-solving, reasoning, spatial abilities, and reaction times.

A fuller appraisal of such theories will be made in relation to Situation Awareness, below, but to illustrate their relevance, it is inhibitory processing, for example, that leads to a tendency amongst older drivers to prioritise accuracy over speed when driving, due to processing all available, than just relevant, information (Welford, 1962; Rabbitt, 1965). It has also been found, perhaps unsurprisingly, that stressful, cognitively demanding situations, seem to exacerbate this need (Szafran, 1969; Kemp, 1973).

Effective on-road decision making relies on a balance between information processing and speed of reaction (French et al., 1993) and it is this that the older driver finds difficult to do, particularly when under pressure. In a sample of UK drivers over 70 years, for example, a relationship was found between reaction time and serious driving errors (Simms, 1993), and in other research that older drivers were slower at recovering from errors and 'incorrect anticipations' (Department for Transport, 2004).

2.2.2.2. Collision analysis in older age-groups

The above research envisages a steady decline in driving performance as the age of the driver increases. To explore this assertion further, consideration is now given to a risk assessment report undertaken by Gandolfi & Dorn (2009). This study considers data relating to injury collisions caused by drivers age 60 and over in Suffolk between 2005 and 2007; sub-dividing its findings into a number of age groupings. The author has sought to use three groups for comparative purposes (60-69, 70-79, and 80+) to investigate whether risk in relation to collisions increased linearly with age in this study. The stand-out findings follow.

<u>Fatalities</u>

Although older drivers are at greater risk of causing a fatal collision compared with the general driving population, collisions caused by drivers over 80 were significantly more likely to involve a fatality than collisions involving the over 70's age group. The mean fatality level of drivers in their 60s was approximately half that of those over 80, with drivers in their 70's displaying the lowest mean fatality rate.

<u>Number of vehicles</u>

The study indicated that 25.4% of the injury collisions caused by older drivers were single-vehicle incidents, 63.5% involved two vehicles, and 11.1% involved three or more vehicles. Collisions caused by drivers in their 60s involved significantly fewer vehicles compared with those caused by drivers in their 70s and 80s.

<u>Road type</u>

Drivers over 80 were least likely to cause a collision (those over 70 the highest) on dual carriageways, three-lane roads, and one-way streets, but were the most likely to cause a collision on roundabouts and single carriageways.

Lighting

In daylight, drivers in their 60's were slightly less likely to cause a collision compared with drivers over 70, but at night they were more likely to do so. On roads with good street lighting, drivers in their 60's were a third more likely to cause a collision compared with the over 80's, and over twice as likely when compared with drivers in their 70's. On unlit roads, drivers in their 60's displayed almost twice the risk of drivers over 70. These results may, though, be due to a higher prevalence amongst the 60-69 age group undertaking nighttime driving.

Type of collision

In regard to the type of collision, the data suggests particular difficulties for all three age groupings with situations involving high cognitive demand, such as junctions (30%, in fact, of all over 60's at-fault injury collisions in the Gandolfi & Dorn study). However, leaving aside the fact that the numbers assessed for each age group here will be different, as there are fewer over-80 drivers, the data provided and summarised by the author for age-related risk (in Table 2.A below) is to simply demonstrate a more complex picture than one indicative of a general worsening of driving performance with age.

Table 2.A: Collision risk comparisons by age-group drawn from Gandolfi & Dorn (2009)

Type of collision	Age Group		
	60-69	*70-79*	*80+*
Loss of control	Lowest risk	Medium risk	Highest risk
Crossing junction on red-light	Lowest risk	Medium risk	Highest risk
Illegal manoeuvre	Lowest risk	Medium risk	Highest risk
Head-on	Lowest risk	Medium risk	Highest risk
Right-turns at junctions*	Lowest risk	Highest risk	Medium risk
Reversing into vehicles	Lowest risk	Highest risk	Medium risk
Oncoming traffic at Junctions	Medium risk	Lowest risk	Highest risk
Over centre-line of carriageway	Medium risk	Lowest risk	Highest risk
Oncoming traffic on roadway	Medium risk	Lowest risk	Highest risk
Overtaking	Medium risk	Lowest risk	Highest risk
(with) Pedestrians (off of road.)	Medium risk	Lowest risk	Highest risk
Rear of another vehicle**	Medium risk	Highest risk	Lowest risk
Skid-related	Highest risk	Medium risk	Lowest risk
Changing lanes	Highest risk	Medium risk	Lowest risk
Merging with traffic	Highest risk	Medium risk	Lowest risk
Total of all collisions for >60's	**51.7%**	**31.5%**	**16.8%** **(inc.1.1% > 90)**

** Most prevalent - 20.3% of total collisions*

*** Second most prevalent – 19.1% of total collisions*

Although 'Highest risk' evaluations were more prevalent for the 80+ age-group, the extent to which driver risk increased with age appeared more dependent on collision type. This itself could reflect an awareness of ability, and so, for the over-80 group in particular, it could indicate that the group may seek out conditions where, for example, there would be less of a need to 'change lanes' or 'merge with traffic'. As a whole, however, the most common collisions found in the study (right turns at junctions, and 'rear-ending' other vehicles), have also been found in other research (Clarke et al., 2010; Hakamies-Blomqvist, 1993; Langham et al., 2002; Preusser et al., 1998), indicating a higher risk for the 70-79 age group.

2.2.2.3. Injury severity

Older drivers have a much higher likelihood of being a fatality in an accident, according to the findings in the Gandolfi & Dorn study, with that vulnerability rising with age increments. This would account for the 85 and over age group being over-represented in serious injury and fatality outcomes (e.g. Staplin et al., 2001). It seems that the higher rates of older drivers' injury and severity are likely to be due, to some extent, to the type of accidents they seem more vulnerable to.

Due to the rising numbers of older drivers it is predicted that: "although the numbers of accidents per unit distance travelled may stay the same over the next 30 years, the absolute numbers of fatal accidents involving elderly drivers are set to increase" (Department for Transport, 2004, p.5).

This prediction is supported by studies that have shown accident involvement and the number of injuries per miles driven to be the highest among the very youngest and oldest driver groups (Dellinger et al., 2004; McGwin & Brown, 1999), and that older drivers are more likely to sustain more critical and fatal injuries (Reinfurt et al., 2000; Cerelli, 1989). Older drivers, incrementally with age, tend to be involved in comparatively more accidents, resulting in higher fatalities and hospital admissions than younger driver age groups; although the actual number of such accidents is relatively small when differences in exposure levels are taken into account (Ryan, Legge, & Rosman, 1998; Williams & Carsten, 1989).

2.2.3. A more complex issue: ameliorating the impact of age?

2.2.3.1. Contradictory evidence

Whilst research is indicative of a general decline in driving performance once a driver reaches the 60 years threshold, this matter is not so straightforward. As Howell puts it "age is not the reliable index of functional impairment that society has customarily taken it to be" (Howell, 1997, p.4). Indeed, although the literature supports age-related changes in driving performance, it is conceded that this does not mean there will be all-encompassing age-related deficits (Hakamies-Blomqvist, 1994; Langford et al., 2006).

The evidence given above shows that older drivers represent a particularly vulnerable group with high relative accident and fatality rates and a propensity to sustain more serious injury to themselves in collisions. On the other hand, it has to be said that evidence can also be produced that shows this driver group is actually relatively safe compared to its younger counterparts, and that enabling unimpaired older drivers to drive for longer may, in fact, have a positive impact on traffic safety. Some brief examples of where research has made the issue of older driver safety more opaque, now follows.

Low-mileage bias

If the proportion of crashes experienced by the entire licensed driver population is considered, then the older groups appear to be the safest, with the least number of crashes. But in terms of exposure, younger drivers tend to cover far more miles per annum, so when crash rates per miles travelled are calculated, older drivers appear to have increased risk compared to all but the young and relatively inexperienced (Williams & Carsten, 1989). However, older drivers undertake far more of their driving on local roads, and so encounter, disproportionately, more intersections, congestion, confusing visual environments, signs, and signals (Eberhard, 1996). Whereas those who drive longer distances are likely to amass much of this mileage on motorways, where there is less chance of an accident. For example, Janke (1991) has shown that there are 2.75 times more crashes per mile driven on roads other than motorways.

Visual abilities

As approximately 90% of information processed in the driving task is visual, the potential effects of age-related visual impairments are clearly a concern with older drivers (Simms, 1985). However, measurements of visual decrements "are not, by themselves, a good representation of the complex visual skills needed in the driving task" (Department for Transport, 2004, p.10). For example, although age-related visual impairments have been found to have significant deleterious effects on sign detection, recognition of hazards, reaction times, and driving task ability and completion times (Wood, 1999; Andersen et al., 2000; Wood, 2002), research conducted amongst drivers with no recognised visual impairment failed to find significant differences in performance between different driver age groups (Underwood et al., 2005). Perhaps this is because older drivers often adapt their driving to compensate for any visual impairments by slowing their speed or avoiding lane-changes (e.g. Szlyk et al., 2002). Furthermore, although accident analysis has made associations between people with disease-related visual impairments and road accident rates, any such link may be confused by the potential interfering effects of medication (Owsley & McGwin, 1999).

<u>Road signage</u>

Another example of conflicting findings is found in relation to the extent to which older drivers can see and respond to road signs. Some findings indicate sign recognition and understanding difficulties (Richards & Heatherington, 1988), even a proneness to ignoring road signage (Otani et al., 1992). However, other findings demonstrate that older drivers are more likely to respond in order to comply with traffic regulations (Hofner, 1982, cited in Al-Madani & Al-Janahi, 2002). Perhaps more relevant, though, is evidence that suggests a drivers' ability to recognize and comprehend road signage is not associated with 'at-fault' accident involvement. It appears that drivers more often involved in accidents are as good at understanding traffic signs as those rarely involved in accidents (Al Madhani, 2000; Al-Madani, 2001).

2.2.3.2. Lessening the impact of cognitive decline

It should also be noted that there are a number of ways in which older drivers may be able to ameliorate or eliminate the important effects of age-related declines in cognitive ability that were considered above:

a) They can engage in what has been termed ‘strategic compensation’ (De Raedt & Ponjaert-Kristoffersen, 2000), i.e. select driving conditions and driving demands to suit their abilities (Molnar & Eby, 2008: see also Baltes & Baltes, 1990). For example, older drivers with poor driving ability have reported that they avoid specific situations, such as turns across traffic, driving on high speed roads, driving in ‘rush hour’ traffic, driving at night, and driving in the rain (Baldock et al., 2006).

b) They can compensate for a declining speed of cognitive processing by ‘tactical compensation’ (De Raedt & Ponjaert-Kristoffersen, 2000). For example, they drive slower (Becic et al., 2007; Shinar et al., 2005), they adopt longer headways in the presence of distracting tasks (e.g. Strayer & Drews, 2004), and they look for bigger gaps when turning at junctions (Middleton et al., 2005). Through these adjustments they are better able to give themselves more time to react to events on the road and to make driving-related decisions (Walker et al., 1997).

c) Older drivers maintain levels of performance by means of ‘optimisation’ (see Baltes & Baltes, 1990), such that practice enables performance levels to be maintained (Krampe & Charness, 2006; Krampe & Ericsson, 1996). This can lead to automatic processing that places minimal demands on cognitive processing resources, and, as such, it has been argued that they are not subject to age-related declines (Hasher & Zacks, 1979).

d) Older drivers compensate for declining cognitive fluid abilities (see below for an explanation) by restructuring the driving task to favourably meet their abilities and skills. For example, Hakamies-Blomqvist et al. (1999) concluded that older drivers are more serial in the performance of component elements of the driving task, thereby compensating for declining ability for multi-tasking (Salthouse & Miles, 2002).

e) Older adults compensate for age-related declines by engaging additional regions of the brain to support cognitive networks that are struggling to cope with task demands (Cabeza, 2002; Cabeza et al., 2002; Dennis & Cabeza, 2007; Reuter-Lorenz & Cappell, 2008).

2.2.3.3. Cessation

Older drivers also seem to naturally reduce their driving exposure as time goes on (Benekohal et al., 1994), with most typically wanting to withdraw from driving slowly and gradually rather than in a fast and imposed manner (Hakamies-Blomqvist & Whalstrom, 1998). It seems the differences between older people's decisions to give up driving are a function of their self-perceptions regarding ability (Eby et al., 2003; Rudman et al., 2006; Hakamies-Blomqvist & Whalstrom, 1998; Owsley et al., 1999) and in particular their levels of confidence (Parker et al., 2001; Marottoli & Richardson, 1998; Stalvey & Owsley, 2000).

2.2.4. Exclusion and measuring risk

The above sections have shown that gauging the risk of older drivers to themselves and others is difficult to measure. It has been alluded to above, for example, that unlike younger age groups, older drivers (from around 65 years) tend to lack confidence when approaching junctions: although from 'tactical optimisation' (De Raedt & Ponjaert-Kristoffersen, 2000) they do tend to slow down earlier and approach more slowly and smoothly. However, this lack of confidence can become a major problem when merging onto motorways as this is said to translate into hesitant, erratic, and sometimes very late and precarious actions (Schlag, 1993).

On country roads, older drivers tend to drive more consistently and smoothly, with fewer accelerations and braking actions, than those in younger age groups. However, on inner city roads, they apparently can make many more serious errors, especially: failing to notice traffic lights; disregarding traffic system priorities; and failing to reduce speed adequately at road-level railway crossings (Schlag, 1993).

Such examples, and more could be given, have prompted consideration of driving assessments and restrictions for the older driver (Department for Transport, 2001). However, as was shown above, the effects of aging on driving safety are complex, and indeed, a large proportion of older drivers maintain a high standard of performance (Dobbs et al., 1998; Hakamies-Blomqvist, 1998). Also, the literature does not offer a great deal in terms of comparing the best approaches to assess older drivers' competence, or how to deal with age-related declines.

In the following part of this review, consideration will be given to the relevance of Situation Awareness to such issues, and the contribution that it can make to understanding age-related driving performance.

2.3. Situation Awareness based investigations into driving and age

One of the principle problems that previous sections have highlighted for older drivers is that roadway environment complexity can decrease their performance far more than younger drivers (for example, in terms of lane keeping, and speed maintenance, Chaparro & Alton, 2000; Ho et al., 2001). Yet, in general, to attain a good standard of driving ability, a driver needs to be able to cope with such complexity, by being more aware of his/her surroundings, and from attending to important and necessary information: abilities that form an intrinsic part of Situation Awareness.

Situation Awareness is of particular importance when unfamiliar and dynamic situations are faced, such as those encountered whilst driving, where there is a need to manage both cognitive and physical workloads across tasks with frequently conflicting goals and opposing demands (Perry et al., 2008). It could be said to begin through the formation of concepts from representations that we find in the environment. These concepts consisting of components that are representative of experiences, rather than full length recreations (Barsalou, 2003), which are then stored in our memory (Schyns, Goldstone, & Thibaut, 1998). This conceptual system then guiding what is perceived, what is inferred, and our actions within an environment (Hampton & Ross, 2003).

The process, by this approach, is said to be a cyclical one, as what is perceived will expand knowledge, which in turn will influence what new information is sought out. So crucially, the quality of the information cues selectively attended to will also influence the level of Situation Awareness (Regal, Rogers, & Boucek, 1988).

This is of relevance to driving, particularly during pressing and unexpected tasks, as a good choice in selecting which movements and cues to attend to could allow a driver to anticipate intentions and react more quickly. If a 'rush hour' driving situation is taken as an example, here, clearly the driver would not attempt to attend to all the cues in an environment - such as every traffic sign, car and pedestrian – as this would be ineffective and potentially dangerous; just if his/her attention was overly narrowed to a single object, such as the car directly in front. The driver would more likely selectively attend to what cues were deemed relevant, and seek to frequently update them.

Whilst there is much debate on how the internal processes underlying the acquisition of Situation Awareness are undertaken, and indeed what drivers do with the resulting information (issues that will be considered in further detail in the following Chapter (3)), what is apparent is that a major source for SA errors stems from our deficiencies in analysing information 'content' (e.g. Jones & Endsley, 1996).

Such deficiencies are of particular relevance to the age-related cognitive demands considered above. For example, our need to frequently update information can present difficulties for older adults due to deficiencies in cognitive functioning and information processing speeds (Damos & Wickens, 1980; Korteling, 1993; Lorsbach & Simpson, 1988; McDowd & Craik, 1988; Schneider & Fisk, 1982; Tun & Wingfield, 1997).

2.3.1. Age and cognitive related declines for Situation Awareness

To explain these declinations further, it is necessary to revisit prominent theories that have been proposed to explain the causes of age-related differences in cognitive functioning, that were alluded to in 2.2.2.1, above. Four will be considered here: fluid versus crystallized intelligence (Horn & Cattell, 1966; Rabbitt, 1993); inhibition deficits (Hasher & Zacks, 1988; Layton, 1975); reduced processing resources (Navon, 1984; Salthouse, 1985, 1988); and cognitive slowing (Birren, 1970; Cerella, 1994; Salthouse, 1985).

The evidence given in support of these theories shows increasing age-related problems (e.g., the capacity to hold information in working memory, performing dual tasks simultaneously, and a general slowing of responses as well as processing speed), so how might these cognitive declines influence performance and Situation Awareness in driving?

To aid an explanation, utilisation will be made of Endsley's three level model of Situation Awareness (Endsley, 1995a) as a reference framework. Endsley proposed that

Situation Awareness is formed through three stages, or levels (see Chapter 3). These are: Perception (Level 1): perceiving the status, attributes, and dynamics of relevant environmental elements; Comprehension (Level 2): integrating that disjointed information to understand its impact on an individual's goals; and Projection (Level 3): extrapolating this information to project future actions and environmental states.

2.3.1.1. Fluid versus Crystallized Intelligence

During our lives we acquire and store knowledge, which through repetition, develops into meaningful information. The processes of accessing this information are known as crystallized intelligence (Horn & Cattell, 1966; Rabbitt, 1993): for example, the retrieval and use of vocabulary.

In contrast, some situations require us to process comparatively new information. In these situations, a lack of previous information requires us to tap into what is termed fluid intelligence. It has been found that ageing brings declines in fluid intelligence; whereas our crystallized intelligence can actually improve (Horn & Cattell, 1966; Rabbitt, 1993).

Relevance to Situation Awareness in driving

In predictable, stable situations, crystallized intelligence remains constant and causes no detrimental effects on Situation Awareness. However, in unpredictable and changing road environments, fluid intelligence is needed to provide accurate comprehension of the unfamiliar cues that the driver would be receiving.

As an example, consider a driver's knowledge of traffic laws, which would have become part of his/her crystallized intelligence. These are unchanging and easy to draw upon when driving along familiar routes. However, when driving in an unfamiliar city during 'rush hour', a driver may need to draw on fluid intelligence to deal with new information and environments. It is here where deficits are likely to occur for older drivers.

To relate this to Endsley's three level model, declines in fluid intelligence from aging would simply impact initially at the perceptual SA Level (1), which would thus cause problems for comprehension (Level 2), which, in turn, could affect the projection (Level 3) of proficient driving-related actions.

2.3.1.2. Inhibition Deficits

It has been proposed that our working memory can only operate efficiently when we can selectively attend to relevant information, whilst inhibiting irrelevant information, in order to achieve a goal (Hasher & Zacks, 1988). As older adults have a more detailed knowledge base, specific situations may activate too much information causing interference in working memory (McDowd, Oseas-Kreger, & Filion, 1995). In other words, older adults find difficulty in inhibiting information, which then interferes with memory retrieval processes, particularly with those relating to perception (Hashtroudi, Johnson, & Chrosniak, 1990).

<u>Relevance to Situation Awareness in driving</u>

Because perceptual-based memories are key to producing good Situation Awareness, an inability to suppress information here will cause deficits across all three of Endsley's SA levels. During the perceptual Level (1), a failure to inhibit information will allow multiple environmental cues to be accessed, causing difficulties in selecting what is most relevant. This places a burden on our working memory, causing further problems for comprehension (Level 2) - such as from having to decide upon what is relevant from an excessive number of cues, and therefrom, appropriate information. While such inhibition deficits do not directly influence Situation Awareness at the projection level (3) both it, and, consequently, driving performance, will be impaired, because of the deficiencies that are occurring at Levels 1 and 2.

2.3.1.3. Processing Resources

The amount and complexity of the information we have to process, the difficulty of the task, and the relative diversity in any dual tasks that we undertake, all extend and degrade our processing resources (e.g., processing speed, working memory, and attention). This is especially the case with older adults (Damos & Wickens, 1980; Korteling, 1993; Lorsbach & Simpson, 1988; McDowd & Craik, 1988; Schneider & Fisk, 1982; Tun & Wingfield, 1997), and particularly for those suffering from attention deficits, as they may ultimately have greater difficulty in registering and encoding information efficiently.

Relevance to Situation Awareness in driving

As dynamic tasks, like driving, involve continuous perception and comprehension of information, any deficits in the processing of that information may cause difficulties in maintaining Situation Awareness.

A lack of processing resources is, in fact, the single most limiting factor for perceiving relevant cues (i.e. for Level 1 SA), particularly in circumstances where multiple stimuli are present or when dual tasks are being performed. So this is of particular relevance for older drivers, given their difficulties, highlighted above, in selectively attending to informative environmental cues. However, comprehension (Level 2 SA) and projection (at Level 3) will also suffer from age-related declines (Bolstad & Hess, 2000; Endsley, 1995) as when processing resources are taxed by the need to retrieve and classify large amounts of information, inaccurate mental models could be created from a poor selection of cues at the perception level (1) of SA.

So if an older US citizen, for example, did not have a mental model of a roundabout whilst driving in the UK, s/he may approach it unaware of the traffic with the right of way, or of correct road positioning. The need for quick action, coupled with this unfamiliarity, may well weaken his/her processing resources to more likely result in an accident.

2.3.1.4. Cognitive Slowing

As mental and physical operations gradually slow during older adulthood (Birren, 1970; Salthouse, 1985), this can become a particular concern in highly demanding situations, where there is often a need for both quick and simultaneous operations that can significantly affect processing speeds (Salthouse, 1996).

Relevance to Situation Awareness in driving

In any time-limited dynamic environment such as driving, the initial task (i.e. processing perceptual cues, at Level 1), will be equally as important to the secondary operation (i.e., comprehension, at Level 2) for effective Situation Awareness to be achieved.

However, when simultaneous and extended processing is needed to comprehend a situation, this could be inadequately based on either little processing effort (at Level 2 SA) or from cue perception alone (from Level 1 SA) due to age-related cognitive decrements. Furthermore, in such circumstances, information from that earlier processing could be lost or become obsolete after later processing has been completed (Salthouse,1996) - all of which impacting on the creation of appropriate mental models for good projection (at Level 3 SA).

So, to give a driving example, when vital cues are quickly presented regarding the speed of traffic and available lanes for entering unanticipated roadworks, a slowing in the processing of perceptual information (at Level 1 SA), or a constraint on the time needed for comprehension (at Level 2), could cause an accident through a lack of appropriate projection (at Level 3).

What the above theories of age-related decline have shown is that ageing would appear to particularly disrupt the perception level (1) of SA acquisition, by decreasing the efficiency with which individuals can extract information from the environment and accurately store it in memory. According to Bolstad & Hess (2000), this may result in older adults creating less complete and/or qualitatively different representations of their environment than younger adults, and that this would be particularly evident when there was a lot of information present, or when it was presented in multiple modalities, and/or where more than one task had to be performed at the same time.

At the comprehension stage of SA (Level 2) it can be concluded that the problems mentioned above in regards to diminished processing resources and inhibition deficits, will particularly affect the ability of an older person to create an accurate mental model of a situation in working memory. Bolstad & Hess (2000) highlight that this would stem from problems associated with the processing of large amounts of complex information, along with difficulties in retrieving and utilising information registered during the perceptual level stage.

2.3.2. Mediating factors

The age-related changes that have been considered above, are not, however, a given in universal form, and consideration as to how they may be tempered is worthy of note. Five are briefly highlighted below, but for the purposes of this thesis concentration will centre on the automaticity of processes through experience, as these appear to have particular relevance for SA performance.

The main considerations against uniformity in age-related declines are that:

a) The extensive training of older adults may overcome some of the negative effects associated with ageing (e.g. Ball et al., 2002).

b) The cognitive changes considered above are now accepted as potentially varying widely in their form and progression across individuals. As Hakamies-Blomqvist (1998) notes, "while earlier research was mostly guided by the question 'why do older drivers have higher accident risk', this has been superseded by 'which older drivers have higher accident risk?" (p.296).

c) There may be problems related to the measurement of SA in older adults, due to these changes in physiological, perceptual, and cognitive functions. In assessing SA acquisition in older adults, and when comparing age-related variations in SA factors, these changes need to be taken into account in order to reduce age biases in measurement (Endsley & Garland, 2000).

d) Ageing effects can be moderated by specific circumstances, such as: more simple driving environments, situations with a great deal of environmental support, and/or unpaced situations. As noted, for example by Molnar & Eby (2008) above, older drivers tend to take on journeys related to their perceived driving skill.

e) Older drivers may show minimal decline in areas where they can draw on their expertise (e.g. Bolstad, 1996). Attention problems attributed to older adults in the literature typically occur within novel contexts (e.g., laboratory driving tasks), however, such effects may be greatly reduced or eliminated where the driver has domain specific expertise (such as driving his/her own car locally).

The most commonly cited alleviant of the negative impact of ageing, however, is driver experience. This is based on the premise that older adults may be able to employ well-developed scripts and schemas that enable them to maintain both good Situation Awareness and circumvent the processing limitations highlighted above. Bosman & Charnes (1996), for example, argue that the latter is achieved from being able to develop automaticity in certain skills, that can compensate for some declines (e.g., in relation to working memory, Bolstad & Hess, 2000).

2.3.2.1. Advantages of experience

We know that as a driver's interactions with other road users increases over time, and as a greater range of events are negotiated, that his/her Situation Awareness can also develop (Lee, Olsen, & Simons-Morton, 2006).

This experience is additionally said to lead to safer driving. Soliman & Mathna (2009), for example, found driving expertise correlated with both SA and driving errors. They found that novice drivers were less situationally aware than those with expertise, and were more often involved in driving infringements: such as, having collisions with other vehicles; driving through stop signs; crossing centre lines; hitting pedestrians; exceeding speed limits; and/or making excursions outside the roadway.

Expertise through experience has also been found to enable better collection, representation, and employment of suitable information to project future actions (Sohn & Doane, 2004) and to build up accurate descriptions of situational elements that are tactically important (Randel et al., 1996).

It has been argued that this is related to levels of visual scanning (e.g. Crundall & Underwood, 1998; Underwood et al., 2002; Underwood et al., 2003). It appears that whilst experienced drivers develop an awareness of when they need to be especially attentive and increase their scanning activity; inexperienced drivers are more uniform in this regard. For example, on safer, uneventful roads, the scanning of both experienced and inexperienced drivers was found to be similar, but on an urban motorway, with other road users merging from both directions, experienced drivers were found to search the roadway around them more extensively (Underwood, Ngai, & Underwood, 2013).

Appropriate scanning of the roadway is important from a Situation Awareness perspective, because without seeing and perceiving necessary information (at Level 1 SA) it will be difficult, perhaps even impossible, for the driver to then achieve sufficient SA at its higher levels (2 & 3) - thereby increasing his/her potential for accidents.

This, in fact, is evident in the better performance of experienced drivers in hazard anticipation/perception tasks (Jackson, Chapman, & Crundell, 2009; Garay-Vega & Fisher, 2005), which again has been explained by narrower visual searches exhibited by novice drivers, that as a corollary required them to undertake extra processing time to completely search a driving scene. This has found to be evident in both on-road and laboratory studies (Mourant & Rockwell 1972; Crundall & Underwood, 1998; Underwood et al., 2002; Underwood, 2007). Therefore, if a driving situation becomes very complex, or contains many cues, then consequently novices will be at a greater disadvantage.

The above findings appear logical. How well we integrate perceived elements of a driving scene should provide a better basis for understanding the scene as a whole (thus enhancing Level 2 SA), and in turn the anticipation of future movements or the behaviour of other drivers or pedestrians (at Level 3 SA). So the more experience we can bring to bear for the extracting of elements for Level 1 SA, the more likely we would be able to maximise our comprehension and decision-making time, which should translate into safer driving. And indeed, McKenna & Crick (1991) have provided some evidence for this by showing reaction time differences between experienced and novice drivers. One should point out, however, that having good Situation Awareness at its higher levels, or informed by proficient processing from its lower, perception, level, does not mean an accident cannot happen (Endsley, 1990). A driver could, for example, have excellent perception of a scene, but still not perceive a potential hazard, such as with 'look but fail to see' accidents (Brown, 2002).

There are also studies that question the advantage of driving experience. Vogel (2003), for example, found that experienced drivers were no more skilful at predicting the development of traffic situations than novice drivers. And although more confident in answering hazard detection/awareness and driving performance questions, Jackson, Chapman, & Crundell (2009) found that this was not reflected in their actual performance. (Though, as noted above, they did find experienced drivers to record higher scores by these measures than novice drivers).

Overall, it would seem reasonable to conclude that as a driver's interactions with other road users increases over time, and as a greater range of roadway events and environments are negotiated, that this should be beneficial both for safer driving, and indeed Situation Awareness - as has been found by Lee, Olsen, & Simons-Morton (2006). The crucial question, however, is whether an older driver's greater driving experience will allow him/her to compensate for age-related cognitive decrements (as argued by McPhee et al., 2004), or perhaps these are more universal deficits that experience cannot compensate for? This is indicated, for example, by DeLucia et al., (2003), who found accuracy in judgments about potential collisions to be significantly lower for older drivers.

2.3.3. The SA capability of older drivers

It is important to preface this section by mentioning that, firstly, there is a sparseness of research considering the impact of an older driver's experience on their SA, or, for that matter, looking at the SA of older drivers more generally. Much of the existing knowledge in these areas still comes from the work of Cheryl Bolstad some 15 to 20 years ago.

It should also be noted that when considering the SA of older drivers that the concentration has been on Level 1 SA (perception). This is due to a belief that differences in age-related abilities (highlighted in the theories given above) would be at their most acute during the initial formation of Situation Awareness, where it is necessary to perceive what is important in a driving environment (e.g. Bolstad & Hess, 2000, supporting this viewpoint given by Jones & Endsley, 1996).

In regards to the benefit of driving experience, then, Bolstad (1996) evaluated and compared, through an extensive 40-item questionnaire, the Level 1 (perception) and Level 2 (comprehension) Situation Awareness of drivers in different age groups. Specifically, she compared the performance of young (18 to 39 year old) drivers with less than 5 years driving experience, with middle-aged (40 to 59 years), and older drivers (60 to 84 years) with more than 20 years experience.

The expectations were that the older drivers would experience more driving difficulties associated with potential SA problems than the younger drivers. In fact, the younger drivers reported experiencing the most problems, such as forgetfulness, failure to stop, and navigating in unfamiliar areas; whereas the middle-aged drivers had the fewest difficulties.

These results could be attributed to experience and expertise with the driving task. In that whereas the younger drivers may not have accumulated enough experience to allow them to perform certain driving components automatically, the older drivers may indeed have done so. And thus, this, together with other compensatory approaches, might have enabled them to overcome many of the negative changes associated with ageing. Such an argument did, in fact, receive some support from Bolstad's findings, in that her older drivers did report certain changes in their driving behaviour indicative of such compensations, and more often than the other age groups. For example, they would avoid motorways during the 'rush hour', and not drive at night.

However, when the older driver group was compared with the middle-aged group (who had more driving experience than the young cohort) the older adults were then found to have reported more driving difficulties and to have exhibited lower levels of Situation Awareness.

In a further study, Bolstad (2001) aimed to understand how ageing affected a driver's ability to attend to important information in driving environments of different complexity, and to see how these impacted on an individual driver's Situation Awareness. Overall, her results showed that older adults again produced lower SA scores. However, although SA performances for all of her age-groupings were significantly worse overall in a highly complex driving condition to that in a moderately complex condition, the older drivers did not, as expected, experience a greater decrease in performance.

In a later related study, that additionally considered the impact of hazards on Situation Awareness, Zhang, Jin, Garner, Mosaly, & Kaber (2009) found that, in general, a younger driver group again exhibited higher levels of SA compared to that of an older driver group. Surprisingly though, after a hazard event was triggered, there was no difference in SA proficiency between them. Zhang et al. argue that this might have been due to the older drivers improving their attention and concentration to avoid potential hazards similar to the one they had experienced (whether static or dynamic). (Actions that may in fact had led to them to show better SA at Level 1 in rural conditions than the younger driver group).

In a rework of that study, Kaber, Zhang, Jin, Mosaly, & Garner (2012) highlighted that older drivers exhibited worse performances at higher SA levels when compared to younger drivers (as measured by SPAM/SAGAT scores). It was argued that although the SA of the older drivers could be enhanced at Level 1 (perception), this then impacted on their SA at Level 2 (comprehension) - perhaps due to reorientation needs - and at Level 3 (projection), which was generally found to be degraded. It was also concluded that the complexity of a driving environment was influential for Level 2 SA, and that this was related to a driver's age. The scores, though, were more mixed at other SA Levels, with the older driver's scores at Level 3 in the rural (non-complex/pre-hazard) condition appearing, comparatively, the most degraded.

Although such studies provide support for the contention that SA will decline with age, and is not arrested by driving experience, the evidence is not conclusive. The latter two studies, for example, show changing age-related SA performance in different driving conditions, and before and after a 'hazardous' event. Though in the latter case this does seem to have been more due to a rise in concentration levels than any invocation of better experience. Also, in a preliminary analysis of SA scores for experienced pilots - where no correlation was found between SA and age - Bolstad & Endsley (1991) tentatively argue that their small number of selected participants may have precluded the impact of ageing on SA due to an accumulation of expertise through experience. Again, though, whether this would also be demonstrated with experienced older drivers is questionable.

2.3.4. Older drivers SA and driving performance

In addition to evaluating the proficiency of an older driver's SA, and whether it can be arrested by driving experience, another important consideration here is in relation to driving performance indicators. If an older driver does have worse SA would this translate into poorer driving?

In this regard it is firstly important to mention that, again, studies that link SA and driving performance, even amongst all driving groups, are rare. The most persuasive is perhaps Rogers, Zhang, Kaber, Liang, & Gangakhedkar (2011), who found that following a car under visual distraction led to a significant negative correlation between Level 1 SA (perception) and steering error and speed variability, as well as between total SA scores and steering error. And that conversely, as SA increased, so steering error decreased and vehicle control became more stable. The negative effects of visual and cognitive distraction on SA amounted to, on average, a 43% decrease in accuracy in time estimates and a 50% decrease in spatial position estimates for passing and following tasks.

The importance of visual and cognitive abilities has, of course, been highlighted in previous sections of this chapter, in relation to attending to important information. These include vision impairments, perception, memory, and attention. It was further suggested that these abilities change with age (Laux, 1995; Salthouse, 1985; Smith & Earles, 1996) and that they are more pronounced as a task's difficulty increases (Tun & Wingfield, 1997). Shinar (1993), in fact, reminds us of the importance of this by highlighting that driver inattention and deficiencies in information processing are major factors in accident causation.

Previous research has indicated that decrements in age-related perceptual and cognitive abilities may also lead to an increased risk of collision (Potts et al., 2004). These may be compounded by difficulties with certain environmental factors, such as increased roadway complexity, which has been found to decrease older driver task performance far more than younger drivers. For example, in terms of lane keeping, and speed maintenance (Chaparro & Alton, 2000; Ho et al., 2001) and, additionally, from a susceptibility to dynamic hazards (Ryan et al., 1998).

Ho et al. (2001), for example, examined the effect of visual clutter on a visual search for traffic signs under normal driving conditions. They found that older adults were slower, less accurate, and required more fixations to acquire a traffic sign. This suggests that in time-limited situations that involve visually complex scenes (e.g., a busy intersection), that older adults are more likely than younger adults to misidentify or miss a sign altogether.

However, it should be mentioned that the older adults in the Ho et al. study did not suffer disproportionately to their younger counterparts as a result of increased roadway clutter. Ho et al. argue, though, that as their stimuli were static scenes with high visibility, it is likely that in a more realistic driving simulation, with dynamic stimuli and varying degrees of visibility, that the older adults would be more dramatically affected by clutter.

An inference is thus made, that due to information processing decrements, an older driver's SA will decrease particularly when exposed to driving environments of high complexity, and thus his/her driving performance will be worse in comparison to younger drivers in such circumstances.

However, the evidence to support this claim is light. In Bolstad (2001), only three measures were found to be significantly correlated with SA and complexity. In a moderately complex driving condition these were: gender; self-reported vision; and perceptual speed. However, in a highly complex condition they included, along with driving experience, two measures of 'useful field of view' (UFOV) - the breadth of an individual's visual focus. Thus, as reductions in UFOV have been correlated with increases in on-road crash involvement by older drivers (Owsley et al., 1991), an indirect link could be proposed between older driver SA and driving performance.

Such a link, though, was not supported in the Zhang et al. (2009) study that also looked for an SA-driving performance relationship. They did find that older drivers were adversely affected by increased clutter in a driving environment (as reported in Ho et al., 2001), and showed poorer SA under city than rural conditions (in similar fashion to Bolstad, 2001). However, contrary to expectation, their older drivers' performance did not significantly differ from that of younger drivers in regards to their lane keeping abilities - either when assessed over two levels of driving complexity, or after encountering a hazard.

Kaber et al. (2012) reporting the same findings, again highlight lower older driver SA scores, but no significantly observed difference from younger drivers in lane deviations before or after a hazard's exposure, and on either city or rural roads.

Kaber et al. argue that the lack of a performance difference was due to the older drivers adopting a conservative driving style to compensate for any age-related declines in ability. Specifically, they note that the older drivers drove slower (31-40% of their normal speed) when negotiating dynamic hazards, presumably to give themselves more time to perceive and process environmental cues (at Level 1 SA). In effect, to maintain risk levels below certain internal thresholds (as also found by Fuller, McHugh, & Pender, 2008; Summala, 1996). It should be noted, though, that such compensations did not allow the older driver group to match the SA performance of younger participants, as was also found for the road simulator task administered by Bolstad (2001).

In addition to driving slower, previous research has also shown that perceptual-motor co-ordination abilities, such as the lane keeping measured in the Zhang/Kaber study, can become automated with longer driving experience (Shinar, Meir, & Ben-Shoham, 1998), and thus to be undertaken without conscious control or by placing excessive demands on the older driver's working memory capacity (Horrey & Wickens, 2006). So although older/elderly drivers may have poorer SA when compared to younger drivers, it may again be experience that enabled them to more proficiently access and undertake such automatic processing. This, coupled with slower vehicle speeds in recognition of poorer cognitive skill, may thus have accounted for their capability to keep within a lane to a similar standard to younger drivers, as Zhang et al. report.

It should be mentioned, however, that the number of studies that have sought such correlations is small, and have focussed on a few, and perhaps more easily achieved, tasks (in addition to lane keeping, for example, spotting signs (Ho et al., 2001), and all driven at a comfortable pace for a short duration). Nevertheless, these findings do run contrary to what might have been expected for SA and performance in the driving domain.

2.3.5. Conclusion and the way forward

The consideration given above to the theories for older driver cognitive declines from a Situation Awareness perspective highlight the concept's usefulness as an explanatory framework for explaining driving performance. It has been seen, for example, how much can depend on what relevant movements and cues a driver selectively attends to, as these can allow for better anticipation of the intentions of others.

It has also been suggested that driving requires Situation Awareness to, for example, monitor a constantly changing environment, understand and manage incoming information, and make decisions under high mental workload conditions. So if drivers are not able to adequately perform such tasks, it would seem reasonable to conclude that their driving performance would ultimately suffer. It has additionally been seen in previous sections that several cognitive and physical abilities are needed to undertake these driving tasks. These include vision, perception, memory, and attention, and that these abilities also change with age, and become more pronounced as a task's difficulty increases. Thus it is proposed that these declinations will impinge on the initial formation of Situation Awareness (Bolstad & Hess, 2000, supporting a viewpoint given by Jones & Endsley, 1996), as they will bring difficulties in perceiving what is important in a driving environment such as lane position, speed, and the location of other cars.

Yet when older drivers undertake the somewhat contrived, simulator-based tasks of Boldstad (2001) and Zhang et al. (2009), although their SA is generally found to be deficient to that of younger groups, it is not (as assessed by Zhang/Kaber) related to a driving performance measure. Intuitively, however, as Rogers et al. (2011) have shown above, there should be a relationship between SA and such performance. So could it be, as Zhang et al. suggests, that the older drivers benefitted from using compensatory mechanisms (such as slowing their speed) to help overcome any cognitive and physical difficulties, and thus produce task performances to similar standards as younger participants? But, then, if cognitive and physical difficulties were overcome to perform a task, why was SA still detrimentally effected?

A more recent Distributed Situation Awareness (DSA) approach to driving studies (as advocated by e.g. Salmon et al., 2008; Stanton et al., 2010) perhaps may help to provide some additional answers. This approach, that considers the driving 'system' as the unit of analysis, rather than one based solely on the individual, will be considered further in Chapter 3. In brief, however, it importantly argues that only by assessing the driving 'system' can a complete picture of a driver's SA be revealed, and that previous SA studies that have focussed solely on the individual will, as a result, carry methodological limitations.

Those adhering to a Distributed Situation Awareness approach also advocate for the evaluation of SA from data gathered during actual journeys, and due to recent advances in software capability, data captured from such environments can now be analysed more rigorously. Such an approach would thus appear to provide a better basis for understanding the relationship between SA and driver age than the 'individualistic' measures considered thus far, which have exclusively focussed on artificially 'freezing' simulated driving tasks to ask recall-based questions.

The merits of the DSA approach, and the SA models they are based on, will also be considered in Chapter 3, and this, in turn, will then inform the method and analysis to be adopted for the studies that follow in Chapter's 4, 6, and 7. Overall, however, when considering research methods for these studies, the aim was to look to gather a greater range and depth of information than had been undertaken previously, and whenever possible, for it to be captured from on-road environments. The routes chosen for investigation in this context would additionally have to be different in their levels of complexity, in order to provide an insight as to whether SA could be degraded by age-related decrements in cognitive processing, or be compensated for by, for example, presumed higher levels of automatic processing and longer driving experience.

Chapter 3: Research Methods

3.1. Two competing models of Situation Awareness (SA)

As has been seen in Chapter 1, there is a divergence of views as to what Situation Awareness actually is. Some contend that it is knowledge held in working memory (e.g. Bell & Lyon, 2000), some a cognitive product of information-processing (e.g. Endsley, 1995a), others externally directed consciousness (e.g. Smith & Hancock, 1995). There are also different views as to whether it is simply a *process* of gaining awareness (e.g. Fracker, 1991b), more the *product* of awareness (e.g. Endsley, 1995a), or a combination of the two (e.g. Smith & Hancock, 1995).

This chapter begins by considering two models of how an individual is thought to gain Situation Awareness, so as to provide a contrast between the one favoured in this thesis (based on externally directed consciousness), and the one still predominant in the literature at this time (based on an individual's information-processing). Further consideration is then given to a 'Distributed system' perspective of Situation Awareness (DSA), and its linkage to the first of these two models, proposed by Smith & Hancock (1995). A number of related measures of SA are then reviewed, leading to a justification for taking a more systems-based approach, and an explanation of a (related) method and technique that would be utilised for the studies reported in the chapters that follow.

3.1.1. SA based on an individual's information processing

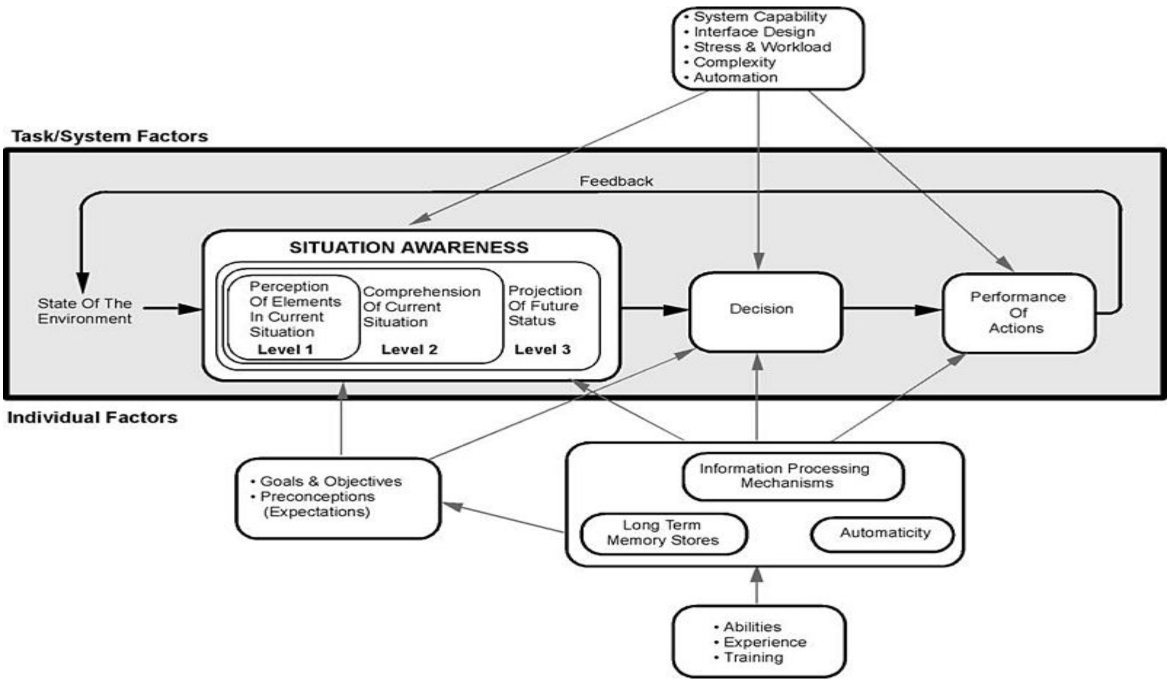
Although numerous definitions of Situation Awareness have been proposed, Endsley's definition (1988, p.97) remains the established and most widely accepted. This, to restate, contends that SA is: "the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future". The reason for this longevity may be due to the fact that whilst some definitions are specific to the environment from which they were adapted, Endsley's definition is applicable across a range of task domains.

Endsley has also provided the most cited and well known theoretical framework of SA (Endsley, 1995a), which Stanton et al. (2001) and Salmon et al. (2009) suggest is, advantageously, both simple to understand and to measure.

3.1.1.1. Endsley's three-level model

As can be seen in Figure 3.1 below, the model is linear in approach with Situation Awareness being formed through three inter-connecting stages or levels: these are the 'Perception of elements in the current situation' (Level 1); 'Comprehension of the current situation' (Level 2); and, 'Projection of future states' (Level 3). These three levels will now be considered in further detail.

Figure 3.1: Endsley's model of Situation Awareness (adapted from Endsley, 1995a)



At the 'Perception' Level (1): we are said to perceive the status, attributes, and dynamics of relevant environmental elements. This involves monitoring, cue detection, and simple recognition of multiple situational elements (objects, events, people, environmental factors) and their current states (locations, conditions, modes, actions).

At the 'Comprehension' Level (2): a synthesis of the disjointed Level 1 elements occurs through the processes of pattern recognition, interpretations, and evaluations. This information is then integrated on the basis of an individual's goals and objectives. Thus at this stage we are said to have the capability to develop a comprehensive picture - a world view, or at least a portion of relevant concern.

At the 'Projection' Level (3): we seek to project the future actions of the elements in an environment. We achieve this through our knowledge of their status and dynamics, and a comprehension of a situation (through our Level 1 & 2 SA processing). We then extrapolate this information forward in time to determine how it will affect the future states of the environment that we are seeking to understand.

The model's formulation is based on the individual, who processes information in a data-driven and linear fashion. The information the person directs attention to and interprets will much depend on his/her goals and preconceptions. Thus, a person's perception of the elements deemed of relevance in an environment will form the basis of their SA, which will then serially inform his/her decision making and actions.

In terms of how information translates into Situation Awareness, the model assumes that features in the environment are mapped onto mental models in the mind of the individual and that these models are used to develop SA. Having to process (excessive) demands through (limited) working memory capacity will restrict this development, as will a situation's or task's difficulty and/or novelty. However, experience can afford an individual an advantage by enabling environmental cues to be matched with existing mental models in memory, aiding recall.

Endsley's model thus illustrates that several variables can influence the development and maintenance of SA, and therefore, although it can support the necessary input processes (e.g., cue recognition, prediction) upon which good decisions are based (e.g. Artman, 2000) we should not expect similar SA-related performances. This is even the case when the same information or training is provided, as each individual will vary in their ability to acquire SA.

Endsley concludes that her model shows how SA "provides the primary basis for subsequent decision making and performance in the operation of complex, dynamic systems" (Endsley, 1995a, p.65). However, other approaches suggest the approach, in essence at least, is too reductionist.

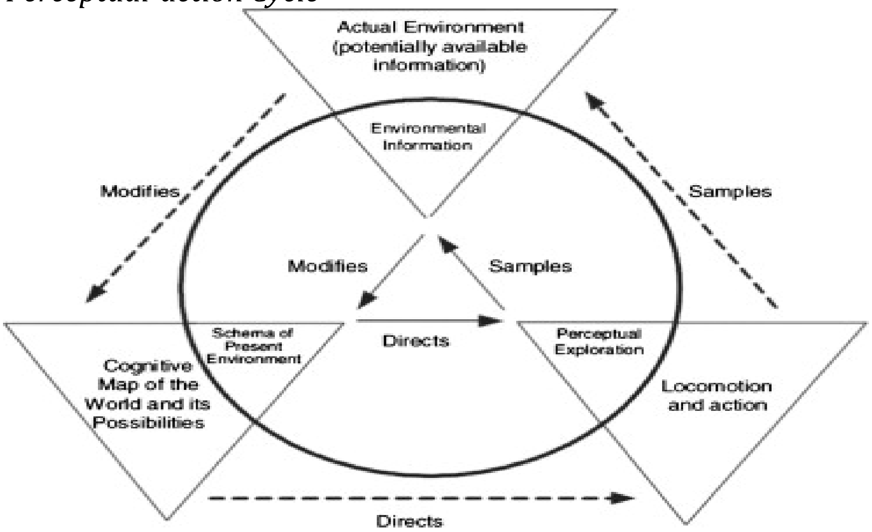
3.1.2. SA based on the 'Perceptual-action Cycle' model

An alternative model of Situation Awareness has been proposed by Smith & Hancock (1995), it is often referred to as having either a systems or ecological approach, and is based on Neisser's 'Perceptual Cycle' (Neisser, 1976). That is not to suggest that it is the only alternative to Endsley's model. There is, for example, the lesser considered Theory of Activity model (Bedny & Meister, 1999), however, Smith and Hancock's is arguably the most widely known and the principal alternative. Macquet & Stanton (2014), for example, state "In the literature, two main models are distinguished to describe SA: Endsley's (1995) three-levels model, which is the most popular, and Smith's and Hancock's (1995) model based on Neisser's perception–action cycle theory" (p.725). The elevation of this model is probably due to other prominent alternatives focussing, like Endsley, solely on the individual when considering SA acquisition and maintenance. Smith and Hancock, in contrast, take a more holistic view of SA by considering how the individual interacts with other technical artefacts to produce a 'generative process of knowledge creation and informed action taking' (Smith & Hancock, 1995, p.142).

The model views Situation Awareness as being achieved through a cyclical interaction between the perceived environment, memory schema, and active exploration. And that, therefore, its 'unit of analysis' should be at the level of such interactions, rather than Endsley's concentration on an individual's more serial processing of information. Like Patrick et al. (2006), Smith and Hancock also advocate that these cyclical interaction activities should be tracked in real time, rather than mere 'snapshots' favoured by methods aligned to Endsley's model, as these would not be able to tell the whole 'SA story', no more than a few still photographs would reveal the nature of a plot in a film.

Produced below, in Figure 3.2, is their 'Perceptual-action Cycle' model of Situation Awareness (Smith & Hancock, 1995). This shows how schema driven sampling and perception of an environment can confirm or modify an individual's relevant schemas, which then directs his/her behaviour. And so the cycle continues.

Figure 3.2: Smith & Hancock's model of Situation Awareness based on Neisser's (1976) 'Perceptual-action Cycle'



The model is based on three strands of thinking: schema theory (including genotype and phenotype schemata); the mapping of these concepts onto a Perceptual-action cycle model of cognition (Neisser, 1976); and, in turn, the mapping of these concepts onto SA. Consideration shall now be given to each of these aspects of the model.

3.1.2.1. Schema theory

Bartlett (1932) introduced the 'schema' concept to describe how people interpret information. He saw them as active organisations (mental templates) of past reactions and experiences, which were combined with current information, goals, available tools, and the situation, to produce behaviour. Our schemata enable us to understand streams of activity. They allow us to anticipate, to make sense of an event, which then informs what we do, and what information we then look for, and attend to. They thus can both modify, and be modified by, an experience.

Norman & Shallice (1986) have suggested that schemata are templates for behaviour that are triggered by cues in the environment. So although several schemata might be activated at any moment in time (offering a range and variety of possible behaviours), a selected schema can often be automatically allocated on the basis of the strength of activation and the motivations of the individual; whereas controlled processes are only activated when the task becomes too difficult, such as novel situations or when errors are made. So in this regards we can contrast *genotype* schemas, that allow us to react automatically or prototypically to specific situations or tasks, such as a strong stereotyped response to turn a tap in a particular direction to turn it on or off (Sanders & McCormick, 1992), with *phenotype* schemas, which are more state specifically activated and controlled, and brought to bear in more novel situations through, say, intuitive interpretations.

Thus, schema-based theories tacitly assume that cognition is not only cyclical (rather than linear) but also parallel (rather than serial) in processing information.

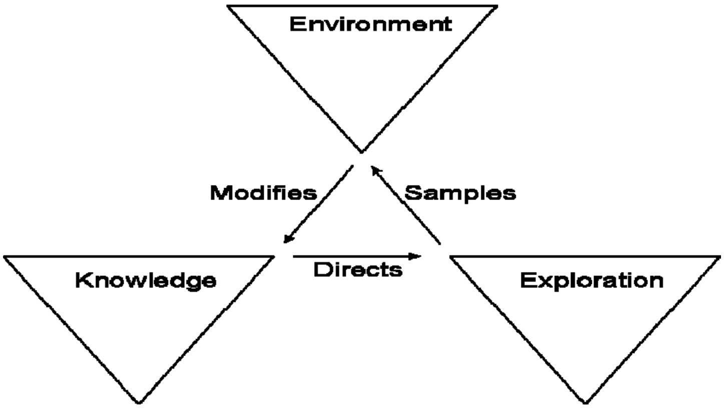
The individualistic nature of schema use could additionally indicate that those with experience of a particular situation could have richer schemata. As a result, they may not only attend to different stimuli (as directed by their schemata), but also derive a better understanding of it through that interaction. Thus an argument is made that different road users could possess different schema even for the same road situations, with, in some cases, the wrong schema being activated or mistimed (Walker et al., 2011). This is likely to include issues such as failing to see other road users (i.e. looked but failed to see errors (Brown, 2002)), or failing to comprehend how other road users are likely to behave.

3.1.2.2. Neisser's 'Perceptual-action Cycle' model of cognition

Neisser (1976) described what he termed the 'Perceptual-action Cycle', which proposed that the anticipatory schemata an individual holds served to anticipate perception and direct action (see Figure 3.3 below). He saw perception as an active, rather than a passive, process that was schema guided as to what was attended to, acted upon, and expected.

Once again, this exploration leads to an adaptation to the environment by the perceiver, which in turn guides future exploration. So, for example, in a driving context, a driver's schemas direct what information s/he samples, which in turn modifies the driver's schema/mental theory of the situation, and thus, his/her behaviour.

Figure 3.3: Neisser's 'Perceptual-action Cycle' model (1976)



3.1.2.3. Mapping onto SA

In a similar fashion, Situation Awareness is seen by this approach as neither resident in the world nor in the person, but as a result of the cyclical interaction between them both.

Adams, Tenney, & Pew (1995) who, like Smith and Hancock, have produced their own SA theory based on the 'Perceptual-action Cycle', illustrate how it is possible for people to maintain SA. Using a driving example, they explain that as a car driver knows from previous experiences how a driving situation should evolve (e.g., the distance to a lead vehicle should remain stable); so s/he will repeatedly and actively attend to relevant aspects in the environment (e.g., the lead vehicle), and compare them to an expected 'situational development' based on prior knowledge. The results of that comparison will then guide both future exploration, and other aspects of, behaviour. However, they add the caveat that "the flow of data [must be] manageably paced and reasonably compatible with the knowledge and experience constituting the perceiver's active schema" (Adams et al., 1995, p.90).

3.2. A 'Distributed' Situation Awareness?

A further important distinction then between Endsley's model, and 'Perceptual-action Cycle' models such as Smith and Hancock's, is in relation to where Situation Awareness is said to reside. For Endsley, Situation Awareness, like cognition, and knowledge, is held solely within the individual; however, for Smith and Hancock it is gained from externally directed consciousness, and thus sourced from across the environment the individual is operating within. To explain this distinction further it is necessary to consider the work of Edwin Hutchins, who introduced a theory of 'distributed cognition' (Hutchins, 1995ab).

3.2.1. Distributed cognition

Hutchins saw our cognitive activities as computations that took place within a system through a transformation of information resources. He argued that the knowledge and cognition to operate a naval vessel, for example, would not exist solely in the head, as contended by Endsley, but rather that it would be *distributed* across objects, individuals, artifacts, and tools on the ship. It therefore wasn't necessary for the individual(s) to know all the required information, just relevant information. As long as the required information was held somewhere in the system (by a human or instrumentation) and correctly activated, a task could be successfully completed. Indeed, this could still be the case even where one individual had degraded SA, as it could be compensated for by another element (either human or instrumentation) within the system.

So to understand Situation Awareness, Hutchins argued that we should analyse the interactions between these different information 'components' over time and place. These would include the physical manipulation of objects, and the creation/exchange of external representations that were evolving between people, or between, say, people and instrumentation. We should take account of the fact that individuals, whether working alone on a task, or in a team, would bring different kinds of knowledge to it depending on their own goals, roles, and experience. And that they would also engage in interactions that would allow them to pool various resources to accomplish a task.

Hutchins therefore believed that SA was better viewed as an emergent property from such interactions, rather than residing within the individual alone. He did not discount the individual, but rather saw his/her role as confined to "providing the internal structures that are required to get the external structures into co-ordination with one another" (Hutchins, 1995a, p.131).

3.2.2. Distributed Situation Awareness (DSA)

Drawing much on the work of Hutchins (1995ab) above, Stanton et al. (2006) have additionally proposed a model of Distributed Situation Awareness (DSA), that, like Hutchins, suggests SA-related knowledge is *distributed* between both human (e.g., human operators) and non-human (e.g., tools, documents, displays) 'agents'.

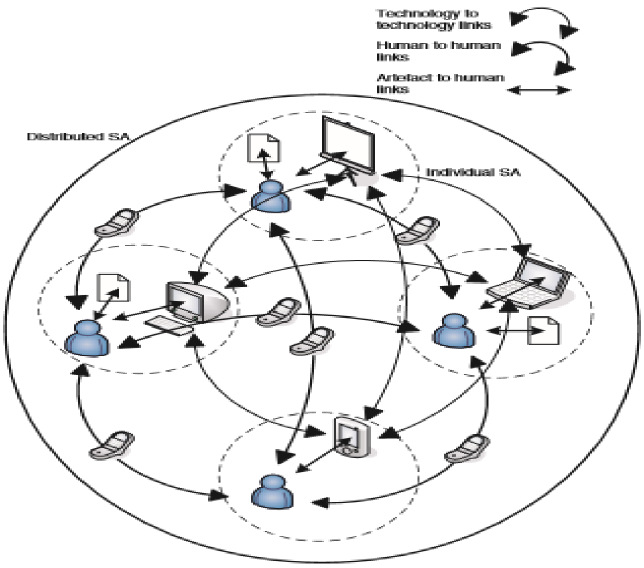
As Situation Awareness will change moment by moment, in the light of changes in a task, an environment, and interactions (both social and technological), it thus is defined as "activated knowledge for a specific task within a system at a specific time by specific agents" (Stanton et al., 2010, p.34). In the context of a driving system, like Hutchins, Stanton argues that it would not matter if the driver, the car's technology, or perhaps the road infrastructure, owned relevant SA-related information, only, that it was held somewhere in the driving system, and was drawn upon at the right time by the right person.

Stanton's theory, however, has more relevance for teams than those involved in individual tasks such as driving. In this regard he draws his ideas from Artman & Garbis (1998) who defined team SA as "the active construction of a model of a situation partly shared and partly distributed between two or more agents, from which one can anticipate important future states in the near future" (Artman & Garbis, 1998, p.2).

According to Stanton et al. (2006), each agent within a system plays a critical role in the development and maintenance of another agents' SA, and again like Hutchins (1995ab), he believes that limited or degraded SA can be enhanced or updated through interactions with other agents. In this respect, some relevance to driving can be noted, as a passenger, policeman, or passer-by could be viewed as such an additional 'agent'.

In Figure 3.4, Stanton et al.'s DSA concept is represented by a graphic reproduced from Salmon et al. (2008). In this example, the information comprising the DSA of the system is held by four human agents and a number of non-human elements (i.e. computers, documents, displays, and mobile 'phones). Although the human agents are physically 'distributed' from one another, they are able to work collaboratively by utilising the non-human elements that will provide them with DSA-relevant information additional to what they hold themselves. A key facet of the model then is the exchanges, or ‘transactions’, between these agents and elements, as their quality will determine how well DSA is maintained throughout the course of a task, and how efficiently, and potentially how safely, it is performed.

Figure 3.4: A visual representation of Stanton et al.’s Distributed Situation Awareness (Stanton et al., 2006)



Although the DSA approach focusses on team working, the theory and method work equally well with what Stanton et al. (2006) term ‘single person-machine’ systems (p.1308), as DSA is concerned with how knowledge is used and parsed between agents in systems interactions. For example, the proficiency of the ‘transactions’ a driver might make with different roadway ‘elements’ – say, other vehicles, pedestrians, road infrastructure, and signage – may inform his/her level of DSA.

As such system-based approaches to SA view it as emerging from a cyclical processing of, and an interaction with, a system’s numerous elements - in effect, a product of the system itself - they tend to be linked to the ‘Perceptual-action Cycle’ models of SA, such as those proposed by Smith & Hancock (1995) and Adams et al. (1995). Salmon et al. (2008) explain that this is because they cater for the dynamic aspects of SA, and that the factors impacting on SA acquisition and maintenance are better described. Neville & Salmon (2015) additionally emphasise their schema-driven exploration of the world, and that the overall system (rather than the individual) is seen as the unit of analysis.

Having knowledge of these two different approaches to SA formulation, one based on systems, but perhaps, moreover, the other established alternative proposed by Endsley, are important precursors for the following section. This is because each approach, as a result of the assumptions that it makes as to the provenance and conceptualisation of SA, will inform the techniques that it employs for its measurement. In the following section, consideration will be given to the main methods that have been utilised to date.

3.3. The main methods of SA measurement

It is firstly important to preface this section by highlighting that the nature of Situation Awareness poses a considerable challenge to its quantification and measurement (see Endsley & Garland, 2000; Fracker, 1991ab). Perhaps partly as a result, one review has identified over twenty different approaches designed specifically for its measurement (Stanton et al., 2005). Generally, these techniques will fall into one of seven main categories. These shall be considered briefly below, moving from those more aligned to the traditional, individualistic, approach to SA measurement, to ones more favoured by researchers who advocate a systems approach.

3.3.1. Freeze probe techniques

Freeze probe recall techniques seek to take a snapshot of the contents of an individual's mind, as it relates to SA, at particular point(s) in time. They have their origin in aviation and along with this domain have been utilised in, for example, road transport, the military, and nuclear power. They involve the administration of SA-related queries during 'freezes' in a simulation of the task under analysis. Typically, at random intervals, all displays and screens are blanked, and a set of SA queries are administered. A participant's answers are judged against what is felt should be recalled at each 'freeze' stage with an overall SA score being calculated at the end of a trial.

3.3.1.1. Examples

Although other tests exist, such as the WOMBAT/HUPEX Situational Awareness and Stress Tolerance Test (Roscoe & Corl, 1987), the most commonly used freeze probe measure is the Situation Awareness Global Assessment Technique (SAGAT: Endsley, 1988, 1995b). SAGAT is, in fact, the partner to Endsley's three-level theoretical model of SA, and was developed to assess pilot SA. SAGAT, unsurprisingly therefore, measures the extent to which a participant is aware of a pre-defined element in the environment, their understanding of the properties of this element in relation to the task they are performing, and also what the potential future states of it might be.

Ma & Kaber (2005, 2007), have used a SAGAT style method to assess vehicle locations and colours (Level 1 SA), driving behaviours (e.g., acceleration, braking, turning) required to improve vehicle following accuracy (Level 2 SA), and the projection of times to certain events, such as the time until a next turn (Level 3 SA). Notably, most other road transport SA investigations have also utilised SAGAT style measures (e.g. Bolstad, 2001; Kass et al., 2007).

3.3.1.2. Strengths

a) Although interruptions are necessary, it can measure SA during a task's performance.
b) It can be applied in a range of domains, and has positive validation evidence.
c) The approach is simple, which allows SA to be easily compared across conditions.

3.3.1.3. Limitations

a) Its measures are deterministic and linear, in that one defines what SA is and then measures it. However, in real world scenarios, arguably it is not possible to determine beforehand what SA should comprise of.
b) The method only captures SA at specified points through tasks being frozen, as such it is difficult to apply in real world settings such as driving.
c) It only captures data relating to an individual's knowledge of SA elements, not how well they may be integrated.
d) The approach's ecological validity could be questioned, as the allocation of attention between task and test elements in a simulator may differ in real world environments.

3.3.2. Real-time probe techniques

Real-time probe techniques involve the administration of SA-related queries during a task's performance, but with no freeze of the task under analysis, and with answers and response times being taken as a measure of a participant's SA.

3.3.2.1. Examples

The Situation Present Assessment Method (SPAM: Durso et al., 1998) is a real-time probe technique developed for assessing air traffic controller SA. It uses task-related queries to probe operators (e.g., which of the two aircraft, A or B, has the highest altitude?) via telephone. The query response time (for those responses that are correct) is taken as an indicator of the operator's SA, and the time taken to answer the telephone acts as an indicator of workload. The method has also been used in driving contexts. For example, a simulator can be paused at unpredictable times (with the scenario being evaluated remaining visible) and the 'driver' then asked to respond to one or two questions about the scenario (Durso, Bleckley, & Dattel, 2006). Alternatively, the scenario is not interrupted, and the 'driver' is asked about a predefined event (e.g., a car swerving) (Greenburg et al., 2003). The most common variables for SA measurement here are, again, speed and accuracy of response.

3.3.2.2. Strengths

a) It has a reduced level of intrusiveness compared to freeze probe approaches, since no freeze of the task is usually required.
b) The technique has applicability for a range of domains, with positive validation evidence.
c) It is a simple approach that allows SA to be easily compared across conditions.

3.3.2.3. Limitations

a) Real-time probe measures suffer from many of the issues (outlined above) in relation to freeze probe approaches.

<u>3.3.3. Self-rating techniques</u>

This approach simply asks the participant to rate their own SA after a particular task has been concluded.

3.3.3.1. Example

The Situation Awareness Rating Technique (SART: Taylor, 1990) is the most popular variant. It uses ten dimensions to measure an individual's SA, is administered post-trial, and involves self-ratings of each dimension by a seven-point rating scale.

3.3.3.2. Strengths

a) The approach is less intrusive than the above techniques, as it is administered post-trial.

b) It is quick, low cost, easy to use, and requires little training.

c) It can be applied in any domain, and to both simulated and naturalistic scenarios.

3.3.3.3. Limitations

a) The measure has difficulty in correlating SA ratings with performance (Endsley 1995b). It was found to have poor sensitivity in driving assessments, and it is questionable as to whether SA is actually being assessed.

b) SART provides a measure of how confident a participant is in their SA and their own performance, but these are subjective and often an individual is unaware of the information they don't know.

c) The results tend to be global in nature and do not provide the detailed diagnostics that objective measures can provide, or how they may relate to the different elements within an environment.

d) It has problems connected with the collection of data post-trial (e.g., a lack of correlation between SA and performance due to poor recall).

3.3.4. Observer rating techniques

Observer rating techniques are most commonly used when measuring SA 'in-the-field' due to their non-intrusive nature. They typically involve experts/experienced observers (e.g., peers, commanders, or trained external experts) who may have more information about the true state of an environment, observing participants during a task's performance and then providing an assessment or rating of their SA. The ratings are based upon pre-defined observable SA-related behaviours that "infer" SA from the actions that individuals choose to take, based on the assumption that good actions will follow from good SA and vice-versa.

3.3.4.1. Examples

The Situation Awareness Behaviourally Anchored Rating Scale (SABARS: Matthews et al., 2000; Strater et al., 2001) is an observer rating technique that has been used to assess the Situation Awareness of infantry personnel in field training exercises (e.g.

Matthews & Beal, 2002; Matthews et al., 2000). In Matthews et al., the technique involved domain experts observing participants during a task's performance and then assessing (28) observable behaviours, by a five-point rating scale, specifically designed to assess platoon leader SA.

3.3.4.2. Strengths

a) It is non-intrusive to the tasks being undertaken.

b) Those with expertise in relation to the tasks can make SA-related judgements.

3.3.4.3. Limitations

a) The extent to which these expert observers can accurately rate the internal construct of SA from actions and verbalisation indicators must be questioned (see Endsley, 1995b).

b) Researchers will no doubt face difficulties in assembling an observer team of sufficient size and experience to rate the tasks.

3.3.5. Recall and imbedded task performance measures

Performance measures have their origins in road transport, where they have mainly been used to date. Depending upon the task, certain aspects of a participant's performance are recorded in order to determine an indirect measure of his/her SA which is "inferred" from the end result (i.e. task performance outcomes). This is based on the assumption that better performance indicates better SA. Common performance metrics include the quantity of output or productivity level, time to perform a task or respond to an event, and the accuracy of the response or, conversely, the number of errors committed.

3.3.5.1. Examples

When assessing driver SA, Gugerty (1997) has used a combination of recall measures (e.g., the percentage of cars recalled and recall error), imbedded task measures (e.g., hazard detection, blocking car detection), and more global measures.

In a Post-Drive Memory Test (Strayer, Drews, & Johnston, 2003), participants were shown pairs of driving scenes: one scene from the drive they undertook; one not. They were asked to choose the one from the drive (i.e. a recognition memory test), with recognition accuracy the main evaluation variable.

3.3.5.2. Strengths

a) These techniques can collect information objectively and without disrupting task performance.

b) Multiple aspects of SA can be measured.

c) Evidence has been found for a correlation between the measures (Gugerty, 1997).

d) It is a simple approach, requiring little training.

3.3.5.3. Limitations

a) Although evidence exists to suggest a positive relation between SA and performance, this connection is argued as probabilistic and not always direct and unequivocal (Endsley, 1995b). In other words, as was suggested in Chapter 2, good task performance is not necessarily refective of good SA (Endsley, 1990).

b) It requires simulation of the task or system under analysis.

c) Since its original application, it has had limited uptake as a technique.

<u>3.3.6. Process indices</u>

Process indices examine how individuals process information in their environment in order to develop SA during a task under analysis. They are typically used in road transport contexts, taking physiological measurements during a task's performance (e.g. Smolensky, 1993) to determine how a participant's attention is being allocated, or how the pressure of a task may impact upon his/her SA proficiency.

3.3.6.1. Examples

Eye tracking systems, that can employ various eye fixation measures (e.g., fixation duration, scan patterns) to assess an individual's attention to items in, for example, a driving environment or an in-car technology.

Psycho-physiological measures that can assess the relationship between performance and an individual's physiological state (e.g. French et al., 2007). For example: electroencephalographic data, eye blinks, and cardiac activity, to determine whether an individual is sleep fatigued, or mentally overloaded; or transient heart rate and electrodermal activity to evaluate perceptions of critical task-relevant cues (Wilson, 2000). In addition, it is also possible to monitor an individual's environmental expectancies, that is, their physiological responses to upcoming events, as a measure of their current level of SA (Wilson, 2000).

3.3.6.2. Strengths

a) It is relatively unobtrusive to the primary task performance.

b) There is a long history of applicability to road transport settings.

c) Newer system models, e.g., eye-trackers, have made it possible for measurements to be taken on actual roadways.

3.3.6.3. Limitations

a) Like 'performance measures' above, process indices suffer from the problem of measuring the extent to which performance and process can be linked to good or poor SA.

b) Equipment and data analysis can require expertise and training, and can be resource intensive.

c) As it is an indirect assessment of SA, there is usually a requirement for additional measures.

3.3.7. Network analysis

Propositional or semantic networks are essentially forms of mind map depicting the information that comprises a person's, group's, or system's SA (Salmon et al., 2009). They are an established way of representing knowledge (e.g. Collins & Loftus, 1975; Collins & Quillian, 1969, 1970) and have been used, for example, in road transport and military domains. They are based on the belief that all knowledge is in the form of associations (Eysenck & Keane, 1990).

3.3.7.1. Examples

(Concurrent) Verbal Protocol Analyses (VPAs) are used to elicit thought processes and knowledge (see Bainbridge, 1990). They involve creating a written transcript of a participant's thoughts by asking him/her to 'think aloud' whilst undertaking the task under investigation. VPA's are used as a means of gaining insights into the cognitive aspects of complex behaviours, and often SA proficiency in military and road traffic contexts (Stanton et al., 2007; Walker, Stanton, & Salmon, 2011).

Networks can also be constructed from Critical Decision Method (CDM: Klein & Armstrong, 2005) and Hierarchical Task Analysis (HTA: Shepherd, 1998; Stanton, 2006) outputs. The CDM procedure involves interviewing the key agents involved in the scenario under analysis using a series of pre-defined 'cognitive' probes, from which information elements are extracted. These are said to present a description of the agent's subjective view of a system's SA in terms of its information elements.

3.3.7.2. Strengths

a) It removes the need for scenario freezes and probes and does not require observer ratings of SA.
b) It can provide a description of SA held by the system, as well as the individual operator.
c) The networks that are produced can be analysed statistically and visually.
d) The technique has applicability to many domains.

3.3.7.3. Limitations

a) Time constraints and technological limitations (e.g., the cost and availability of speech recording systems and speech-to-text translation software) make this approach less practical and viable in time-pressured, fast paced, operations.
b) The method can be criticised for its inability to identify tacit SA-related knowledge (i.e. knowledge used but not openly expressed), and sometimes, as a result, the quality of the system's SA has additionally been based on task performance and SME's (Subject Matter Experts) subjective judgements.
c) As the data used to construct a network is subjective, it could be construed as being either prone to error or lacking content.
d) CDM data is collected post-task, and so could potentially suffer from problems associated with post-trial data collection, such as memory degradation.
e) Without software support, the construction of a network is highly subjective and resource intensive.

Summary

It can be concluded from the above section that in the road transport sphere, which is of relevance to this thesis, that the traditional, individualistic, approach to SA measurement, stemming from the work of Endsley (1995a), will tend to utilise environmental simulations. This is because, with a simulator, it is possible to be exact and explicit as to the knowledge objects that 'should' be reported, and it also allows for precise and repeatable information 'probes', which would not be possible in a naturalistic setting.

The problems with such approaches, however, are that often no kinetic motion cues or interactive traffic conditions can be represented in the simulation. This is augmented by a lack of highly realistic and complex driving tasks, and as participants know SA-related questions are to occur at the end of each segment of a trial, they may take advantage of this knowledge to prepare/anticipate for the questions.

The systems approach as advocated by Hutchins (1995ab), and more recently by Stanton et al. (2006) and Salmon et al. (2008), tends to favour more naturalistic methods in road transport research. These provide more ecological validity as, for example, actual, more meaningful, driving environments are utilised. A preference is also given to the participant using his/her own car, allowing him/her to undertake real driving within a familiar environment. This perhaps, as a corollary, provides the best chance of capturing realistic task feedback, particularly as it is usually based on what the participant decides to verbalise, rather than it being structured by questioning.

The principal problem here though is that experimental control is much harder to achieve. Even simple factors, such as having an unfamiliar passenger present in the vehicle (who could be perceived as evaluating the participant's ability) might influence his/her driving style and behaviour. This could lead to 'correct' driving being undertaken that, in general, may not be evident – such as strictly keeping to speed limits, and enunciating procedural doctrines as one would for a driving test. It is also impossible to create the exact same driving environment for each participant, as weather and traffic density cannot be 'precisely' repeated between trials.

3.4. Justification for a systems-based methodology

3.4.1. Discrete or structured elements?

It could be argued that the crucial point from the above consideration of the techniques employed to measure Situation Awareness is in regards to whether the information elements a person perceives are structured in some way. Is SA more about the presence or absence of discrete elements that can be measured by tools such as SAGAT, or is it reflected more from the interconnection of those elements, and thus better measured by, say, information networks?

Walker et al. (2009) has shown how simple recall of SA-related information might not be reflective of SA proficiency by considering the comparative advantage of four media for a simulated mission-planning task.

a) Voice only (a telephone link between participants)
b) Voice and video (a live video link between participants)
c) Voice and data (an electronic shared workspace)
d) Voice, video, and data.

At various stages in the mission planning, the work was stopped and participants were asked questions about the tasks. It was found (from SAGAT measurements) that the best SA performances came in the voice-only condition, and, in fact, as the media became richer, the SAGAT scores became poorer.

This counter-intuitive finding is explained by a changing reliance on memory. As the awareness within the system became more 'distributed' across more media, so the SA held by the individual declined, as there was less of a need to remember information. However, in circumstances where the information was less 'distributed', the individual was forced to remember more information and thus was more able to score highly on the recall-based SAGAT measure.

No one, however, would advocate having just a voice only configuration to undertake a task in preference to one based on voice, video, and data. It would not be more SA proficient for a pilot to have no instrumentation, or in collaboration with an observer on the ground, to guess what speed s/he was at for each stage of a descent. The pilot's passengers would probably feel more relaxed if they knew s/he had speed indicators and pre-set speed settings that allowed for more consideration of necessary changes to say, wing flaps.

As such, it can be argued that instruments and flying aids not only inform SA in aviation contexts, but that it is only by looking at the interaction with, and awareness of them, that we can explain how SA is maintained. This contrasts with traditional SA measures, where our experienced pilot, although more likely to extract the critical cues needed for each flying task and to organise them more consistently, would more likely be seen as demonstrating worse SA than a novice pilot, due to the latter's higher utilisation of feedback control.

Although Endsley and her colleagues believe SA can be distributed between human agents, they are critical of a technology-led view of SA, stating that "SA does not exist by creating information in some technical system. SA exists only when it is developed within the cognition of a person who assesses the information" (Endsley & Jones, 1997, p.22)**.** Endsley (2004) further argues that a systems approach is an alternative one to her individual cognitive view, but through the systems approach the level of analysis can still be chosen. This could, like Endsley, be the individual, or alternatively a team, or a socio-technical system. But for systems-based advocates it would still have to encompass all such elements and their interactions, as they would argue that you cannot claim to understand an entire system by studying the individual (or any other discrete aspect of it) alone.

3.4.2. How do people process information?

In addition to the potential importance of the structure of the various elements that constitute SA, further questions can be raised in regards to the way Endsley assumes people process information.

She contends that people passively accept inputs from the environment in a linear fashion, process them, and then initiate some form of output. But is it not possible that a chain of events, our experiences, or dispositions, might bias us to respond to information in a particular way? It has been found, for example, that we do place a great deal of importance on expectancy, for example, in military decision making (Famewo et al., 2007; Gadsen et al., 2008; Gadsen & Outteridge, 2006; Greitzer & Andrews, 2008; Wilson et al., 2007; Dean & Handley, 2006). Endsley's model does allow for 'expectations', but it appears to influence all three SA levels *after* information from the environment has been received. But, here again, are such factors influential in primarily a conscious fashion, particularly in regards to driving?

Gugerty (2011) suggests, for example, that three levels of cognitive processing are probably involved in maintaining SA whilst driving. In addition to conscious, controlled processing, he suggests there is also:

a) automatic, pre-attentive processing that occurs unconsciously and places almost no demands on cognitive resources; e.g., perceiving the changing shape of the road and using this information to control speed and heading, and;

b) recognition-primed decision processing, that may be conscious for brief periods (less than one second) and which places few demands on our cognitive resources; e.g., making routine decisions about whether to change lanes, back up, or stop in response to a yellow light.

Some researchers have argued that a large proportion of driving tasks may actually be performed in a predictive, feed-forward manner, such as the Driving Without Attention Mode (DWAM) (Kerr, 1991; May & Gale, 1998). As a result, perception could become automatic for long periods (Kerr, 1991), leading to higher levels of SA being developed on extremely parsimonious, or even no, instances of Endsley's lower 'perception' level.

Thirdly, as Endsley portrays the individual as merely a passive recipient of information, or an information-processing unit that encodes and retrieves information from memory, no account is given for information retrieval failures and meaning misunderstandings. Thus, interactive processing (say, with other system elements) and technological support are discounted (Artman & Garbis, 1998).

Finally, Endsley's approach to SA suggests that whereas information in an environment can be independently perceived (Level 1 SA), it then apparently has to be combined to be comprehended (Level 2), but then again unpacked into both individual and combinations of information for projection (Level 3) to occur. This would appear counter intuitive, as where comprehension is achieved by integrating elements from perceptions, projection then requires them to be disintegrated. Niesser (1976) believes that it is unlikely this packing and unpacking process of cognition would occur in reality.

3.4.3. Explanatory value

As a device for explaining how SA is derived, Endsley (1995) describes the different cognitive resources and mechanisms that might be involved in constructing and maintaining Situation Awareness. However, her model is rather vague about the nature of these processes and how the different functions of SA are realised. A network approach appears to offer more explanatory value, by being able to give an indication of what the key elements of SA are and how they may be related.

It also can be said that viewing SA solely as an individual psychological phenomenon does not sit easily with the modern approach of evaluating socio-technical systems (see Walker et al., 2008). Hollnagel (1999, 2001) goes further, suggesting that due to the complexity of modern day systems, the study of information processing in the mind of individuals has lost its relevance. And for Ottino (2003), it is no longer possible to understand a system by studying its parts in isolation: real meaning can only be found by considering interactions within a system, and the resulting behaviour that emerges from them.

The approach taken in this thesis for the evaluation of Situation Awareness in road environment contexts is to incorporate the individual within the system s/he is operating, but to allow the component parts of that system, most notably that of the individual driver or driver group, to be extracted and evaluated. To achieve this, the driving system from the driver's perspective has to be represented, and it is proposed that this can best be realised by creating a semantic or knowledge-based network.

3.5. Knowledge networks

Networks are an established way of representing knowledge (e.g. Collins & Loftus, 1975; Collins & Quillian, 1969, 1970). In order to create one that is representative of an individual's SA, it is necessary to extract information elements and establish links between them. This can be achieved when these elements become temporally, spatially, causally or semantically interlinked. Typically a network would be formed by concepts, and as, it is claimed, that dictionary-like definitions of concepts can be produced (Ogden, 1987), perhaps this has provided encouragement for the development of computer software (such as, Leximancer, considered below) that can now produce various network representations.

The network approach to SA also fits well with systems thinking, in that the network is characterised not only by its parts, but by the relations [or mapping] between those parts (Anderson, 1983; Ausubel, 1963), and that the activity through them need not be linear. Baumann & Krems (2009) describe how this approach might work in practice, from their view of SA being constructed by a comprehension process. They suggest that perceived information activates knowledge linkages that are stored in long-term memory. From this activated knowledge network, a coherent representation is constructed by a 'constraint satisfaction process'. This process constrains the spreading of network activation to only that of compatible (than incompatible) knowledge elements. For example, an event such as a traffic light turning red would activate deceleration-related driver interpretations and actions, whilst inhibiting acceleration-related driver interpretations and actions.

In order to create such networks, and to assess how the information theirin may be interrelated, it is necessary to gain an insight into the individual driver's thoughts and thought processes. Arguably, the only way to achieve this during actual driving is through a technique known as the 'Think aloud' method.

3.6. 'Think aloud' method

The overall aim of this method, developed by Ericsson & Simon (1984), and sometimes referred to as Verbal Protocol Analysis, is to extract an extensive narrative that pertains to an individual's actions as s/he undertakes a problem solving task. A participant is encouraged to give a concurrent account of his/her thoughts, whilst avoiding interpretations or explanations of what s/he is doing (although these can also usefully be included). Unlike other techniques for gathering verbal data, there are advantageously no interruptions or suggestive prompts or questions from the researcher that may hinder the driving task.

The method enables a capture of what information a participant concentrates on, how it is structured, and (if required) the reasoning and decisions behind a particular task's resolution. In short, it allows a researcher to understand, at least in part, the thought processes that an individual is bringing to a task, and for the participant, it is an opportunity to relay (and sometimes explain) their approach in regards to undertaking it.

For most people, and indeed this was also found in the series of studies that follow, thinking 'aloud' becomes routine after a few minutes, and because of the continual nature of the driving-related tasks undertaken, there was advantageously little time for a participant to reflect on what s/he was saying. In addition, providing a narrative appears to neither interfere with the speed of performing a particular task, nor the performance itself (see Thomas et al., 2015).

Like other qualitative captures, the 'Think aloud' method seeks rich, in-depth data from a small sample. Kuipers & Kassirer (1984) have justified the approach, thus: "a methodology of discovery appropriate to the undoubted complexity of human knowledge requires rich data about individuals rather than easily analysed data about a population" (p.365). That said, the method does allow for comparisons to be made both between individual participants, and participant groups, through inferences drawn from the structure of the captured texts.

3.6.1. Network analysis of transcripts

The transcripts of commentaries produced by each participant from the 'Think aloud' method provide the input for a network-based analysis of Situation Awareness. Each participant's SA can subsequently be represented by information 'elements' and the relationships between them. In recent times, capturing narratives for network analysis has become a popular approach to investigate driver SA on the road (e.g. Walker et al., 2011; Walker et al., 2008; Salmon, Young, & Cornelissen, 2013). This is probably because, in tandem, they enable the keywords and concepts that may underlie a person's awareness, and the relationships between them, to be revealed; and also how the same information may be uniquely processed. This relies, of course, on the notion that knowledge comprises of concepts and how they are related (e.g., as argued by Shadbolt & Burton, 1995).

A mathematical analysis of the content and structure of a network can further reveal quantifiable SA comparisons across different individuals and groups (e.g. Walker et al., 2011). These evaluation tasks can be undertaken by Leximancer and Agna computer software, and the comparative data that these programmes can produce, as they relate to the studies undertaken in this series, will now be outlined in more detail.

3.7. Assessing the network

3.7.1. Leximancer

Leximancer software, developed by Andrew Smith (Smith, 2003) at the University of Queensland, Brisbane, Australia, uses text representations of natural language to interrogate verbal transcripts and identify themes, concepts and the relationships between them. It does this by using algorithms linked to an in-built thesaurus and by focussing on features within verbal transcripts such as word proximity, quantity, and salience (Walker et al., 2011). The software employs a five stage process:

a) Conversion of the raw text data (definitions of sentences and paragraph boundaries, etc.).

b) Automatic concept identification (keyword extraction based on proximity, frequency, and other grammatical parameters).

c) Thesaurus learning (the extent to which collections of concepts 'travel together' through the text is quantified and clusters formed).

d) Concept location (blocks of text are tagged with the names of concepts which they may contain).

e) Mapping (a visual representation of the semantic network is produced showing how concepts link to each other).

As ‘e’ above indicates, the software is able to produce a network that contains any number of prescribed concepts derived from a transcript, and also the relationships between them (reflected within the text). In addition, it provides the basis for how each network is formed by taking, for example, a word count of all the concepts it ‘finds’, and from producing algorithmic scores for how well they are related to one another. Relevant sentences containing a concept are also provided as supporting evidence/text.

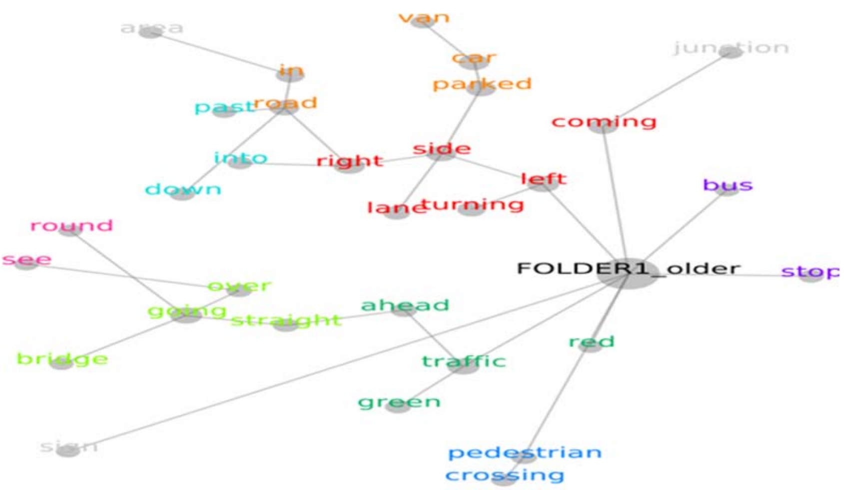
The Leximancer software can also make centrality/sociometric status calculations, which allows for the most important nodes within a network to be revealed. The sociometric status metric is used to identify the key concepts underpinning SA within a network (Salmon et al., 2009). It provides a measure of how ‘busy’ a concept is relative to the total number of concepts within the network under analysis (Houghton et al., 2006). The key concepts that are extracted are defined as having ‘salience’, as they are the ones most highly connected to others in the network. They also are said to have ‘centrality’, as they tend to act as hubs in the network. Concepts with high centrality have, on average, shorter distances to other concepts, they are likely to be well clustered, and to be near the centre of the network. Concepts with low centrality, in contrast, are likely to be on the periphery of the network, and to be semantically distant from other concepts.

Leximancer can also identify those concepts that are the same across individuals or groups (i.e. present in many networks), and those that are unique to each (i.e. present in only one network). These can be revealed through an assessment of relevant network depictions (or ‘maps’), and from the ‘Prominence’ scores that it produces, reflecting the comparative ‘uniqueness’ a main concept has for a particular individual or group.

3.7.1.1. Justification for use

The Leximancer software was chosen to assess Situation Awareness for these road-base trials, as it can uniquely identify and quantify concepts within an individual narrative - either as a whole or in part, or collectively as part of an inter or intra group analysis. It can produce visual outputs in the form of tables, charts, and network 'maps' (see Figure 3.5), allowing a researcher to visually explore the conceptual nature of a narrative. The 'maps' are created from concepts that are derived from a weighted list of words from the text, removing the need for coding by the researcher. The software further allows direct text searches to be undertaken, and provides numerical assessments of the importance particular concepts may have through word frequencies and algorithmic values to other concepts.

Figure 3.5: A typical Leximancer concept 'map'



3.7.1.2. Leximancer's advantages over a leading alternative, NVivo

Although Leximancer and NVivo software packages can be used on similar sets of empirical materials (e.g., interview transcripts, documents and open survey responses), they actually work in very different ways. Although NVivo helps a researcher manage and organize data, and facilitate its analysis, it critically requires him/her to code the data and to develop themes or categories. The data analysis is thus principally subjective, and although it does allow for meaningful engagement in the analysis process, this could include a researcher's preconceptions and biases towards a particular individual's or group's narrative.

Leximancer, in contrast, produces results without the requirement for such manual intervention. The software has been developed to identify any number of concepts and their interrelationships automatically. According to Hansson, Carey, & Kjartansson (2010) this is its main limitation, as the researcher's skill in interpretation is effectively suppressed by the manner in which it analyses the data. However, as Leximancer can link complex algorithmic analysis with aspects of psychology and language when interpreting transcript data, it is able to analyse, consistently and reliably, vast amounts of text that would be equal to a human analysing it 1000 times over (Gapp et al., 2013).

NVivo also appears of more use when an 'a priori' model, or set of factors, exist(s) that allows the researcher to categorise and summarise the coded results easily. Leximancer, on the other hand, is a useful tool when a researcher is exploring textual data to uncover important factors (Davies et al., 1994). In other words, it is particularly relevant when the researcher does not have that 'a priori' set of factors or a model by which to analyse the data, which was the case with the SA driving studies undertaken for this thesis.

Leximancer is also capable of immediately giving a 'birds-eye' view of data, from which a researcher can advantageously explore concepts and their connectivity by linking the software's findings back to the original text. S/he can then remove concepts that the software has highlighted, but in validation are not relevant, and then rebuild a network. As such, new and undiscovered meanings could be found from this process that may be missed in a manual Nvivo analysis.

Finally, Leximancer, unlike Nvivo, can also provide quantitative outputs in 'Excel' format for each of the networks it produces. These Excel sheets can then be entered into Agna network analysis software (see below) for further quantifiable content and structural scores.

3.7.2. Agna

This software, from geocities.com, employs techniques from graph theory to interrogate a semantic network in terms of its nodes and linkages (or edges). In basic terms, it can reveal the underlying structural properties of a network from the times a main concept is recorded and the times it is related to other main concepts. Thus, advantageously, it can reveal configurations that would not readily be apparent from a visual inspection alone. The software is capable of providing an analysis of a network by a number of metrics. In regards to Situation Awareness, however, two are of particular relevance: its Density and Diameter.

3.7.2.1. Density

Density refers, in effect, to the cohesiveness of a network as a whole, and represents a measure of its interconnectivity in terms of the linkages between its concepts. A score is expressed as a value between 0 and 1, with 0 representing a network with no connections between its concepts, and 1 representing a network in which every concept is connected to every other concept (Kakimoto et al., 2006; cited in Walker et al., 2011). For SA assessments, higher levels of interconnectivity indicate an enhanced, richer level of SA, since there are more linkages between concepts and shorter average path lengths between them. Poorer SA is embodied by contrasting lower levels of interconnectivity, with underpinning concepts that are not so well integrated and often reflected by longer average path lengths.

3.7.2.2. Diameter

Diameter also refers to an analysis of the connections between concepts, but here this is in relation to distances across a network. Higher diameter values being indicative of more concepts per pathway through the network, whereas lower diameter scores indicate the routes through the network are shorter and more direct. As such, lower diameter scores are indicative of better SA, since the holder is able to generate awareness through a shorter linkage between the concepts within his or her network. Higher diameter scores, in contrast, are indicative of a network with potentially more concepts but with longer linking distances between them.

Thus, essentially, both measures relate to the speed of accessing information. And so, if a network is overfilled with poorly connected concepts, then this will impact on the speed and proficiency of an individual's awareness.

Summary

In general, when consideration is given to studies of Situation Awareness in road transport contexts there are few in number. Consequently, relatively little is known about the factors that may inhibit or augment it. When studies have been undertaken they have also tended to utilise the model that was prevalent in aviation at the time, Endsley's three level model, to evaluate SA; and indeed, still continue to do so (see Ward, 2000; Matthews et al., 2001; & Reason, 2008). Consequently, the limitations associated with this model (as highlighted e.g., by Salmon et al., 2008; Stanton et al., 2009; and above in this chapter), also apply to the majority of the road transport-related SA research undertaken to date, that have taken it as a basis for their methodology.

As has been argued above, the main problems with Endsley's model in contexts like driving are in both the way it conceives SA to operate, and to be measured. By viewing SA as a cognitive phenomenon, where the processing of information is undertaken by a driver in a linear, conscious, fashion, necessarily devalues the awareness that s/he has for, say, important interactions with other components of the driving task. Thus measuring these interactions could conceivably determine the character of SA more effectively than traditional SA methods that, for example, may simply ask a driver to recall information elements for matching against those on a predetermined list.

It has been shown that those who advocate a systems approach to driver SA, in contrast, take a wider perspective than the individual, defining driver SA as activated knowledge (Salmon et al., 2012). This encompasses the relationships between the driver's goals and behaviours, other vehicles, the road environment, and the road infrastructure. It is related to Smith and Hancock's 'Perceptual-action Cycle' sampling of the driving environment, in that it understands that our behaviour can be directed, with that output then modifying our schemata in a cyclical manner (Smith & Hancock, 1995). SA is seen by this approach, then, as much a feed-forward phenomenon, as one based on feedback (alone), as with Endsley's model.

Also central to this more contemporary view of SA is the notion that in order to fully understand it, the entire relevant system, with its many interacting component parts, should be taken as the unit of analysis (Salmon et al., 2009, 2010a; Stanton et al., 2010; Walker et al., 2010), and additionally that performance variability is seen as a natural occurrence of those interactions (e.g. Shahar et al., 2010; Walker et al., 2011). This is because different road users will perceive and interpret the same road environment situation differently due, for example, to their differing goals and experience. This will be the case whether they fall within a particular road user group (e.g., car drivers) or across different road user groups (e.g., car drivers, motorcyclists, pedestrians, van drivers). Thus the level of SA compatibility between these different 'agents' is said to be the key to a transport system's overall performance (Stanton et al., 2010) as they bind this socio-technical system together.

In terms of methodology, the most commonly adopted measure that has been utilised to assess SA to date is the individual-centric, Situation Awareness Global Assessment Technique (SAGAT: Endsley, 1995b). As has been seen, this is a simulator-based recall approach that involves probing participants for their knowledge of SA elements during simulation 'freezes'.

In contrast, the 'systems' approach has had a preference for considering process indices, and network analyses. This later approach has typically involved the use of 'Think aloud' narratives along with post-trial cognitive task analysis interviews (e.g. Walker et al., 2009).

Both the SAGAT and network methods have their limitations, as was highlighted above, and both are reliant to some degree on inferring inner processes, thus raising questions in regards to their construct validity. However, the network's relationship to naturalistic driving contexts arguably retains compelling advantages for SA assessments. Specifically, the attributes/information that underpin a driver's SA (as part of the driving system) are extractable, observable, and can be reported on within actual roadways. Additionally, the use of the participant's own vehicle probably affords the best chance of capturing the feedback the driver might normally exhibit. It can also be added, of course, that these advantages can conversely act as criticisms for simulator-based research. As here, any gains in experimental control could be lost by using far less ecologically valid methods (Jackson & Blackman, 1994).

3.8. Conclusion

The Distributed model of SA (DSA), although more relevant to teams, would appear the most persuasive perspective for the assessment of driver SA in the studies that follow, as it allows for a more holistic examination of a driver within different driving systems. The system's perspective of SA, that embraces Smith & Hancock's (1995) ecological model, and which proposes that SA exists within the system itself, also appears a more useful conceptualisation for driving than Endsley's three-level model of information processing. A driving system or environment, after all, will have 'agents', both human (e.g., vehicles) and non-human (e.g., traffic lights). These will have 'different, but potentially compatible, requirements and purposes' at any instant (Stanton et al., 2006), and indeed it is the extent of their compatibility that will inform the proficiency of the driving system, which, like SA, would appear capable of change over time.

Recent movements in the wider ergonomics community additionally vouch for a systems approach, not just to assessments of SA (e.g. Salmon et al., 2010a), but to other ergonomics concepts - such as error and accidents (Reason, 2008), cognition (e.g. Hutchins, 1995ab), resilience (e.g. Hollnagel et al., 2006), and command and control (e.g. Walker et al., 2008).

However, approaches focusing more exclusively on the individual, with their related SA measurements, do remain appropriate. For example, with individual training programmes and assessments of, perhaps, particular information elements. For driving research more generally then, a combination of naturalistic and simulator research would therefore seem of value. As the ecological validity of real world driving could provide the evidence for the sorts of questions that could be better answered in a more controlled and safer simulator environment.

Chapter 4: A Study investigating the comparative proficiency of older and younger driver's Situation Awareness whilst driving a route with limited periods of cognitive taxation

4.1. Introduction

4.1.1. Background to the issues investigated

In Chapter 2, data was provided that showed that with continuing advances in health and medicine, that, in western societies in particular, this had led to a rapid increase in older age groups. In the UK alone, an estimate was given that by the year 2031 almost 23% of the population will be over 60 (Office for National Statistics, 2010).

This rise has, in turn, led to an increase in the number of older drivers in the UK, up 10.3% to 14.5m from the year 2000 (Department for Transport, 2014), with the expectation that this number will not only increase, but will do so faster than any other age group (e.g. Burkhardt & McGavock, 1999; Lyman et al., 2002; Box, Gandolfi, & Mitchell, 2010). It was argued that a major reason for this continual rise in older driver numbers was borne of a necessity to compensate for physical frailties and disabilities that impede mobility (Bendixen, Mann, & Tomita, 2005; Cannon, Hendrickson, & Mann, 2005), particularly as communities have become larger and amenities more diffuse.

The increase in the number of older drivers, and drivers more generally, has fomented predictions that road traffic accidents will continue to rise. In the UK, although casualties from road accidents have actually fallen since 2009, in 2014 this trend was reversed. Those killed on UK roads that year rose, for example, by 5%, with this figure including a statistically significant rise of 16.6% for those aged 60 and over. Furthermore, older drivers being seriously injured also rose (by 11.1%) that year, to reach levels not seen since 2003 (Department for Transport, 2014).

It is because of such statistics, and, as was highlighted extensively in Chapter 2, the range of age-related physiological, perceptual, and cognitive declines that may negatively affect driving ability, that attracts road safety research to older driving groups. There is perhaps a rightful concern that older drivers are more susceptible to having accidents, as they have been found to be more likely to be considered responsible for the accidents in which they are involved (Langford, et al., 2006) - especially when over 70 (Box, Gandolfi, & Mitchell, 2010). They also are more likely to be involved in multiple vehicle accidents (Department for Transport, 2004), and to sustain serious injuries in comparison to younger driving age groups.

4.1.2. SA and driving

Researchers of Situation Awareness (SA) are also interested in age-related physiological, perceptual, and cognitive declines, as their impact on an individual's information processing capability should lead to related declines in SA. This has led to research that typically has sought to assess how ageing impacts on a driver's ability to attend to important information in driving environments of different complexity. For the most part, as was shown in Chapter 2, it has been found that older drivers demonstrate poorer Situation Awareness (e.g. Bolstad, 2001; Zhang et al., 2009; Kaber et al., 2012). However, there are studies that have found similar (poor) levels amongst young drivers (Bolstad, 1996), changing SA performance according to environment conditions (e.g., rural, urban, hazards: Zhang et al., 2009), and in Bolstad & Endesley (1991), no age effects at all.

Overall, however, there has been a surprising paucity of research in this area, considering the rapid rise in older driver populations, and the potential for Situation Awareness to provide insights into information processing capabilities and driving performance in general. In the latter respect, for example, Rogers et al., (2011) have found significant negative correlations between SA and car steering error and speed variability.

An investigation of issues such as whether older drivers can maintain good Situation Awareness would therefore seem of value, and particularly if this could be measured on actual roadways. This is due to the unique usage of simulators in previous older driver SA studies, where computer-simulated journeys were broken-up by pre-formulated questions, and where SA was measured by how well a participant's answers matched a researcher's expectations. As a result, the ecological validity of these studies has been questioned (notably by Salmon et al., 2008) and as was seen in Chapter 3, different, 'distributed', approaches to SA measurement have now been proposed.

Furthermore, if any linkages could be found between SA and safer driver proficiency, this could also be important as there then could be, for example, potential benefits from producing training programmes directed, say, at appropriate levels of SA.

In view of age-related information processing decrements affecting SA, there is also an expectation that older drivers will demonstrate related declines in driving performance, when compared to other driver age-groups. However, in studies that have assessed older drivers as a separate grouping, no such clear correlation has been found (e.g. Bolstad, 2001; Zhang et al., 2009; Ho et al., 2001; Kaber et al., 2012). It could be, as Lee, Olsen, & Simons-Morton (2006) and Randel et al. (1996) have argued, that as driver Situation Awareness can develop with driving experience (and, in turn, produce safer driving (Soliman & Mathna, 2009)), perhaps that experience can also feed back information that helps to prolong both adequate levels of SA and driving performance?

Finally, it should be noted that the paucity of research that has been undertaken to date to consider the influence of SA in driving contexts, applies as much to younger as it does to older drivers. Therefore, the approach taken in this study, and those that follow, will be to compare, in depth, the SA of both of these driver age groups. This should more illuminate any of the expected SA deficits that the literature presumes the older driver groups will have, but could also reveal useful SA-related information for the benefit of the younger drivers.

4.1.3. Objective and hypotheses

This study's objective is to assess the Situation Awareness of two driving groups: one with participants above 60 years old (in line with ROSPA guidance, see Chapter 2, ROSPA, 2010); and one with participants below 40 years old. The assessment will be made whilst driving a non-taxing route (and thus address RQ1). It will allow the driver to provide a commentary that subsequently will reveal a SA driving network from the information elements that are considered of relevance and how well they are related. These networks can be compared quantitatively by a mathematical evaluation (undertaken by software) that can indicate the proficiency and cohesion of the concept linkages that comprise them, and qualitatively by the relevance those concepts have to the task under investigation.

It is hypothesised that the quantitative scores will be lower on average for the older (than younger) age grouping, in line with previous findings in the literature. And additionally, when the networks of the two age groups are compared, that, overall, different concepts will be focussed on, and gain prominence.

4.2. Method

4.2.1. Design

Generally, research that has considered older drivers and SA has tended to utilise driving simulators and 'freeze probe' methods of measurement (e.g. SAGAT), as was discussed in Chapter 3.

This study, in contrast, required participants to drive their own cars around a pre-defined course, and whilst doing so to provide a verbal commentary of what information they were taking in from an environment, what they intended to do with it, and to explain their driving actions (for instructions, see Appendix 1).

These commentaries were recorded via an audio capture device, whilst simultaneously being listened to via earphones to ensure that what was being said could be clearly heard. For all of the driving trials undertaken for this thesis, only two people were present in the vehicle – the researcher, who undertook all of the trials to improve reliability within the research; and the participant.

The narratives captured were then later transcribed verbatim, after which they were run through software capable of extracting a detailed network of the main cognitive and physical concepts that were considered of importance whilst driving the route. Additionally, and again through computer software, an individual's or a group's Situation Awareness was scored from how proficiently those concepts that comprised a driver's or group's network were interrelated. The method has been used in previous driving research (e.g. Cornelissen et al., 2013; Walker, Stanton, & Chowdhury, 2013), but was pre-tested on a different route and found to work well.

It has been argued that this approach provides a better and more realistic basis for extracting the level of detail needed to provide a comprehensive understanding and comparison of the SA of different driver age-groups.

4.2.2. Participants

20 participants undertook the trial (15 male; 5 female), ranging in age from 23 to 82 years. They were divided into two groups: either to one comprising of an age range of up to 40 years; or to another comprising of an age range of above 60 years.

The older participants (8 male/2 female; average age: 75.6 years) were UK drivers recruited through local Probus retirement clubs; the younger participants (7 male/3 female; average age: 31.1 years) were research students and associates at the Loughborough Design School. They were compensated £20 for their time and travel expenses. In deciding who was to take part, preference was given to the oldest and youngest volunteers.

4.2.2.1. Inclusion criteria

The inclusion criteria stipulated was for potential participants to have a full UK driving licence with no recent major endorsements, to be regular drivers, and to be aged either up to 40 years old, or above 60 years old.

4.2.2.2. Exclusion criteria

Due to the need for accurate transcriptions, potential participants who had a poor clarity of spoken English would be excluded.

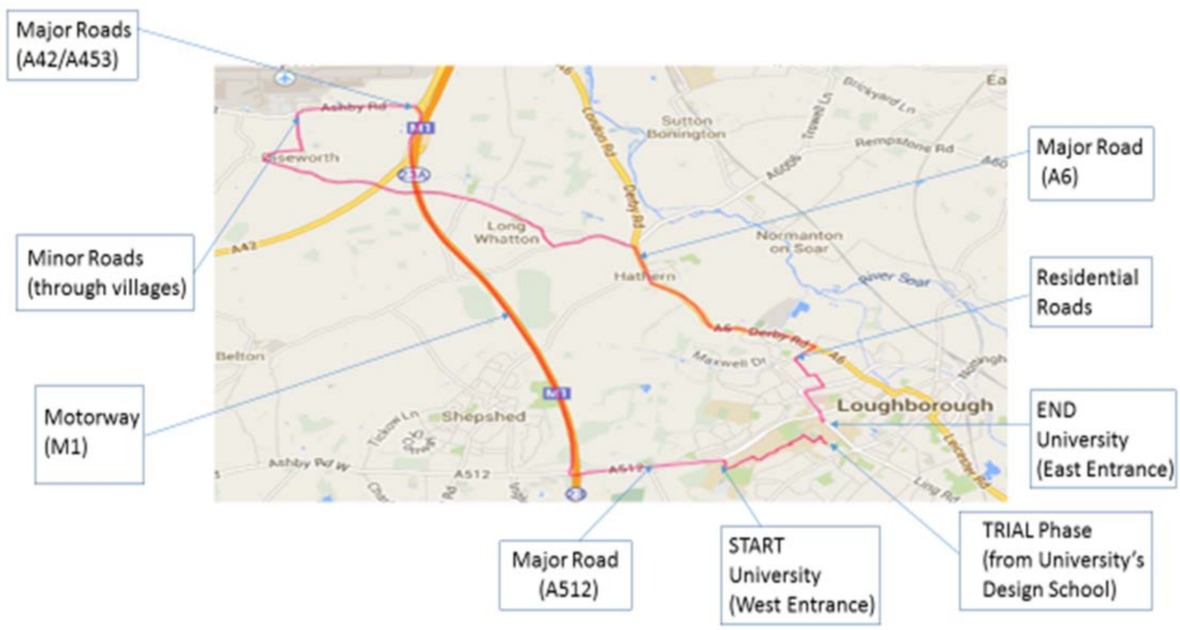
4.2.3. Materials

The vehicle used to drive the route was provided by the participant. The researcher required a digital device to record the driver's commentary, and latterly a PC capable of running the required software packages.

4.2.3.1 Route

The test route was 14.9 miles in length (following a short warm-up phase of 1.26 miles) running mainly through Leicestershire, but briefly, also in Derbyshire, UK. This route was pre-tested for its suitability for giving a commentary, for potential roadwork delays, and surface condition – in this latter regard the route was adjusted slightly due to the poor condition of one residential street. What a participant faced was a fairly straightforward drive, though did expose him/her to all classifications of UK roadways. Specifically, it comprised of 3.89 miles of motorway (M1); 3.51 miles along major roads (e.g., the A6); 2.87 miles along urban roads; 3.46 miles of rural roads; and 1.19 miles within residential roads. The route was estimated to take about 30 minutes to drive (40 minutes were allocated for each journey) and started and ended at Loughborough University (see Figure 4.1). Prior confirmation was sought the preceding day that it was generally unknown to the participants (as some local roads would be familiar). In addition, the older drivers were previously consulted on two alternative routes (one without motorway driving; one with), in case a potential participant had any difficulties with motorway driving.

Figure 4.1: Route map and major route sectors



All trials took place in good visibility and at pre-defined times (9.30am, 11.30 am, or 2pm) in order to avoid peak traffic conditions and to retain some control over traffic density. As the weather could not be controlled, it was important to ensure a participant's safety by not allowing any driving in dangerous conditions. Also in this regard, care was taken by the researcher not to overly distract a driver with instructions, particularly as this was, for them, an unfamiliar route.

4.2.4. Procedure

4.2.4.1. Pre-run phase

Firstly, informed (ethical) consent was obtained from all participants before the route was driven (see Appendix 3). At this time, it was also emphasised that control of the vehicle, and the safety of other road users, remained the participants' responsibility at all times, and therefore that they should drive as they normally would do on each roadway. An instruction sheet (Appendix 1) on how to provide a commentary was then re-read by the participant (who had received this the preceding day) and the researcher again provided examples relating to its desired style and content. Emphasis was placed here on what information was being sought from a driving environment, and what actions were being taken and why, but essentially the message conveyed was that all thoughts were useful and none could be 'wrong'.

4.2.4.2. Warm-up phase

The participant then walked the researcher to his/her car, and once comfortable, the short 1.26 mile journey to the start of the test route through the University's sprawling campus began. This enabled the participant to practice his/her commentaries, and for the researcher it provided an opportunity to suggest additional input and to encourage as constant a flow of relevant information as possible. It was also important during this phase for the researcher to ensure that the recording equipment was switched on once the car moved off, and was adequately capturing the driver's comments. At the end of this phase the participant was required to stop their vehicle, and asked if they were happy with the task. Final further instructions, if necessary, were then given at this point.

4.2.4.3. Data collection phase

During this (14.9 mile) phase the researcher remained silent and simply monitored the audio capture process. He did, however, give route directions (and whenever possible these were conveyed at times when a participant had taken a pause in his/her commentary). It was felt of importance not to interrupt or break a train of thought that was being enunciated.

4.2.4.4. Debriefing stage

A debriefing session, in the participant's car, took place on return to the university, at which point the full purpose of the study was revealed and views were taken as to the perceived difficulties of the drive and task (if any).

4.2.5. Data analysis

The verbal commentaries that were recorded were transcribed verbatim post-trial, and then subjected to analysis by Leximancer software (Smith, 2003) capable of creating semantic networks (i.e. themes, keywords, key concepts, and the relationships between them) unique to each participant and/or group. These networks represented the cognitive elements of the driving task through changing journey environments, and thus provided an insight into an individual's or a group's SA within a driving 'system'. In each network were nodes of variable size that related to its relevance, that is, how frequently it occurred and how it related to other elements within the network – what is termed, its 'semantic connectivity' (Leximancer, 2009).

The application of this technique to verbal commentaries in real-life transport contexts is a relatively new one, but proven as a useful tool for evaluating Situation Awareness in driving research (e.g. Walker, Stanton, & Chowdhury, 2013; Walker et al., 2007; Stanton et al., 2007; Salmon, Stanton, & Young, 2012; Walker, Stanton, & Salmon, 2011). However, commentaries from a short (pilot) trial journey were analysed through the Leximancer and Agna software and were found to produce acceptable results.

4.2.5.1. Network analysis

The raw quantitative data sets that the Leximancer software provides can be entered into a mathematical program (Agna, published by geocities.com) for structural analysis comparisons of particular networks. Two of the measures that the software can produce, as discussed in Chapter 3, are of particular relevance for calculating Situation Awareness. For clarity and reference these are explained again below:

a) Density

A Density score represents the level of interconnectivity within a network, in the sense of how proficient the linkages are between its concepts. For SA assessments, higher levels of interconnectivity are indicative of enhanced, richer, SA, since there are more linkages between the network's concepts, thus aiding information retrieval. Poorer SA, in contrast, is embodied by networks with lower levels of interconnectivity.

b) Diameter

A Diameter score is also representative of the connections between the concepts in a network, but moreover it reflects the efficiency of the paths across it. Greater diameter values are indicative of more concepts per pathway through the network (Walker et al., 2011) suggesting poorer SA, whilst lower diameter scores are indicative of better SA, since the holder is able to generate awareness through shorter, more proficient, and thereby, faster linkages.

To identify the unique and common concepts for each group, and the key concepts underpinning SA in general, the Leximancer software also makes a sociometric status analysis of each of the networks it produces.

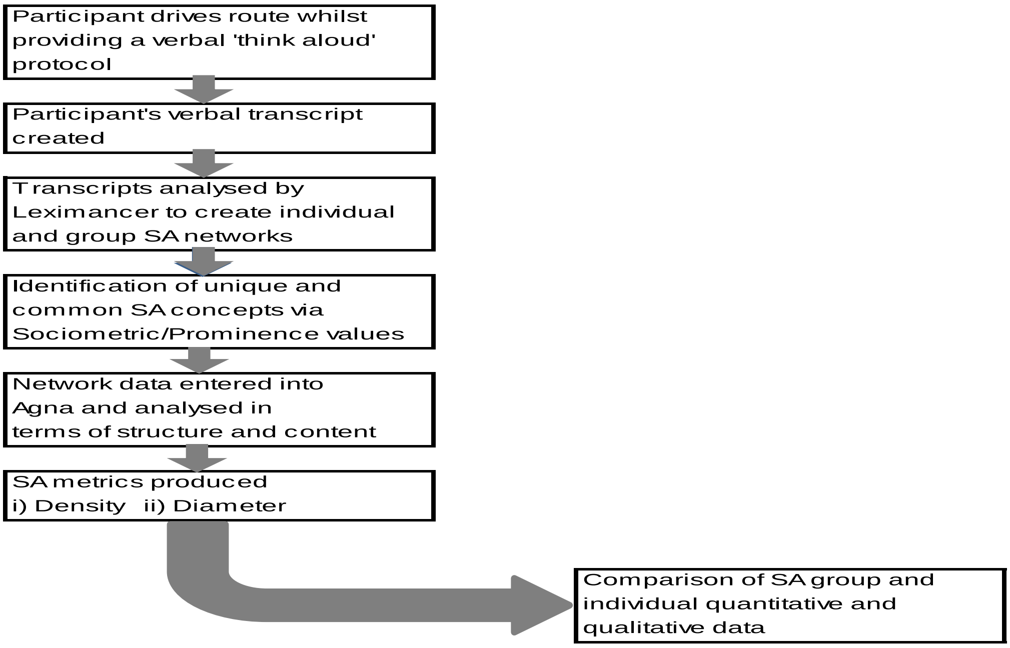
<u>Sociometric status</u>

The software will also identify a network's key or main SA concepts by providing a measure of how 'busy' a concept is relative to the total number of concepts within the network (Houghton et al., 2006). These concepts are defined as having salience as they act as hubs and are highly connected to other concepts in the network. Typically, concepts with a sociometric status value above the mean value for the network as a whole are taken to be key or main concepts.

4.2.6. Summary of the approach to data capture

Figure 4.2 below summarises the stages involved in capturing and comparing the data for this study.

Figure 4.2: Study 1 data analysis stages



4.3. Results

4.3.1. Quantitative data

4.3.1.1. Group SA scores and other comparative data

As was expected, and as is generally found in the literature, the younger drivers exhibited the better SA scores (Table 4.A). The network Density scores showing that when the narratives were allocated to, and evaluated collectively as, a group, that it was the younger participants who had demonstrated the better cohesion and linkage of their concepts. This would aid the speed of their recall, and thus assist their Situation Awareness.

Table 4.A: Group network as a whole

	SA assessment scores		Participant data					
Group	Network Diameter	Network Density	Av. age (yrs.)	Gender	Av. exp. (yrs.)	Av. time on course	Av. word count
Older	2	0.7417	75.6	8M/2F	53.9	32.3 mins.	2643
Younger	2	0.8238	31.1	7M/3F	11.2	29.7 mins.	2655

It should be noted that Table 4.A also shows other comparative 'Participant data' between the two groups. This is included to show acceptable differences (in age and driving experience) and similarities (in gender, and length of narrative) between them. The average course completion times for the groups also appear similar, however the younger group were found to have competed the course significantly faster ($p<0.013$). This, though, had no relevance for the task's results.

4.3.1.2. Individual SA scores and other comparative data

Although the older drivers, as a group, had a wider range of journey perceptions and interpretations (arguably also of more varying relevance), when they were assessed at the individual level with their SA scores totalled and averaged, they then were found to have a similar SA cohesion to that of the younger group (Table 4.B).

Table 4.B: Average of individual network scores

SA assessment scores		
Group	Av. Network Diameter	Av. Network Density
Older	3.1	0.3819
Younger	3.2	0.3847

When individual performances were assessed more closely (see Table 4.C, below), it was found that although the younger drivers occupied four of the top six positions in terms of SA performance scores, they also occupied four of the bottom five positions. So if an individual performance approach is taken, it can be seen that not only could some older drivers score well, but moreover that there was no relationship between the SA Density and Diameter scores and age.

Table 4.C: SA rankings and scores, and other individual data

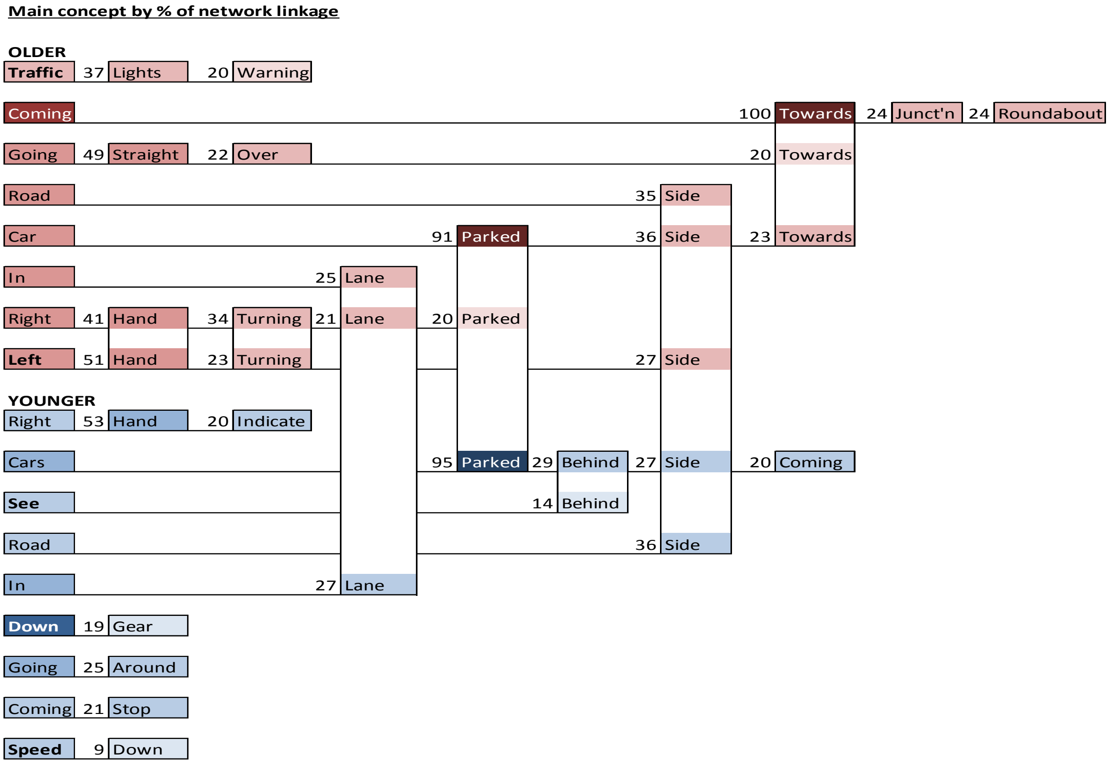
Rank.	Group	Network Diameter	Network Density	Age	Driving Exp. (yrs.)	Course time (mins.)	Word Count	M/F
1	Younger	2	0.6984	22	2	30	3905	F
2	Younger	2	0.6866	26	7	28.5	2044	M
3	Older	2	0.6428	81	56	33	4457	M
4	Older	2	0.6084	76	59	32	3107	M
5	Younger	2	0.5846	39	22	30.5	2858	M
6	Younger	2	0.5541	39	21	31	3972	F
7	Older	3	0.4729	82	61	33.5	2419	M
8	Older	2	0.4433	77	60	33	2268	M
9	Older	3	0.4242	74	50	30	1102	M
10	Younger	3	0.3105	26	9	30.5	2178	M
11	Younger	3	0.3103	26	9	33.5	4273	M
12	Older	4	0.3078	74	42	31.5	3963	F
13	Older	3	0.2934	72	45	32.5	1475	M
14	Older	4	0.2301	78	60	33.5	3014	M
15	Older	4	0.2116	68	50	31	2874	F
16	Younger	4	0.2095	40	2(UK)	32	1377	M
17	Younger	4	0.1937	28	10	28.5	3305	M
18	Older	4	0.1851	74	56	33	1756	M
19	Younger	4	0.1699	29	12	26	957	F
20	Younger	6	0.1300	36	18	26.5	1682	M

4.3.2. Qualitative data

4.3.2.1. Individual Group data

In Figure 4.3 (below) the key or main concepts for each group, from combining their narratives, are given. (An example narrative is provided as an appendix). Those concepts that are in bold text being found to be unique to a particular group, with the background shading indicative of three word count ranges (400+, 300+, or 200+). The Figure also shows the percentage of occurrence with other important concepts in the text (with darker background shading denoting a stronger connection), and where such linkages were unique or similar for each group. The two Tables that follow (4.D & 4.E) then show the words that were linked to these main concepts for each group.

Figure 4.3: Major concepts for the Older and Younger Groups



**major concepts are those above a 50% relevance for the network and with over a 200 word count*

a) Older Group

So, for the older drivers, Figure 4.3 indicates that there was more of a focus on 'Traffic', particularly in relation to 'Lights', and more of a preoccupation as to what was 'Coming' or 'Going' 'Towards' the 'Car', and on the 'Left' 'Hand' 'Side'. The act of 'Turning' the vehicle also had more relevance for this group, with both 'Left' and 'Right' turns being mentioned. Like the younger group there was a similarity in the relevance assigned to being 'In' 'Lane' and 'Car(s)' 'Parked'.

As for the words related to these main concepts (see Table 4.D, below), again there was much that suggested a focus on what could be seen to the front of the vehicle, with words such as 'Towards', (in) 'Front', 'Ahead'. Like the younger Group, again there was a similarity in the awareness of 'Parked' cars.

Table 4.D: Main concepts and related words important to Older Drivers

Main Concepts (and word count)	Related to these words (w/algorithmic score)
1. Coming (442)	Towards (6.16)
2. Right (387)	Turning (3.96)
3. In (374)	Front (5.85), Case (4.11), Fact (4.02)
4. Car (372)	Parked (6.31)
5. Road (355)	Main (4.86), Slip (4.5), Windy (3.57)
6. Going (353)	North (4.35), Slipway (3.47)
7. Left (349)	Bearing (3.23), Entry (3.23)
8. Traffic (248)	Ahead (8.14)

**Main concepts are those with over 50% network influence and appear in the texts on over 200 occasions*

b) Younger Group

The younger Group, in Figure 4.3, paid more attention to gear changes, as in 'Down' 'Gear', and also to their 'Speed' as in slowing 'Down'. This may be indicative of the group travelling faster and exhibiting more variable speeds. There were also indications of a better awareness of what was 'Behind' the vehicle with linkages to 'Cars' and 'See' - there was no similar rearward concept(s) of importance for the older group.

As for the words related to these concepts (in Table 4.E, below) it was found that the 'Speed' concept was probably regulated by a (better?) awareness of particular road artefacts, such as 'Bumps', 'Limits', and 'Cameras'. However, generally it could be said that there was more awareness of speed regulation by this group from concepts/word associations, such as: 'Slow'/'Slowing' 'Down'; 'Coming' to a 'Full (stop)'; and 'Go' with 'Going'.

Overall, the concepts and the related words that the software provided for the younger participants were arguably more diverse (as they uniquely included such speed regulation and rearward observations) and included more specific artifacts (e.g. orange (lights), national speed limit signs, speed cameras, and bumps), which perhaps was indicative of deeper information processing.

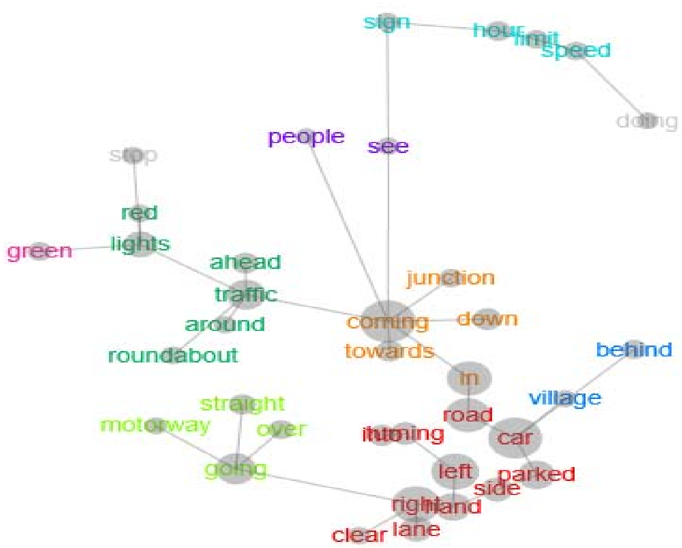
Table 4.E: Main concepts and related words important to Younger Drivers

Main Concepts (and word count)	Related to these words (w/algorithmic score)
1. Down (412)	Slow (6.01), Slowing (5.92)
2. Cars (393)	Parked (5.88), Front is (3.47)
3. Going (376)	Go (6.74), Orange (3.81)
4. In (358)	Front (4.97), Case (4.62)
5. Coming (272)	Towards (4.78), Full (stop) (3.23)
6. Road (269)	Slip (4.32)
7. See (260)	Gaps (3.35)
8. Speed (252)	Limit(s) (4.44, 3.32), Bump (4.1), National (3.57), Cameras (3.12)
9. Right (239)	*None of note*

**Main concepts are those with over 50% network influence and appear in the texts on over 200 occasions*

These main concepts, along with others of less significance, can also be represented as a network by the Leximancer software (see Figures 4.4 & 4.5 below), with the degree of a concept's importance reflected by its nodal size and its linkages to other concepts. Groups of concepts, that the software calculates as sharing a similar 'theme', are denoted by different colours. So, for example, in Figure 4.4, 'sign', 'hour', 'limit', and 'speed', are often found together in the group's texts.

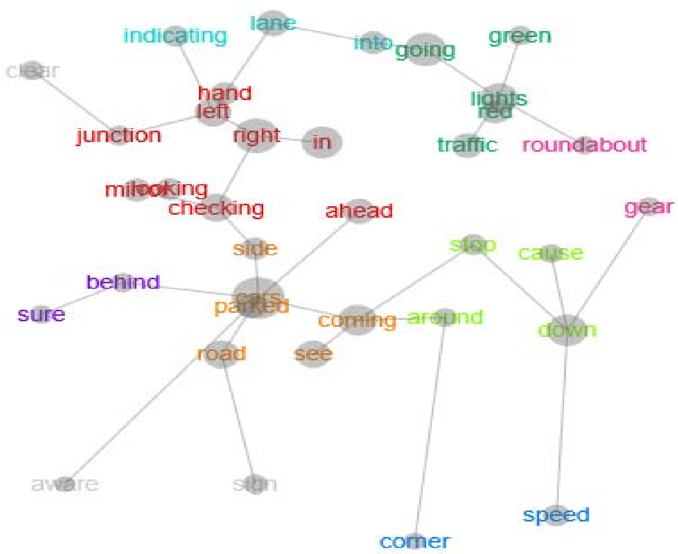
Figure 4.4: Concept network for the Older Group



What is also particularly apparent from this Figure is the centrality and importance of the 'Coming' concept, particularly what the vehicle is coming 'Towards'. There is also a closeness and interrelation between a number of other main concepts, such as 'Car' and 'Road'. The important 'Going' concept for the group is highlighted as a separate theme, as is the 'Traffic' concept - that was one of two unique for the group. This seems to be particularly related to traffic lights and roundabouts.

The younger groups' network is given below in Figure 4.5. Like the older group there is again good linkages between the main concepts, though no single concept appears to dominate the network, as was the case with the central 'Coming' concept for the older group, above. This is also reflected in Tables 4.D/E, also above.

Figure 4.5: Concept network for younger group



The result is that although the importance of the 'Cars' concept is evident, the network's other main concepts, 'Down' and 'Going' appear advantageous more spread out and discrete, and thus perhaps improving network density.

4.3.3. Combined Group data

The Leximancer software also has the capability of assessing two (or more) individual or group texts to reveal the most distinguishing concepts for each. In Table 4.F (below) it combines the frequency and strength of a concept to produce Prominence scores for the two driver groups.

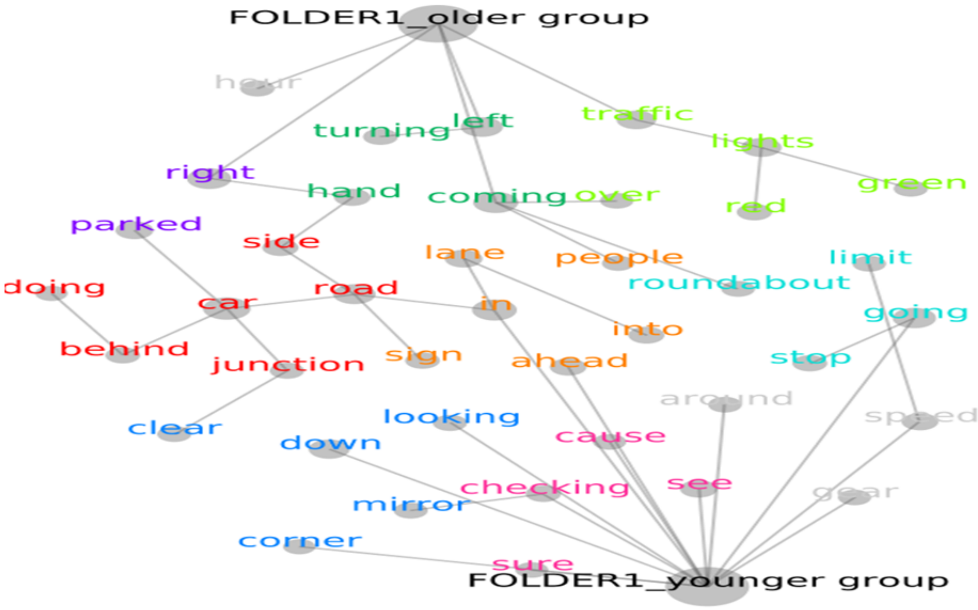
The Table shows that the younger group's awareness of 'Speed' and (in particular) their need to 'See' what was behind their vehicles, as particularly differentiating concepts for the software (although 'Down' which has a 68-31% split also seems worthy of mention here). For the older group, it was what was on the 'Left' hand side of the vehicle, and 'Traffic'- ahead or lights. It should be noted that the uniqueness of these concepts for the groups was also reflected in Figure 4.3, above.

Table 4.F: Concept Prominences for the older and younger groupings based on text strength and frequency (expressed as a percentage)

	Relative Prominence of main concepts for both groups							
	Older Group				Younger Group			
Concept	**Rk.**	**Freq. ↓**	**Strength ↓**	**Prom. ↓**	**Rk.**	**Freq. ↑**	**Strength ↑**	**Prom. ↑**
Left	7	6	67	1.4	12			
Traffic	8	4	62	1.3	16			
Coming	1	7	61	1.3	5	4	38	0.7
Right	2	6	61	1.3	9	4	38	0.7
Road	5	6	56	1.2	6	4	43	0.8
Lights	9	4	53	1.1	10	3	46	0.9
In	3	6	51	1.1	4	6	48	0.9
Car	4	6	48	1.0	2	6	51	1.0
Going	6	6	48	1.0	3	6	51	1.0
Down	10	3	31	0.6	1	7	68	1.3
Speed	19				8	4	69	1.3
See	27				7	4	77	1.5

Finally, any further differences between the two group's perspectives can be revealed through a combined network that includes many (in this case 40) of the concepts that the two groups generated collectively: not just the main ones compared in Figure 4.3 above. For this output, all twenty narratives are run through the software, the desired number of concepts is set, and a network is then produced showing the relevance a concept has for a particular group - indicated by its proximity to a group's 'Folder' node (see Figure 4.6 below).

Figure 4.6: Concept relevance to each group in network format



This network again highlights the importance of the 'See' (behind) and 'Speed' concepts for the younger group and the 'Left' and 'Traffic' concepts for the older group by their direct link, and often their proximity to the relevant group 'Folder' node. The evidence that the younger group had a better awareness of what was behind their vehicles again had support here from the inclusion of the 'Mirror' and 'Checking' concepts, and indeed their interrelation in the network. For the older group 'Turning' – relating to 'Left' turns; and 'Hour' – as in miles per hour, were also strong differentiating factors. More neutral concepts for the two groups were, for example, 'In', 'Car' and 'Roundabout'.

It should be noted that this network is in a 'social' format to allow the nodes to be of similar size and more evenly spaced. This was felt necessary to retain clarity for this particular (network) data. The Figure, then, is slightly different to the networks in Figures 4.4 & 4.5, which are in a 'topical' format, and where the size of each node and its spatial relationship to other nodes within the network represent its importance.

It therefore is worth mentioning that in Figure 4.6, an impression is given that the 'Mirror' and 'Checking' concepts appear to have similar relevance to the 'See' concept for the younger group, which is not the case. All three of these concepts are particularly related to the younger (than older) group narratives, but the extent of their importance to the group will be different. For example, a contrast can be made with the word count and network relevance of the 'See' concept (260/63%), with that of the 'Mirror' (123/30%), and indeed, the 'Checking' (178/43%) concept.

4.4. Discussion

4.4.1. SA scoring and concept comparisons

It is worth prefacing this section by reiterating a number of group parities in Table 4.A above. Specifically, it should be noted that the two groups were of similar gender composition, took a time to complete the route that, although statistically significantly, equated to an average difference of only three minutes (over 15 driven miles), and provided, again on average, similar lengths of narrative (a 0.45% group difference). All participants also undertook the task with seemingly little inhibition or difficulty, and in the main encountered very similar traffic conditions. So, in short, it can be said that there is a good basis to make group network comparisons.

4.4.1.1. Quantitative data

If consideration is firstly given to the overall SA scores in Tables 4.A & 4.B, it can firstly be seen that a group's SA proficiency is dependent on how it is calculated. If the narratives for a group are analysed together, then the younger group out-performs the older group (Table 4.A). However, if the individual narratives for each group are considered separately and their SA scores averaged, then both groups actually exhibit similar levels of network cohesion (Table 4.B).

This raises the important question as to which score better reflects a group's performance. With the group scores in Table 4.A, it is as if all ten drivers comprising each one are in a single vehicle seeking to aid SA, and in such an instance the younger group is relying on more similar information which is also better in its cohesion. Additionally, the group's score is unlikely to change too much here if one participant's narrative is removed at random.

SA group scores based on the average of individual scores, however, whilst appearing a more accurate indicator, could, with a small sample, be unrepresentatively skewed by just one extreme result. So in this study, if just the worse performing driver's data was removed, on the basis, say, that this person had demonstrated particularly poor cohesion in relaying information, the younger group's average score would then rise to: Diameter: 2.8; Density: 0.4130, and appear clearly superior to that of the older group (Diameter: 3.1; Density: 0.3819).

However, for this data set, the worse performing driver's scores did not merit exclusion, and overall it has to be conceded that the individual scores in Table 4.C do, in fact, show surprising consistency. Specifically, two younger participants head the scoring, but then generally blocks of older, then younger drivers alternate, until finally there is a block of two younger participants in the lowest scoring positions. The Density scores also fall by similar margins, with the largest gap between the 9th and 10th rankings (0.1137). But again, if just the top nine scores are extracted and considered, both age groups are similarly represented (five younger drivers and four older drivers).

So, in summary, if the older driver population could have its SA quantified, it would probably record a lower score than any younger age grouping. However, this would mask individual performances that in this study suggest a limited relationship between SA and age, and some notable individual performances by the older drivers. For example, the 81 year old who produced the third best SA score (only 0.0556 points behind first position). This suggests caution in assuming that SA proficiency falls linearly with age due to information processing deficits.

4.4.1.2. Qualitative data

Before considering the qualitative data from this study, of which much was produced, and much more could still be extracted if time permitted (for example, SA comparisons for particular roadway categories), one caveat should first be borne in mind. Although better cohesion in information processing will undoubtedly assist with a driver's Situation Awareness, whether this translates into safer driving is, however, another issue. For example, a person may try to evaluate, very cohesively, but too broadly, too much information and miss what is safety-critical. Another might simply, but again, cohesively, seek to assess only sub-optimal safety-related information, or very cohesively process information coming from only one direction, say from the front of the vehicle. Yet in all these cases participants who adopted such strategies could score highly on the SA measures taken here. That is why it is important to compare the driving concepts that underlie an individual's or group's score, to gain a sense of what she, he, or the group, is seeking to process.

In this regard a contrast is found between the older drivers' predilection for more general concepts derived mainly from the front of their vehicles, to the younger drivers' focus on more specific concepts that included those more indicative of the act of driving in itself. This indicates that the younger group is deriving its SA scores from potentially more relevant information.

If consideration is given to Figure 4.3, and Tables 4.D and 4.E, it can be seen, for example, that the younger drivers appear to take information (more) from a 360-degree perspective around their vehicles, as they spoke far more about what they could 'See' 'Behind' and the 'Cars' 'Behind'. The older drivers, in contrast, concentrated, perhaps in an anticipatory mode, more on what was coming 'Towards' them, such as a 'Junction' or a 'Roundabout', and 'Traffic' ('Lights'/'Warning') 'Ahead'. This was also indicated by the 'In' and 'Front' concept/word relationship (Table 4.D). There was also more interest to the 'Left' 'Side' of the vehicle, and 'Bearing' 'Left', and also to the 'Right' 'Hand' 'Lane' and what was 'Parked' on the 'Right'.

The younger drivers spoke more about the operation of their vehicles, e.g., the need to go 'Down' 'Gear', or to 'Indicate', and much in respect of speed regulation - slowing 'Down' 'Speed' due to 'Limits' or 'Bumps', or 'Coming' to a '(Full) stop', and to 'See' 'Gaps' in the traffic (Table 4.E). The older drivers had more interest in the direction their cars were heading, such as 'Going'- 'Straight' 'Over' or 'North', and both 'Right' and 'Left' 'Hand' 'Turning'. This lack of interest in driving operations may be demonstrative of more automatic processing, but equally it could reflect less awareness of speed regulation and of other (specific) road vehicles.

Finally, here, both groups showed a strong interest in 'Parked' 'Car(s)', although the older drivers more so to those on the 'Right' (Figure 4.3). 'Cars' at the 'Side' and what was at the 'Side' of the 'Road' also figured for both groups to similar degrees, although as was mentioned above the 'Left' 'Side' was particularly discriminating for the older group.

Network map data

When consideration is given to the network maps (Figures 4.4 and 4.5), which include the most relevant concepts drawn from each group's transcripts, further interesting data is revealed.

For the older group, two concepts: 'Down' (as in 'Coming' down); and 'Hour' (as in miles per hour speed limits), are worthy of note - due to having a word count around the 150 mark. The 'Down' concept is once again reflective of the group's directional preference, the 'Hour' concept indicative of an interest in speed limits (a related 'Sign' concept also has some relevance here, and was also linked to traffic speeds - 'Hour'/'Limit'/'Speed'). Perhaps, then, the older drivers relied more on such signs to regulate their speed?

The younger group's network, in contrast, showed some interesting additional safety-related actions, and an interrelation between them. Of note are the 'Mirror', 'Checking', and 'Looking' concepts in this regard, which surprisingly did not figure in the older driver's network at all. Both group networks did include a 'Behind' concept, however. This reached a 123 word count for the older group, but this concept was somewhat peripheral in their network and seemed only to become particularly relevant when traversing 'Village'(s) (see Figure 4.4). For the younger group whilst the 'Behind' word count was actually lower at the 92 word count mark, it was better linked (to the central 'cars' concept) in the network (see Figure 4.5), and as will be seen below, when other rearward relevant concepts are taken into account, this group demonstrated a far better awareness of what was 'behind' their vehicles.

By way of a postscript for the network graphics, an argument can be made that they are not as useful as the data from which they are drawn (and represented e.g., in Figure 4.3, Tables 4.D, 4.E, & 4.F). The networks can be inconsistent on occasion and potentially misleading. For example, whilst the centrality and importance of the 'Coming' concept for the older group (in Figure 4.4), and, albeit to a lesser extent, the 'Cars' concept for the younger group (in Figure 4.5) can be seen, the same prominence cannot so easily be discerned for the 'Right' and 'Down' concepts for these respective groups.

Also, whereas the main concepts in the network are generally quite stable, the more peripheral ones tend to move around on each iteration of the same data. This random element for the network maps is acknowledged by the Leximancer team in their website's FAQ's, but that does not absolve the problem.

4.4.1.3. Combined Group data

When all of the participants' narratives are considered and compared as one entity, it then becomes possible to reveal which concepts stand-out as being of particular relevance to each (age) group, and in tabular form (Table 4.F). This comparison, however, does not provide an exhaustive list of all the concepts found. The software draws on the main concepts from all twenty of the narratives, and then allocates a 'Prominence' score for their relevance, or not, to each group. So taking a Prominence score of 1.3 as a cut-off point, where the comparative strength of a concept to one particular group was then over 60%, it was firstly found, in Table 4.F, that 'See' was particularly discriminating for the younger group (with a 77-22% split). This concept had a strong relationship with that for 'Behind' (Figure 4.3), and to words like 'Gaps' (Table 4.E). The other six concepts with over a 60-40% split have less of a pronounced difference, but of these the two highest in terms of group discrimination were again with the younger group. These are 'Speed', as in slowing 'Down' speed (see Figure 4.3) for such things as speed 'Limits', 'Bump(s)', and 'Cameras' (Table 4.E), and the related concept, 'Down', which also had the highest occurrence in the younger group's narratives at 7% (Table 4.F). This concept, in turn, had linkages to going down 'Gear' (Figure 4.3), and a direct relationship with words such as 'Slow' and 'Slowing' (Table 4.E). So it is reasonable to conclude from such data that an awareness of speed adjustments and a consideration of what was behind the vehicle were aspects in the narratives that were of particular discriminating relevance for the younger group.

The final four main differentiating factors, with scores above 60% (see Table 4.F) all fall to the older group. The first, the 'Left' concept, stands out in particular here with a 67-32% split. This seems to be related to what was on the left 'Hand' 'Side' of the vehicle, and the act of ‘Turning’ or ‘Bearing’ left (Figure 4.3/Table 4.D). There are also similarities here with a second distinguishing concept for this group, ‘Right’, that actually was mentioned more times in the texts than ‘Left’ (387 to 349), but had a less unique split (at 61-38%) for the older group. However, taken together, the indication here is that the older drivers invested considerably more effort into being aware of what was to the left and right front aspects of their vehicles, and additionally it would seem, the direction the vehicle was taking. This latter conclusion is derived from a third differentiating concept, ‘Coming’ (61-38%), which had the highest text occurrence (7%/442 word count) for the group. It is also known from Figure 4.3/Table 4.D that it is a concept highly related to that of (and words relating to) ‘Towards’, which in turn is related to road artefacts, such as ‘Roundabouts, and ‘Junctions’. (In contrast, for the younger drivers, the ‘Coming’ concept was more relevant to the act of stopping the car). Finally, the last of the main discriminating concepts in Table 4.F for the older group was ‘Traffic’ with a 62-37% split. This again appeared indicative of a forward focus, due to its relationship with observing ‘Lights’ (Figure 4.3) and from a particularly strong linkage to words like ‘Ahead’ (Table 4.D).

Also, in terms of the combined data, a network was produced (in Figure 4.6) that gave an indication as to how relevant a concept was for a particular group from its proximity to a group’s ‘Folder’ node. As might be anticipated, the ones that stand out here reflect what was found in the standalone networks considered earlier (in Figures 4.4 and 4.5).

For the younger group, this was, again, ‘Checking’, ‘Mirror’, ‘Looking’, and ‘See’. However, three other concepts can now be differentiated, which were somewhat peripheral in the younger group’s individual network (Figure 4.5). These are: ‘Sure’, which in that network had a close link to ‘Behind’; ‘Gear’ which had a connection to ‘Down’; and ‘Corner’ with ‘Around’.

For the older group, the concepts that were most distinguishing were those (four) familiar from the ‘Prominence’ Table (4.F): ‘Traffic’, ‘Coming’, ‘Left’, and ‘Right’. In addition, the ‘Turning’ concept became a discriminating factor, which in the individual group network (Figure 4.4) had a linkage to the ‘Left’ concept: however, in Figure 4.3/Table 4.D it could also be seen to be related to the ‘Right’ concept. Finally, once again the 'Hour' concept (as in miles per hour) stood out for the older group in this combined Figure as it did in the group's network. This appears related to an awareness of speed limit signs, that perhaps, more than the younger group, assisted them with speed regulation.

Overall, it briefly can again be concluded from these comparisons that the younger group exhibited more awareness around their vehicles, particularly from behind, and regulated their speed, perhaps more consciously, through gear manoeuvres. The older group had less unique concepts, and where found, they appeared to be related to a directional focus – particularly to what was coming towards their vehicles. In contrast to the younger group, they additionally appeared to regulate their speed of travel more by road signage than continual, conscious, gear changing.

4.4.2. Potential lines of further enquiry

The general approach to assessing SA in the literature is to have groups of participants undertake a SA-related task on a simulator and then have their responses scored against those perceived to be of relevance for the researcher. This study, in contrast, sought to evaluate SA from an actual driving experience and took no view as to what SA might comprise of - merely a quantitative measure of the information that it was based upon. How well a driver's thoughts were structured was the key here. By this approach, the older drivers in this Study, who were active, professional people, and many of whom were still working, appeared to demonstrate a good and coherent awareness of their driving environment, judging by the SA metric scores.

However, the qualitative data that was generated appeared to show indications, as outlined above, for the older drivers to have, in particular, an undue focus to the front of their vehicles, and furthermore, to potentially be processing driving environment related information that was of less safety relevance. It cannot be known from the methodology what key information might have been missed by a driver, but like other SA studies, comparisons to what the researcher deems indicative of such assertions can be made to evaluate whether they have any merit.

For example, in Table 4.H below, a short list of concepts has been created that potentially could indicate the extent to which a driver had an awareness of what was happening behind his/her vehicle. A concept and word count (in Leximancer) can then be taken for each group as a means of comparison. For the concept count, the Leximancer software assesses a sentence for a concept; for the word count it simply records instances of that concept.

Table 4.H: Rearward-related concept comparisons

Concept	Older Group		Younger Group	
	Concept Count	Word Count	Concept Count	Word Count
Behind	123	125	92	91
Mirror	12	21	123	132
Rear	0	0	8	40
Wing (mirror)	2	1	17	10
Totals	**137**	**147**	**240**	**273**

From this data, it could be argued that the younger driver group was exhibiting almost twice as many rearward glances during the driving trial than the older group. It is possible, however, that this difference might be due to a form of double counting, in the sense that for the younger group the 'Mirror' and 'Behind' concepts might have been closely related, perhaps spoken together on a high number of occasions in the same sentence. This, though, does not appear to be the case. The highest percentage likelihood of such an association was actually found for the older group (see Table 4.I), but it is rather weak one when consideration is given, say, to the relationship between the 'Wing' and 'Mirror' concepts.

Table 4.I: Likelihood of a 'Mirror' and 'Behind' concept relationship

Concept	Group	
	Younger	Older
Mirror (Related to:)	Wing(100%), Rear (38%), Check (31%), Checking (24%), **Behind (11%)**	Check (50%), **Behind (2%)**
Behind (Related to:)	Rear (12%), Wing (12%), Space (9%), **Mirror (8%)**	**Mirror (17%)**, Space (11%), Check (10%).

A second aspect of interest is the potentially sub-optimal amount of relevant information being processed by the older drivers. This is also more difficult to substantiate from the text alone, but again, perhaps an indication can be gleaned from what the participants themselves enunciated in relation to driving safely(?). The concepts presumed of relevance are compared by concept and word count in Table 4.J (below).

Table 4.J: Safety-related concept comparisons

Concept	Older Group		Younger Group	
	Concept Count	Word Count	Concept Count	Word count
Checking	6	19	178	220
Check	10		45	
Indicating	31	108	117	142
Indicate	28		45	
Blind	6	7	29	33
Clear	66	71	112	122
Sure	18	19	105	98
Gap	0	0	9	12
Safe	6	11	14	19
Looking	0	57	136	161
Look	19		46	
Aware	10	10	63	69
Warning	10	11	12	12
(having)Time	22	10	20	12
(enough)Space	9	9	11	10
(enough)Room	16	9	13	13
Totals	**257**	**341**	**955**	**923**

Here a substantial difference in overall scores is revealed. In fact, the younger group performs better on all but two concept scores and in every relevant word count, which was a surprising result.

There were indications during the task of the older drivers being more easily distracted from, and having less awareness of, the driving task. Equally, though, it might be that their driving experience was just leading to less information processing, resulting in less relevant text, but it is hard to conclude that this could account for all of such a difference.

If there was a deficit in processing relevant information, and then taking actions relating to driving safely, it would appear of interest to investigate how an older driver would cope with an unexpected hazard or a more taxing driving environment than the one encountered in the Study.

4.4.3. Limitations

Due to a limited number of volunteers for this study, it was not possible to match the two participant groups for mileage driven, accidents incurred etc. Emphasis was placed on producing the most descrete groups, by age, as possible. However, there was no evidence that the driven milieage in a given week was significantly different between the two groups, or that its form gave any advantage. For example, for the most part, the students tested for this study mainly drove short distances to and from the University's campus. The older group may have driven more varied routes over a similar time period, but that variation did not appear to translate into better SA. One older participant, for example, who undertook quite varied driving for his work, saw himself as a very proficient driver. However, for SA-related scoring he was ranked 13th, and thus was outscored by many younger (and older) drivers who drove, potentially, less diverse routes.

The 'Think aloud' methodology chosen for this study, whilst being less obtrusive and easy to understand, also impacts on the number of participants that can be assessed within a reasonable time period. This is principally due to the need for commentaries to be accurately transcribed, and then formatted as truly as possible to a participant's enunciation. Thus with limited numbers also comes related limits on generalisations, though this issue is not uncommon in SA research. The 'Think aloud' approach, like many other SA-related techniques, also has its limitations. Whilst it can be said that strong and related connections between knowledge concepts in any context will aid their recall, and indeed, Situation Awareness from a better processing of incoming information, the approach can only assess what the participant says s/he is aware of. Thus whilst one driver may less optimally organise a higher number of safety-related cues from around his/her vehicle, another may, very proficiently, organise a similar number of more general concepts mainly from looking forward from his/her front windscreen. It therefore is possible from this method that the latter driver could be calculated as having a more cohesive information network indicative of better Situation Awareness, but it is arguable if this is correct. It would therefore seem advantageous to firstly investigate whether SA, as measured by this approach, can be correlated to a driving proficiency measure, and secondly, to investigate whether it can show variability in scoring for driving environments of different complexity.

4.5. Conclusion

This study showed that at the individual level, older drivers can show good Situation Awareness. There was no suggestion of presumed perceptual or cognitive deficits impacting on the quantitative scoring measures of SA utilised here. In fact, the two oldest participants, both of whom were in their early 80's, performed well, ranking 3rd and 7th overall. At the group level, though, there were suggestions of a less cohesive performance in information processing by the older drivers, which appeared evident during the study from them being more likely to stray in their commentaries from the driving task. Qualitative and quantitative comparisons of relevant concepts, and their interrelations for each age-grouping, tended to support this view by showing the older driving group to rely, in particular, on less rearward and safety-related cues, and from exhibiting seemingly less awareness of the need for speed regulation.

The principal question raised here then is why the apparent poorer awareness indicated more by the qualitative data was not matched by the metric scores in the quantitative data. The reasoning for this may lie in the fact that the route driven was insufficiently demanding, thus allowing for any sub-optimal processing of information to have a limited effect. This may also explain the apparent lack of impact of age-related cognitive decrements, as in less demanding driving situations these too could have been compensated for by, perhaps, the older driver's greater driving experience (53.9 to 11.2 average years in this study), as has been found by McPhee et al. (2004). The group may, as a result, have been better able to anticipate environments that might cause them difficulty, and slowed their speeds to allow for more information processing time. (Table 4.A. above shows that they traversed the route (significantly) slower than their younger participants: but admittedly, only by three minutes on average over 15 miles). There is also the possibility, of course, that they may have undertaken more automatic processing of information (as found, e.g., by Bosman & Charnes, 1996). That does not mean the group necessarily processed all the relevant information in this way, merely that the driving environments they encountered here may have allowed them sufficient time for such automatic processing whilst delivering a cohesive and continual commentary.

The question that flows from such contentions is whether the quantitative SA proficiency demonstrated by the older driving group in this study, would be retained in more taxing driving conditions. As in such circumstances the need for optimal awareness of safety-related cues and potential hazards would become more critical, and thus impinge on information processing time.

Chapter 5: Hazard Perception literature review

5.1. Introduction

Having good Situation Awareness is an important aspect of successful and safe driving, and in the previous chapter/study it was shown that age-related cognitive decrements did not necessarily reduce an older driver group's Situation Awareness whilst driving, what was, a non-taxing route. However, this better than expected performance may have come from a more limited awareness from what was to the front of their vehicles, in contrast to a younger group's better all-round awareness. Two main questions arose from this work. Firstly, whether the older driver's SA performance levels would be retained in more taxing driving conditions, and secondly, whether the approach to measuring SA had sufficient construct validity to be able to relate it to an actual driving performance indicator. In the study that follows in Chapter 6, these issues will be investigated further. This will be achieved by utilising journeys verified as being different in their levels of cognitive taxation, and by incorporating a driving performance measure into the study's design. In this chapter, a justification will be made for the driving performance measure chosen for that research, Hazard Perception (HP), by considering its relevance to Situation Awareness and to older drivers.

5.2. Justification for the use of a Hazard Perception measure

In considering an appropriate driving measure for Study 2, Hazard Perception was found to have four clear and important advantages. Firstly, it could be tested in a reasonable timeframe, through media that can be purchased at insignificant cost and run through most portable computers. Secondly, it has been correlated with traffic accident involvement across a number of studies (e.g. Peltz & Krupat, 1974; McKenna & Crick, 1991; Darby et al., 2009; McKenna & Horswill, 1999; Quimby et al., 1986; Wells et al., 2008). Thirdly, it has been found to decline with age (e.g. Wallis & Horswill, 2007) - a principal exploratory aspect of this thesis - and finally, and most significantly, it potentially has performance linkages to Situation Awareness. Hazard Perception is, after all, about anticipating potentially dangerous situations on roadways, and has been viewed as an ability to read the road (Mills et al.,1998) and even, having Situation

Awareness for hazardous situations involving roadway environments and users (Horswill & McKenna, 2004).

Furthermore, Endsley's three-level model of Situation Awareness (Endsley, 1995a) would appear to provide a basis for understanding why drivers have different Hazard Perception abilities, and for potentially identifying the causes of those differences. In her model, as was seen in Chapter 3, Level 1 SA corresponds to perception, Level 2 to comprehension, and Level 3 to projection. Thus, it could be argued that if we perceive a wide range of relevant cues, we will then be better able to comprehend a current environment, and, as a result, better able to project future actions. So in road driving contexts, good Situation Awareness might mean that we would be better able to predict a potential hazard by more proficient projection of the behaviour of other road users, and how that might impact on the development of a current driving situation.

To take an actual example, say when driving along a street you perceive a group of children, a ball, and a small area of open space. You will then be better able to comprehend that a game of football is likely to be in progress, than if you only perceived, say, one of the children and the open space. As such, you would also be better able to project that there is a chance that the ball, and possibly one of the children, may run into the road. Thus a better SA proficiency here would more likely lead to those potential hazards being detected, and, as a result, a better driving action. You may, for example, then slow the car's speed to allow for adequate braking should the ball and/or child appear on the roadway. Hazard Perception therefore has similarities to Endsley's view of Situation Awareness in the sense that it is the process of detecting, evaluating and responding to dangerous events on the road that have a high likelihood of leading to a collision.

In addition, however, it also has relevance to the cyclical-based definitions/models of SA, preferred in this thesis, as proposed by, for example, Smith & Hancock (1995). For this approach, Hazard Perception could be said to reflect a driving skill that, like Situation Awareness, involves constructing continuous and updated representations of traffic conditions from around a vehicle. These representations, in turn, would determine how effectively an environment is measured for risk, and therefrom, how well the driver anticipates and plans for appropriate courses of action (Isler, Starkey, & Williamson, 2009).

5.3. What factors influence Hazard Perception ability?

In previous chapters the factors that influence an individual's Situation Awareness have been discussed in some detail, it therefore would appear of use to also assess those thought to be influential for Hazard Perception by way of comparison.

Overall, Hazard Perception skills are said to reflect how well an individual can cope with the complex cognitive demands that a traffic environment can impose, through his/her conscious and effortful processes (Horswill & McKenna, 2004). In this regard, four factors will be briefly discussed: under-developed eye movements, visual attention, accuracy of self-evaluations, and driving experience.

5.3.1. Under-developed eye movements

A first area of explanation for differences in Hazard Perception performance is said to be related to less developed frontal lobe executive functions of the brain. These include: goal-directed behaviour, visual search, impulse control, divided attention, and working memory. These deficits are of particular relevance to young (teenage) drivers (Lenroot & Giedd, 2006; Dahl & Spear, 2004; Keating, 2007; Isler et al., 2008) who are also said to have under-developed control of their voluntary eye movements. Evidence for this comes from studies (e.g. Munoz et al., 1998; Klein et al., 2005) that have linked younger participants' difficulties with voluntary saccadic eye movement tasks to delayed maturation of their frontal lobes. This could suggest that younger drivers may be disadvantaged in their visual search behaviour by not being able to move their eyes fast and frequently enough to fixate on all relevant traffic information. This has been demonstrated by Mourant & Rockwell (1972), who found that young and novice drivers fixated longer on irrelevant traffic information and moved their eyes less frequently. This would, of course, also impact on the proficiency of their Situation Awareness, particularly at Level 1, but therefrom, also at Levels 2 and 3.

5.3.2. Visual attention

A second aspect related to good Hazard Perception is said to be good visual attention (Fitzgerald & Harrison, 1999). This relates to the processes that find, extract, and define features in the visual environment (Jenkin & Harris, 1999). With similarities to the 'constraint satisfaction process' approach (Baumann & Krems, 2009) alluded to in Chapter 3, Ball (1997), has described how these processes must be constantly utilised to detect potential hazards (whilst inhibiting non-hazardous related information) for adjustments to be made for the avoidance of collisions.

It would appear that visual attention would be a particularly important factor for Hazard Perception when driving in unfamiliar areas, as a driver would then require more concentration to process road and traffic conditions, which would thereby reduce the resources available to him/her to detect potential hazards.

Visual attention can also be degraded by distraction, for example by stimuli in the external driving environment (Underwood et al., 2003), such as another road user suddenly moving into a driver's field of view. This could adversely influence his/her capability to utilise existing knowledge to anticipate emerging problems, and therefrom to avoid a hazard. The importance of distraction is supported by evidence that has significantly related insufficient visual attention to traffic violations and accidents (Owsley et al., 1998) and a threefold increase in the risk of crashes and/or traffic violations (Richardson & Marottoli, 2003).

Other concurrent factors that may also cause drivers to fail to allocate their visual attention optimally, are said to be inexperience (Falkmer & Gregersen, 2005; Underwood et al., 2005) and, significantly, for the purposes of this thesis, age (Lee et al., 2003; Lee & Lee, 2005).

5.3.3. Accuracy of self-evaluations

In addition to the above cognitive-based factors, proficiency in Hazard Perception may also be affected by a driver's roadway confidence. In that, if s/he is over-confident in his/her ability to cope with a hazard, it could lead to collisions. In this regard several studies have shown that, for driving in general, younger drivers have more of a tendency to overestimate their own skill, but underestimate the skill of other drivers (Groeger & Brown, 1989; McKenna et al., 1991; Sexton et al., 2006).

However, in regards to Hazard Perception, such over-estimations are surprisingly higher than both overall driving, and elements of it - such as vehicle control. Farrand & McKenna (2001), for example, have found a disassociation between young novice drivers' ratings of their Hazard Perception and their actual driving performance on a video-based test, even when evaluated on a scene-by-scene basis. And this over-confidence is not just limited to younger drivers, it appears to be prevalent across all age-groups. Horswill et al. (2004), for example, have found that all drivers generally rate their Hazard Perception ability as better than the average driver, and also better than their peers (where a peer is defined as someone of the same age, sex, education, training, experience, etc. as themselves).

5.3.4. Driving Experience

A final major factor that influences Hazard Perception ability appears to be driving experience, as younger novice drivers have been found to detect fewer hazards (e.g. Underwood et al., 2005) and more slowly (e.g. McKenna & Crick, 1991; Wallis & Horswill, 2007) than experienced drivers. This despite Farrand & McKenna (2001) finding that they demonstrated no difference in their ability to discriminate traffic scenes according to their hazardousness level. A reason for this may be the inefficient eye scanning behaviour, alluded to above, and insufficient 'mental maps' (schemas), that in tandem may lead to sub-optimal processing of relevant cues relative to experienced drivers (Horswill & McKenna, 2004; Underwood, 2007).

Another major reason for poorer Hazard Perception amongst inexperienced drivers might be a lack of cognitive resources for adequate attention. Underwood (2007), for example, suggests that for novice drivers, the driving task (such as steering, changing gears, and speed control) may not have been automated enough to free up the attentional capacities required to enable effective road Situation Awareness and the searching for hazards.

McKenna & Farrand (1999), have also found that experienced drivers' Hazard Perception reaction times were slowed more than novices' reaction times when the drivers were required to perform a secondary verbal task. They argued that this indicated that the experienced drivers were utilising cognitive resources to undertake more sophisticated and proactive visual searches, as they were diminished once diverted elsewhere.

Experienced drivers are also said to be better able to detect a potential hazard. Armsby et al. (1989), for example, asked participants to classify pictures of different traffic situations, and found that fog (a potential hazard) was considered more hazardous among experienced than novice drivers. Additionally, Finn & Bragg (1986), found that novice drivers rated a pedestrian walking along a road (an actual hazard) as more hazardous, and 'tailgating' (a potential hazard) less hazardous, than experienced drivers.

It has therefore has been argued (e.g. Benda & Hoyos, 1983; Brown & Groeger, 1988; Armsby et al., 1989) that, overall, experienced drivers take a more holistic perception of traffic environments, and (e.g. Chapman & Underwood, 1998ab) that they are better able to adapt their visual scanning patterns to different road situations, and then process this information with longer fixation durations.

5.4. Hazard Perception ability and age

Like any skill, it is reasonable to assume that drivers will improve their ability to detect hazards as their experience grows, as has been suggested by the studies reported above. In simple terms: with more experience, more relevant feedback will be taken from an environment, resulting in better Hazard Perception (e.g. Matthews & Moran, 1986; Naatanen & Summala, 1976).

However, it would appear that certain cognitive-related age deficiencies, that were considered in some detail in Chapter 2 (e,g., general cognitive slowing (Salthouse, 1996), inhibitory deficits (Hasher & Zacks, 1988), and task-switching deficits (Mayr & Liebscher, 2001)), may impact upon the advantages of experience. And like Situation Awareness, they may also affect the proficiency of Hazard Perception sufficient to make them an important factor in determining crash risk amongst older drivers (Watzke & Smith, 1994). The reason for this would appear to lie in the dynamic nature of Hazard Perception (and indeed SA). Thus inhibitory deficits that impinge on identifying relevant from irrelevant cues; and task-switching deficits that affect attention to multiple sources of information, will affect HP (as they do with SA) performance.

As visual performance also becomes more variable with advancing age, both through the normal aging process, as well as through an increase in the prevalence of ocular disease later in life (Haegerstrom-Portnoy, Schneck, & Brabyn, 1999), this too can affect Hazard Perception. Thus, factors such as visual acuity and contrast sensitivity may impinge on an older driver's capability to process visual stimuli, which may result in him/her being less likely to anticipate hazards effectively if s/he has difficulty seeing the cues associated with them.

Additional age-related difficulties related to Hazard Perception have also been proposed by Bolstad & Hess (2000) in regards to attentional problems, particularly in novel contexts, and Schacter (1996), in regards to the recall of past actions. However, Schacter also suggests that with proper retrieval cues, an older driver's performance may be able to reach standards commensurate with younger drivers, due to a dependency on their schemata. As these will only be minimally affected by ageing, he argues that the older driver would be able to utilise them to focus, encode, and retrieve, via a probabilistic basis, relevant information from a particular driving environment. This appears related to SA being produced via Neisser's Perceptual-action cycle (Neisser, 1976), discussed in Chapter 3.

Finally, Borowsky et al. (2009), have found that older-experienced and experienced drivers tend to classify video of traffic scenarios according to environmental similarities (e.g., grouping all of those that included residential traffic environments), whereas young-inexperienced and inexperienced drivers tended to classify them according to hazard instigator similarities (e.g., grouping those that included pedestrians crossing the road). These findings suggest that as with experienced adults, older drivers similarly perceive hazards in an advantageously holistic manner and that possibly this skill remains intact into old age. These findings build on earlier work by Underwood et al.

(2005), who also found similar scanning patterns between older (60-75 years) and experienced (30-45 years) drivers, and that the older group could, in fact, detect more hazards.

5.5. Older driver Hazard Perception performance

The above findings have much in parallel to Situation Awareness research, in that both Hazard Perception and SA are said to be affected by age-related declinations that perhaps can be arrested by longer driving experience. So has the Hazard Perception performance of older drivers also, like SA, been found to be less proficient?
In small sample studies of older drivers, such as the Underwood et al. (2005) (n=12) study reported above (but also in e.g. Olson & Sivak, 1986 (n=15)) no significant difference in reaction times to hazards between older and younger drivers was found. However, in larger sample studies, such a correlation has been evident. In Quimby & Watts (1981) (n=60), for example, Hazard Perception response times were found to be slower for drivers aged under 25, but then became quicker with experience and age until 55. Between 55 and 65, performance levels then dipped back to under 25 year old standards, and then further worsened from 65. Horswill et al. (2008) also used a large sample (n=118) to investigate the Hazard Perception ability of older drivers by measures of cognitive ability, vision, and reaction time. They found that Hazard Perception response times increased significantly with age and that this was related to contrast sensitivity, useful field of view, and simple reaction time.

However, as any aggregate decrease in Hazard Perception ability for older drivers in these studies could have been due to specific pathologies in certain individuals, rather than normal age-related declines, Horswill et al. (2009) (n=79), subsequently investigated a sample of health-checked drivers. They found that those aged 75–84 were significantly slower at Hazard Perception than groups aged 65–74 and 35–55, who did not in fact differ. The differences between the older group, and the other groups combined, were again found to be related to contrast sensitivity, useful field of view, and simple reaction time. Given that Hazard Perception ability has been linked with crash risk, these results suggest that healthy older drivers, at least those over 75, are more vulnerable to road accidents.

One should add here, though, an aspect that has been mentioned in Chapter 2 in regards to a gradual cessation of driving amongst older drivers. This is the idea that the driving behaviour of older drivers is determined by both their capacity to drive safely, and their own self-beliefs about their driving capabilities. Anstey et al. (2005), for example, have argued that while the capacity to drive safely may decline with increasing age, there may be an equivalent change in driving behaviour, as older drivers notice that their capacity is declining and take compensatory action (such as restricting their driving to safer environments).

Other research has supported this assertion, by showing that older drivers do indeed restrict their driving exposure across a range of situations (Baldock et al., 2006; Marottoli & Richardson, 1998; Molnar & Eby, 2008), and furthermore that this appears to be driven by confidence levels in driving ability, at least for some aspects of their driving (Baldock et al., 2006).

There are, however, two related points here. Firstly, such self-regulation amongst older driver groups will only be effective if it is accurate, and as was indicated in '5.3.3' above, it may not be accurate enough. Groeger & Grande (1996), for example, add to the view given in that section - that younger drivers tend to over-estimate their driving performance (i.e. Groeger & Brown, 1989) - by finding similar over-estimations for all age groups. Also, other studies have shown that older drivers, like drivers of all ages, tend to exhibit a self-enhancement bias, considering themselves, on average, to be considerably better than the average driver (Freund et al., 2005; Marottoli & Richardson, 1998). In fact, Freund et al. (2005) have found that the higher older drivers rated their expected performance in a driving simulator, the more likely they were to be rated unsafe when they actually 'drove' in it.

A second important aspect here is that there is also evidence that this cessation-compensation for age-related declines is not effective in eliminating increases in crash risk. For example, Ross et al. (2009) found that those who performed poorly on a UFOV sight test may have restricted their driving but, despite this, that they were still twice as likely to be involved in an at-fault crash compared with those who performed well on that test.

In sum, older drivers who demonstrate a diminished Hazard Perception capacity may be at greater risk of crashing. Though they may be able to moderate this risk if they can accurately and effectively monitor that diminished capacity, so allowing them to regulate their driving appropriately. Thus how accurately older drivers' self-monitor their Hazard Perception is crucial. It is conceivable, due to them having much greater driving experience, that they may be better placed than other driver groups to accurately undertake this evaluation: however, evidence suggests otherwise. Horswill et al. (2011), for example, have found, from a large sample (n=307) of older drivers, that their judgements of confidence for a Hazard Perception Test performance had little or no relationship to their actual test scores.

5.6. How Hazard Perception is measured

The test utilised in Horswill et al. (2011), above, is one typical for the measurement of Hazard Perception, and for the purposes of the study to be undertaken (and subsequently reported in Chapter 6), its format deserves further consideration. The usual approach that such tests take has been to use video clips of traffic situations taken from the driver's perspective (Quimby & Watts, 1981; Olson & Sivak, 1986; McKenna & Crick, 1991, 1994, 1997; Chapman & Underwood, 1998ab; McKenna & Horswill, 1999; Horswill & McKenna, 2004; Sagberg & Bjørnskau, 2006). Each short clip typically contains one (though sometimes two) hazard(s) (e.g., a pedestrian steps into the road from between parked cars; another road user moves into the path of the car being driven), which usually would require a driver to brake or perform steering changes. An individual's ability to perceive and react to such events is measured by his/her timing of simple push-button, or (in Horswill et al., 2011) screen touch, responses. In rarer cases, a continuous recording is taken, with the participant moving a lever between settings marked "safe" to "dangerous" (e.g. Crundall et al., 2003; Pelz & Krupat, 1974).

Researchers have demonstrated that Hazard Perception response times are longer for crash-prone drivers (McKenna & Crick, 1991; McKenna & Horswill, 1999; Quimby et al., 1986) and inexperienced drivers (e.g. Quimby & Watts, 1981; McKenna & Crick, 1991; Renge, 1998; Wallis & Horswill, 2007). Thus it has been argued that poor Hazard Perception ability is an important contributor to increased crash risk (Horswill &

McKenna, 2004), and particularly for newly qualified drivers who are over-represented in the UK and US crash statistics compared to more experienced drivers (Braitman et al., 2008; Maycock et al., 1991; Underwood, 2007).

The UK Government has considered this research sufficiently convincing to introduce a Hazard Perception element to the UK driving test in 2002. It has also been incorporated into the driving licence procedures in some states in Australia. The validity of Hazard Perception Tests is said to be demonstrated by the correlations highlighted above with crash risk (see also Hull & Christie, 1992; Transport and Road Research Laboratory, 1979), differences between novice and experienced drivers (e.g. Sexton, 2000), and also with expert ratings of drivers' performance on real roads (Mills et al., 1998).

The rationale behind their introduction was that if a learner driver does not respond fast enough to video-based hazards, s/he might equally not respond fast enough to actual on-road hazards and thus increase his/her probability of crashing (see Drummond, 2000). So by including an HP Test, the aspiration was that it might encourage learners and instructors to focus more upon hazards during driver training.

It is arguable, however, as to whether this has been achieved, and there have been studies that question the validity of such tests. For example, Chapman & Underwood (1998ab); Crundall et al. (2010); and Sagberg & Bjørnskau (2006) failed to find expected differences in Hazard Perception ability as a function of age, driving experience, and accident propensity.

It has also been suggested that Hazard Perception testing may not be a good predictor of driving proficiency, and that its benefits may be limited to quite specific driving situations (such as high-speed accidents, especially where the driver accepts some blame (Wells et al., 2008)).

Nahvi (2007) has made a 'Freedom of Information' request to the UK Government, and obtained Hazard Perception Test (HPT) pass rates measured over a one year period (from December 2005 to 2006) (see Table 5.1). This data shows a lower than expected success rate for Potential and Approved Driving Instructors, who would be assumed to be particularly proficient at Hazard Perception. However, the pass score required for these candidate groups was higher than for a learner driver or motorcyclist.

Table 5.1: Percentages of applicants passing the UK HPT between December 2005/2006.

Driver Type	Pass score required	Percentage achieving score
Car	44	86.06
Motorcycle	44	94.31
Large Goods Vehicle	50	85.70
Passenger Carrying Vehicles	50	84.06
Potential Driving Instructor	57	62.46
Approved Driving Instructor	57	62.33

Although the results from this data are not clear-cut, and regrettably similar information is unavailable at this time, it does indicate that the Hazard Perception Test used in the UK driving test is no easier for experienced drivers to pass. This, then, raises questions as to how older drivers might perform, particularly when consideration is given to the fact that the test appears to place much emphasis on response and reaction times (McKenna & Crick, 1991; McKenna & Horswill, 1999; Quimby et al., 1986; Olson & Sivak, 1986; Underwood et al., 2005; Quimby & Watts, 1981; Horswill et al., 2008; Horswill et al., 2009). To undertake the test successfully, split second proficient 'clicking' of a button is required: one second late, and the tested individual is rated as being unaware of the hazard being assessed, even though in some cases the time frame to respond appears to the author to be rather fast and in some cases arbitrary. The car driven in the video clips also travels at consistent speeds that match the limits given for a particular roadway. Although this would appear normal for younger drivers, for an older driver such speeds may appear excessive. Thus whereas an older driver might decrease his/her speed to increase information processing time on roadways that s/he may anticipate as dangerous, on a typical HP test this would not be possible, and thus their Hazard Perception performance, as a result, may be affected.

5.7. The way forward

In the following chapter, a study will be undertaken to measure an older driver's Hazard Perception ability. In view of potential difficulties for older drivers in spotting hazards at higher speeds, as highlighted above in relation to certain age-related cognitive deficits. And bearing in mind that the participants in the study will not be aware that they are taking a Hazard Perception Test, nor have any training or lengthy practice beforehand, a variation on the standard test's measure is proposed. In short, participants will still have their HP scored by the timeliness of their response, but separately, credit will also be given for spotting a hazard outside of the given timeframe. A total score from the sum of these two parts will then be made. This total score, and the score for detecting a hazard, can then further be related to a participant's SA score derived from his/her commentaries on similar, though longer, video footage of car journeys undertaken just prior to the HPT element. Thus, the study will be able to show, perhaps more accurately, whether older drivers do demonstrate poorer HP. And in addition, whether this could be related to the SA measure utilised for the study, and for those in the series, based on 'Think aloud', narrative-based, information networks.

Chapter 6: A Study investigating the Situation Awareness and Hazard Perception proficiency amongst older and younger drivers

6.1. Introduction

In Study 1 the Situation Awareness (SA) scores of an older driver group were found to be similar to that of a younger group. However, when the concepts in the narratives were extracted and compared, the older group showed indications of being aware of far fewer safety-related concepts and words, and of being less aware as to what was happening around their vehicles. They also appeared to process information less rigorously - demonstrating a more general, directional-based, awareness, in contrast to the younger drivers who focussed more on specific driver actions and roadway artefacts.

If older drivers do undertake more cursory observation, and process, potentially, an insufficient number of safety-related cues, then whilst this may not necessarily impact on them driving safely in less demanding conditions, such as those encountered whilst driving in Study 1, it could (as was argued in Chapter 4) if those conditions became more complex, and thus more cognitively demanding.

6.1.1. Approach to measurement capture

6.1.1.1. Situation Awareness

To investigate this further, participants in an older driver group were again evaluated against those in a younger driver group, though with a preference given to volunteers who had previously undertaken Study 1 to allow for a comparison. Once again 'Think aloud' commentaries were recorded, but video footage of two car journeys of different complexity replaced the single driven journey assessed for Study 1. It was felt that to drive a very complex route, such as the one to be shown on video, whilst giving a continual commentary, could potentially present ethical difficulties as it may unduly distract a driver.

6.1.1.2. Hazard Perception

In addition to capturing driver SA through a different, video, format, this approach also afforded the advantage of seamlessly allowing a participant to be assessed for his/her Hazard Perception. As was argued in the preceding chapter, this measure was chosen for four main reasons. To briefly recap, these were:

a) because it represents an important aspect of driving safely, sufficiently so to have it tested as part of the UK Driving Licence procedures since 2002.

It has been argued that newly qualified drivers have a deficiency in identifying emerging road hazards (Horswill & McKenna, 2004) due to their over involvement in road accidents (Braitman et al., 2008; Maycock et al., 1991; Underwood, 2007). Thus, by testing for Hazard Perception, it was hoped to enhance a learner driver's skill for the identification of potential hazards – those that would cause a driver to change speed, direction, or stop, and, as a corollary, have him/her more mentally prepared to take action if they then turned into actual hazards.

b) as a result of its inclusion in the UK driving test, there are numerous video-based examples available on CD and the internet of the kinds of hazards learner drivers will encounter when they come to take their test. Often these will include measures of performance that will help a student driver assess his/her progress. These will usually include whether an appropriate hazard (or hazards) were recognised within a particular video clip, and also within the predefined time periods that the test sets. These video databases are therefore both easy to obtain, extract, and incorporate into studies of Hazard Perception, and advantageously, for the purposes of the present research, without affecting any SA measurement objectives.

c) Hazard Perception has relevance for the measurement of older driver ability. It appears from Chapter 5 that generally proficiency in detecting a hazard will decline after the age of 75, but not necessarily be demonstrated between age groups below that threshold (see Horswill et al., 2009).

d) it has potential links with Situation Awareness. For example, Zhang et al. (2009)/Kaber et el. (2012) have found that if a hazard is encountered in a rural environment it can actually improve an older driver's SA, but decline it if encountered within an urban environment. And additionally, that being exposed to a hazard, particularly a dynamic one, can worsen an older participant's driving performance in either environment.

6.1.2. Objectives and hypotheses

As with Study 1, this study again sought to compare SA proficiency scores, and the related concepts underlying them, for both an older and younger 'driver' group. Two video journeys: one 'Complex'; one more 'Standard' and similar to that actually driven in Study 1, provided the media for a participant to provide a commentary for. Such an approach was chosen to satisfy RQ1 and RQ3. The narratives subsequently produced were measured, as before, by SA metric scores and word count/relevance, Prominence, and network indicators, with the aim of looking for age-group differences relating to driver safety.

In addition, the quantitative SA cohesion/proficiency scores found were then compared to the scores indicative of Hazard Perception, and the speed of that detection, to see if there were any inter or intra group correlations (as sought by RQ2).

The aim was to recruit, as far as possible, those participants who had volunteered for the previous study. Given that the younger participants tended to be final year research students, there was less scope to achieve this for that grouping. However, for those who did agree to volunteer again, an assessment would be made as to whether SA was (quantitatively) found to be easier to achieve for those participants whilst they actually drove (Study 1) or, in this study, whilst they watched videos of driving (from the driver's perspective).

Finally, the concepts generated by all of the participants in this study were then compared to those from Study 1 to assess for any differences.

It was hypothesised that due to age-related perceptual declines, that the Hazard Perception (HP) scores and the Situation Awareness metrics would be more deficient for the older, than younger, group, and particularly so for the more 'Complex' video journey. And in addition, that higher SA metric scores, whether found for an individual or a group, would be related to higher HP indicator scores.

No hypotheses were made in regards to whether the SA scoring (for those who undertook both studies) would be higher for these video-based tasks, or whether (for all participants) different main concepts would be considered as relevant.

6.2. Method

6.2.1. Design

The study was based on the assumption that a video-based 'driving experience', undertaken by twenty individuals (within two designated age groupings) would be capable of providing sufficient and relevant driving-related information to make group SA network and HP comparisons possible. A pre-test, with two volunteers, provided a satisfactory amount of commentary from the two videod journeys for analysis purposes.

Although a video-based approach offers, for example, the option of having a journey 'frozen' at certain points to have participants answer SA-related questions (as is often undertaken in SA studies), the 'Think aloud' approach was retained as it was felt to provide a more realistic 'driving' experience, and would beneficially allow performance comparisons to be made for those participants who had also undertaken Study 1.

Thus, participants viewed two actual and complete car journeys (links given in 6.2.1.1. below), rather than the computer-based, truncated journeys, often utilised in the literature. They were asked to contemporaneously provide a verbal commentary of what information they were taking in from the different environments encountered, what they might do with it, and what driving actions they might undertake if they were driving the vehicle. The commentaries were recorded by the researcher (who undertook all the trials) via an audio capture device, whilst he simultaneously listened through earphones to ensure that what was being said could be clearly heard.

The narratives were then later transcribed verbatim, after which they were (as with Study 1) run through software capable of extracting a detailed network of the main cognitive and physical concepts that were considered of importance whilst 'driving' the route. And additionally, an individual's or a group's Situation Awareness related scores from how proficiently the concepts that comprised a driver's or group's network were interrelated.

The study sought to provide a realistic driving experience from the driver's viewpoint, by using video footage of actual car journeys. The footage was run from a pc in a quiet room, and comprised of two formats (see 6.2.1.1. and 6.2.1.2. below). The approach provided a realistic basis for safely extracting the level of detail needed to produce a comparison of the SA of different driver age-groups, when encountering both 'straightforward' (non-taxing) and more 'complex' (taxing) 'driving' conditions.

6.2.1.1. Commentary for SA measurement

For this first aspect of the study, the participants were told to take a 'drivers' perspective and to provide a verbal commentary of what they considered of importance in the video footage of two different journeys. In particular, they were told to bear in mind facets that would enable safe transit of the routes, including where the vehicle might optimally be placed. Given that the older drivers might be less likely to have encountered video footage to consider (whereas all the younger drivers would have due to their driving test), it was decided to always show the easier journey first. This journey, with footage that lasted 7 minutes and 28 seconds, had similar urban driving conditions to that in Study 1, though on this occasion along suburban roads in the outskirts of Poole http://www.youtube.com/watch?v=WhlW782ZJPw.

The second journey, lasting 7 minutes and 50 seconds, was a more 'complex' journey involving a drive through Bristol City Centre http://www.youtube.com/watch?v=MSZ2diCG1ho#t=150. No sound was audible on either footage.

6.2.1.2. Commentary for Hazard Perception measurement

For this second aspect of the study, the participants were (later) judged from their commentaries as to their awareness of either one hazard (present in twelve videos) or two hazards (in three videos), and whether they were detected in a timely manner. Each hazard usually included two elements: the hazard itself - such as a narrow gap between vehicles; and a necessary related action - such as slowing down, or moving to avoid the hazard. Examples included: pedestrians crossing the road; cyclists encountered at high speed; vehicles emerging from parking bays; meeting oncoming vehicles on narrow roads; and animals wandering onto the road.

The clips used were indistinguishable in format from the two, seven minute, journey clips that the participants had previously viewed and also provided commentaries for. However, as they lasted for only one minute, they were felt to be of insufficient length to be transcribed for SA assessment purposes. The clips that were chosen were from 221 examples that had previously been used in the Hazard Perception element of the UK driving test. Their presentation was in the same order, as due to the very different nature of the hazards involved, no practice effect was likely (or found).

As with the first part of the Study, participants were asked to give a verbal commentary (for each video clip), with consideration to safety-related information, including vehicle movement, once again being emphasised by the researcher.

6.2.2. Participants

20 participants undertook the trial (14 male/6 female), ranging in age from 23 to 82 years. They were divided into two groupings: either to one comprising of an age range of 40 years and younger; or to another comprising of an age range of 70 years and older. The older participants (7 male/3 female; average age: 75.5 years) were UK drivers recruited through local retirement clubs - eight of the group had undertaken Study 1. The younger participants (7 male/3 female; average age 25.7 years) were research students and associates at either the Design School or the School of Engineering at Loughborough University - two of this group had undertaken Study 1. They were all compensated £15 for their time and travel.

6.2.2.1. Inclusion criteria

The inclusion criteria stipulated was for potential participants to be regular drivers, have a full UK driving licence, and to be aged either up to 40 years old, or above 70 years old. For Study comparison purposes, preference would be given to those who had participated in Study 1, and who wished to volunteer again.

6.2.2.2. Exclusion criteria

Due to the need for accurate transcriptions, potential participants who had a poor clarity of spoken English were excluded.

6.2.3. Materials

The Study required a PC capable of running 'Leximancer' and 'Agna' software packages and the Hazard Perception Test videos, and a device for recording each participant's 'driving' commentary.

6.2.4. Procedure

Each participant was briefed on how the research was to be conducted and its overall aims. They were then offered an opportunity to read again a copy of the 'Think aloud' instruction sheet (see Appendix 2) that informed them of how to give an appropriate verbal commentary (should that document sent out the day before the trial be unclear or need refreshing in memory). The researcher then re-emphasized the need for the participant to act as s/he would normally do whilst driving, and to provide a constant commentary. The participant was then given an opportunity to ask any questions, and if content, to sign an 'Informed Consent' form (see Appendix 3), after which s/he was asked to adjust their seat so that they could clearly see the pc's screen.

Once comfortable, the participant was notified of the audio recording equipment (which was then set to record) and a one minute trial phase followed. On conclusion, the researcher added further suggestions and guidance, whilst the participant could raise any problems or further questions. Once happy, the participant was then invited to provide commentaries for the two seven-minute video journeys, in quick succession, and then, after a short break, the fifteen one-minute segments of journey footage that contained either one or two identifiable hazards.

6.2.4.1. Commentary and timing aspects

During the data collection phases, the aim was for the researcher to remain silent and simply monitor the audio capture process as the participant commented on the (17) videos.

It was possible, due to each session running for no longer than one hour, for four participants to be tested in one day. The time slots allocated started at: 9.30 am; 11.30 am; 2pm; and 4pm (Monday–Friday).

<u>6.2.5. Data analysis</u>

The verbal commentaries for the two recorded seven minute journeys were transcribed verbatim post-trial, and then subjected to analysis by Leximancer software (Smith, 2003) capable of creating semantic networks (i.e. themes, keywords, key concepts, and the relationships between them) unique to each participant and group. These networks represented the cognitive elements of the 'driving' experience through changing journey environments, and thus provided an insight into an individual's or a group's Situation Awareness. Within each network were nodes of variable size that related to each element's relevance, that is, how frequently it occurred and how it related to other elements within the network – what is termed, its semantic connectivity (Leximancer, 2011).

The application of this technique to verbal commentaries in real-life transport contexts is a relatively new one, but proven as a useful tool for evaluating Situation Awareness in driving research (e.g. Walker, Stanton, & Chowdhury, 2013; Walker et al., 2007; Stanton, et al., 2007; Salmon, Stanton, & Young, 2012; Walker, Stanton, & Salmon, 2011).

6.2.5.1. Network analysis

The raw quantitative data sets that the Leximancer software provides can be entered into a mathematical program (Agna, published by geocities.com) for structural analysis comparisons of particular networks. Two of the measures that the software can produce are of particular relevance for calculating Situation Awareness:

a) Density

A Density score represents the level of interconnectivity within a network, in the sense of how proficient the linkages are between its concepts. For SA assessments, higher levels of interconnectivity are indicative of enhanced, richer, SA, since there are more linkages between the network's concepts, thus aiding information retrieval. Poorer SA is embodied by a lower level of interconnectivity, since the concepts underpinning it are not so well integrated.

b) Diameter

A Diameter score also represents the connections between the concepts in a network, but moreover it reflects the efficiency of the paths across it. Greater diameter values are indicative of more concepts per pathway through the network suggesting poorer SA; whilst lower diameter scores are indicative of better SA, since the holder is able to generate awareness through a better (and faster) linkage across his/her network's concepts.

To identify the unique and common concepts for each group, and the key or main concepts underpinning SA in general, the Leximancer software also makes a sociometric status analysis of each of the networks it produces.

<u>Sociometric status</u>

This analysis identifies a network's key or main SA concepts by providing a measure of how 'busy' a concept is relative to the total number of concepts within the network (Houghton et al., 2006). These concepts are defined as having salience as they act as hubs and are highly connected to other concepts in the network. Typically, concepts with a sociometric status value above the mean value for the network as a whole are taken to be key or main concepts.

6.2.5.2. Hazard Perception proficiency

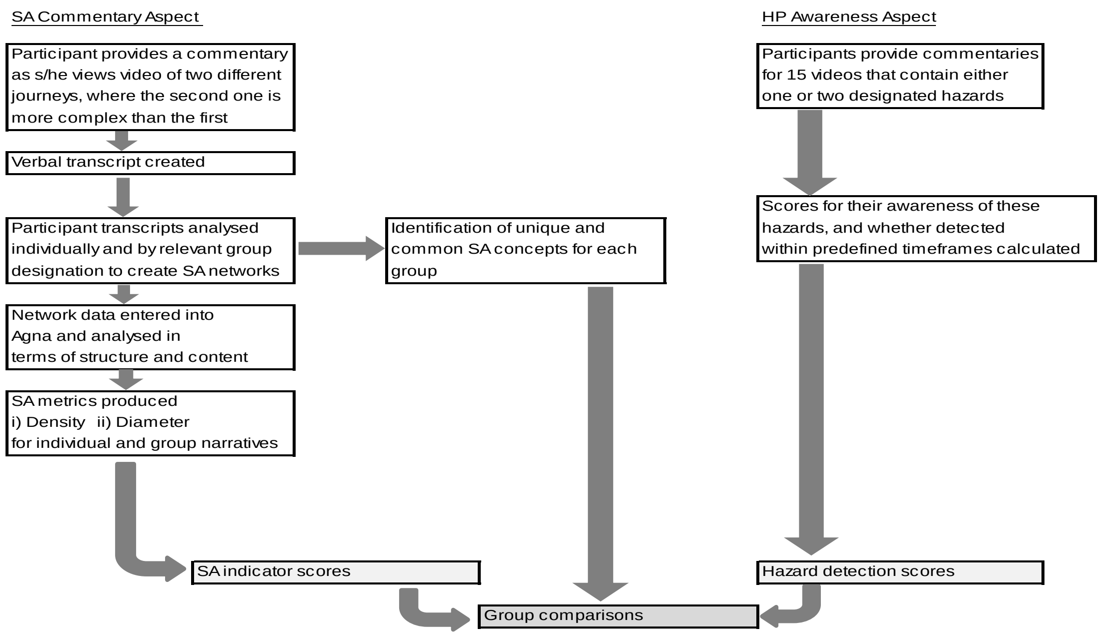
The fifteen hazard clips used in the Study were of similar difficulty, chosen from 221 available examples at random, and presented in the same order to each participant. By chance, the first three contained two hazards, the following twelve, one hazard. As mentioned in the 'Design' section above (6.2.1.2.), each hazard usually had two elements: the hazard itself, and a related action. The more elements a participant spoke about, the higher hazard identification score s/he (later) obtained. The scoring system was 0.5 pts for detecting the hazard, and 0.5 pts for mentioning the appropriate driving action(s). So if the required action for a hazard involved both moving and slowing down, then 0.25 pts would be given for each of these elements, whereas if, say, only slowing or moving was required, then the full 0.5 pts would be given for that detection. In addition, a further 1 point would be awarded for mentioning the hazard 'in time'. If only the related movement associated with a hazard was mentioned, then 0.5 pts would be awarded.

When a video was later being reviewed, the researcher was able to see a time bar beneath each clip. On starting each one, an indicator traversed this time bar and at different times, dependent on the hazard, it passed through a time period of varying lengths that prescribed when a hazard should be detected. If a participant began mentioning the appropriate hazard, or the related movement cues, during this time period, then s/he was awarded 1/0.5 pts as appropriate.

6.2.6. Summary of the approach to data capture

Figure 6.1 below summarises the stages involved in capturing and comparing the data for this study.

Figure 6.1: Study 2 data analysis stages



6.3. Results

6.3.1. Quantitative data

6.3.1.1. Group SA scores and other comparative data

As was discussed in Chapter 4 (Study 1), previous SA studies have tended to evaluate older and younger performance on a group score basis. If the approach taken to produce that measure combines the 'Standard' and 'Complex' journey texts into one narrative for each participant. And these are then further combined and processed as one complete narrative for each group, then the younger 'drivers' once again produce the better SA performance. However, if the narratives for the two journeys are (similarily evaluated) separately, then the older drivers are found to perform better on both, and particularly on the more 'complex' variant (see Table 6.A).

Table 6.A: Group-based SA scores

SA assessment scores (Diameter/Density)				Other Data			Study 1 scores
Group	Standard Journey	Complex Journey	Journeys combined	Av. Age yrs.	PPt's in S1	Gender	
Older	2/0.7610	2/0.7956	2/0.8427	75.5	8 of 10	7M/3F	2/0.7417
Younger	2/0.7578	2/0.7586	2/0.8597	25.7	2 of 10	7M/3F	2/0.8238
Av. Words	742	860	1602				2649

*Note: lower Diameter scores and higher Density scores equate to better SA

If the groups are evaluated by averaging the individual SA scores from each of its participants, however, then the older group's advantage becomes more pronounced. This is particularly the case when the two journey's narratives are combined as one (see Table 6.B/6.C). In addition, the majority of these SA scores are higher in proficiency than was found for the driving study (1), suggesting that perhaps for the older group in particular, the video-based task might have been easier for them to undertake.

Table 6.B: Average of individual network scores

SA assessment scores				Study 1 scores
Group	Standard Journey	Complex Journey	Journeys combined	
Older	2.8/0.4310	3/0.4386	2.4/0.5563	3.1/0.3819
Younger	3.1/0.3789	3.4/0.3743	2.7/0.4633	3.2/0.3874

Table 6.C: SA group differences (by t-test) based on individual Density scores

SA Density measure of:	p<*
Standard Journey	0.209
Complex Journey	0.237
Journeys combined	0.062

** all differences in favour of the older group*

To consider the three variants given in Table 6.C in more detail, firstly, in the 'Standard' journey, the SA scores between the two groups were not significant, but in less parity than for a similar journey driven (than watched) in Study 1. This despite Study 1 producing significantly longer narratives (2649/742 – Table 6.A), which perhaps accounted for its wider range of SA Density scoring to that found from this study's shorter time trials. There were, however, some similarities in the scoring distribution by rank between the two studies, with again the younger participants occupying the top two, and much of the lower ranking positions.

In regards to the second, 'Complex' journey, variant, however, the older group showed a more pronounced and wider range of scoring to the younger group. This despite a lesser average word count difference between the two groups here, in comparison to the 'Standard' journey. However, overall, the group differences in SA Density score were still similar to the 'Standard' journey.

Finally, and thirdly, when the journeys were combined, raising the average word count to 1602, the older driver's SA Density group scores were found to be appreciably higher when compared by the individual scores (see Table 6.C) and close to being significant. This reversed the finding for when the group's narratives were considered as one text (Table 6.A).

It is worth noting that the SA Diameter scores were not similarly compared statistically, due to insufficient group differentiation from the length of narrative produced.

6.3.1.2. Hazard Perception Scores

In terms of Hazard Perception, it was found that the younger participants out-performed their older counterparts in overall scoring, with around two thirds of that difference being attributable to the older group identifying the appropriate hazard outside of the allotted timeframe (see Table 6.D below).

Table 6.D: Group Hazard Perception Test scores and t-test significance

Hazard Perception (overall point scores)			
Group	Identification of hazard	Within allotted timeframe	Total score
Older	87	78	165
Younger	96	99.5	195.5
p<	0.394	0.083	0.138

In terms of how pronounced these scores were between the two groups, the 'speed of detection' comparison shows a difference that fell just short of being statistically significant, despite what was a small sample.

6.3.1.3. Does better SA lead to better Hazard Perception?

If the SA of both of the journeys that these twenty participants undertook are compared to their overall Hazard Perception (HP) point scores, then no argument can be made for SA assisting the identification of a dynamic road hazard (see Table 6.E). However, if the speed element is discounted and the SA scores are compared only to the detection of a hazard, whether or not it was spotted within the designated time frame, then a relationship very close to significance is found.

A further investigation of the factors of age, and the influence of the speed of hazard detection, found further interesting and unexpected results.

In regards to the older group, the SA scores appeared to have no relationship with hazard identification. If the speed aspect of the Hazard Perception Task is taken out, however, then more of a relationship emerges, with the higher SA scorers then being found to detect the most hazards. But this was not a statistically significant relationship.

If the younger group is assessed in a similar fashion, however, then a relationship between the SA and Hazard Perception scores does emerge, and significantly so. Furthermore, the four members of this group that had relatively higher SA scores, were also the individuals who consistently recorded the best HP total scores over three separate assessments. If the speed element is once again taken out, then this correlation becomes slightly more pronounced.

Table 6.E: SA to Hazard Perception: (t-test) comparisons

SA (Density score - from combined journey) to HP score (with or without (w/o) speed element)	Statistical Significance (p<)
SA to Total HP score (all participants)	0.450
SA to HP score w/o speed element (all participants)	0.060
SA to Total HP score (Older Group)	0.936
SA to HP score w/o speed element (Older Group)	0.360
SA to Total HP score (Younger Group)	0.008
SA to HP score w/o speed element (Younger Group)	0.005

It should be noted that whilst the combined journey's SA Density score is probably the best indicator of an individual's SA for this study, it was also found that the SA Density scores for the 'complex' journey in isolation, and an alternative SA measure for when the journeys are combined (averaging participant scores from the two individual journeys) also showed an SA/HP relationship for the younger group (Table 6.F).

Table 6.F: Further SA to Hazard Perception (t-test) comparisons for the Younger group

SA calculation basis	Measure	Statistical Significance (p<)
Average of individual scores (both journeys)	**SA to HP total score**	0.036
	SA to HP score w/o speed element	0.027
Standard Journey (only)	**SA to HP total score**	0.146
	SA to HP score w/o speed element	0.106
Complex Journey (only)	**SA to HP total score**	0.035
	SA to HP score w/o speed element	0.034

6.3.1.4. Is SA easier to produce whilst driving or when watching a video of a driven journey?

For those participants who undertook both Study 1 & 2, the video tasks of Study 2 produced significantly better SA Density scoring ($p<0.015$) than when driving (in Study 1) (see Table 6.G). In fact, all but one participant scored higher on the video task. It should be noted that the SA scores for Diameter were, again, not similarly calculated for significance as they were not discrete enough between the two groups.

Table 6.G: Average SA score comparison (by t-test) for those undertaking both studies

SA score comparison for both studies		
Study	Diameter	Density
1 (Driving-based)	3	0.4173
2 (Video-based)	2.4	0.5585
p<	Not calculated.	0.015

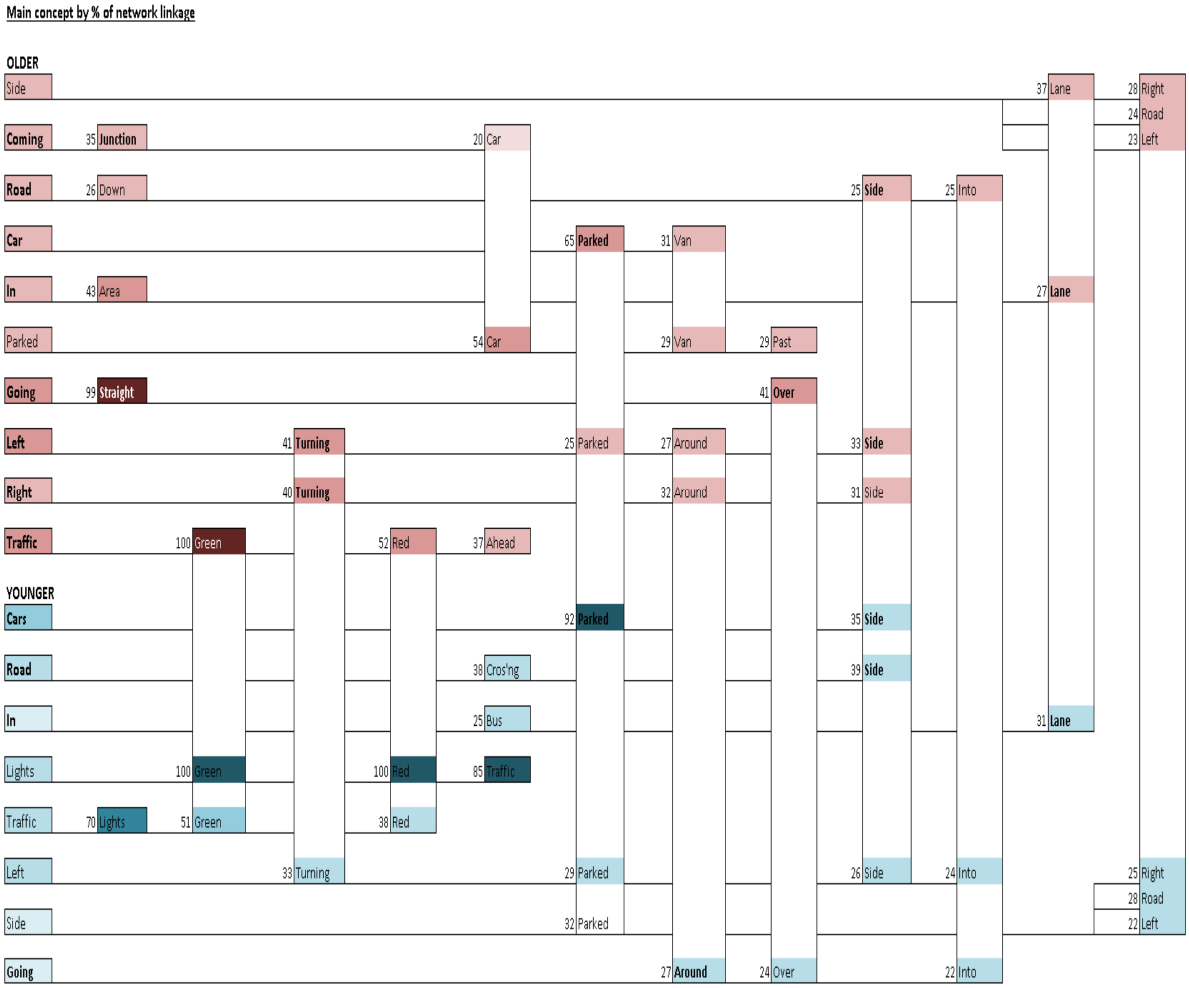
Overall then, it would seem that the video tasks were appreciably easier to produce scores indicative of cohesive Situation Awareness than when driving. This could have been due to a practice effect, but this is doubtful. Setting aside the fact that some months had passed since Study 1, each participant retained his/her style of commentary (reflected in word count), and tended to stay consistently around the same SA score ranking for both studies - nine out of the ten moved no more than two places up or down. The one exception was an older driver who rose five rankings from 9th in Study 1 to 4th in Study 2. This participant, who had the most pronounced increase in SA Density score from Study 1 (up. 0.2237), was also the stand-out performer in the Hazard Perception element of the study for the older group. He was ranked 3rd for hazard detection and 7th for speed of detection, which placed him 5th overall out of the twenty participants. Thus for this most improved participant, at least, better Situation Awareness appeared to assist with Hazard Perception.

6.3.2. Qualitative data

6.3.2.1. Main and related concepts and words

In Figure 6.2 below, the main and related concepts that were important for the two participant groups from their narratives are recorded with the relevant percentage between each being given. (Once again an example narrative is provided as an appendix). The main concepts in Study 1 that retained their importance for a group in this study are in bold type. The darker the background shading the greater the word count (for the main concepts); or the interrelation (between more general concepts and a main concept).

Figure 6.2: Main concept comparisons and concept linkages



**major concepts are those above a 50% relevance for the network and with over a 150 word count*

Although, overall, the key concepts for both groups were more similar in this study, than for Study 1, there were some interesting differences.

a) Older Group

For the older group, the main (eight) concepts that were important for Study 1 were again represented here, but their relative importance did change. The 'Going' concept rose in prominence, and had a particularly strong relationship with 'Straight', whereas the 'Coming' concept fell in importance, with its formally strong relationship with 'Towards' disappearing altogether. The 'Traffic' concept became far more evident, but became more related to 'Lights' than in Study 1, with actual indicator colours now rising to relevance. The 'Car' concept also fell in its ranked importance, as did its direct relationship to 'Parked' car(s), with the focus, in this respect, moving from 'Right' in Study 1, to 'Left' with the video footage. 'Van'(s) also appeared to have relevance for the older group here, which was not evident in the driving study.

In terms of the related words to the main concepts (see Table 6.H, below) there was again more awareness of the colour of traffic lights in this study, and a change in the relationship with the 'Going/Go' concept to more movement (e.g., 'Slowly') than direction-related words (e.g., 'North'). There was also seemingly more awareness within the group of road type (Major, Minor, Secondary), and of more specific cues, such as 'Police', 'Pub', 'Van', 'Car', 'Mirror', 'Silver', and 'Youth'.

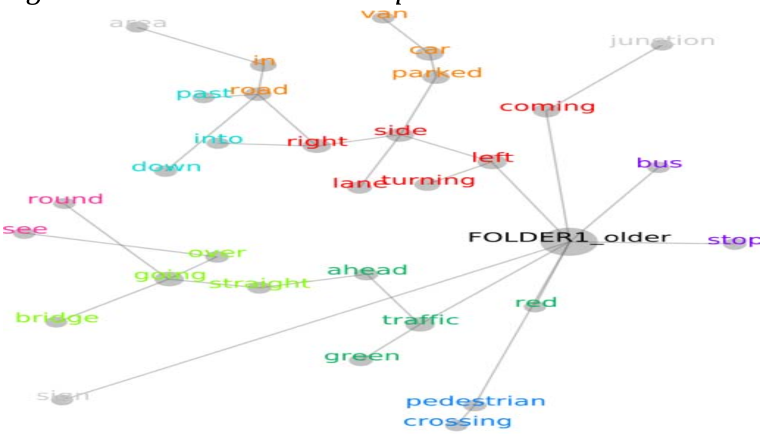
Table 6.H: The concepts and words related to the main concepts given by older drivers

Rk.	Main Concepts & word count	S1	Main related concepts	S1	Main related words	S1
1	Traffic (365)	8	Green (100%); Red (52%); Ahead (37%)	Lights, Warning	Lights (6.58); Green (5.7); Light (4.49)	Ahead
2	Left (340)	7	Turning (41%); Side (33%); Around (27%); Parked (25%)	Hand, Side, Turning	Pub (4.05); Swinging (3.91)	Bearing, Entry
3	Going/go (332)	6	Straight (99%); Over (41%); Past (40%)	Straight, Over	Slowly (4.28); Ready, Underneath (3.58)	North, Slipway
4	Right (268)	2	Turning (40%); Around (32%); Side (31%)	Hand, Turning, Lane	Bear, Course (3.23)	Turning
5	Coming (257)	1	Junction (35%); Car (20%)	Toward, R'bout, Junct'n	Towards (6.01); Watching, Youth (3.31)	Towards
6	Road (248)	5	Down (26%); Into (25%); Side (31%)	Side	Major (4.36); Minor, Secondary, Travelling (3.14)	Main, Slip, Windy
7	Car (246)	4	Parked (65%); Van (31%)	Parked, Side, Towards	Silver (3.64); Police (3.42)	Parked
8	Side (236)		Lane (37%); Right (28%), Road (24%); Left (23%)		Hand (5.48); Wrong (3.53)	
9	In (210)	3	Area (43%); Lane (27%)	Lane	Built-up (3.67); Fact, Mirror (3.44)	Front, Case, Fact
10	Parked (206)		Car (54%); Van, Past (29%)			

*Main concepts are those with over 50% network influence and appear in the texts on over 200 occasions

In regards to the network of all the significant concepts provided by this group (Figure 6.3), there seems to be a more in-depth awareness here than in Study 1, with, again, more mention of specific aspects of a road environment, such as 'Pedestrian' and 'Crossing', 'Red' traffic signals, and also 'Bus' 'Van' and 'Bridge'. These concepts are, however, somewhat peripheral in the network. The 'Traffic' and 'Left' concepts, in contrast, appear to have more centrality and therefore of more importance, as do the 'Side' and 'Going' concepts, which have more linkages within the network.

Figure 6.3: Older driver concept network



b) Younger Group

The younger Group, which was less homogenous between the two studies, produced more new main concepts (4), though with less associated word counts than the older group (see Table 6.I, below). However, that appeared to be due more to the change of task than the group's composition (see, Discussion, below). The most prominent new main concepts were 'Traffic' and a related 'Lights' concept, which in combination were potentially as influential as the 'Traffic' concept was for the older participants. Also of interest was more apparent awareness of 'Red' signals by this group, and the inclusion of a new 'Side' concept related mostly to 'Parked' cars (32%).

The concepts retaining importance from Study 1 were the 'Cars' concept, which again had a strong link to 'Parked' (as it did for the older group, though to a lesser degree) and 'In' to 'Lane' (also found with the older group though with a different emphasis ('In' to 'Area')). The 'Going' and 'Road' concepts swapped ranked position between the two studies, though retained similar main concept linkages.

In terms of the words related to these main concepts, there was again an awareness of traffic 'Light' colours, but here, additionally, the 'Amber' light and the fact that some lights were 'Temporary' (this was also found for the 'Traffic' concept). With the exception of the important 'Cars' concept, the other three concepts that were retained as main concepts for this study had a change in word emphasis. The 'Going' concept now appearing to be more specifically related to speed; the 'Road' concept more reflective of configuration and position than merely (road) type; and the 'In' concept, referring to ‘Bus’ ‘Lane’ than merely ‘In’ ‘Lane’ as in Study 1. In general, like the older group, there were more specific words given, such as ‘Estate’, ‘Police’, ‘Bays’ and traffic signal colours.

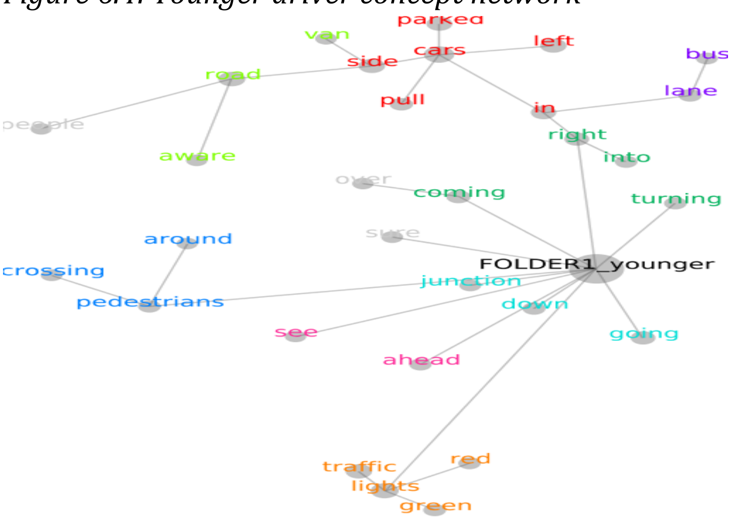
Table 6.I: The concepts and words related to the main concepts given by younger drivers

Rk.	Main Concepts & word count	S1	Main related concepts	S1	Main related words	S1
1	Cars (339)	2	Parked (92%); Side (35%)	Parked, Behind, Side, Coming	Parked (4.82); Police (4.23)	Parked, Front
2	Lights (256)		Green, Red (100%); Traffic (85%)		Green (5.15); Red (4.99); Amber, Temporary (2.89)	
3	Road (248)	6	Side (39%); Crossing (38%)	Side	Wide (4.74); Middle (4.14)	Slip
4	Traffic (211)		Lights (70%); Green (51%); Red (38%)		Lights (6.55); Temporary (3.14)	
5	Left (207)		Turning (33%); Parked (29%); Side (26%); Into (24%)		Estate, Smaller (3.37)	
6	Going (178)	3	Around (27%); Over (24%); Into (22%)	Around	Straight (4.29); Slower (3.53); Fast, Room (3.32)	Go, Orange
7	Side (175)		Parked (32%); Road (28%); Right (25%); Left (22%)		Hand (5.95); Anyone (3.06)	
8	In (172)	4	Lane (31%); Bus (25%)	Lane	Front (5.29); Bays, Case (3.31)	Front Case

*Main concepts are those with over 50% network influence and appear in the texts on over 170 occasions

The network map for the younger drivers (Figure 6.4) indicates, like Table 6.I above, the importance of the ‘Cars’ concept with many linkages to related concepts that additionally now include ‘Pull’ ‘Left’ and ‘In’. Also the ‘Lights’ concept looks a prominent cluster with its linkages to ‘Traffic’ and traffic light colours, whereas the ‘Road’ concept appears of less importance. Like the older group there is an awareness linkage between the ‘Pedestrians’ and ‘Crossing’ concepts, though, additionally here, also to those who may be ‘Around’.

Figure 6.4: Younger driver concept network



6.3.3. Combined Group data

The differences between the narratives given by the older and younger participants were also assessed to reveal the most distinguishing main concepts for each group. In Table 6.J (below) the software has combined the frequency of a concept (based on its word count) with a 'strength' percentage (which reflects the extent it uniquely applies to one group over another). These two category scores are then combined to produce a Prominence score.

Table 6.J: Main concepts by a Prominence score for both groups

	Relative Prominence of main concepts for both groups							
	Older Group				Younger Group			
Concept	**Rk.**	**Freq.↑**	**Strength↑**	**Prom.↑**	**Rk.**	**Freq.↓**	**Strength↓**	**Prom.↓**
Turning	11	6	69	1.2	16			
Coming	5	9	65	1.2	11	6	34	0.8
Going	3	11	65	1.2	6	8	34	0.8
Right	4	9	64	1.2	10	6	35	0.8
Left	2	12	62	1.1	5	9	37	0.9
Side	8	8	57	1.0	7	8	42	1.0
Lane	12	4	56	1.0	12	4	43	1.0
Traffic	1	12	56	1.0	4	12	43	1.0
In	9	8	56	1.0	8	8	43	1.0
Road	6	9	51	0.9	3	11	48	1.1
Cars	7	11	47	0.8	1	16	52	1.2

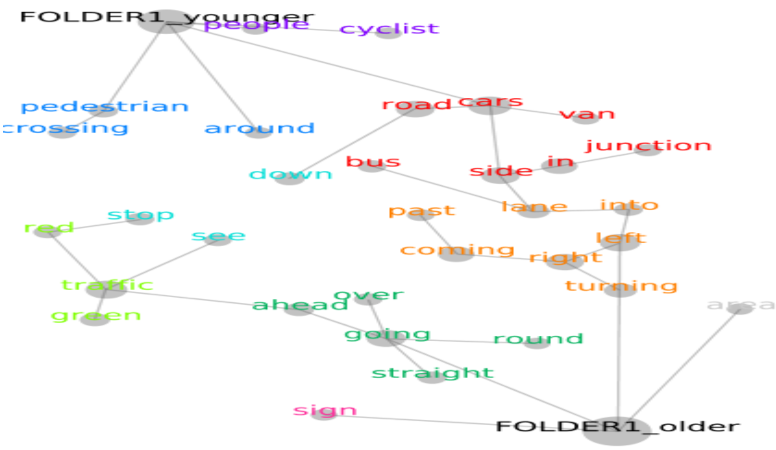
As can be seen in Table 6.J, a distinguishing main concept for the older group is 'Turning' – as in the act of turning 'Into', or 'Left' and 'Right'. The low frequency of its use within the text (6%) perhaps excludes it as a main group concept, but due to its relative 'strength' within the network for the older participants it then emerges as a distinguishing concept when the two groups are directly compared (i.e. mentioned 69% to 31% in favour of the older group). Figure 6.2 appears to confirm this 2:1 ratio, as both the 'Left' and 'Right' main concepts for the older participants (but only 'Left' for the younger participants) links to the 'Turning' concept. Four other concepts: 'Coming', 'Going', 'Right', and 'Left', all of which were main concepts for the older group (Table 6.H), also show some uniqueness here, whereas the important 'Traffic' concept has little distinguishing value due to it being mentioned to a similar frequency (12%) to that of the younger group.

The younger participants, in contrast, generally produced fewer outstanding distinguishing concepts for this study, with additionally the 'Lights' concept, that was a main concept for the group, surprisingly omitted from Table 6.J. It can be speculated that when all the narratives were combined this concept perhaps became related to the 'Traffic' concept and thus lost the individuality it had demonstrated in Table 6.I(?). The 'Cars' concept, with a 52% strength score is thus, perhaps as a result, the only concept for the Group to gain a 1.2 rating, due to its high text frequency (16%). This gives it a Prominence scoring that matches the top four distinguishing concepts for the older group, though it is not as distinctive in the text (as shown by the 'strength' scores).

Finally, Figure 6.5 again shows the relevance of particular concepts to each of the two groups in a network format. Here it can be seen that whereas 'Cars' maybe an important main concept for the younger group (see Figure 6.2 and Table 6.I, above), it is not as unique to the group as 'People' and 'Cyclist'. For the older group, 'Turning' remains a distinguishing concept, and also 'Going', but it can now be seen that in addition, 'Area' and 'Sign' are particularly relevant to this group. These concepts can potentially, though, be mentioned to very different degrees, for example a contrast can be made between the word counts for 'Turning' (252) and 'Going' (178), with those for 'Area' (60) and 'Sign' (72).

It should also again be noted that the position of the concepts in these networks can change with each iteration of data processing. Thus their usefulness and accuracy, unlike the quantitative data from which they are based, can often depend on a number of iterations being undertaken before a stable visual representation can be concluded. This limitation was touched upon in the previous chapter, and it is mentioned again in the Discussion section below.

Figure 6.5: All concept relevance to each group in network format



6.4. Discussion

<u>**6.4.1. Quantitative data**</u>

6.4.1.1. Group SA scores and other comparative data

In regards to the group scores, an issue is firstly again raised here, as it was for Study 1, over which score best reflects its SA, and this is particularly relevant here as the two different methods of calculation have led to different results. Although a narrative does not have to be long to be analysed and calculated as containing cohesively good or poorly structured information, it nevertheless seems reasonable to conclude that the more text it has, the more confident we can be that it accurately reflects SA proficiency. In the Group scores far more text is produced for evaluation, as its member's narratives are combined as one. Thus when the texts from the 'Standard' and Complex' journeys are considered in this way, twenty narratives, two from each participant, inform a group's score. An assumption is made here, of course, that the two journeys can be combined, but this would seem reasonable, as on a single car journey it will often be the case that a driver will encounter both the individual journey environments that were experienced in the videos. Also, both journeys were advantageously administered consecutively after a very short break, making the likelihood that they constituted one journey more plausible.

As was shown in Table 6.A, the younger group, by this group-based approach, exhibited the better SA. However, for the two individual journeys: one 'Standard'; one 'Complex', which combined ten narratives for each group, the SA cohesion for each group falls, despite the texts potentially being more homogenous, with the older group being found to exhibit the better SA scores for both journeys.

When SA is calculated, though, by averaging the individual narrative scores (Table 6.B), a further pronounced scoring difference is found in favour of the older group for both of the individual journeys, and even more so when they are combined: much in contrast to the group-based score. The older group, then, is shown to be better able to cohesively manage the information that it is taking in from the video environments, and more able to do so than when actually driving (a conclusion corroborated by the SA scores of those participants who undertook both studies).

Three aspects, however, are worthy of note here. Firstly, for a statistical comparison, SA scores have to be based on individual narrative scores alone, not 10 or 20 combined as in the group-based assessments. This could allow for more volatility in scoring, and potentially in favour of the older group - as they produced 26.57% more average text. Secondly, the video task may have been much easier for the older drivers to undertake, as they may have had to make a greater and more debilitating cognitive effort whilst driving, relative to a younger group. Thirdly, as was demonstrated in Study 1, at the individual level of analysis, removing just one outlying score can make a considerable overall comparative difference. For example, in the combined journey analysis one participant in particular out-performed the other nineteen. If his data is excluded, the SA Density averages for the two groups then moves more into parity (Older Group, 0.4772; Younger Group 0.4633).

The merit of the first two of these contentions can be considered further by the additional evidence discussed below. However, in terms of the individual quantitative data given here it should be noted that the participant performance differences between Study 1 & 2 appear to provide support for the second of these contentions (ease of task). For example, the worst performer's SA score for the combined journey video-based comparison, would still have enabled him/her to be placed 10th in Study 1's driving task. Additionally, whereas some older drivers reached SA Density scores above what they could achieve in the driving trial, the younger drivers (although not performing as well on this video-based study) still did not record scores below that of 40% of their counterparts in the driving study. This potential difference in difficulty was also quantified statistically and will be discussed further, below, when looking at data from those participants who had undertaken both of the studies.

6.4.1.2. Hazard Perception Scores

In terms of the Hazard Perception scores, it should be noted that although the younger participants identified more hazards (53% to 48%), there was not a great deal of difference in scoring here between the two groups (5%). However, this widens to a point just short of statistical significance ($p<0.083$), when consideration is given as to whether a hazard was recognised 'in time' (55% to 43%). The combination of these two elements produces an overall 54% to 45% score in favour of the younger group.
It was the case, of course, that the participants were not alerted to the advent of a hazard in this study. If they were, one could envisage that, on average, the younger group would make up the 4% they would need to pass this element of the UK Driving Test (58%). However, as speed of detection is crucial to good scoring here, it does seem questionable as to whether the older drivers would likewise be able to make up the 13% that they, on average, would need to pass.

This could represent a potential bias against an older driving test candidate, as generally the older drivers in this study were more likely to say that they would drive far slower than the speeds they encountered in the videos. Thus if the videos were slowed, perhaps they may have been able to produce scores more commensurate with their younger counterparts? It can be assumed, of course, that the drivers in the Hazard Perception example videos were driving to appropriate speed limits, but the speeds did indeed seem a little excessive at times, particularly along narrow country roads, and this was also commented on by a couple of the younger drivers.

6.4.1.3. Does better SA lead to better Hazard Perception?

In view of the possibility that the driving speed of the vehicles may have placed the older drivers at a disadvantage to the younger group, two hazard perception indicators were measured against what was considered the best measure of SA here – a score from combining the text of the two video-based journeys.

As a result, six measures are gained (see Table 6.E). Firstly, if consideration is given to the two produced for the older group, then, in both cases, an individual's Situation Awareness proficiency did not appear to help with the detection of a hazard. The reason for this finding is unclear. But again, account has to be taken of the driving speeds in the videos, which may simply have not given the older drivers sufficient time to process hazard-relevant information, and thus negating any advantageous SA proficiency. Secondly, there are two measures that consider all of the participant's SA and HP scores. Here again, there is no correlation between the overall totals, but with the speed element taken out, a statistically significant relationship is very nearly achieved. This may be much due to, thirdly, an interesting and statistically strong relationship being found between the younger group's SA and their Hazard Perception scores, with or without the speed element taken into consideration ($p<0.005$/$p<0.008$).

To corroborate this last finding, an alternative method of evaluating the 'Combined journey' score was made by averaging the SA scores from the two individual journeys for each of the younger participants. This necessarily led to lower overall SA Density scores, but these still had a statistically significant relationship to those indicative of Hazard Perception. This was also found to be the case for the individual 'Complex', but not for the 'Standard', journey - although that too was close to significance when the speed element was removed (see Table 6.F).

In terms of SA and HP capability, then, it appears that SA (however calculated for a group) may be of more relevance for younger than older driver performance. It may be possible that due to declinations in perceptual processing capability with age, that some of the older drivers were unable to detect certain hazards, and more often, not within safe reaction times due to the 'excessive' speeds in the videos. Perhaps such deficiencies reach points that even good SA cannot compensate for? Or that by trying to proficiently process a volume of information that s/he cannot cope with, the older driver was more likely to miss specific data and to comprehend environments in a more simplified form? As younger drivers, in contrast, do not have the encumbrance of slower or wider variances in processing speeds, maybe their Situation Awareness levels are thus a more reliable indicator of Hazard Perception performance?

If the SA/HP proficiency relationship found in this study is confirmed for younger drivers, then potentially by training them to improve their SA may also improve their Hazard Perception as a result. There is evidence that SA can be improved with training (Stanton et al., 2007; Soliman & Mathna, 2009; Walker et al., 2009), as can Hazard Perception (Horswill & McKenna, 2004), but not, as yet, Hazard Perception through enhancing SA proficiency.

With older drivers, on the basis of these results at least, attempts to improve their SA may not result in better Hazard Perception. However, it should be borne in mind that this group would not have encountered video footage of hazards before, whereas all of the younger group would have done so from having taken their driving tests after 2002. It could therefore be that with more practice, and with tailored slower speeds, that the older drivers might be able to improve their HP scores sufficient to bring them more into line with their higher SA scores for this study.

6.4.1.4. Is SA easier to produce whilst driving (Study 1) or when watching a video of a driven journey (Study 2)?

An indication can be gained as to which of these two tasks were the easier to undertake from the individual SA scores recorded for the two studies. What these reveal, in particular, is a more rapid decline in scoring by rank in the driving study (1), particularly by the middle ranked scorers. In relation to the Combined journey video-based SA scores, an initial similarity in scoring at the higher end rankings is then marked by a rapid comparative fall in the driving study from rank 6 to 10, followed by a similar degree of decline to the present study from rank 11 to 20.

Also, a comparison between just the ten participants who undertook both of the studies shows that in all but one case a higher score was recorded for the video-based assessments of this study. This was sufficient to make the difference between the two tasks significant at $p<0.015$.

It would appear, then, that it is easier to produce better Situation Awareness when looking at a video of a journey (from the driver's perspective) than when actually driving a similar journey yourself. This could be due to a reduction in mental workload, from removing the physical driving element involved in Study 1. This could also explain, at least in part, the better SA performances amongst (in particular) the older group. This, though, in turn, raises an important question over the usefulness of video, and potentially also simulator-based assessments of driver capability, given the pronounced differences here to the SA scores derived from actual driving in Study 1.

6.4.1.5. Task difference between the 'Standard' and 'Complex' video journeys

In regards to the two individual videoed journeys, these surprisingly produced more similarity in scoring, which was more challenging to explain - particularly as both were considered by all participants as being different in activity and difficulty. After viewing both video journeys, all participants were asked whether the videos differed in their difficulty to produce a commentary, and if so why. They all indicated that the second 'Complex' journey to be the more difficult as it had more 'going on' and thus often had more to comment on than could be achieved in the available time.

It could be that for both journeys, that ran quickly in succession, a too consistent approach to commentary was thereby taken, which, together with lesser overall text being produced, simply pulled the scores into parity. It may also be that the lack of dangerous consequences for missing important information could have aided this proposed consistency in commentary, which may also have fostered more similar information being processed by the groups for the two journeys?

6.4.2. Qualitative data

6.4.2.1. Main and related concepts and words

a) Older Group

In terms of the main concepts identified for this group, it was found that all eight of those given by the older participants in the previous study were again deemed to be of relevance here. This may in part be due to the retention of eight of the ten participants for this group from Study 1. Of these main concepts, 'Traffic' was found to be the most important, though with an increasing interrelation with 'Lights' than previously, and with more mention of their colours. Much of the data also showed an importance for movement cues for this group, as in 'Going' straight or slowly, and 'Turning' 'Left' and 'Right'. Whereas the direction-based 'Coming' 'Towards' a road artefact, that was very evident in Study 1, disappeared as a relationship at the concept level here, but remained so as a word association.

b) Younger Group

The younger group in contrast had more change in the main concepts that it felt was important, with four of the nine considered of relevance in the last study being retained for this. This might be explained by the group's composition, which was rather different with only two of the participants that also volunteered for Study 1. However, it is more likely to be reflective of the change in task between the two studies. This is proposed as a member of the younger group in Study 1 was far more likely to mention his/her driving actions, such as in regards to gear changes, checking mirrors, and indicating. Additionally, they generally spoke far more about what was occurring behind their vehicles. In this Study, with all the relevant information visible only through the front windscreen, and no actual driving required, this perceptual awareness was no longer relevant. This is perhaps reflected in the loss of important driving and rearward vision-related concepts (notably, 'Down' 'Speed' and 'See'), which were the most prominent and distinguishing concepts from that of the older group in Study 1. Now, like the older group, there was a focus on parked 'Cars', 'Lane', and the 'Side' of the road, and also, though to a lesser degree, with 'Traffic'/'Lights'.

Generally, the new main concepts that became prominent in this study for the younger group were less distinguishing and generally also seen as being of importance by the older group. This lack of distinction might have been augmented by lesser amounts of text, potentially the video study being easier to undertake, or contrary to belief, that the videos actually provided less scope for a commentary. All these factors could also account for the better older driver performance.

6.4.2.2. Network maps

The network maps appear to reflect a better interrelation of concepts for the older than younger group. There is an awareness for the older participants of 'Pedestrian'(s) with 'Crossing', many concepts linked out of 'Right', 'Side, and 'Left', and a cluster around 'Going'. Additionally, specific vehicles are mentioned, such as 'Bus' and 'Van' (only by this group), along with specific actions like 'Stop', and unique road artefacts such as

‘Sign’ and ‘Bridge’. Overall, there is more similarity here with the younger group, than in Study 1.

The younger group’s network, in contrast, appears more spread out with fewer connections but with more distinct clusters. The importance of the ‘Cars’ concept is evident in this regard, with many linkages to related concepts’; also the ‘Lights’ concept looks another prominent cluster, with its linkages reflective of Table 6.I above (‘Traffic’, ‘Green’, ‘Red’). Like the older group there is also a cluster that includes ‘Pedestrians’ and ‘Crossing’, though additionally here with ‘Around’. As for individual concepts, more awareness of ‘People’ is demonstrated, and in line with the previous study, being ‘Sure’ of their actions.

6.4.3. Combined Group data

The older group produced a 26.57% higher average word count (1790.5: 1414.6) than the younger group in this study. In contrast, in Study 1 the average word count difference was 0.45% (2655:2643) in favour of the younger group. Yet despite this group difference in narrative length, a lack of concept distinction was evident here. The software only highlights ‘Turning’ (see Table 6.J), a directional concept for the older group, as being particularly distinguishing (69-30%). However, this had a relatively low frequency in the text, was identical in Prominence score to four other concepts, and was not evaluated as a main concept.

For the younger group the software found no particularly distinguishing concept, which was not found in Study 1, although the ‘Lights’ concept would appear to merit inclusion. Also unlike Study 1, Table 6.J shows that a number of concepts had far higher frequencies in the text. For the older group: ‘Traffic’ (12%); ‘Left’ (12%); ‘Going’ (11%); and ‘Cars’ (11%) can be highlighted. For the younger group: ‘Cars’ (16%); ‘Traffic’ (12%); and ‘Road’ (11%). (In Study 1 the highest frequency of a main concept was 7%). Not surprisingly all these concepts were analysed as being main concepts for each group, but the scores reflect more intra and inter group similarity in word usage.

The combined network (Figure 6.5), however, does provide some distinguishing information for the two groups. Generally, it could be said from looking at this network that there were indications that whereas the older drivers gave more consideration to facets of car movement, such as ‘Going’, ‘Straight’, ‘Turning’, ‘Right’, the younger drivers appeared to take more notice of individual objects in the road environment, such as ‘Pedestrian’, ‘People’, ‘Cyclists’ and ‘Cars’.

However, it should be noted that whereas both the ‘Pedestrian’ and ‘Crossing’ concepts appeared in both of the individual group networks (Figures 6.3 and 6.4) and had similar word counts (i.e. ‘Pedestrian’:104 (older)-94 (younger)/ ‘Crossing’ (67-56), here both are seen as particularly relevant to the younger group.

This is also the case for ‘Cyclist’, which also had a similar word count between the two groups (32 (older) - 41 (younger)), but appeared in neither group’s network. It could be that the ‘Cyclist’ concept was seen as more relevant to the younger group due to its linkage through the ‘People’ concept, which the software calculated as only relevant to the younger participants (0-38).

The limitations of these networks has been discussed previously, however this is not to discount that the younger group may have been more aware of specific roadway information. The main two concepts for this group were, after all, ‘Cars’ (with a 339 word count) and ‘Lights’ (with 256) whereas for the older group it was ‘Traffic’ (365) and ‘Left’ (340), with ‘Cars’ (246), for example, being rated 7th, despite having more scope for a higher word count due to the group’s greater (26.57%) volume of text.

6.4.4. Limitations

As with Study 1, although the participants were regular drivers, they could not be matched for mileage driven per week, or accident history etc. It was felt there was particular value in trying to recruit, as far as possible, those participants who had volunteered for Study 1, and consequently that any such matching should now be abrogated. However, as argued in relation to that study, it was unlikely that this variable confounded the results that were found.

In addition to certain anomalies in regards to the Leximancer software’s visual network representations (alluded to above), limitations with the ‘Think aloud’ methodology again need to be highlighted. Whilst being less obtrusive and easy to understand, the approach once again impacted on the number of participants who could be assessed within a reasonable time period - which was particularly disappointing here as 156 people had volunteered. This was principally due to the need for commentaries to be accurately transcribed, and then formatted as truly as possibly to a participant's enunciation. And having utilised the method for Study 1, there were demonstrable advantages in using it again here for comparison purposes: notwithstanding that this constrained group sizes, and once again limited the study's power for making group generalisations.

Similar issues also apply to the assessments of Hazard Perception, as by using narrative data it took time to gain accurate individual scores. Although the rankings of the participants were virtually the same here over three separate assessments, there were slight variations in scoring sufficient to suggest an advantage for perhaps three judges to record scores independently, with those totals then being averaged.

The amount of text being produced by the two groups may also be worthy of mention here, as an argument could be made that the differences (26.57%) might have impacted on comparisons in SA scoring, both here, and with Study 1. Clearly a reduction in text was very likely for this study due to the shorter journeys being commented on, however it is important to note that word counts differences should not influence SA scoring. This indeed was found, as, for example, a lesser average word count difference (per group) on the 'Complex' (149.8) than 'Standard' journey (225.5), still brought a wider range in SA Density scoring. That said, if viable (as two older participants experienced vertigo during this short study), thirty to forty minutes of video footage would probably have been advantageous for study comparison puposes.

6.5. Conclusion

In this Study, older participants identified fewer hazards, and in a less timely manner, than younger participants. Yet their group SA was found to be as good, and, in fact, better, when assessed by an average of individual scores. Although the younger drivers produced lower SA Density scores, these were found to be related to their Hazard

Perception scoring. This was the case for both a 'Complex' journey, and a 'Complex' and 'Standard' journey in combination.

These findings raise an issue of how relevant SA might be for older driving groups for the detection of hazards. For example, being able to demonstrate a good cohesive awareness from a high degree of information processing may not necessarily help detect a hazard, if, say, too much information is being sought that cannot be processed in a timely fashion. Or alternatively, when the wrong kinds of information are being processed, however cohesively, under perceived time pressure.

Overall, the younger participants were found in this study to give less, but more cohesive, information relative to the older participants at the group level, but not at the individual level. It can be speculated that this shows the younger group exhibiting more similarity in information processing, despite it being a more heterogeneous group, with participants from across Europe, Asia, and the UK. The older group, in contrast, with participants exclusively from the UK, still appeared to have undertaken more idiosyncratic processing at the group level. As with Study 1, there were also indications of the younger participants giving more consideration to specific information. The contrast in the three main concepts given by the younger group ('Cars', 'Lights', 'Road'), to the more general main concepts given by the older group ('Traffic', 'Left', 'Going'), are perhaps indicative of this. However, in general, the gap closed here from Study 1.

Thus, once again, depth of processing may be an important explanatory variable here, particularly in regard to hazard detection. Perhaps by undertaking more shallow processing, the older group was able to produce a more cohesive broader awareness due to having more time to process information than when driving, and with less critical consequences. However, such broader processing, when under more time pressure (due to vehicle speed) did not appear optimal for observing specific dynamic hazards, and when age-related cognitive deficits are also factored in, perhaps this explains the group's poorer relative performance. In contrast, more in-depth but less cohesive processing may have better enabled the younger participants to perform better in this regard. And if so, it would appear possible that if they were trained to undertake better co-ordinated information processing, that not only would their Situation Awareness improve, but also, as a result, their Hazard Perception.

Chapter 7: A study investigating the Situation Awareness of older and younger drivers when driving a route with extended periods of cognitive taxation.

7.1. Introduction

In Study 1 of this series, scores demonstrative of Situation Awareness (SA) whilst driving were found to be very similar between that of an older and younger participant group ($p<0.975$). However, when the narratives on which those scores were based upon were evaluated and compared, the older group was found to have given far fewer safety-related concepts and words, and appeared to be less aware as to what was happening around their vehicles. They also appeared to process information less rigorously - demonstrating a more general, directional-based, awareness, in contrast to a younger driver group's focus on more specific driving actions and roadway artefacts.

An argument was made that if older drivers do undertake more cursory observation, and process, potentially, an insufficient number of safety-related cues, then whilst this may not necessarily impact on them driving safely in less demanding conditions (such as encountered in Study 1), it could if those conditions became more cognitively demanding.

To investigate this further, Study 2 again evaluated an older against a younger driving group. The same 'Think aloud' method was employed, but the commentaries requested were for two car journeys shown on video: the latter of which having particularly high levels of roadway and peripheral activity. It was assumed that the participants, who were asked to imagine themselves as the driver, would find this task more cognitively taxing than Study 1, and that due to age-related processing deficits, that it would impact more on the older group's performance and thus their scores indicative of SA.

The results from the Study were, however, contrary to expectation, with the older driving group demonstrating more Situation Awareness for both journeys, and particularly so when the narratives of both were combined ($p<0.062$). A similar comparative assessment with the commentaries of those participants who had also undertaken Study 1 further found significantly improved SA Density scores ($p<0.015$). Finally, although the two individual video journeys from Study 2 were considered by all participants as being very different in roadway complexity, they nonetheless produced similar group level scores for SA proficiency. To investigate these findings further, a return is made in this final study to actual roadway assessments, to consider whether driving a more 'complex' route to that of Study 1 would similarly show a lack of effect on a participant's SA.

7.1.1. Approach

In order to evaluate the relative difficulty of this Study to those undertaken previously in this series, a preference was given firstly to volunteers who had undertaken Study 2, or both Study 2 and Study 1, and if insufficient, then to those who had just undertaken Study 1. A comparison could then be made between their SA Density scores, and they could be asked, in connection to Study 2, whether the task of providing a commentary whilst driving, or whilst watching a video, was the easier to undertake, and to give their reasons.

7.1.2. Objectives and hypotheses

The principal objective was to capture an appropriate and sufficient commentary from a participant for his/her SA to be assessed. This would be achieved by having him/her drive out and back to Loughborough University, UK, along a more cognitively challenging route than employed for Study 1, and for around the same time period.

This route, however, could not be as 'complex' as the one utilised previously on video. It would not be viable or fair, for example, to expect participants to drive, at distance, to a city centre location on par in complexity with Bristol (used in Study 2), and then return to Loughborough. The closest candidate would be Leicester, over 12 miles away. Moreover, this ethically would not be advisable, as safety could potentially (if not likely) be compromised. What was required was a circular route from the University that would present more challenges to the driver than Study 1, though not place him/her in conditions above what s/he might normally experience (given the additional commentary task). The route chosen was tested and found to be sufficiently taxing for the puposes of investigating RQ3, yet retained sufficient gaps before directional input was needed by the researcher. As such, it was considered safe for giving a commentary, but to support this view, the route, as before, was presented to potential participants some weeks in advance for them to consider for difficulty. No one felt it to be overly taxing (or, for that matter, after driving it whilst providing a commentary).

As with Studies 1 and 2, SA-related proficiency scores, and the constituent concepts and their links within each of the networks that informed them, would be determined from computer software. In addition to intra study comparisons of, once again, older and younger driving groups, some inter study observations were also made with the findings from Studies 1 & 2. However, these are considered in further detail in the following 'Overview and Synthesis' Chapter.

It was hypothesised that due to age-related perceptual declines, that the Situation Awareness metric scores would be more deficient for the older, than younger, driving group, as they would be facing a more difficult journey (than Study 1) and a more demanding overall task (than Study 2). As such, the two groups would also consider different main concepts as being of relevance.

7.2. Method

7.2.1. Design

The study once again adopted a 'Think aloud' (or Verbal Protocol Analysis) approach to data capture. As with Study 1, this required participants to drive their own cars around a pre-defined course. And whilst doing so, to provide a verbal commentary of what information they viewed as relevant from a particular driving environment and how that impacted on their driving actions. These commentaries were recorded via an audio capture device, whilst simultaneously being listened to via earphones by the researcher, to ensure that what was being said could be clearly heard. The same researcher was present for all of the journeys, either driven or watched in this series, and the only person involved in later (verbatim) data transcription. This approach was taken to improve reliability. The narratives produced for the study would, as before, be run through Leximancer software, which is uniquely capable of producing detailed visual networks of the main concepts considered of importance whilst driving the route. Additionally, an individual's or a group's Situation Awareness would again be assessed through Agna software, from how proficiently the concepts that comprised a driver's or group's network were interrelated.

It has been argued previously that this approach provides a better and more realistic basis for extracting the level of detail needed to provide a comprehensive understanding and comparison of the Situation Awareness of different driver age-groups.

7.2.2. Participants

21 participants undertook the trial (12 male/9 female), ranging in age from 23 to 84 years. They were divided into two groups: either to one comprising of an age range of up to 50 years; or to another comprising of an age range of above 70 years.

The older participants (7 male/3 female; average age: 77.2 years) were UK drivers who had undertaken previous studies in this series (all had undertaken Study 2/7 had additionally undertaken Study 1). The younger participants (5 male/6 female; average age: 28.2 years) were research students and associates at the Loughborough Design School and School of Engineering (6 had undertaken Study 2/2 had additionally undertaken Study 1). They were compensated £20 for their time and travel expenses. In deciding on who was to take part, preference was given to the oldest and youngest volunteers.

7.2.2.1. Inclusion criteria

The inclusion criteria stipulated was for potential participants to have a full UK driving licence with no recent major endorsements, be regular drivers, and to be aged either up to 50 years old, or above 70 years old.

7.2.2.2. Exclusion criteria

Due to the need for accurate transcriptions, potential participants who had a poor clarity of spoken English would be excluded.

7.2.3. Materials

The vehicle used to drive the route was provided by the participant. The researcher required a digital device to record the driver's commentary, and latterly a PC capable of running the required software packages.

7.2.3.1 Route

The test route was 11.9 miles in length (following a short warm-up phase of 0.5 miles) running through Leicestershire to Swithland reservoir (see Figure 7.1). It comprised of 2.5 miles along dual carriageway (A6); 2.25 miles along a major 'A' class road (A6004); 3.2 miles through towns (Quorn: 1.5 miles; Mountsorrel 1.7 miles); and 4 miles of countryside driving (including 2.66 miles along single car width roads). The route, which was pre-tested a few days previously for safety, difficulty, and potential delay from roadworks, was found to take about 30 minutes to drive (with 45 minutes then being allocated for each journey), and was to start and end at Loughborough University, UK. However, no data was captured once a driver had exited the roundabout off of the A6 and back onto the A6004 (see red symbol/Figure 7.1). This was because it was felt that sufficient commentary would have been captured by that time, and the roadways from that point had already been commented upon.

Figure 7.1: Route map

All trials took place in good visibility and at pre-defined times (11.40 am, 1.40 pm, or 3.30pm) in order to avoid peak traffic conditions, and to thereby retain some control over traffic density and the time taken to traverse the route. As the weather could not be controlled, it was important to ensure a participant's safety by not allowing any driving in dangerous conditions. Also in this regard, care was taken not to overly distract a driver with instruction and directions.

The route was chosen to present a participant with more challenges than in Study 1 (though within reason for safety). In the SA literature, 'complex' and 'non-complex' routes are assumed from a simple numerical comparison of the (rather artificial) roadway artifacts presented via a pc or simulator. For this study, a more detailed route comparison was made. Table 7.A below, gives some comparative data.

Table 7.A: Study 1 & 3 route difficulty comparisons

Route comparisons	Study 1	Study 3
Roadway artefact		
Traffic/pedestrian lights	16	17
Roundabouts	6	12
Totals	**22**	**29**
Cornering/turning		
Left turns	1	2
Left bends (sharp & blind)	1	13
Left bends (sharp)	0	2
(Of which were 90 degrees)	(0)	(3)
'T' Junction Left turn	3	1
Right turns	4	2
Right bends (sharp & blind)	1	12
Right bends (sharp)	0	3
(Of which 90 degree turns)	(0)	(3)
'T' Junction Right turn	1	2(1 blind)
Totals	**11**	**37**

The aim was to produce more occasions that required the driver to increase his/her cognitive effort. Thus negotiating sharp bends than when driving on straight and open roads was felt of relevance - Taylor et al. (2002), for example, argue that bend density contributes to driving difficulty. This difference, although generally found and recorded in Table 7.A. above, was particularly evident during the 4 miles of countryside driving, which presented a driver with progressively more difficult tight cornering with either blind or restricted views. This element also included roadways, not utilised in Study 1, where there was only enough space for one car to pass (see top left image: Figure 7.2). So the driver on this route had to be more aware of oncoming traffic. Additionally, it is also assumed in the literature that intersections (including traffic lights), and changing lanes and entering traffic flow (such as at roundabouts) constitute more complex driving (e.g. Teh et al., 2014; Ernst & O'Connor, 1988 - see also Fildes et al., 2000). Thus the comparative number of roundabouts encountered and recorded for Table 7.A. was of relevance.

To these aspects it can be added that the drivers were uniquely exposed to a right turn from a 'T' junction with no visibility from the right (Figure 7.2: top right image). Restricted road widths through towns with oncoming vehicles (Figure 7.2: bottom left image), a small angled bridge with room for only one car and no view of oncoming traffic (Figure 7.2: bottom right image), and an entrance onto a dual carriageway with a limited slip lane, making acceleration and lane entry difficult.

Figure 7.2: Examples of blind turns and narrow roads on the route

7.2.4. Procedure

7.2.4.1. Pre-run phase

Firstly, informed (ethical) consent was obtained from all participants before the route was driven (see Appendix 3). At this time, it was also emphasised that control of the vehicle, and the safety of other road users, remained the participants' responsibility at all times, and therefore that they should drive as they normally would do on each roadway. An instruction sheet (see Appendix 1) on how to provide a commentary was then once again offered to the participant (they had initially received this the day before attendance) to re-read.

7.2.4.2. Warm-up phase

The participant then walked the researcher to his/her car, and once comfortable, began the short 0.5 mile journey to the start of the test route through the University's campus. This enabled the (5) new participants to practice their commentaries. For the (16) participants who had undertaken previous studies, this stage was optional.

During this time the researcher checked whether the new participants had a grasp of what was required, and where appropriate, suggested additional input. A check was also made of the recording equipment to ensure that it was adequately capturing the driver's comments. At the end of this phase all participants was asked if they were happy to commence the recorded route, and if so, the data collection phase commenced.

7.2.4.3. Data collection phase

During this (11.9 mile) phase the researcher remained silent and simply monitored the audio capture process. He did, however, give route directions (and whenever possible these were conveyed at times when a participant had taken a pause in his/her commentary), and when necessary (which was very rare), prompt the participant for more commentary.

7.2.4.4. Debriefing stage

A debriefing session, in the participant's car, took place on return to the university, at which point his/her views on the route were taken, and additionally for the participants who had undertaken Study 2, one standard question - whether commenting on this drive was a more difficult task (than doing so for the videos of car journeys in Study 2) and to give their reasoning.

7.2.5. Data analysis

The verbal commentaries that were recorded were transcribed verbatim post-trial, and then subjected to analysis by Leximancer software (Smith, 2003) capable of creating semantic networks (i.e. themes, keywords, key concepts, and the relationships between them) unique to each participant and/or group. These networks were representative of the elements of the study's driving task through its changing journey environments, and thus provided an insight into an individual's or a group's SA. Within each network were nodes of variable size that related to a concept's relevance, that is, how frequently it occurred and how it was related to others within the network – what is termed, its semantic connectivity (Leximancer, 2011).

The application of this technique to verbal commentaries in real-life transport contexts is a relatively new one, but proven as a useful tool for evaluating Situation Awareness in driving research (e.g. Walker, Stanton, & Chowdhury, 2013; Walker et al., 2007; Stanton et al., 2007; Salmon, Stanton, & Young, 2011; Walker, Stanton, & Salmon, 2011).

7.2.5.1. Network analysis

The raw quantitative data sets that the Leximancer software provides can be entered into a mathematical program (Agna, published by geocities.com) for structural analysis comparisons of particular networks. As with previous studies in the series, two of the measures that the software produces were used to calculate Situation Awareness:

a) Density
A Density score represents the level of interconnectivity within a network, in the sense of how proficient the linkages are between its concepts. For SA assessments, higher levels of interconnectivity are indicative of enhanced, richer, SA, since there are more linkages between the network's concepts, thus aiding information retrieval. Poorer SA, in contrast, is embodied by a lower level of network interconnectivity, and since the concepts here will not be as well integrated, this will slow information retrieval.

b) Diameter
A Diameter score also represents the connections between the concepts in a network, but moreover it reflects the efficiency of the paths across it. Greater Diameter values being indicative of more concepts per pathway through the network, suggesting poorer SA; whilst lower Diameter scores indicate better SA, since the holder is able to generate an awareness through less linkages, and therby faster access to relevant concepts across his or her network.

To identify the unique, common, and main concepts underpinning the SA for each group, the Leximancer software also makes a sociometric status analysis of each of the networks it produces.

<u>Sociometric status</u>
This analysis identifies a network's key or main SA concepts by providing a measure of how 'busy' a concept is relative to the total number of concepts within the network (Houghton et al., 2006). These concepts are defined as having salience as they act as hubs and are highly connected to other concepts in the network. Typically, concepts with a sociometric status value above the mean value for the network as a whole are taken to be key or main concepts.

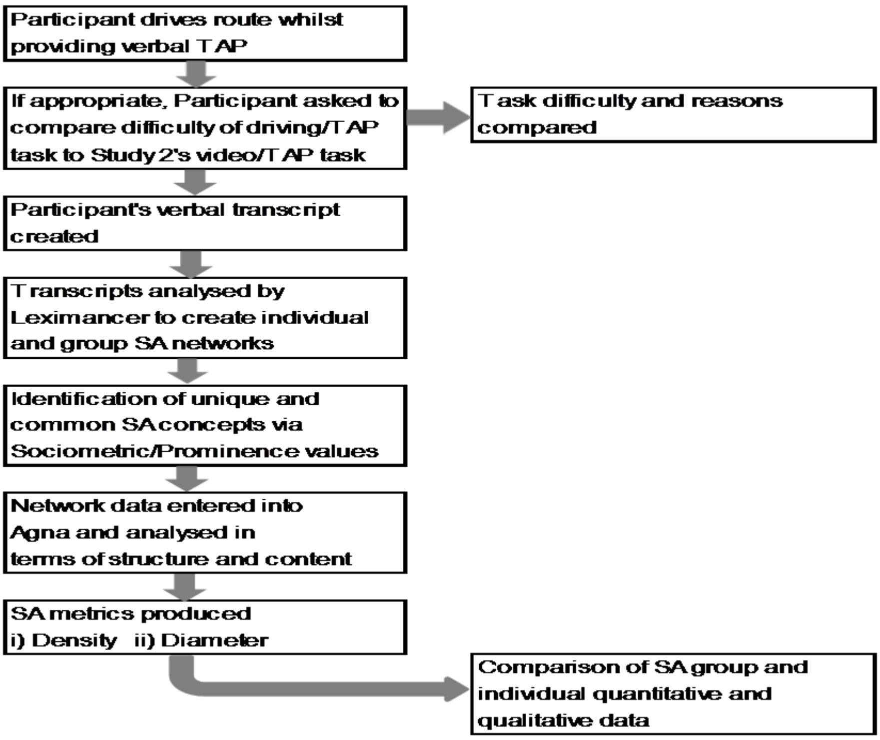
7.2.5.2. Task difficulty

For those who undertook both this and Study 2 (16 participants), the Study that was felt to be the easier to undertake was recorded, and the main reasons given (if any) captured.

7.2.6. Summary of the approach to data capture

Figure 7.3 below summarises the main stages involved in data capture and comparison.

Figure 7.3: Study 3 data analysis stages



7.3. Results

7.3.1. Quantitative data

7.3.1.1. Group SA metric scores and other comparative data

As is generally found in the literature, the younger drivers in this study exhibited the better SA-related scores, and unlike previous studies in this series, this was found to be the case whether their commentaries were collated and assessed as two groups, or from a comparison by their (averaged) individual scores (Table 7.B).

Table 7.B: Group SA metric score comparisons

SA assessments					
Group	Ppts.	By Group score		By Individual scores	
		Diameter	Density	Diameter	Density
Older	10	2	0.7247	2.70	0.4321
Younger	11	2	0.8895	2.55	0.5333

*Note: lower Diameter scores and higher Density scores equate to better SA

Furthermore, the individual SA Density scores were found to be significantly in favour of the younger group ($p<0.024$) from an independent sample t-test (Table 7.C). The Diameter scores could not be likewise assessed due to insufficient differentiation. As can be seen in Table 7.D (below), these scores were always either '2' or '3'.

Table 7.C: SA Density score comparison by independent sample t-test

Group	SA scores		Statistical significance			
	Diameter	Density	T	Ppts.	df.	Sig.
Older	2.8	0.4321	-2.454	21	19	0.024
Younger	3.1	0.5333				

It should be noted that in Study 2, when its video journeys were combined to measure SA, an opposite result was evident, with far better Density scores being recorded by an older group ($p<0.062$).

7.3.1.2. Individual SA scores and other comparative data

The individual scores and other related participant data are shown in Table 7.D (below). In terms of course completion times, both groups drove slower on average than in Study 1, with the older group taking around 2 minutes longer (32.80 minutes) than the younger group (30.86 minutes) - in Study 1 they took 3 minutes longer on average, though that route was about 20% longer. Unlike Study 1, the course completion times between the two groups was not significant.

The average length of a narrative was 7% higher for the younger group (2827 words) than their older counterparts (2648 words). In contrast, for Study 2, it was the older group that produced more average text (26.57%); for Study 1 it was more in parity (a 0.45% advantage for the younger group).

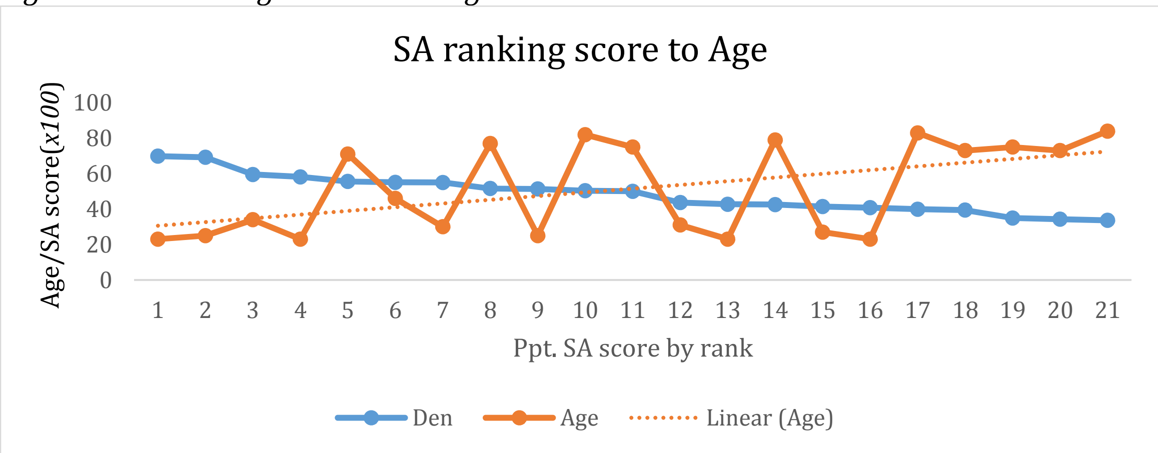
Table 7.D: SA rankings and scores, and other individual data

Rk.	Group	Dia.	Density	Age	M/F	Text	Time (mins.)
1	Younger	2	0.6984	23	F	3845	31
2	Younger	2	0.6923	25	F	3276	30
3	Younger	2	0.5952	34	M	4098	33.5
4	Younger	2	0.5815	23	F	2416	29
5	Older	2	0.5555	71	F	3729	34.5
6	Younger	3	0.5507	46	F	1870	28.5
7	Younger	3	0.5500	30	M	2654	31
8	Older	2	0.5159	77	M	2293	30
9	Younger	2	0.5132	25	F	2837	33.5
10	Older	2	0.5032	82	M	5425	37
11	Older	3	0.5000	75	M	1417	30
12	Younger	3	0.4366	31	M	1825	31.5
13	Younger	3	0.4268	23	F	1544	33
14	Older	3	0.4253	79	M	2900	34
15	Younger	3	0.4137	27	M	3861	30.5
16	Younger	3	0.4074	23	M	2867	28
17	Older	3	0.3990	83	M	2604	35.5
18	Older	3	0.3942	73	F	2310	32
19	Older	3	0.3492	75	M	2010	30.5
20	Older	3	0.3424	73	M	2125	31.5
21	Older	3	0.3360	84	F	1667	33

In terms of individual rankings, the younger participants occupied six of the top seven placings, whereas the older drivers occupied the last five placings. Also, the female participants appeared to perform particularly well in the Study, occupying five of the top six positions with nine participants - in Study 2 it was three of the top six with six.

These results therefore show more of an age to SA relationship in regards to the network SA Density scores (see Figure 7.4 below), particularly for those participants performing very well or poorly.

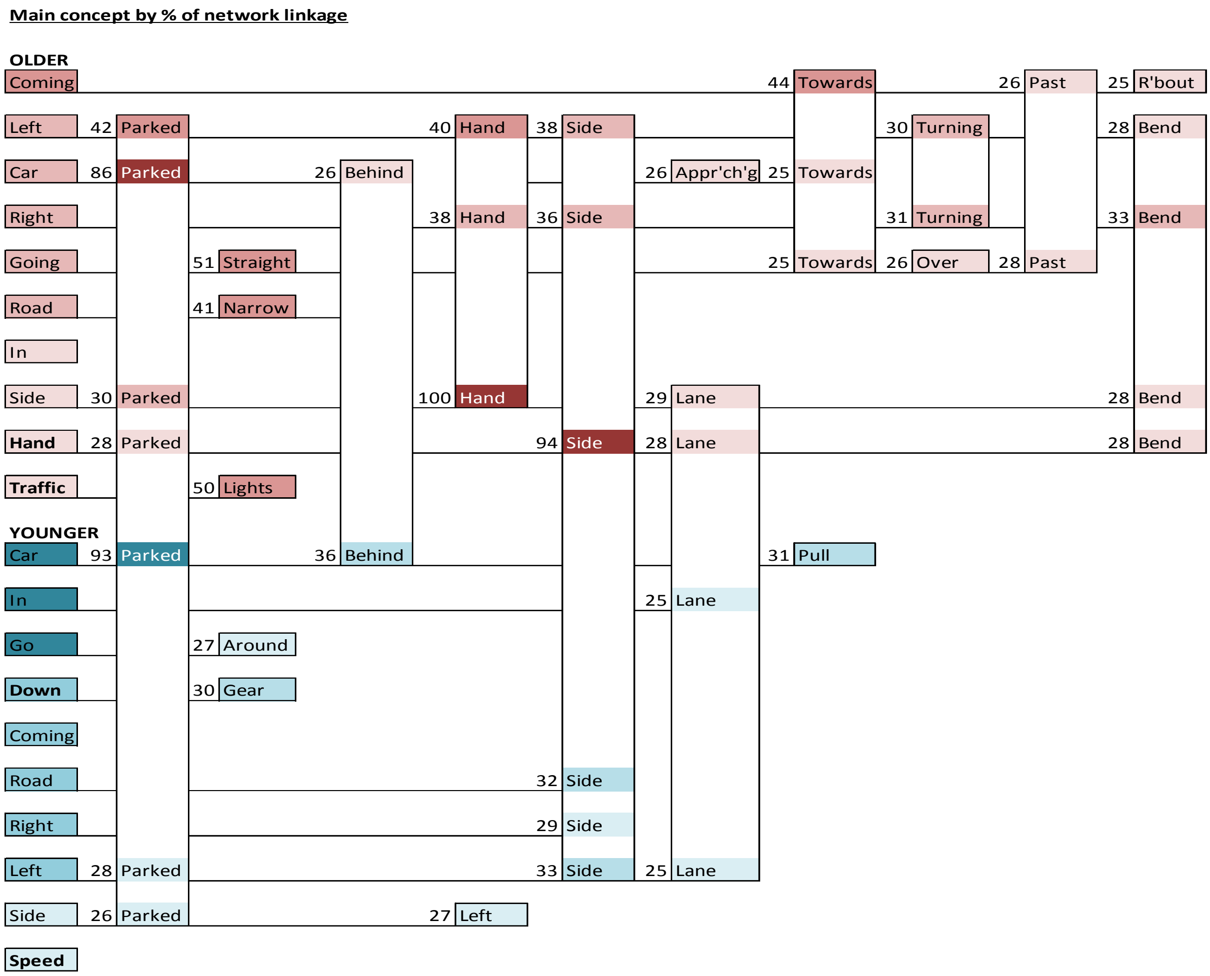
Figure 7.4: Declining SA scores to Age



7.3.2. Qualitative data

7.3.2.1. Individual Group data

Figure 7.5: Major concepts for the Older and Younger Groups



major concepts are those above a 50% relevance for the network and with over a 200 word count

In Figure 7.5 (above), the key or main concepts for each group derived from their narratives are given on the left. (Once again an example narrative is provided as an appendix). Those that are in bold text being unique to a particular group (e.g., 'Hand' or 'Speed'), with the background shading indicative of three levels of concept count (399, 299, or 199 hits and above). The Figure also shows the percentage of occurrence with other concepts in the text (again, the darker the background colour the stronger the connection) and where linkages are unique to a group, or of relevance for both. Due to a lack of differentiation between the main concepts and the words associated with them, these were omitted from analysis in this study (though are included in Study1 & 2).

a) Older Group

For the older drivers, it was found that two main concepts were unique: ‘Hand’ – as in ‘Side’ and ‘Lane’; and ‘Traffic’ – related mainly to ‘Lights’. It could be that the ‘Hand’ concept might merely be a reflection of more precise speech, whereas the ‘Lights’ linkage to ‘Traffic’ denotes more of an interest with road signalling. As has been found previously, there was again a preoccupation for this group with what was ‘Coming’ or ‘Going’ ‘Towards’ or ‘Past’ the ‘Car’, and additionally, particular interest in ‘Turning’ the vehicle in response to the many ‘Left’ and ‘Right’ ‘Hand’ ‘Bend(s)’ along the route.

b) Younger Group

The younger group also had two unique main concepts: ‘Down’ - as in going down ‘Gear’; and ‘Speed’. The latter, unlike the other main concepts, had no concept linkages of note - the best given by the software was with ‘Checking’ (at 9%). As both of these concepts were also unique for the differently comprised younger group of Study 1, it would seem that speed regulation is an important differentiating factor for the younger driver.

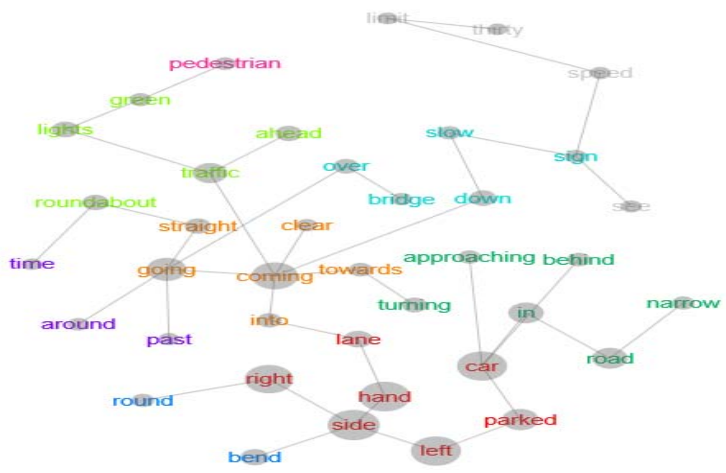
c) Both groups

For both groups, much importance was attached to the ‘Parked’ concept, particularly to ‘Cars’ for the younger group, and for the older group an indication of more emphasis to those parked to the ‘Left’. The route had many parked cars that caused obstructions, and this was also indicated by the linkages for both groups to the ‘Side’ concept. What was also evident was apparently a more similar interest in what was happening ‘Behind’ the vehicle (36% - 26% in favour of the younger group). This indicated a change from similar visual-based data in Study 1, but this was latterly contradicted by additional numerical data given in Table 7.H (below).

Overall the younger group had less major linkages from their main (to related) concepts, despite producing more narrative text and a higher concept category total word count (5077 to 4519).

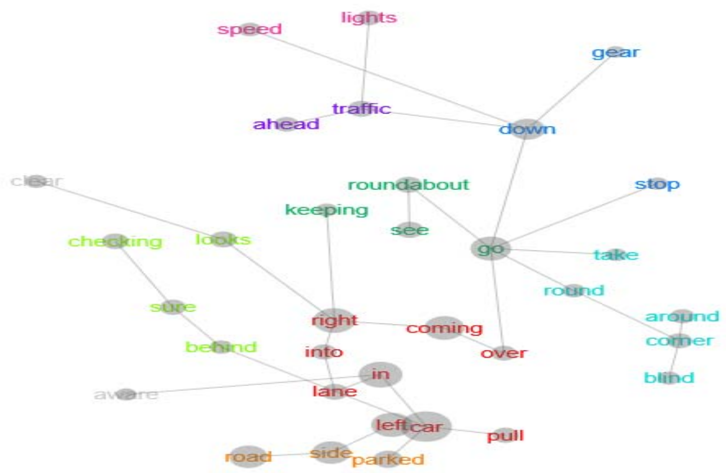
How the concept linkages that were made for both groups is shown in the networks produced in Figures 7.6 & 7.7 below.

Figure 7.6: Concept network for the Older Group



In Figure 7.6, the centrality and importance of the 'Coming' concept is clearly revealed for the older group, as it was for Study 1, with a closeness and interrelation with 'Going' and 'Towards'. The 'Right', 'Hand', Side' and 'Left' concepts are also shown to be as an important interelated cluster; 'Traffic', less so, but it is linked to the 'Coming' concept.

Figure 7.7: Concept network for the Younger Group



For the younger drivers in Figure 7.7, there are arguably three important concept clusters that are more spread out in the network. The closely related 'Car', 'In', 'Right' and a number of other important concepts, and two other distinct clusters emanating from the 'Go' and 'Down' concepts. These appear more detached, but both have a link (albeit tenuous) to the larger 'Car', 'In', 'Right' cluster.

7.3.3. Combined Group data

The Leximancer software also has the capability of assessing two (or more) individual or group texts to reveal the most distinguishing concepts for each. In Table 7.E (below) it combines the frequency and strength of a concept to produce Prominence scores for the two driver groups.

Table 7.E: Concept Prominences for the Older and Younger Groups

Relative Prominence of main concepts for both groups								
	Older Group				Younger Group			
Concept	**Rk.**	**Freq. ↓**	**Strength ↓**	**Prom. ↓**	**Rk.**	**Freq. ↑**	**Strength ↑**	**Prom. ↑**
Parked	11	4	58	1.2	23			
Traffic	10	6	58	1.2	17			
Left	2	8	55	1.2	8	6	44	0.8
Coming	1	9	53	1.1	5	7	46	0.9
Right	4	8	50	1.1	7	7	49	0.9
Side	8	5	49	1.1	9	5	50	0.9
Road	6	7	47	1.0	6	7	52	1.0
Going	5	7	45	1.0	3	8	54	1.0
Car	3	8	44	0.9	1	9	55	1.1
In	7	7	42	0.9	2	8	57	1.1
Down	16				4	7	71	1.3
Checking	270				12	4	96	1.8

a) Older group

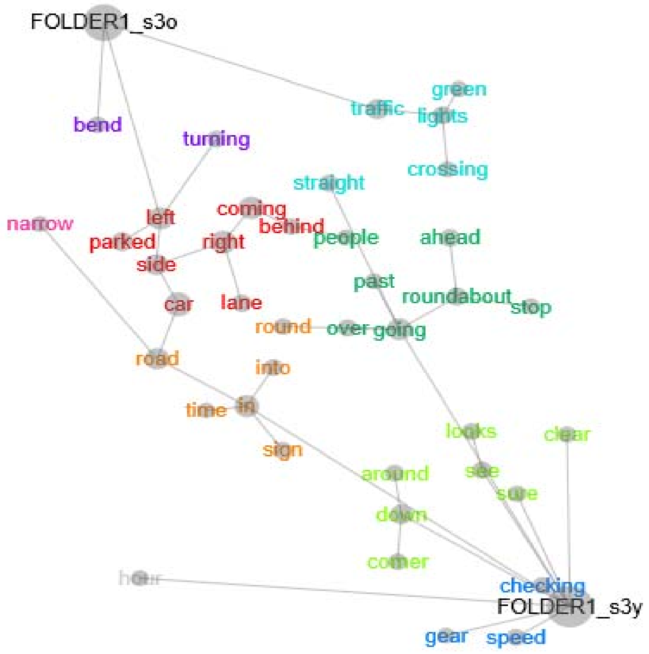
The older group showed little uniqueness in its concepts, with ‘Parked’, ‘Traffic’, and ‘Left’ appearing to be the most differentiating for the group with Prominence scores of 1.2.

b) Younger group

For the younger group, in contrast, the need for ‘Checking’ was particularly unique. Its Prominence score of 1.8 being considerably high, and based on a concept ranking difference not found in the other studies for this series. The 1.3 rating given to the ‘Down’ concept – as in going ‘Down’ ‘Gear’ (see Figure 7.5) – is also worthy of mention here with its high (71%) ‘Strength’ score.

Finally, any further differences between the two group’s perspectives could be revealed through a combined network ‘map’ that reflected the relevance that the forty most commonly cited concepts had for each group. This is indicated by their proximity to a group's 'Folder' node (see Figure 7.8 below) where 's3o' relates to the older group and 's3y' to the younger group.

Figure 7.8: Relative relevance of a concept for each group



This network again highlights the importance of the 'Checking' concept for the younger group, and additionally two other concepts, 'Speed' and 'Gear'(s), that appeared distinguishing in Figure 7.5, but not so for Table 7.E due to comparison limitations (see Discussion). None of these concepts however, appear to be interrelated, which was also apparent from Figure 7.5.

For the older group 'Traffic' once again appeared to be a distinguishing concept, as was 'Bend', which also appeared to be of particular relevance for this group in Figure 7.5. In addition, the 'Left' concept, which had a direct linkage to the older group's folder node, appears here to be particularly related to a third distinguishing concept, 'Turning', which did not register in Table 7.E, but was again unique to the older group in Figure 7.5.

7.3.4. Was this study or Study 2 the harder to undertake?

Relevant participants were asked on completing the route whether they had found the drive, or the video-based task of Study 2, the easier to undertake. All of the older drivers said the drive was the easier task of the two to provide a commentary for (see Table 7.F).

Table 7.F: Task difficulty and main reasons

Group	Which Study was the easier to undertake?			Why?
	S2 (video)	S3 (driving)	Neither	Main Reasons
Older	0	10	0	Can drive at preferred speed/familiar with vehicle /unrestricted view/control of vehicle and knowledge of its direction.
Younger	3	2	1	Unfamiliar route/have to drive and comment.

A common theme conveyed by the older drivers was that as they were familiar with their vehicles, they could proceed at a speed that was comfortable for them (whereas in the videos the driver was perceived as driving too fast), and although the route traversed was unfamiliar (as it was in Study 2), that they had preferred to have been given directions than not know where the car would be going (as in the videos). The younger drivers, in contrast, marginally found the video task easier, and when not, this was due to becoming more familiar and confident with giving a commentary, rather than the driving task itself being viewed as easier. In general, having (more) familiarity with video footage, they saw advantages of simply commenting, than having to both drive and comment. They also felt the driving task became more difficult once the route became unfamiliar, i.e. away from the University's environs, even though the route taken in the video footage was actually less familiar to them.

7.4. Discussion

7.4.1. SA scoring and concept comparisons

It is worth prefacing this section by briefly commenting on some parities between the older and younger groups that were highlighted in Table 7.D, which provide a good basis for group comparisons to be made. Specifically, the average time to complete the course was similar for both groups (with comparable volumes of traffic and weather conditions), as was the average length of narrative that was provided (a 7% difference in favour of the younger group).

7.4.1.1. Quantitative data

In this Study, measures indicative of Situation Awareness, showed that a younger group out-performed an older group, as is generally found in the literature. This was the case whether the narratives of the two groups were considered as a whole, or from an averaging of their individual scores (Table 7.B). In the latter case, which allows for a statistical evaluation, the Group differences by SA Density score were found to be significant ($p<0.024$) (Table 7.C).

Unlike the driving route in Study 1, where care was taken not to challenge drivers with difficult roadways, this Study, in contrast, actually sought out road environments that would require extra concentration and awareness by the participant driver, and often for long periods. Perhaps as a result, the Study produced different individual quantitative results to that of Study 1. As Table 7.D indicates, for the route driven in this study the younger participants held the highest four ranking positions, and the older drivers the lowest five positions. For Study 1, the younger drivers occupied four of the five lowest positions, and there was more group parity at the highest five positions. The participants in this Study also improved (and brought more consistency in) their network Density scores. For example, the last placed participant by this measure for this Study would have been placed 10th in Study 1. Thus a more difficult route, rather than degrading SA, actually appeared to improve it. However, with the higher scoring rankings, although the same participant was placed first for both studies with exactly the same Density score, the easier drive undertaken in Study 1 produced more Density scores in the 0.6 and above bracket.

Overall then, as was shown in Figure 7.4 (above), a clearer SA to age relationship was found for this driving study that was not evident for Study 1. This was particularly the case for the more extreme ranked scores, but far less so for the middle ranked scores. So perhaps the more 'complex' drive simply provided a better basis for differentiating between those participants who had the very best and worst awareness?

7.4.1.2. Qualitative data

It has been argued in previous chapters that the quantitative results given above reveal only how cohesively a participant organises the information s/he extracts from an environment. Whilst a more cohesive network with many linkages must aid information retrieval, and that this must be important in driving contexts when on occasion seconds can be very important, the SA indicative measures taken here do not, of course, reflect the quality of the information within a particular network. This too, though, is obviously an important element for good driving proficiency, and thus it is necessary to extract and compare the driving concepts that underlie an individual's or group's score - to gain a sense of what she, he, or the group, is seeking to process.

In this regard, despite the varying routes and group scores found for the two driving studies undertaken in this series, in terms of what information was being comprehended and considered of value, there was some similarity in regards to what each group viewed as important. In short, the older drivers tended to perceive and evaluate more concepts to the front of their vehicles; whereas the younger drivers paid more attention to concepts indicative of speed regulation. However, in this present, more difficult driving study, the older drivers gave indications of being more aware of driving movement and specific artefacts; whilst the younger drivers appeared, on occasion, to have undertaken more broader (top-down) processing.

a) Older group

The main concepts that were considered important for the older group of Study 1 retained their status in this study. Figure 7.5 shows that this was particularly the case for 'Coming', which again had the highest concept count. The importance of the 'Going' concept was also evident once more, as was its linkage (also found for the 'Coming' concept) to 'Towards'. The bias for taking information from the 'Left' (front) side of the vehicle was retained for this group, but it was less pronounced. For example, what was 'Parked' on the left 'Hand' 'Side' was apparently of importance, but when it came to 'Turning' and 'Bends', the right side of the vehicle then became marginally more of a focus. The new main concepts for the group were 'Side', probably due to the many narrow roadways encountered, and 'Hand', which appeared to be merely a product of more precision in speech than better awareness per se. A general 'Traffic' concept, was again a unique main concept for the group, but lessened in importance, and became more specifically related to 'Lights'. Finally, the prevalence of a 'Bends' concept indicated a specific awareness of a necessary driving action, particularly due to its linkage with 'Turning' the vehicle.

b) Younger Group

For the younger group, Figure 7.5 showed that there were less distinguishing and less concept relationships than were found for the older group. The interest in gear changes relating to slowing 'Down' was more evident than in Study 1, but the 'Down' concept had considerably less importance for this study, and there was now no tangible links between 'Speed' and 'Down', and 'Coming' to a 'Stop'. In regards to the older group's awareness of a need for 'Turning' around 'Bend'(s), for the younger group the processing of such information appeared to be less deep, with 'Go' 'Around' seemingly the only relationship reflective of this action. Additionally, there seemed to be a bias for the group to the 'Left' 'Side' of their vehicles, and to what was 'Parked' on the 'Left, and to both the 'Left' and 'Right' side more generally.

c) Both groups

For both groups the importance of 'Parked' 'Cars' was more evident in this study, due largely to the road conditions. For the older group the cars parked to the 'Left' of the road were considered of slightly more importance. The 'Side' concept was evident for both groups (though more distinguishing for the younger group), as was the 'Behind' concept, which now was shown as being more in parity with a 'Car(s)' concept, whereas in Study 1 it only had that linkage for the younger group (along with 'See'). In fact, it could additionally be inferred from Figure 7.5 that the older group paid equal attention as to what was 'Approaching' their 'Car,' as they did to what was coming from 'Behind'.

<u>Network map data</u>

The network maps reflect the information given in Figure 7.5 in a visual form. It was evident from these Figures (7.6 & 7.7) that the older group's concepts emanated principally from the important 'Coming' concept. As a result, the speed theme concepts, such as 'Speed', 'Limit', and 'Thirty', do seem somewhat detached in the network. However, these, and other more specific concepts, such as 'Bridge', 'Pedestrian', 'Roundabout', 'Sign', and 'Lights' are more evident in the network than for Study 1. The younger group, in contrast, had main concepts slightly more spread out within its network e.g., 'Go', 'Down', and 'Car', giving the impression of a better overall linkage. There were also more indications of anticipating potential hazards here, from concepts such as 'Checking', that a 'Corner' maybe 'Blind', and that a roadway 'Looks'- 'Clear'. The older group did also have 'Clear' in their network, but it was related to the 'Coming' concept that had a focus more on what was being seen out of the front windscreen.

It should be reiterated from previous chapters, though, that these network graphics can often be of less value than the data they are drawn from (in Figure 7.5). The peripheral concepts can change position on each map iteration, and the prominence of certain concepts can also be less easy to discern (e.g., between 'Coming' and 'Left' for the older group in Figure 7.6). However, that said, the group networks do appear to retain some similarity between the two driving studies – particularly the centrality of the 'Coming' concept for the older group.

7.4.1.3. Combined Group data

When all of the participants' narratives were considered and compared to produce one combined network, it then became possible to reveal which concepts stood-out as being of particular relevance to each group. This comparison, however, reproduced by the software in tabular form (in Table 7.E) does not provide an exhaustive list, rather a limitation to about twelve concepts with a bias to those that appear a high number of times in the narratives.

So considering the Prominence scores in Table 7.E, it becomes evident that for the older group there were few, if any, main concepts that showed a particular uniqueness. The software calculates 'Parked' and 'Traffic' in this category, each with a 58% relevance, but those concepts also figured strongly for the younger group (42%). The 'Left' concept, also had an identical Prominence score (1.2) due to its high frequency in the texts (8%).

The younger group, in contrast, did show more uniqueness in their concepts. The 'Checking' concept, for example, was particularly differentiating for the group with a 96% strength score (from a 181- 6 concept comparison count). This appeared to have similarities with the most distinguishing concept for this group in Study 1 - 'See' (with a

1.5 Prominence score) - in that both were related to looking 'Behind' the vehicle. To a lesser degree, the 'Down' concept also retained the uniqueness it had for Study 1 with a 71% strength score (from a 373-121 concept comparison count), and, again, a 1.3 Prominence score.

As suggested above, the software, for combined numerical data, tends to place a limitation on the number of (usually main) concepts that are assessed. On this occasion, this may have omitted some additional data of relevance. Specifically, whereas the concepts ranking just below those included in Table 7.E for the older group showed little discrimination, that was not the case for the younger group. The 'Speed' concept, for example, which was ranked 10th (23rd for the older group), showed a text difference of 213-80 in favour of the younger group (a 72% strength score) and a 4% to 2% relevant frequency advantage. This would seem worthy of inclusion in any tabular comparison. Likewise, the 'See' concept, 11th in count (33rd for the older group), showing a text difference of 182-53 in favour of the younger group (a 77% strength score) and a 4% to 1% relevance, also appeared distinguishing from the older group.

It should also be noted that 'Hand', a main concept for the older group (9th) with 229 hits and a 5% relevance, did not register for Table 7.E or the network map that followed (Figure 7.8). This was due to it having a zero hit for the younger group, which the software then simply discounts. This concept, though, was very discriminating for the two groups, leaving aside that it seemingly had little relevance to awareness.

<u>Network map data</u>

A network map of concepts that was produced from the combined data (in Figure 7.8) shows visually how relevant a (top 40) concept was for a particular group from its proximity to a group 'Folder' node. As might be anticipated, the ones that stand out here reflect what was found in the standalone networks considered earlier (in Figures 7.6 and 7.7).

For the older group, the concepts that were the most distinguishing were not, as might be expected from Table 7.E, the four top ranking concepts. These, 'Coming', 'Left', 'Car', 'Right', were found more towards the centre of the network as a cluster, also having relevance for the younger group. The more distinguishing concepts were said to be 'Turning' (with a 88-43 concept count comparison) and 'Bend' (123-54) which were shown to be particularly relevant for this group in Figure 7.5, but were too low in frequency/strength combination to be included in Table 7.E.

For the younger group, three concepts showed particular relevance: 'Checking', 'Speed' and 'Gear'. The 'Checking' concept was unsurprising given the data provided in Table 7.E above. The 'Speed' and 'Gear' concepts, also considered above, are now included by the software. Both concepts also appeared distinguishing in Figures 7.5 and 7.7, but probably had too low a word comparison count (e.g., 'Gear' (56-17)) to be included in Table 7.E.

7.4.2. Task difficulty

The findings given in Table 7.F above could be particularly important both for this series of studies and for our understanding of Situation Awareness more generally. They suggest that rather than a (perceived) easier task bringing higher SA proficiency, as was concluded after Study 2, that it actually is more likely to be the case that a harder (perceived) task would bring a general uplift in SA scoring. However, this effect did seem less relevant at the very highest scoring levels.

In summary, then, it was shown in Study 1 that all participants, young and old, could drive a relatively standard journey without difficulty, and produce, at that time, what appeared to be surprisingly similar SA scores given other findings in the literature (e.g. Bolstad, 2001; Zhang et al., 2009). In Study 2, which was considered by the older drivers to be more difficult to undertake, it was found that their SA scores were appreciably higher in comparison to those from a younger group. Whereas in the present Study, which, overall, the younger drivers felt to be more difficult, the opposite result occurred. The changes in SA scoring from Study 2 to the present study, for those who undertook both, are summarised in Table 7.G below.

Table 7.G: SA Density score uplifts from Study 2

SA Density scores improving or worsening from Study 2			
Group	Participants	Improving	Worsening
Older	10	1	9
Younger	6	5	1

Notwithstanding the low comparison sample here, particularly for the younger participants, this data further underlines that firstly SA could be variable according to the task, rather than being, say, uniformly poor for older drivers as is usually proposed in the literature (e.g. Bolstad, 2001). And secondly, that the danger for these older drivers in motoring contexts might be more related to them lessening their awareness due to perceived easier driving conditions, rather than any general deficiency per se.

7.4.3. Findings relating to rearward and safety-relevant concepts

In Study 1, it was argued that the older driver group had shown indications of having an undue focus to the front, and front/left of their vehicles, at the expense of what was occurring behind. As such it was felt that this less optimal awareness might result in the older drivers missing important safety-related information. This assertion could not be measured in Study 2, but in this Study, it could be re-considered. The initial evidence appeared to show that the older drivers had taken more note of what was happening 'Behind' their vehicles. This was due to the strong linkage between that concept and the main 'Car' concept in Figure 7.5 (above), and the central position of the 'Behind' concept in Figure 7.8. However, when a comparison was made of the times a rearward looking concept or word was mentioned in all of the twenty-one narratives, the results showed the younger group to have mentioned them around twice as much (Table 7.H).

Table 7.H: Rearward-related concept comparisons

Concept	Older Group		Younger Group	
	Concept Count	Word Count	Concept Count	Word Count
Behind	99	105	83	86
Mirror	0	3	117	97
Rear	0	0	32	35
Wing (mirror)	2	1	5	14
Totals	**99**	**108**	**237**	**232**

A second aspect of interest from Study 1's findings was a potentially sub-optimal amount of relevant information being processed by the older drivers. This was more difficult to substantiate from the text alone, but an argument was made that perhaps an indication could be gleaned from what the participants themselves had enunciated in their narratives. In Table 7.I, below, it is shown that the younger group mentioned these concepts about three times more often than the older group.

Table 7.I: Safety-related concept comparison

Concept	Older Group		Younger Group	
	Concept Count	Word Count	Concept Count	Word count
Checking	0	6	181	183
Check	5		0	
Indicating	23	76	26	71
Indicate(d)	30		25	
Blind	18	20	78	81
Clear	46	55	113	121
Sure	0	23	144	124
Gap	5	5	12	12
Safe	9	12	12	20
Looking	16	64	165	175
Look	0			
Aware	0	3	75	79
Warning	7	8	0	2
(having)Time	33	7	36	23
(enough)Space	0	9	0	28
(enough)Room	27	27	13	14
Totals	**219**	**315**	**756**	**933**

These results surprisingly mirror those of Study 1, despite the drive for this study being more onerous.

There were indications whilst traversing the route that the older drivers were more easily distracted from, and therefore had less awareness of, the driving task. This would most likely be reflected by the group's overall (SA metric) scoring, and indeed the younger group showed better SA proficiency scoring here, as it did for Study 1. It could be, of course, that any lack of focus by the older group could only have been evident at times when they perceived a driving environment as being less risky - due to their far greater driving experience. Additionally, it should be borne in mind that the younger group did produce 7% more average text in their commentaries. However, with the drive being a more difficult one to that undertaken for Study 1, it would be reasonable to expect more parity in the enunciation of such safety-related concepts.

These aspects would no doubt benefit from further research with different methodologies, as they could indicate important precursors for accident involvement amongst older drivers.

7.4.4. Limitations

As has been mentioned in regard to previous studies, the participants could not be matched for potentially influencing factors such as annual mileage driven, or accident history, due, latterly, to an emphasis on volunteer continuity.

Also, the 'Think aloud' methodology utilised for the series, whilst being less obtrusive and easy to understand, again impacts on the number of participants that can be assessed within a reasonable time period. This is principally due to the need for commentaries to be accurately transcribed, and then formatted as truly as possible to a participant's enunciation. A task that is not helped in driving contexts, with engine and exogenous noise. So with such limited numbers, also comes related limits on generalisations - though this issue is not uncommon in SA research (whether or not narratives are utilised).

It also should be noted, once again, that whilst it can be said that strong and related connections between knowledge concepts will aid their recall, and thus in this context an individual's SA from better processing of incoming information, the method can only assess what the participant says s/he is aware of.

7.5. Conclusion

This study showed that the Situation Awareness of an older driver group, driving what was a rather cognitively taxing route on occasion, was significantly poorer than that of a younger driver group. This, despite these same older participants out-performing a similarly comprised younger group on video-based measures of driving SA only a few months previously.

In the present Study, the older participants surprisingly felt less challenged. In periods they demonstrated that they could 'switch off' awareness. Whereas, whilst watching a video of a car journey in the previous study, travelling at what to them was perceived to be higher than comfortable speeds, they had to concentrate more fully on the task.

For the younger drivers, generally the opposite was true. Driving a car was seen as an additional effort, whereas watching video footage was nothing new, it presented no problems, and advantageously the car 'drove itself'.

The results in this Study also indicate that the older group could (once again) be giving less comparative consideration to what was behind their vehicles and to safety-related cues, whilst arguably improving their processing of specific driving environment information.

In the literature, this study's findings support the general contention that older drivers exhibit less Situation Awareness. However, much in regards to the measured proficiency of SA may be down to perceptions of task difficulty and motivation. If the older drivers here did consider the drive being undertaken as presenting little difficulty, due, perhaps, to their wealth of driving experience, then potentially insufficient awareness did occur given the nature of the route. Alternatively, it could just be simply a problem of them not being able to consistently process high levels of relevant information over sustained periods of time, due to cognitive slowing and processing resources (as highlighted in Chapter 2).

Finally, it is important to recognise that the older participants in these studies were proficient drivers, who, despite any age-related processing limitations, would no doubt drive safely on all classes of roadways, and particularly on ones that they were familiar with. However, confidence from experience could mask, perhaps an unknown decline in awareness here (as consider in Chapter 5), that is likely to increase with age. Driving more slowly, and employing in-car automated driver assistance devices, will no doubt help to give these older drivers more time to process sufficient information. But moreover, a method for keeping them concentrating on the driving task, particularly for longer journeys, would seem invaluable for increasing their, and others, road safety.

Chapter 8: Overview & Synthesis

8.1. Introduction

This thesis has sought to investigate the Situation Awareness of car drivers, particularly those aged over 70 years. However, the concept is of relevance to drivers of all ages as driving requires Situation Awareness to, for example, monitor constantly changing environments, understand and manage incoming information, and make decisions - often under high mental workload conditions. It can therefore reasonably be contended that if a driver is not able to adequately perform such tasks, then his/her driving performance will ultimately suffer.

The approach taken to investigate, and ultimately seek to measure both a group's and an individual's Situation Awareness, was to focus on what information a driver selectively attended to, as such perceptions would inform both his/her comprehension of a given driving environment, and, in turn, how to react to it.

As several cognitive (and physical) abilities are needed for a driver to gather that information, such as vision, perception, memory and attention, and given they are known to decline with age, the thesis's interest was whether those declines might impinge on a driver's Situation Awareness. And, in particular, when a driving task had an increased level of cognitive complexity. It has been proposed in the literature that age-related declinations will affect our information gathering, and thereby be detrimental for initial formations of SA (Bolstad & Hess, 2000: supporting a viewpoint given by Jones & Endsley, 1996). This is because they will bring difficulties in perceiving what is important on roadways: such as lane position; speed; and the location of other cars. Thus the proficiency of older drivers has become of particular interest to researchers in Western societies, due to related concerns that such processing limitations and an expected further growth of this driving group, will ultimately result in more road accidents.

As Situation Awareness is considered to have use as an explanatory framework for evaluating driving performance (e.g. Salmon, Stanton, & Young, 2012: "Appropriate conceptualisations and assessments of SA have much to offer future road safety efforts" (p.473)), the SA levels of drivers in differing age-groups has understandably been explored and compared (e.g. Bolstad, 2001; Zhang et al., 2009; Kaber, et al., 2012; Ho et al., 2001). Yet, surprisingly, research in this area has been sparse, and when undertaken it has exclusively utilised rather artificial driving simulators and simulations.

This thesis sought to add to the literature by considering, over a series of studies, whether older drivers would exhibit poorer SA in relation to other age groupings, as has generally been assumed and found. To achieve this, consideration was given to the advantages of a methodology that would take SA measures from actual driving environments (Aspect 1), and of different complexity (RQ1 & RQ3). Additionally (in RQ2), participant SA proficiency by age would be assessed for any correlation with a driving performance measure (Hazard Perception). And finally, Aspect 2 added a requirement to draw conclusions and suggest recommendations for improving the SA of older drivers. These were considered throughout the thesis, but are discussed collectively below.

This Chapter is structured by summaries and synthesises of the main findings from the thesis in relation to these Aspects and Research Questions, each of which are now considered below in the order envisaged and researched (as highlighted in Chapter 1).

8.2. (Aspect 1): What theoretical perspective and method would be the most useful for evaluating Situation Awareness in driving contexts?

8.2.1. Theoretical perspective

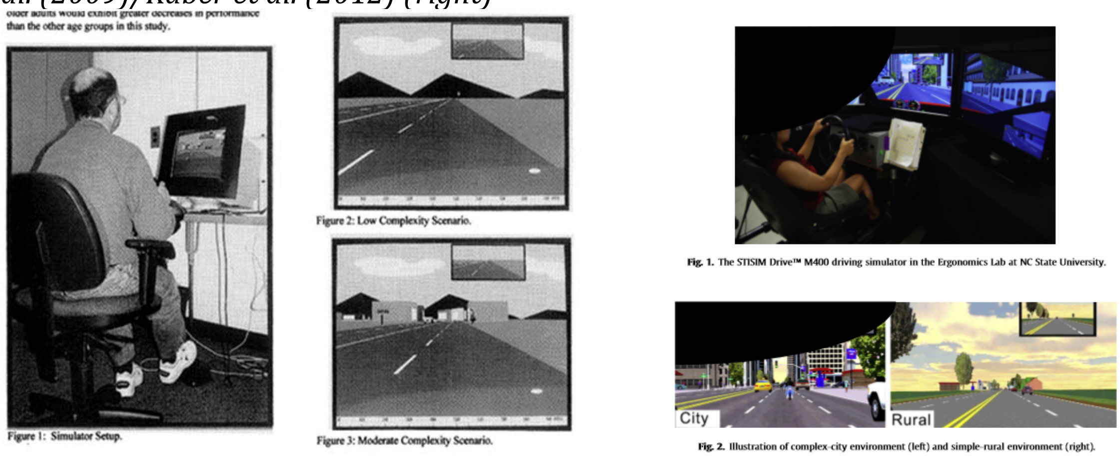
It is important to firstly recognise that how a researcher conceptualises Situation Awareness will inform how she or he measures it. In any such discussion, one has to firstly defer to the work of Mica Endsley, whose definition of Situation Awareness back in 1995, still remains the most established and widely accepted. She contended that SA is: "the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1988, p.97). Thus Situation Awareness by this definition is a cognitive product of information processing, and she seeks to describe the different cognitive resources and mechanisms that might be involved in constructing and maintaining it. The related methods to this approach therefore measure the extent to which an individual is aware of a pre-defined element in an environment, their understanding of the properties of it in relation to the task they are performing, and also what the potential future states of it might be.

Thus there is a preference for adherents of this approach for recall techniques that take a snapshot of the contents of an individual's mind, as it relates to SA, at particular point(s) in time. SA is measured from the answers that a participant gives, based upon his or her knowledge and understanding of a particular situation at the point of recall. The responses given then being compared to 'perceptions' of the state of the system being investigated at that recall point. Therefore, like other approaches similar in kind, e.g., observer ratings and personal performance measures, the participant's responses or inferred actions are measured against what is considered as indicative of good SA.

To achieve this, notably in the road transport sphere, simulations of relevant environments are usually utilised, as they can exactly and explicitly produce knowledge objects that 'should' be reported. They also allow for precise and repeatable information recall points or 'probes', which would not be possible on actual roadways.

An important problem with such simulations, however, particularly at the time of the principal studies investigating the effects of age and Situation Awareness (Bolstad, 2001; Zhang et al., 2009), were, that to different degrees, they lacked realism (see Figure 8.1).

Figure 8.1: Example equipment and driving screens from Bolstad (2001) (left), and Zhang et al. (2009)/Kaber et al. (2012) (right)



Such deficits were further augmented by a lack of highly realistic and complex driving tasks, and as the participants knew SA-related questions were to occur at the end of each segment of a trial, they may have taken advantage of this knowledge to prepare or anticipate for them.

It could also be argued that Endsley's view of SA as solely an individual psychological phenomenon, gained from linear processing of information, does appear rather limited. In particular, to fully understand the driving task, perhaps more consideration should be given to the interactions within it? In the sense of the driver enacting personal experience to cope with roadway environments that, in turn, will modify that experience and his/her actions.

This thesis has therefore argued for a different methodological approach for the assessment of older driver's Situation Awareness, and this again stemmed from how the concept was defined. At the outset, the author agreed with researchers such as Smith & Hancock (1995), who argued that SA cannot just be a product of awareness, as Endsley (1995a) suggests, but that account should also be taken of the processes for gaining awareness.

From this approach, more emphasis is placed on a cyclical interaction between the individual's perception of an environment, his/her memory/experience, and active exploration (e.g. Adams et al., 1995). A driver knows, for example, from previous experiences how a driving situation should evolve (e.g., that the distance to the vehicle in front should remain stable); so s/he will repeatedly and actively attend to relevant aspects in the environment (in this case, say, the speed of the other vehicle), and compare it to an expected 'situational development'. The results (and thus the quality) of that comparison, would then guide future aspects of driving behaviour.

This thesis has further argued that Situation Awareness would be better measured in road environment contexts. And that the driving 'system', the environment within which the individual is operating, should be incorporated, whilst allowing its component parts, most notably that of the driver or driver group, to be extracted and evaluated. To achieve this, a driving 'system' from the driver's perspective had to be represented. It was proposed that the best way to achieve this was to create individual (or group) semantic or propositional networks to depict the information comprising a person's or group's SA. Propositional networks (Anderson, 1983) capitalise on a number of important principles of systems thinking. For example, they can represent SA by the proficiency of the connections between the information elements that comprise a network, and show that individualistic representations of awareness, and the propagation of SA activity, need not be linear as Endsley suggests.

This approach also sat well with the more naturalistic methods favoured by the author for evaluating SA. It was argued in Chapter 3, for example, that there would be benefits from assessing a participant' SA in their own cars on actual roadways. Specifically, this would allow for driver sensitivity to familiar vehicle feedback, on-road events would be meaningful and not contrived, and, as a consequence, a good chance would be afforded of capturing accurate driver awareness. Additionally, as network data can be captured in one continuous session, this advantageously would obviate the need for recall 'freezes' of a task, as well as observer or post-hoc individual evaluations.

Propositional networks can now also be created and evaluated by computer software, rather than subjectively by a researcher. It is possible to compare quantitatively and qualitatively both individual and groups of networks from participant commentaries. The approach to achieving such output, and its advantages, are now considered below.

8.2.2. Method (for capturing the SA network)

The thesis utilised a 'Think aloud' or Verbal Protocol Analysis (Ericsson & Simon, 1984) method to capture the data required to produce a network. This involved participants thinking aloud, or more specifically, saying whatever came into their mind as they completed a particular task. This approach was chosen because it could produce an in-depth amount of information of relevance to the participant, which subsequently could be structurally evaluated. As such, it potentially could provide insights as to the thought processes that an individual or a group brought to a particular journey or road environment.

In addition, the method is simple to explain, understand, and can allow for data to be captured over long time periods, such as on the routes proposed for the studies, that were up to 16 miles in length. Although the 'Think aloud' approach can be utilised in a variety of settings, its usage was limited to a quiet room to watch videos of car journeys in Study 2, and the participant's own vehicle in Studies 1 & 3. These more familiar environments can be contrasted with, for example, an unknown instrumented vehicle, or a simulator, which may distract a participant from providing his/her actual thought processes. The researcher could also remain somewhat inconspicuous, there were no questions to ask, and no distracting additional equipment in the participant's view - such as would be required by an eye-tracking device that may also need to be set up. The commentaries could be recorded unobtrusively, with the participant left simply to remark on what s/he considered as relevant during a video or a drive.

The aim of the studies was not so much about the quantity of commentary captured, more how relevant the concepts enunciated were, and how cohesively they were structured. To that end, once a commentary had been recorded and later transcribed, it was then interrogated by computer software (Leximancer) developed by Andrew Smith at the University of Queensland, Brisbane, Australia (Smith, 2003). This software remains unique in the detail of the analysis that it can undertake and display. It is capable of producing both a visual network 'map' that reveals the linkages between (if necessary, hundreds of) concepts, and the quantitative data from which it is based upon (such as word counts and algorithmic scores).

Leximancer can also analyse narratives either collectively or individually, and provide a quantitative output for each in 'Excel' format. The relevant 'sheets' can then be 'pasted' into Agna mathematical software for further quantitative evaluations relating to each network's structural cohesion. This software has been used successfully in previous transport studies (e.g. Salmon, Young, & Cornelissen, 2013; Walker, Stanton, & Salmon, 2011; Walker, Stanton, & Chowdhury, 2013), however, for the studies in this thesis, this was the first time it was utilised to assess the comparative SA performance of older and younger drivers, and the first time its outputs were statistically compared.

8.3. (RQ1): Is Situation Awareness worse amongst older (than younger) drivers in cognitively non-taxing driving conditions?

In previous studies of note that have looked into the Situation Awareness of older drivers using simulations, there was perhaps a reasonable assumption that this age grouping would perform poorer than young or middle-aged groups. Bolstad (2001) "older drivers that have deficits in certain cognitive and physical abilities will also be deficient in their ability to attend to important information" <thus> "If drivers are not attending to the necessary information, it seems logical that performance will ultimately suffer" (p.272). Zhang et al. (2009) "age related decline in sensory, cognitive and physical function may place elderly drivers at risk and more vulnerable to an accident" (p.1) <because> "driver inattention and deficiencies in information processing are major factors in accident causation" (p.2).

Bolstad (2001) found from a recall probe technique that an older driver group (average age 70.4 years (n=16)) reported significantly less SA relevant information. Zhang et al. (2009) found that "The effect of age on SA is consistent with the findings of the previous research under normal driving conditions (Bolstad, 2001, Shinar, 1993). i.e. elderly drivers exhibited poor SA compared to young drivers." (p.6). The older group's average age in this study was 72.2 years (n=10). Kaber et al. (2012), discussing Zhang's work, go further: "As perceptual and cognitive abilities decline with age, older drivers show lower SA at all levels compared to young drivers" (p.609).

In Study 1, where the average age of the older participants was higher than in these previous studies at 75.6 years (n=10), a Situation Awareness 'score' was sought for both an older and younger driver group. As was discussed in Aspect 1, the approach taken was very different to the studies mentioned above, as the data was captured on actual roadways than in simulators. It also was not compared by content to what 'expert' drivers felt should have been observed (e.g. Bolstad, 2001). Of more interest was how cohesively the participant processed the information that s/he felt was relevant. This, it was argued, would produce results more indicative of Situation Awareness proficiency.

The Agna software, based on the Leximancer data, can produce two SA 'scores' in this respect. And it can provide these for each individual participant, and for each driving group (as its narratives can be combined and analysed as one entity).

It was found that when the individual participant scores were averaged, that they produced overall scores for the two groups that were unexpectedly similar. The expectation was for a better younger group performance, as having a higher average age (at 31.1 years) than the Bolstad (19.5 years) and Zhang/Kaber (20.7 years) studies, it was presumed to have had much more driving experience. Overall, though, the older drivers in Study 1 tended to occupy the middle ranking positions (7 out of the 10) for SA Density (which was the more discriminative of the two scores), whereas the younger driver's performances tended to be more inconsistent, for example they held the two highest and the two lowest ranked positions by this measure. As no age to SA correlation was found, the study thus raised doubts as to the perceived importance in the literature of age-related perceptual and cognitive deficits, particularly as the two oldest participants in their early 80's had ranked 3rd and 7th overall (out of 20).

At the group level, though, there were suggestions of a less integrated performance by the older drivers from their lower SA Density scoring. This was also reflected in qualitative comparisons of relevant concepts and their interrelations. In particular, the older driving group placed less emphasis on rearward and safety-related cues, and seemed to exhibit less awareness of the need for frequent speed regulation. Much of the focus for the group was related to what their vehicles were 'coming – towards' or what was 'in – front', whereas the younger group was more appreciative of 'slow(ing) –

down', where 'cars were parked', and to 'see' what was coming from 'behind'. This seemingly more proficient awareness appeared to mirror Bolstad's findings, as her younger drivers had demonstrated better recall of what were considered as important driving cues.

Thus in regards to whether SA was more deficient for older drivers in non-taxing environments, the answer from this study was unclear. Although older drivers could take in cues from a driving environment, and process that information as cohesively as younger drivers, the information that they drew upon to inform their SA appeared disadvantageously more diverse, general, and of less task relevance. It was unclear, however, why this was the case. As has been seen with previous SA research of older drivers, much has been made of age-related cognitive decrements. So perhaps the route driven was insufficiently demanding, and thus allowed for those decrements to be compensated for, by, for example, a greater degree of automatic processing? Bosman & Charnes (1996) have, in fact, found older drivers to undertake more automatic processing of information, and furthermore, this could be related to their greater driving experience (see McPhee et al., 2004). If this is the case, then they may have been better able to anticipate environments that might cause them difficulty, and by generally driving at more constant speeds, concepts relationships indicative of driving actions such as 'slowing' and 'down' may thus have appeared of less relevance for the group?

This somewhat generous interpretation of their perceptions does, though, still imply a lower level of cognitive effort. An assertion that has some support from the SA metric scores that another older group (with many of the same participants) produced for the second driving study (3).

In Study 2, however, a contrasting effort appeared to be shown for a route comparable to that driven in Study 1(in terms of roadways and traffic levels), when viewed on video. With task difficulty assumed to be easier for this route, it was felt that similar SA quantitative scoring would again be produced by a younger and older participant group. The older drivers, though, surprisingly produced an uplift in the cohesion of their SA-related networks. This was initially explained as being due to the task being far easier for them to undertake than might have been expected. The journeys commented on were, after all, shorter, and had participants consider only roadway information from a forward looking perspective, rather than all around the vehicle whilst driving. A bearing from the findings of Study 1 that could provide an advantage for the older driver. However, an unknown element here (later revealed after Study 3) was that the older drivers found providing a commentary for a video to be a relatively more difficult task (than whilst driving), which beneficially appeared to have raised their attention and concentration, and, as can reasonably be inferred, their SA. Table 8.A provides SA score comparisons between Study 1 and the relevant journey from Study 2 (the bolder scores indicate the higher intra-study scoring, the shaded backgrounds the degree of higher inter-study scoring).

Table 8.A: SA metric score comparisons between Study 1 & 2

	Group			
	Older		Younger	
Study	Group score	Average ppt. score	Group Score	Average ppt. score
1	2/0.7417	**3.1**/0.3819	2/**0.8238**	3.2/**0.3874**
2	2/**0.7610**	**2.8/0.4310**	2/0.7578	3.4/0.3743

The impact of task difficulty on Situation Awareness, then, appears to potentially be an important factor for determining its proficiency, but in SA-related studies it appears to have been either removed by screening or not considered. For example, in Ho et al. (2001) "To ensure that all participants understood the task, an accuracy of 90% had to be obtained on the practice trials before continuing to the actual testing. If the participant failed to obtain 90% accuracy, the instructions were repeated, and the practice trials were presented again." (p.109).

In Kaber et al. (2012) "Participants were instructed to follow a pre-defined route, which was presented on a hardcopy map placed adjacent to the right side of the simulator steering wheel and was readily accessible for navigation at any point during a trial. Participants were required to maintain speed limits, comply with traffic rules, negotiate surrounding traffic and respond to SA probes." (p.605). In this case, the study is, in effect, asking older participants to use a navigation aid to 'drive' around predetermined routes for eight minutes. This, in a sense, combines both video and driving tasks. So might this produce more effort among the older drivers due to its novelty, or perhaps, less, as ‘driving’ a short route could be viewed by them as a straightforward task? Moreover, in view of performance difficulties for older drivers associated with lower levels of mental energy or attentional capacity (Craik & Byrd, 1982), would having them drive for 2 hours and 40 minutes (eight trials of twenty minute duration) not be a relatively harder undertaking?

Task difficulty also has particular relevance for RQ3 where its influence will be revisited. However, before leaving this RQ, it is important to note that although Study 2 was verified by the older drivers as being more difficult, and where presumed extra effort may have accounted for their 26.57% more commentary (than the younger group), this did not translate into more specific than general cues being mentioned. Although, perhaps due to the short length of the videos, there was more similarity in the two group’s concepts than with Study 1, nonetheless, the younger group’s main concepts of 'car', ‘lights’ and ‘road (side)’ were still arguably more specific and useful for safe driving, than the older group’s focus on ‘traffic’, ‘left (side)’ and ‘going’(?).

8.4. (RQ2): Does Situation Awareness proficiency assist in the detection of roadway hazards?

A driving performance measure was chosen for Study 2 to assess for any relationship with Situation Awareness. It was felt that if any such relationship could be found that this would both advantageously give credibility to the method used in the thesis for the measurement of SA, and raise the possibility that the concept could indirectly improve driver performance through training.

The performance measure chosen to be investigated was Hazard Perception (HP) - as it was in the Zhang et al. (2009)/Kaber et al. (2012) studies mentioned above. As Chapter 5 & 6 highlight, this was due to four main reasons: it is testable by commentaries, and thus could be measured together with Situation Awareness; it has linkages to traffic accidents (e.g. McKenna & Crick, 1991); like Situation Awareness it has been found to decline with age (e.g. Wallis & Horswill, 2007); and potentially there is a performance relationship between the two concepts. This last factor can be demonstrated by similar conceptualisation, such as the ability to read the road (Mills et al., 1998), or to anticipate potentially dangerous situations on it - in effect, having Situation Awareness for hazardous situations involving roadway environments and users (see, Horswill & McKenna, 2004).

In Study 2, two Hazard Perception indicators were assessed against what was considered the best measure of SA within that study - a Density metric score from combining the text of the two video-based journeys that were assessed. As a result, six comparative scores were obtained, and these are reproduced below in Table 8.B.

Table 8.B: HP and SA score correlations

	Group		
	SA Density scores for combined journey		
HP measure	Both	Older	Younger
Total HP score (p<)	0.450	0.936	0.008
HP score w/o speed element (p<)	0.060	0.360	0.005

For the older group, by either HP measure, an individual's Situation Awareness proficiency did not appear to help with the detection of a hazard. However, account has to be taken of feedback given by older group participants after the study, that considered the driving speeds in the videos as being too fast (though they were actually within appropriate speed limits). This could indicate that they simply may not have had sufficient time on certain trials to process the relevant information for a hazard's detection. That perceived lack of time, coupled with the fact that sometimes the hazards were only briefly visible, suggests cognitive decrements may have been of relevance for this aspect of the study. As Bolstad (2001) contends "We can therefore speculate that the ability to attend to important information (initial formation of SA) will also change with age due to changes in these [related] cognitive abilities and these differences will be more apparent as task complexity increases." (p.272). Thus an inference can be made that experience and even good SA-related processing of information may not always be sufficient in certain driving contexts. And indeed, Bolstad further states "There may come a time, however, when the experience will no longer insulate the [older] driver from performance decrements" (p.272), as is suggested here with Hazard Perception.

It could equally be though, as Kaber et al. (2012) propose (see also RQ3 below), that complex roadway environments may actually raise the SA performance of older participants at its perception level; though at the expense of better comprehension and action. In other words, the increased effort in perceiving cues may impinge on their ability to comprehend a hazard, and how to react to it, and, indeed, it was these two HP elements that were measured in Study 2.

As a result of the low SA to HP relationship amongst the older group, perhaps unsurprisingly, when the scores from both groups were considered together, again no correlation was found between the overall HP total scores and the SA Density scores. However, when the speed of detection element was taken out, and a correlation assessed simply between the number of hazards a participant detected and his/her SA Density score, then a statistically significant relationship was very nearly achieved ($p<0.060$) (Table 8.B). This was encouraging given the small sample sizes, and given the fact that participants were unaware that hazards were being presented and scored.

Furthermore, in contrast to the older group, the younger participants showed an interesting and statistically significant relationship between both their group's 'Combined journey' and 'Complex journey' SA Density scores, and their Hazard Perception Test scores. This was the case whether or not the speed (of detection) element was taken into consideration: for the 'Combined journey' - $p<0.005$ (without the speed element)/$p<0.008$ (with the speed element); for the 'Complex journey' - $p<0.034$/$p<0.035$.

In terms of a Situation Awareness to Hazard Perception relationship, then, this study showed that SA proficiency may indeed be an important precursor for hazard detection at least amongst younger driving groups. Perhaps this was due to them not having the encumbrance of slower information processing speeds, whereas to different degrees, these could have masked an SA to HP relationship for the older group. Additionally, it should be borne in mind that the older drivers would not have encountered video footage of hazards before, whereas all of the younger group would have done so from having taken their driving tests after 2002. It could therefore be that with more practice, and with tailored slower speeds, that the older drivers might be able to improve their HP scores sufficient to bring them more into line with their higher SA Density scores, or bring that about through perhaps a better balance between their

Level 1 SA (perception) and Levels 2 & 3 (comprehension & projection). Indeed, Kaber et al. (2012) observe "older drivers appeared to adopt a conservative driving style as a method to compensate for any declines in abilities. Specifically, they drove slower when negotiating hazards, especially under dynamic conditions. It is possible that older drivers may intentionally give themselves more time to perceive and process environmental cues after hazard exposure in order to maintain perceived risk below a certain internal threshold (Fuller, McHugh, & Pender, 2008; Summala, 1996). However, young drivers maintain higher speeds than older drivers in the presence of hazards as compared to normal driving, especially under static hazard conditions." (p.609).

In view of that information, perhaps the Hazard Perception Tests, utilised for Study 2 and the UK Driving Test, unfairly disadvantages older drivers? The author is unaware, for example, as to whether consideration is given by the DVLC to the fact that older drivers purposely drive slower for safety reasons, or that they might in some instances experience mild vertigo whilst undertaking such tests (as was found in Study 2)?

In addition to quantitative data, consideration can also be given to qualitative data for this RQ. In particular, the similarities or differences in the main concepts that informed the SA of the best and worst Hazard Perception Test performers can be assessed. It was found that they were surprisingly similar - only those in bold in Table 8.C (below) differed between the two groups.

Table 8.C: Concepts informing the top and lowest 5 ranking HPT performers

HPT scores	SA scores	Concept Rank and count					
		1	2	3	4	5	Total
Top 5	2/0.8115	Traffic (197)	**Lights (180)**	Cars (175)	Going (135)	Road (125)	812
Lower 5	2/0.7011	Car (149)	Road (138)	**Left (114)**	Traffic (110)	Going (103)	614

It therefore would seem that for better Hazard Perception, it is not so much about knowing what concepts may be relevant, but more the times those concepts are checked in a driving environment. The better HPT scorers mentioned the concepts important to them (particularly the top 3) considerably more often within an assessed (combined) journey time of just over 14 minutes. As has been found with high SA performers in general in this research, and discussed further under Aspect 2 below, it is a high awareness of the concepts that are perceived as important to the individual that generally (and arguably, rightly) leads to better SA cohesion scores. This was also found here with the higher HPT scorers, who further produced a high group SA Density score of 0.8115, against the lowest performers 0.7011.

Thus, quantitatively at least, evidence is provided here for good SA informing better Hazard Perception, but not conclusively so. One might expect, for example, more of a difference in the overall SA Density scores, and perhaps the Diameter scores, for these 'Top' and 'Lower' HPT groups (given the average overall scoring differences for them on the test were 23.6pts to 12.2pts). That said, it is important to restate that the participants were not made aware prior to the study that any specific hazard(s) would be present in a video, or that they were being judged on their detection. This approach was adopted as it was felt that as hazards are not generally presumed in a driving environment, that it would be more realistic to have them measured by how well they were unexpectedly reacted to. However, if the participants had been forewarned, perhaps the concepts seen as important might have informatively changed?

In summary, again the need for further work is highlighted here, as it would be of value to discover what perception strategies might aid Hazard Perception, and whether they could be learned through training: particularly given that both SA (Stanton et al., 2007; Soliman & Mathna, 2009; Walker et al., 2009) and HP (Horswill & McKenna, 2004), have been improved by training programmes.

8.5. (RQ3): Is Situation Awareness worse amongst older (than younger) drivers in more cognitively taxing driving conditions?

One of the interesting aspects of this series of studies related to what would be perceived as a taxing driving environment (particularly) for the older drivers, and how this would affect SA scoring expectations. This was relevant for Studies 1 & 3, as much as it was for Study 2, but as those studies involved actual driving, consideration had to be given to a participant's safety.

In Study 2, as videos of (two) car journeys were to be shown to participants, more demanding environments could be considered. Thus the journeys chosen were of very different complexity: one was a drive around a mainly residential suburban area with little traffic; the other through a city centre with more pedestrians and a greater range and number of vehicles. To corroborate that perception, all of the participants were asked after they had seen the two videos whether they felt the journeys were different or similar in their difficulty/complexity, and all indicated that the city centre drive was the more onerous as it was busier and had more to comment on.

The two driven journeys for Study 1 and 3, although both undertaken by ten of the same participants, could not similarly be assessed for relative difficulty due to a time lapse of over a year between them being driven. However, the route chosen for Study 3 was quantifiably more difficult, and consequently felt to be more taxing due to the comparative number of, for example, tight corners, single carriageway roads, and roundabouts that the driver faced. Table 8.D below, reproduced from Study 3, provides some further data, and additionally, here, two miscellaneous factors.

Table 8.D: Study 1 & 3 route difficulty comparisons

Route comparisons	Study 1	Study 3
Roadway artefacts		
Traffic/pedestrian lights	16	17
Roundabouts	6	12
Totals	**22**	**29**
Cornering/turning		
Left turns	1	2
Left bends (sharp & blind)	1	13
Left bends (sharp)	0	2
(Of which were 90 degrees)	(0)	(3)
‘T’ Junction Left turn	3	1
Right turns	4	2
Right bends (sharp & blind)	1	12
Right bends (sharp)	0	3
(Of which 90 degree turns)	(0)	(3)
‘T’ Junction Right turn	1	2(1 blind)
Totals	**11**	**37**
Miscellaneous		
Single car width roads	0	2.66 miles
Three-point turn	0	1

In terms of Situation Awareness, for the older drivers an assumption was made (as given in previous research above), that due to age-related cognitive deficits their SA would worsen on the more ‘complex’ video journey. Kaber et al. (2012) “As expected, the complexity of the driving environment was also influential in driver SA and performance, and this was related to driver age." (p.609). Zhang et al. (2009) "interaction of age and complexity has a considerable effect on SA after hazard. Elderly drivers were adversely affected by increased clutter in driving environment and hence showed poor SA under city than rural scenario" (p.7). And relatedly, Ho et al. (2001) "search efficiency declined with increased [roadside visual] clutter and with aging." (p.194).

In terms of whether the SA of older drivers worsens in relation to younger drivers in more taxing conditions, the results from the two related studies in this series were again interestingly diverse (see Table 8.E below). When an SA measure was taken whilst actually driving (Study 3), the results mirrored the general beliefs given in the literature - that the older drivers would perform (in this study, significantly ($p<0.024$)) worse than those in a younger driver group.

However, when viewing and commenting on a complex, more cognitively taxing, journey shown on video footage, the opposite result was found. Here, the older participants now out-scored their younger counterparts, particularly when the individual SA Density scores were averaged and compared - though the differences were not significant.

Table 8.E: SA metric scores for the 'complex', more cognitively taxing trials

	SA metric scores			
	Younger Group		Older Group	
Study	Group based	Av. Individual	Group based	Av. Individual
2 (video)	2/ 0.7586	3.4/ 0.3743	2/ **0.7956**	**3/ 0.4386**
3 (driving)	2/ **0.8895**	**2.5/ 0.5333**	2/ 0.7247	2.7/ 0.4321

** bolder scores indicate higher intra-study scoring, the shaded backgrounds higher inter-study scoring*

As was discussed above, these two trials (in Table 8.E) were evaluated as being more cognitively taxing than the two given in Table 8.F (below). In Study 2 by the participants themselves, and in Study 3, by objective measures of the route configuration in comparison to Study 1.

Table 8.F: SA metric scores for the 'standard', less cognitively taxing trials

Study	SA metric scores			
	Younger Group		Older Group	
	Group based	Av. Individual	Group based	Av. Individual
2 (video)	2/ 0.7578	3.1/ 0.3789	2/ **0.7610**	**2.8/ 0.4310**
1 (driving)	2/ **0.8238**	3.2/ **0.3874**	2/ 0.7417	**3.1**/ 0.3819

** bolder scores indicate higher intra-study scoring, the shaded backgrounds higher inter-study scoring*

If the age-related decrement assertions in the literature are correct, then it could be assumed that the older driver's SA would be worse for the trials in Table 8.E than the trials in Table 8.F. However, higher SA scores tend to be found in the more taxing trials. Thus SA was not worsened by cognitively taxing environments for the older drivers, nor for that matter the younger drivers, rather it was unexpectedly enhanced. This is not, though, such an unusual finding per se. Kaber et al. (2012), for example, found "Young drivers exhibited degraded Level 1 SA in the complex environment after hazard exposure, while older drivers exhibited improved Level 1 SA in the same condition." (p.605). Kaber's complex condition had the effect of bringing additional attention from his older drivers once they encountered a hazard, but that "higher Levels SA, comprehension and projection, were degraded for older drivers due to hazard exposure" (p.609). The extra perceptual effort seems to have cost them better comprehension, and this could have relevance for their Hazard Perception Test performance. Additionally, Bolstad (2001), although not finding any increased SA proficiency with her older driver group when encountering complex driving conditions, equally did not find them more affected: "While differences in SA performance between the age groups were hypothesized to become more pronounced as the complexity of the task increased, this did not bear out. Results show that SA for all age groups declined from the moderate complexity condition to the high complexity condition; however; older adults did not experience a greater decrease in performance when compared to the other age groups." (p.276). Thus perhaps what Studies 2 & 3 show is that SA performance can actually be uplifted through greater effort to meet the demands of increased cognitive taxation and a task's unfamiliarity or difficulty. However, this would only seem prevalent when the individual is aware of that difficulty. A contrast can thus be made for the older groups in this regard between their uplift in scoring from Study 1 to Study 2 (when they were conscious of the need for increased cognitive activity) and their subsequent decline in scoring for Study 3 (when they were less aware). This assertion is considered further under Aspect 2 below.

8.6. (Aspect 2): What conclusions can be made in regards to older driver SA? Could it be improved and how?

8.6.1. Quantitative data

The SA Diameter and Density scores for the three studies undertaken in this series are given below in Table 8.G. At the overall group assessment level there was both more consistency and higher scoring by the younger participants across the three studies. The shaded backgrounds and bolder text denote the higher comparative scores.

This reflects that the younger driver groups, on the whole, drew on more similar concepts and related them more proficiently. This, despite these groups being more diverse, both in number (23 to 13 older participants), and background - as they included a number of foreign students who had also driven abroad.

Table 8.G: SA metric scores across the three Studies

SA assessment scores (Diameter/Density)							
Group	Comparison	Study 1		Study 2		Study 3	
		Dia.	Density	Dia.	Density	Dia.	Density
Older	Group	2	0.7417	2	0.8427	2	0.7247
	Individual	**3.1**	0.3819	**2.4**	**0.5452**	2.7	0.4321
Younger	Group	2	**0.8238**	2	**0.8597**	2	**0.8895**
	Individual	3.2	**0.3848**	2.7	0.4628	**2.5**	**0.5333**

* bolder text indicates the higher comparative score; the darker background the greater the difference

However, when individual performances were compared the picture became more mixed. Individual older drivers were found to produce SA levels that could match and exceed the younger drivers. This was particularly reflected in the video-based study (2), where older drivers were ranked 1st, 2nd, and 4th overall. In contrast, for the driving studies (1 & 3) the less taxing variant (Study 1) produced parity in SA scoring with the younger group, whilst a more taxing route (Study 3) found the younger group to perform (significantly $p<0.024$) better.

Such scoring differences are now considered further by quantitative data provided in Tables 8.H to 8.J below. In Table 8.H, the SA Density scores for the older group from Study 2 are compared to those from the more difficult second driving Study (3) - advantageously all of the older drivers in that study also took part in Study 2. The difference in scoring here was significant ($p<0.002$), as it was between Study 1 and 2 ($p<0.009$) for the seven older participants who undertook both those studies. It is important to note that the Diameter scores were not similarly considered for such comparisons due to their insufficient score differentiation for the length of narrative produced.

Table 8.H: Older driver SA metric comparisons with sig. levels for the Density scores

Study	SA scores		Statistical significance				
	Diameter	Density	T	Ppts.	df.	Correlation	Sig.
3 (Driving)	2.7	0.4321	-4.483	10	9	0.682	0.002
2 (Video-based)	2.4	0.5505					

In contrast, an opposite effect, though less pronounced, was found for the Density scores of the younger participants who had undertaken Study 2 and 3, though they were fewer in number, see Table 8.I.

Table 8.I: Younger driver SA metric comparisons with sig. levels for the Density scores

Study	SA scores		Statistical significance				
	Diameter	Density	T	Ppts.	df.	Correlation	Sig.
3 (Driving)	2.3	0.5696	1.785	6	5	0.438	0.134
2 (Video-based)	2.7	0.4793					

Such findings were investigated further by considering how the SA Density scores had improved or worsened for those participants who had undertaken more than one of the three studies.

Table 8.J shows, for the two driving studies (1 & 3), participants had both improved and worsened their SA Density score in about equal measure. Those worsening their scores tended to come from the higher scoring thresholds - 7th and above (falling 0.1020 on average), whereas those improving tended to come from the lower ranking echelons of Study 1 – 9th and below (improving by 0.1210 on average).

However, the performance changes in relation to the video-study (2) were far more striking with all of the older drivers who took Study 1 improving in Study 2, and all but one then worsening for Study 3.

Table 8.J: How SA Density scores improved or worsened for those undertaking all three studies

	Comparison								
	Study 1 to Study 2			Study 2 to Study 3			Study 1 to Study 3		
Group	Ppts.	Imp.	Wor.	Ppts.	Imp.	Wor.	Ppts.	Imp.	Wor.
Older	8	8	0	10	1	9	7	4	3
Younger	2	1	1	6	5	1	2*	1	0

* *to note: one ppt. scored exactly the same Density score*

Notwithstanding the low comparison sample here, particularly for the younger participants, this data supports the contention made in earlier sections of this chapter, that SA could have a relationship to a task's perceived difficulty rather than being, say, uniformly poor for older drivers, as is usually assumed in the literature (e.g. Bolstad, 2001). This assertion had further support from participant feedback, and this deserves further consideration.

After Study 3 was concluded, all of the participants who had also undertaken Study 2 were asked which study they felt was the easier to undertake. Surprisingly, all of the older drivers said that the driving task (Study 3) was easier. The video-based study (2), in contrast, was considered as more difficult, and, indeed, many of the older participants felt that as a result they must have missed something to comment on. There was a general feeling that the speed of the vehicle was often excessive and could not, of course, be regulated. There was also no indication of where the car would turn from a junction, which was seen as disorientating. And interestingly, that the front-only viewpoint was limiting (despite being a preference for the driving studies), as there was a desire to be able to see what was coming from the 'Left and 'Right'. Concepts, incidentally, that had high relevance for the older participants across all three studies relative to the younger drivers (discussed further below). It should also be added that two of the older participants experienced some level of vertigo in undertaking the video trials, with one needing to withdraw from the study as a result. In contrast, no problems were highlighted by any younger driver, either during or after any of the studies.

It was assumed that due to age-related cognitive decrements, exposing older drivers to a taxing journey would result in a worsening of their SA. However, even taking into account that taxing environments can have an opposite effect with older drivers (Kaber et al., 2012), task difficulty would still appear to be an important variable. It was speculated above that with the tasks the older drivers found difficult, such as in Study 2, that their concentration and attention perhaps rose. Could this, though, have also been assisted by the short, 7 minute, duration of these journeys? Craik & Byrd (1982), for example, propose that a reduction in available mental energy or attentional capacity is one of several major factors underlying declining cognitive efficiency in the elderly. Thus, perhaps these declines were not as influential as they might have been in the longer (two) driving studies? And although not seen as an advantage by the older drivers, a limited frontal view to comment on in the video footage may also have assisted the group in capturing more cues, more cohesively, than when driving, due to potential age-related peripheral view problems (e.g. Ball et al., 1988).

Whether such factors influenced the older driver's performance or not can only be speculated, but what is clear is that when they were later faced with what they considered to be an easier task (driving their own vehicles in Study 3), a related fall in SA proficiency was found for nine of the ten older participants (all of whom had participated in Study 2). This despite this second driving route being objectively more cognitively taxing, particularly to that of the 'Standard' journey viewed in Study 2.

The conclusions that can therefore be made here are that older driver SA is quantitatively more inconsistent when assessed as a group (in comparison to younger drivers), and that this inconsistency could be linked more to perceptions of task difficulty than roadway complexity alone. In short, the older drivers in these studies were proficient drivers. They were confident on the road, though drove at (quantifiably) slower speeds, presumably to give themselves more reaction time. They had no difficulty explaining their thoughts, often drawing on their long driving experience. However, although their SA was heightened for the more complex driving route of Study 3 ($p<0.393$) when compared to Study 1, arguably insufficiently so, given the far higher uplift in SA scoring ($p<0.062$) recorded by the younger driver group. Whether this was due to superior confidence, less awareness of the difficulties that the more taxing route provided, or, in contrast, an inability to process and cohesively vocalise commentaries in more taxing driving conditions over longer time periods, remains open to question.

8.6.2. Top 5/Lower 5 SA performer comparisons

The SA scoring from the three studies could further be compared by the computer software to see whether there might be any differences between the best and worse SA performers in terms of their Diameter and Density scoring and what concepts they felt were of importance (see Table 8.K).

Table 8.K: SA concept referral comparison between the best and worse SA performers

Study	Top 5 performers			Lowest 5 performers		
	Dia./Den.	Main Concepts	Top 5 concepts mentioned (No.)	Dia./Den.	Main Concepts	Top 5 concepts mentioned (No.)
1	2/0.8467	32	1168	3/0.3472	29	565
2	2/0.8387	31	864	2/0.5828	30	519
3	2/0.8427	32	1299	2/0.5597	35	681
Top ranking Concepts	1. Road (side); 2. Car (parked); 3. Coming (**stop**); 4. In (lane); **5. Left (side)**; 6. Going (**straight**)			1. Car (parked); 2. In (lane); 3. Road (side); 4. Coming (**towards**); 5. Going (**past**)		

It will first be noted that the top five performer's narratives were collectively both more cohesive and also very consistent across all three studies. These participants therefore considered the same concepts more often and related them in a similar fashion for each study. For the lowest five participants, their SA Density and Diameter scores showed less cohesion, though still creditable, and also consistency between the more difficult studies (2 and 3). In Study 1, however, the group's performance was markedly poorer, but this was not explained by the concepts the group focussed on, or tried to interrelate. Like the HPT data above (Table 8.C), and across all three studies, four of the top five concepts were identical and had similar main concept relationships (i.e. 'Car' with 'parked', 'In' with 'lane'). It was, again, more the number of times these main concepts were perceived and referred to that appears to have given the Top 5 SA performers their better Density and Diameter scores.

Having a greater perception of these main concepts necessarily will bring more network linkages to other related concepts, aiding their later recall and comprehension. Thus better SA proficiency, from a systems perspective, will emerge from how well the data the individual perceives is interrelated. However, the relevance of that information must also be considered, and the findings from this series of studies do suggest some important overall group differences as to what was considered as relevant.

8.6.3. Concepts comparisons

In Table 8.L below, the main concepts given by the older and younger groups are ranked. For the younger group, which was more varied in composition across the three studies than the older group, a clear interest was demonstrated in parked cars whatever the journey, and whether driven or not. Another distinguishing concept and related action, which did not register for the older drivers, was that of speed regulation. This was highlighted by the 'Down' concept - from its high association with slowing through 'Gear' changes; and the 'Speed' concept itself. Younger drivers have been found to be more likely than older drivers to drive with an increased level of risk, by driving at faster speeds (Baxter et al., 1990; Galin, 1981; Fancher et al., 1998; Fildes et al., 1991; Quimby et al., 1999a; Quimby et al., 1999b; Smeed, 1972). This might, of course, have accounted for their greater interest in speed regulation when their driving was being 'evaluated'? However, it could also be related to more cognitive capacity to consider a range of driving cues, or a (advantageous?) need for more focus on driving actions (due to less experience) relative to the older driving groups.

Table 8.L: Main concepts utilised by the two age-groupings across all three studies

Rk.	Younger Group			Older Group		
	Study 1	**Study 2**	**Study 3**	**Study 1**	**Study 2**	**Study 3**
1	Down	**Car(s)** (parked)	**Car** (parked)	**Coming** (towards)	Traffic	**Coming** (towards)
2	**Cars** (parked)	Lights	In	Right	Left	Left
3	Going	Road	Go(ing)	In	Go(ing)	Car
4	In	Traffic	Down	Car	Right	Right
5	Coming	Left	Coming	Road	**Coming** (Junction)	Going
6	Road	Going	Road	Going	Road	Road
7	See	Side	Right	Left	Car	In
8	Speed	In	Left	Traffic	Side	Side
9	Right		Side		In	Hand
10			Speed		Parked	Traffic

**background shaded concepts appeared in the 'top 10' for all three studies*

The more homogenous older groups produced more consistency in their concepts (as denoted by the darker shading in Table 8.L), with an awareness of what was 'Coming - towards' their vehicles of particular importance. This general focus to the front seems to be augmented, although to a lesser extent, by what was to the 'Right' and 'Left'. In terms of ranking, both these concepts appear in the top four placings for the older groups in two of the studies, and 2nd and 7th in the third (Study 1). This observational need may, as considered earlier, have been a factor for the perceived difficulty of the video tasks for this group in Study 2. In comparison, for the younger group: only 'Right' figures in Study 1 (9th); 'Left' only in Study 2 (5th); and both 'Right' and 'Left' at comparatively low rankings (7th and 8th) in Study 3.

Table 8.M (below) compares the most prominent concepts for each age grouping. That is, those concepts that were the most distinguishing between the two groups. There is, not surprisingly, much similarity here with Table 8.L above, with more consistency in the main distinguishing concepts for the older group. The four concepts that appear twice, in bold text, are also again those considered as major concepts for the group in Table 8.L.

Table 8.M: Prominent Concepts (above a 1.2 score) across the three studies

Younger Group			Older Group		
Concept	**Prominence**	**Study**	**Concept**	**Prominence**	**Study**
Checking	1.8	3	Left	1.4 + 1.2	1 + 3
See	1.5	1	Traffic	1.3 + 1.2	1 + 3
Down	1.3 + 1.3	1 + 3	Coming	1.3 + 1.2	1 + 2
Speed	1.3	1	Right	1.3 + 1.2	1 + 2
Cars	1.2	2	Turning	1.2	2
			Going	1.2	2
			Parked	1.2	3
			Road	1.2	1

**background shaded concepts appeared in more than one study*

The younger drivers in this Table show, in contrast, that they had a lesser number of distinguishing concepts across the three studies, but where found that they were more pronounced: i.e. the 'Checking' concept (with a 1.8 Prominence score); and the 'See' concept (with 1.5). Interestingly both these concepts related to looking behind the vehicle, a preference for younger drivers that is considered further below.

<u>8.6.4. Rearward and safety-related concepts</u>

In Study 1, it was argued that the SA-related data for the older driver group had shown indications of them having an undue focus to the front, and front/sides of their vehicles, at the expense of what was occurring behind. As such it was felt that this less optimal awareness might result in the older drivers missing important safety-related information, and this seemed evident from further concept comparisons. This assertion could not be effectively measured in Study 2, but in Study 3 it could be re-considered. The initial evidence from the group networks in that latter study appeared to show that the older drivers had taken more note of what was happening 'Behind' their vehicles, due to linkages between that concept and a main 'Car' concept that were not found in Study 1. However, when a comparison was made of the times a rearward looking concept or word was mentioned in isolation in both of the driving studies, the results were only marginally improved by the older drivers for the more taxing second drive (Table 8.N).

Table 8.N: Rearward-related concept comparisons for Study 1 & 3

	Older Group				Younger Group			
	Study 1		**Study 3**		**Study 1**		**Study 3**	
Concept	Concept Count	Word Count	Concept Count	Word Count	Concept Count	Word Count	Concept Count	Word Count
Behind	123	125	99	105	92	91	83	86
Mirror	12	21	0	3	123	132	117	97
Rear	0	0	0	0	8	40	32	35
Wing (mirror)	2	1	0	0	17	10	5	14
Totals	137	99	147	108	240	273	237	232

A second aspect of interest from Study 1's findings was a potentially sub-optimal amount of safety-relevant information being processed by the older drivers. This was more difficult to substantiate from the text alone, but an argument was made that perhaps an indication could be gained from what the participants themselves had enunciated in their narratives. In Table 8.O, below, the concepts that were felt to have safety relevance are compared by concept and word count for the two groups for both of the driving studies.

Table 8.0: Safety-related concept comparisons for Studies 1 & 3

Safety-related Concepts	Older Group				Younger Group			
	Study 1		**Study 3**		**Study 1**		**Study 3**	
	Concept Count	Word Count	Concept Count	Word Count	Concept Count	Word Count	Concept Count	Word Count
Checking	6	19	0	6	178	220	181	183
Check	10		5		45		0	
Indicating	31	108	23	76	117	142	26	71
Indicate	28		30		45		25	
Blind	6	7	18	20	29	33	78	81
Clear	66	71	46	55	112	122	113	121
Sure	18	19	0	23	105	98	144	124
Gap	0	0	5	5	9	12	12	12
Safe	6	11	9	12	14	19	12	20
Looking	0	57	16	64	136	161	165	175
Look	19		0		46			
Aware	10	10	0	3	63	69	75	79
Warning	10	11	7	8	12	12	0	2
(having)Time	22	10	33	7	20	12	36	23
(enough)Space	9	9	0	9	11	10	0	28
(enough)Room	16	9	27	27	13	13	13	14
Totals	257	341	219	315	955	923	756	933

It was found that the younger group performed better on all but two concept scores and in every relevant word count in Study 1, and overall that it's participants mentioned these safety-related words around three times more often.

For Study 3, where the drive was more demanding, the expectation was that this large gap would close, however the Table again shows a remarkably similar ratio in overall scoring to Study 1. The more reliable word count comparison actually shows a widening gap here, with again the younger group giving far more consideration to 'Checking', 'Looking', and being 'Sure' and 'Aware'. As expected, for both groups the 'Blind' (corners/turns) concept increased in prominence, given the topology of Study 3's route.

There were indications during the driving-based studies that the older drivers were more easily distracted from, and therefore had less awareness of, the driving task. This was usually reflected in the group's overall (SA metric) scoring, but here there are additional, demonstrably large, differences in relation to safe-driving actions. It could be, of course, that such differences could be due, as argued earlier, to the older drivers processing such cues less consciously or automatically, and/or that they considered a lesser number of the driving environments encountered in need of 'looking' or ‘checking’ due to their greater driving experience. Additionally, it should be borne in mind that the younger group did produce 7% more average text in their commentaries for Study 3, whereas in Study 1 there was more parity with the older group. But in view of the similar ratios for these concepts between the two studies (of almost identical time duration), coupled with the reasonable belief that a need for more safety awareness should have been apparent when driving Study 3’s more cognitively taxing route, it would be expected that these related concept and word counts should narrow. After all, the participants were aware that their driving proficiency, in the sense of what they were aware of, was being ‘tested’, and thus they may actually have been more inclined to enunciate and demonstrate ‘safety-correct’ driving procedures.

What these findings show for the purposes of Situation Awareness are that older drivers are potentially deficient in perceiving these safety-related cues, despite their longer driving experience. This could present difficulties for them whilst driving as that perception is arguably the most important precursor for good Situation Awareness. This is because what we perceive will inform both how well we comprehend a driving scenario, and how well we then act in the face of it. Thus, these findings would no doubt benefit from being corroborated by further research with different methodologies, as they could indicate important precursors for accident involvement amongst older drivers.

8.6.5. Can SA be improved and how?

The concentration of this work has been on older driver SA. Those older drivers who took part, often undertook all three of the studies, and produced SA scores that could match and in some cases exceed that of younger age groups. This was particularly evident for Study 2’s video-based trials, where it has been argued their SA improved due to difficulties arising from the novelty of the task, and its format. The aim here, however, is to improve older driver’s SA on actual roadways.

To that end, it can firstly be proposed that there is perhaps a need to increase their concentration and attention levels in line with roadway risk. These appeared to be too uniform across the two driving tasks that were quantifiably different in their complexity. This was indicated by a substantially different uplift in Situation Awareness scoring between the younger ($p<0.062$) and older ($p< 0.393$) groups from Study 1 to Study 3.

The older drivers were confident on a roadway whatever its complexity. But this appears to have led to insufficient cohesive processing of cues, particularly for Study 3's more taxing drive, where vehicles could often quickly approach from the many blind corners on the route. This could leave the older driver at more risk when unexpected hazards occur, particularly as cognitively and physically they may be less able to respond effectively. And, as was argued in Chapter 5, this is likely to be augmented by them being unaware of the extent and prevalence of those decrements.

Another way in which an older driver's SA could be improved would potentially be by coaching them on what should be attended to. In Study 2, it was found, at least for short durations, that when faced with what was perceived to be a difficult task, that they could undertake a higher degree of information processing relative to a younger group (as demonstrated by a 26.57% higher average word count). Furthermore, this increased awareness was also more cohesive than the younger participants when assessed by individual performance. In fact, it was the only occasion over six measures of SA Density scoring when the older participants out-performed their younger counterparts. This shows that the potential for increased awareness is possible for older drivers. However, that improvement will not translate into a safer driving if, for example, the additional information is not processed in a timely fashion, or if it leads to the wrong kinds of information being processed, perhaps due to time pressure. In fact, it was argued in Chapter 6 that it could have been for such reasons that the older drivers faired worse than younger drivers in detecting hazards.

It has been shown from qualitative assessments in the studies undertaken for this research that the younger groups commented more consistently on relevant information, despite them forming more heterogeneous groups. This was the case for the commentaries taken both from video studies, and whilst driving. In the latter case it was shown (in Table 8.L above) that the older group attended more to what was 'Coming' towards their vehicles, what was to the 'Left' and 'Right', and 'Going'-'Straight' (over). For the younger group, it was more about parked 'Cars', 'Going'-'Around' (corners), and in Table 8.M, ‘Checking’ and to ‘See’ what was behind their vehicles. Additionally, the younger drivers demonstrated an awareness of speed regulation, not exhibited by the older drivers, through the importance they attached to that concept through interrelations such as ‘Down’ and ‘Gear’. In Study 1 there were also unique concepts relating to indicating, stopping and going, cars behind and to the side, gear changes, seeing gaps, and specific traffic light colours than just the lights themselves. To these can be added the finding discussed in section 8.6.4 above, of a more specific awareness of safety-related cues.

A consistent difference in what was perceived by the two groups is thus evident. The reason for this could be related to experience, and its relationship to perceptions of risk and depth of processing. It could also be due to older group difficulties in maintaining sufficient awareness over longer time periods. Whatever the reason, though, the findings from this series of studies indicate that the older driver should gain a safety-related improvement in SA from a change in perceptual focus. This could be achieved by undertaking more processing of a range of relevant and specific artefacts from all around the vehicle, rather than relying on fewer and broader, direction-based, ones predominantly from the front aspect. More consideration to speed regulation would also seem beneficial, and from participant feedback this was often acknowledged as a problem. So much so, in fact, that a number of the older drivers utilised a ‘cruise-control’ function set to a road’s speed limit. In this regard, however, additional speed signage might be a simple aid or even a solution, so no doubt benefits would be gained from research that sought to evaluate where and to what extent such additional information of this type would be helpful. From anecdotal evidence, this could, in fact, derive benefits for all drivers, as often narratives would include comments such as: I don’t know the speed I should be doing along here, but that x suggests that it should be y miles an hour.

The data across the three studies undertaken for this thesis show that an older driver’s SA would seem adequate during non-taxing and familiar routes (not withstanding their less proficient cue processing). It was also shown that it could be cohesively raised for shorter time periods, when roadways were perceived as hard to evaluate. However, and perhaps crucially, it could similarly fall to levels that might be inconsistent with their cognitive and physical capabilities during more (and actual) demanding driving environments.

It may not be possible, due to age-related decrements, for the older driver to sustain information processing capabilities to the level of younger driver groups over a long journey. The key here, then, would seem to be raising their awareness at propitious moments, and to direct it to relevant safety-related cues. This could be assisted by automated devices that are able to evaluate and provide information about different driving environments, the likely dangers, and the necessary related driving actions to operate effectively within them.

In terms of training for better SA, it might be that more bespoke approaches might be more relevant, but in general the following techniques seem worthy of consideration.

8.6.5.1. What an SA training programme might include

Any training in regards to Situation Awareness should be based around developing a strategy that seeks to enhance how we look, interpret what we see, and then to combine that information in a way that increases our anticipation of relevant threatening events. These are the three basic components for SA as described by Endsley. These may, of course, not be undertaken hierarchically, as Endsley suggests, but in parallel, however, to leave that discussion to one side, they do provide a useful framework for explaining a potential training programme, and so will be utilised here.

Thus, a first improvement to enhancing SA would be to try to improve how we look, as this would allow for a more complete assessment of our field of view. To achieve this, we need to become more systematic and specific in the way we perceive information. As if a roadway environment is sampled more effectively, and applied on a more continuous basis, we should be able to increase our chances of spotting dangerous events in time.

Each driver therefore needs a scanning strategy, and it is proposed here that this should include a cyclical search of threats to safety, and in parallel, a search for any immediate threat(s). An example might involve looking at the car directly in front as a starting point, and then moving focus to another slightly ahead. Concomitantly, however, it will also be necessary to seek out those items that look the most immediately threatening. These should be found and then held visually in memory, as our gaze range looks further ahead along the route. This pattern should then be repeated, starting again with the car directly ahead.

Whilst undertaking this process, it might also be useful to silently (or out loud) talk through what is being looked for. This has proved to be helpful for one of the participants of the studies in this series. Indeed, a more systematic scanning (with talk-through) of roadway environments, should better alert the driver to more possible threats to safety, and thus ensure that fewer of them are missed.

It is appreciated that any such strategy of this kind would take time to master and become effective. This is due to the difficulty of maintaining concentration on two visual processes simultaneously. In this latter regard, training would have to target better focus and movement of concentration, prioritisation, and the need to increase scanning proportionate to any threat.

In addition, the driver would also have to learn to adapt to incorporate a wider range of new items, and thus improve his/her effectiveness in discarding non-relevant ones. On the plus side, however, the proficiency of such techniques can be evaluated – for example, by memory tests of scenes along a test route - and over time they should become automatic.

As has often been argued in previous chapters, effective information perception is only one part of good Situation Awareness. All SA models also incorporate some method of understanding of what will be a vast array of visual information, yet perhaps less is made of the ineffective ways we tend to do this. In most cases, for example, we will consider an inadequate number of variables, and then calculate the probability of something happening. An example might be the under-estimation of the speed of other vehicles. The proficiency of our comprehension and decision making may also be debilitated by, say: negative behaviours - such as using a hands-free mobile phone whilst driving; our emotional states; and our attitudes. So to counter such effects a thinking strategy will also be needed, as this should make our mistakes and internal states more obvious. That way, errors could be self-managed and corrected in good time.

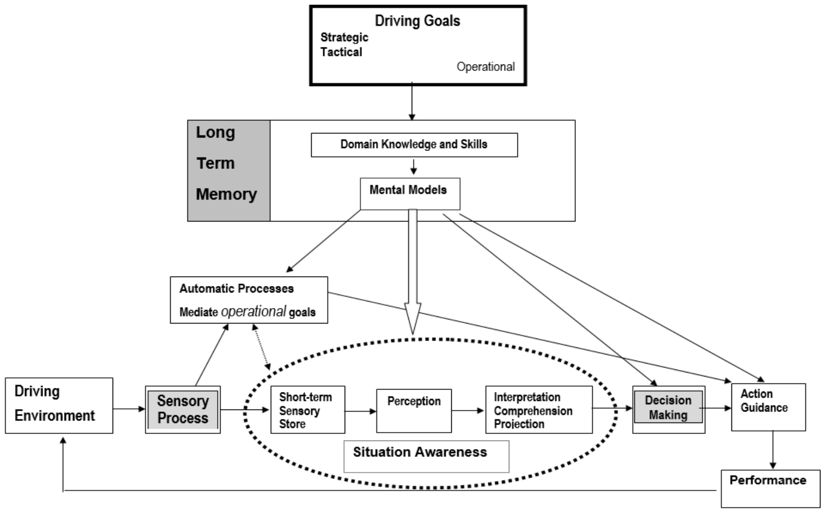
To achieve this, a step-by-step thinking though of events could be employed to reflect on the consequences likely to be produced from any given roadway environment. This would allow for a better filtering out of potential errors, and by comparing more variables we should develop a better basis for anticipating what constitutes an approaching danger. This, in turn, should produce better decisions, both for ourselves, and for other road users and pedestrians. An approach might be to adopt more defensive driving actions, such as keeping several seconds of safe decision space to the car directly in front, to allow sufficient time for this 'thinking through' process.

As with the scanning strategy, discussed earlier, the anticipatory and action elements forming part of any thinking strategy (given above) would also need to be undertaken in small and cyclical steps. In that we would need to check our predictions and actions against incoming information and its possible meanings. So, overall, in regards to training, this approach would have to be learned as part of a larger, combined, method of producing cyclical processes for both looking and thinking, and, in similar fashion, anticipating. In effect, to learn a continuous mental cycle of picking up and evaluating an increased amount of relevant information based on Endsley's three levels of Situation Awareness. This may seem a difficult task, but it should, over time, become both unified, natural, and beneficial.

8.7. In summary, a proposed model for SA whilst driving

One aspect of this research that has evolved from its undertaking, is the usefulness, highlighted again above, of Endsley's three level model for describing Situation Awareness. On the other hand, Perception-Action models appear better at explaining the cyclical nature of how we produce good awareness and how that it based very often on our own preconceptions. There is, therefore, merit in both approaches, and an attempt has been made in a model below, see Figure 8.3, to drawn the two together. Driving models of SA are rare. The only one found to be published as a paper in a peer-reviewed journal is by Michael Matthews and colleagues (Matthews et al., 2001) who kindly sent the author their work (see Figure 8.2).

Figure 8.2: SA and driving model by Matthews et al (2001)

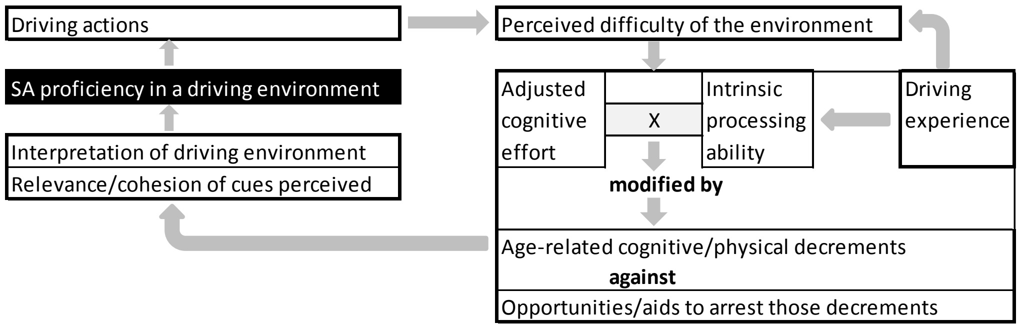


Matthews et al. view SA as involving spatial, temporal, goal, and system awareness, and have integrated these aspects into a goal-oriented model of driver behaviour that encompasses the strategic, tactical, and operational goals of driving.

The model draws much on Endsley's three level model of Situation Awareness (Endsley, 1995a), as information processing is undertaken linearly, with SA providing the decisions and actions from goals that can be automatically processed, though usually based on knowledge and skill based in long-term memory.

In contrast, a more cyclical and constantly updating model is proposed (see Figure 8.3), based more on the work of Smith & Hancock (1995) considered in Chapter 3. It differs from the Matthews et al. model by its emphasis on SA constantly being updated in tandem with changes in the driving environment, which can sometimes be rapid. It also uniquely takes account of driver effort and, specifically, the impact of cognitive and physical decrements. For Matthews et al. these would be subsumed under their more general 'skill' input (Endsley's model takes no direct account of the individual's skill or effort).

Figure 8.3: A proposed model of SA for the older driver



SA has not been shown by this research as a static, constant, phenomenon. Rather it is one that changes with each different driving environment encountered through, initially, the quality of the perceptions that are processed.

For a driven journey, it is proposed that a change in Situation Awareness proficiency becomes likely when a driver encounters an environment perceived to be different in complexity. With that awareness s/he then makes an evaluation, based on his/her driving experience, and adjusts cognitive effort accordingly. This, together with his/her intrinsic ability to process information, again based upon relevant driving experience, will then produce a level of conscious awareness in regards to the environment. It may be that the environmental change denotes less risk, and in such circumstances the effort to process information could then fall to levels where pre-conscious, automatic, processing occurs.

Having attained a level of information processing deemed sufficient for safe transit of the new environment, this may then be further modified by age-related decrements (if appropriate) and the driver's ability to mollify them, resulting in a new processing level. This will then determine the extent to which relevant cues are perceived, and how cohesively they will be processed, which, in turn, will subsequently inform how well the driver interprets the new environment. A new Situation Awareness proficiency is thus attained which then will inform his/her driving actions until the driving environment is perceived to have changed again (e.g., moving from a motorway to a major roadway environment), at which point this evaluation process will recommence. Depending on the journey, and a driver's perceptions of environmental change, this cyclical process could be undertaken to quite varying degrees by different drivers. From the evidence of this series of studies, it would arguably be the younger, than older, drivers who would undertake this cyclical processing more often.

Chapter 9: Summary & Conclusions

9.1. Introduction

The overall aim of this thesis was to assess the Situation Awareness (SA) proficiency of older drivers. This was achieved by producing and comparing spoken commentaries to those of other, younger driver, groups, to gain an indication of what was being perceived. This might then help to explain other related and important cognitive processes and the actions that flowed from them (a link between cognitive process and action has, for example, previously been found by Kass et al., 1991, 2007; Wickens & Hollands, 2000).

The studies undertaken in pursuit of that aim also took a consistent primary objective: to corroborate whether a commonly held view in the literature - that older driver SA was deficient due to age-related cognitive decrements - was justified. This was important to ascertain because a lack of Situation Awareness has been said to constitute a primary factor in accidents attributed to human error (Hartel, Smith, & Prince, 1991; Merket, Bergondy, & Cuevas-Mesa, 1997; Nullmeyer et al., 2005; Gugerty, 1998). And that age-related decrements have been found to result in slower motor responses (Rinalducci, Smither, & Bowers, 1993) and a poorer judgement of gaps (Darzentas, McDowell, & Cooper, 1980). Thus taken together, and given that life expectancy continues to increase in the UK and other Western societies, there are reasonable on-going concerns that the number of road accidents involving older drivers could rise.

This thesis also aimed to investigate the proficiency of older driver SA on the basis of two main tenets. The first was a methodological one: to utilise real road environments, rather than the somewhat artificial simulations used in previous related studies. This based on a view that capturing a driver's perceptions on actual roadways, from the concepts that they perceived and felt to be informative, would provide more useful data, particularly if this could be achieved unobtrusively and non-evasively. A 'Think aloud' continual commentary was identified as a suitable method to meet that aim, and this sat well with the thesis's arguments as to how Situation Awareness should be conceptualised and measured: as considered in Chapter 3 in response to Aspect 1.

The second tenet was to consider driving environments of different complexity. This was felt necessary due to the potential influence of cognitive taxation deficits whose provenance could derive from an individual's age and/or the roadway environments that s/he encountered. As alluded to above, these may crucially affect how proficiently information is processed, and as a corollary, would likely affect an individual driver's Situation Awareness. The literature tends to undertake research on the assumption that an older driver's SA will be deficient whatever the context. Thus it was considered of value to evaluate whether firstly this SA deficiency was present on actual roadways (rather than just in simulators), and if so, whether it was then prevalent in both non-taxing driving environments - when the driver had sufficient time to consider and react to relevant cues; and/or more taxing environments - when the chance of an overload of information was more likely to occur. Such considerations were operationalised as RQ1 & 3 and investigated in the thesis's three studies (Chapters 4, 6, & 7).

Although the scope of the work was anchored around the aim of assessing Situation Awareness, the need to incorporate video to safely evaluate complex roadway environments offered an opportunity to additionally consider whether the concept would be useful for improving a driving performance measure. Hazard Perception was chosen for this purpose due, principally, to its close relationship to SA, and because it had also been said to decline with age. RQ2 (considered in Chapters 5 & 6) directed an evaluation for any correlations between the 'scores' for these two measures. The basis for that analysis was that, if they were found, this would increase the validity of the 'Think aloud' method being utilised to measure SA, and, depending on the strength of the relationship, that it might demonstrate the usefulness of Situation Awareness training for improving Hazard Perception.

This final chapter will now consider three aspects of the work that stemmed from these foundations, and the studies related to them. Firstly, a brief conclusion in regards to the main findings, and how these relate to the present literature. Secondly, a summary of the limitations of the methodological approach, thirdly, and in many cases as a corollary of those limitations, a section that considers possible areas for future research, and finally some brief reflections.

9.2. Main findings

9.2.1. Situation Awareness

As alluded to above, Situation Awareness is presumed in the literature to decline with age, and thus be related to poorer driving task performances amongst older driver groups (e.g. Bolstad, 2001; Zhang et al., 2009). It does not matter what the driving task is, that is the default position. As it is a given that age-related cognitive decrements will affect us all at some point in our lives, this is not an unreasonable assumption. However, findings in Chapter 2 suggested that drivers in their 60's and 70's may not suffer from these decrements uniformly, and thus they may not necessarily have a universal effect on safe driving until an individual reaches at least 75 years old.

Furthermore, it appeared questionable as to whether the recall 'probes' used by the previous studies to measure the SA of older (and younger) driving groups had sufficient construct validity. In particular, concerns were raised in Chapter 3 in relation to driving tasks being paused at predefined points, and that the computer-generated driving environments and simulators at the time had both appeared to lack realism.

Taking older drivers out on the road and experiencing their actual driving quickly confirmed such doubts, but it was found to have been of particular benefit to have sought to evaluate their SA within environments of different complexity. As was shown in the driving studies of Chapters 4 and 7, a cognitively non-taxing and a more cognitively taxing route could produce rather different relative levels of SA proficiency. Specifically, for the first route, which was rather straightforward, had limited traffic, though did encompass a major motorway, the Situation Awareness of the individual older and younger drivers was found to be in parity. This, despite the fact that both age groups were older, on average, than those used in comparative studies in the literature. However, the concepts from which that SA was based upon was found to differ. The older drivers drew more on general, direction based, concepts, whilst the younger driver's focus was more on specific, action based, concepts.

For the second, more difficult driving route, however, the expected deficiency in older driver Situation Awareness was evident, with a younger group producing significantly higher ($p<0.024$) individual SA (Density) scores. In addition, there was a widening in the average of these scores for the two groups between the easier, first (0.0821), and more difficult, second (0.1648), route. Yet, the main concepts from which SA was based upon, and the ratio of those indicative of a rearward and safety-related focus, remained similar, and arguably deficient for the older group.

The obvious conclusion from such findings would be that age-related cognitive declines had led to a fall in SA proficiency for the more taxing second drive. And this would, in fact, have been the only plausible explanation if it were not for the different approach taken for the assessment of SA in Study 2 (Chapter 6).

This study produced two further and significant findings. Firstly, that commenting of videos of car journeys, which was thought to be a simple exercise, and indeed was for the younger participants, was a surprisingly difficult one for their older counterparts. And, secondly, and relatedly, that this perceived task difficulty for the older group did not lead to a fall in their SA performance as might have been expected. On the contrary, it was enhanced. As if to reinforce this, the individual SA performances for nine of these same ten older participants then fell when driving for the following Study, which, without exception, was considered to be a far easier task to provide a commentary for than the video footage of Study 2. To some extent, this unexpected phenomenon was also supported by the opposite results being found for the younger group. Here, five out of the six participants who had undertaken both Study 2 and the following driving study, improved their scores on the latter, which they (in general) had considered to be a more difficult task.

This raised questions as to the impact of cognitive decrements, relative to task difficulty, in driving contexts. It also provided evidence that Situation Awareness, rather than being uniformly good or bad, is, like other psychological constructs, prone to change. In driving contexts, it may therefore increase and decrease depending on how an individual perceives the difficulty of a driving environment or task. This actually would seem useful as a rule, but the problem here in regards to the older drivers was that their score fluctuations appeared insufficient when compared to the younger driver groups. Specifically, the high video-based SA scores that the older group attained for Study 2 were not reproduced by this same group when driving the quite cognitively taxing route of Study 3. There were also only small increases in average individual SA scoring for this study when compared to the relatively easy drive of Study 1, which seven (out of ten) of those participants had also driven. Furthermore, similar levels of safety-related cues were being drawn upon by the older drivers for both of the driven routes, despite their difference in cognitive complexity. In fact, the more difficult drive of Study 3 actually produced a fall in the word count of suggested safety-related cues by 26 (whereas for the younger group it increased by 10 from a far higher level). In addition, a 3-1 comparative ratio between the two groups by this measure, and a 2-1 ratio for cues perceived from behind the vehicle, were also retained in favour of the younger group.

It could be, then, that age-related cognitive deficits may have some relevance here, along, and in combination with, driving experience and important perceptions of perceived task difficulty. Together, these factors may have led to the apparent lesser relative degree of cue processing undertaken by the older participants during the two driving studies.

9.2.2. Hazard Perception

In regards to Hazard Perception, the thesis's findings indicate that older drivers are less proficient in detecting hazards than younger driver participants. This, despite an uplift in their SA performance from when actually driving. However, whilst having a good cohesive network of driving-related information will no doubt help in perceiving and comprehending a hazard, that cohesion will be insufficient if it is not backed by a cognitive capability to utilise the network. Or, alternatively, if the cues processed, whatever their number, were less optimal. In both such cases the important variable would appear to be the ability to manage information under time pressure, and this apparently was a problem for the older drivers in the video-based trials of Study 2.

Here, an unfamiliar medium provided a high number of cues for processing within a limited timeframe due to driving speeds that were, for them, often perceived as being excessive. Although this appeared to lead to an uplift in effort, judging by a comparatively higher number and a better cohesion in the cues being perceived and processed, these factors were apparently unable to compensate for the speed of processing often required to spot a particular hazard. In short, no strong SA to HP relationship emerged for the older group. However, as the vehicle speeds in the videos were not an issue for the younger participants, where their SA was, conversely, strongly correlated with their HPT scores, it appeared that the processing speed difficulties demonstrated by the older group could be attributable to age-related cognitive and physical declines in this instance.

It is important to point out, however, that less relevant, though cohesive, SA-related networks from driving-related information could still be useful to older drivers for detecting a hazard. Of the group's top four SA scorers, for example, three were also in the top four for the group's Hazard Perception scoring. Thus, if age-related cognitive deficits can at the least be ameliorated by slower driving speeds and in-car technologies, then potentially more relevant cues could be processed by older drivers, and assuming network cohesion is maintained, better Hazard Perception should result.

9.2.3. Literature implications

In terms of how these research conclusions relate to SA findings in the literature, it can firstly be said that on actual roadways, the SA of older drivers can be deficient to that of younger groups, as Bolstad (2001), Zhang et al. (2009), and Kaber et al. (2012) contend. The findings in the thesis also support Zhang et al. (2009)/Kaber et al. (2012) in relation to older drivers improving their SA when encountering complex driving environments, and decreasing their SA in non-complex environments. In Bolstad (2001) complexity had (an unexpected) lack of effect on the SA of older drivers relative to that of younger groups. Where the studies in the thesis add to these findings, is in regards to differentiating between the actual complexity/difficulty of a task and a participant's own perceptions - which could be rather different. The results from this series of studies suggest that the younger drivers had a better judgement, at least in regards to the *actual* complexity of the driving tasks, whereas *perceived* complexity for all studies brought a consistent uplift in SA score for both the older and younger groups.

It should be reiterated, of course, that different methods were utilised by the studies being compared here. In Bolstad (2001) and Zhang et al. (2009)/Kaber et al. (2012) - simulators with computer-generated driving environments, and with SA measures taken at specific points during a trial; in this thesis, in effect, from an on-going assessment during a trial, that included complex journeys that were both seen on video, and actually driven. As such, complexity, as a measure, was different, and with the previous simulator-based studies, it could arguably be better manipulated. The result was probably a greater differentiation between the non-complex and complex conditions used for those studies and more potential in-depth SA analysis, whereas on the actual roadways used for this research, although significant differences between age-groups were still found, they were not capable of being quantified, for example, at each of Endsley's SA levels.

Where this research perhaps more crucially differs with those previous studies, however, is in relation to the cause of such SA differences. For the studies in the literature, the reasoning is primarily placed on age-related deficits. For the studies in this series, these are given less importance due to the variability in SA scoring demonstrated by the older driver groups, and their capability to cohesively process information to similar levels as the younger driving groups (even by those in their early 80's). Like Kaber et al. (2012), (presumed) age-related cognitive deficits were also found to be capable of being arrested by slower driving speeds, though additionally here through in-car technologies. The cause of any SA deficit by the older groups thus appeared to be more due to a consistent, but insufficient, depth of information processing (in relation to the younger groups). This could, of course, be a product of age-related decrements, but not necessarily so. In addition, and perhaps, moreover, much also depended, as mentioned above, on how difficult a task was perceived to be. These factors, in turn, then appearing to inflate or deflate the relevance and cohesiveness of that processing. And as was seen in the previous chapter, these aspects were drawn together and included in a proposed model of driving SA.

9.3. Methodological advantages and limitations

9.3.1. The value of the DSA approach

As has traditionally been proposed, an individual's SA is product of the passing, merging, and reflection on information through a number of sequential levels. The Distributed conceptualisation of Situation Awareness (or DSA), however, usefully places more emphasis on how well that information is integrated, rather than merely focussing on its product. In this regard, it has also been shown in the studies reported here, and elsewhere (e.g. Walker et al., 2009), that good levels of SA can still be achieved with seemingly insufficient information processing. For example, a participant could have a high word count on his/her narrative, indicative of high Situation Awareness, but still produce SA indicative scores deficient to others with lower narrative word counts. Furthermore, in some cases, perhaps when a driver needs more task concentration, recalling less, but better integrated information elements, might be more appropriate.

The DSA approach is better able to account for differential change in information processing, as it defines SA as activated knowledge for a task, at a specific time, and within a particular environment (Stanton et al., 2010). From a road user perspective, this knowledge will encompass the relationship between the driver's goals and behaviours, and numerous information elements (e.g., vehicles, the road environment, and infrastructure). Each of these elements, in turn, providing different information, for example: other vehicles – manoeuvres; the road environment – traffic density; and road infrastructure - route information (i.e., directions and distances). Thus, in order for the driver to achieve good SA, it becomes incumbent upon him/her to extract these information elements from what is termed the driving 'system'. Furthermore, the efficiency and safety of that system will be a product of the compatibility of those elements, that each individual road user (vehicle driver and pedestrian, alike), extract.

A further advantage for the DSA approach lies in its methodology, which will seek to evaluate the driving system as a whole, rather than considering its component parts in isolation (e.g., the individual driver). So, for example, in the context of driving errors and accidents, the concentration will not simply be with aberrant driving behaviours. These would be viewed as more likely a product of the interaction between many different and varied factors within the driving system being operated in when the accident occurred. Such factors might be infrastructure design, driver training, road rules and regulations, car information feedback, environmental conditions, and the behaviour of other road users. Thus the DSA/systems approach would seem better placed to enhance our understanding of these errors and road safety in general, and also, as a corollary, to foster more appropriate countermeasures.

9.3.2. The value of the 'Think aloud' approach and the Leximancer software

Due to taking this DSA, or systems, approach to evaluate participant drivers on actual roadways, a method had to be utilised that was could capture the relevant influence of a particular driving environment's elements, whilst not over-burdening and placing the driver at undue risk. A 'Think aloud' narrative was felt appropriate to achieve this aim as it involves merely verbalising externally about a task, which, for the most part, might otherwise be undertaken internally. As such, the task is, and was found in this series of studies, to present no difficulties. On occasion, when cognitive resources were stretched by, say, a complex roundabout or junction, a commentary might have to momentarily be suspended. But these pauses were brief, and participants were advised that when such circumstances arose, to concentrate fully on the driving task. They could then report their thoughts soon after, when driving had once again become easier. The approach also has the additional advantage of not directing participants to talk about what is considered as important and worth commenting on (by others) in any given roadway, neither does it evaluate awareness of a given route by memory tests. Guidance of a general nature is given prior to commencing a study, but it is emphasised that there is no right or wrong statement – what is important to the participant is what counts, however idiosyncratic.

A disadvantage of the 'Think aloud' approach, however, is that it requires very accurate, verbatim, transcriptions of participant commentaries. This can be a problem if additional or expert transcribers cannot be utilised, as to produce just one narrative is a very time-consuming exercise. As a corollary, this limits the number of participants who can be assessed, as other studies that have also used the approach testify. For example: Salmon, Young, & Cornelissen (2013) investigating driving behaviour (15 participants); Aitken et al. (2011) investigating patient assessments (7); Eveland & Dunwoody (2009) investigating usage of the world wide web (16); and Sullivan & Blackman (1991) investigating pilot behaviour (12). So if funding allowed for professional transcribing of narratives, many more participants could be considered for a study. This might usefully include, in the case of the studies undertaken here, potentially more age groups -such as above/below 20 years and above/below 85 years. The evidence suggests that it is those on the more extreme ends of any age grouping who would appear to be more likely to show differentiations in SA scores: due to, for example, age-related scanning deficits (amongst younger drivers); and cognitive decrements (affecting older drivers). However, finding, say, teenage drivers, and those over 85 years can be a difficult task. For example, of the 132 older driver volunteers for Studies 2 and 3, only one was over 85 years old.

The production of lengthy commentaries from the 'Think aloud' method additionally necessitated an evaluation of relevant software. The more widely used, and one favoured at Loughborough University for narrative analysis, is Nvivo (produced by QSR International), but Leximancer, developed by Andrew Smith (Smith, 2003), was felt the better option. The rationale behind this choice was considered in detail at 3.7.1.2 above, however, a further summarised consideration of Leximancer would seem of relevance here.

Leximancer has usefully been employed in this research to reduce potential preconceptions relating to older driver SA proficiency. It also advantageously allowed for an in-depth exploration of any revealed concept's value, its relevance, and its relationship within a network to other important concepts, which may not necessarily have been discovered by manual coding. This is due to Leximancer's clustering process, which undertakes around 1,000 iterations of any length of text-based data, to produce outputs usefully based on a combination of complex algorithmic analysis with aspects of psychology and language.

The software also allows for flexibility, in that concepts demonstrably found to be irrelevant to a project can be removed, and a network quickly recalibrated, without having to start the process afresh. A task that a researcher might be burdened with when undertaking manual coding, and indeed, with Nvivo.

Such advantages over human critical thinking, however, do not, and should not, make that effort redundant. Time and commitment are still required if useful conclusions are to be drawn from the software. After all, it is the researcher him/herself who will have the best understanding of their data - such as its context, linkages, and subtleties in aspects of language usage – and these should be reflected back on the software's outputs.

When using Leximancer, however, from first use, it is easy to believe that it will automatically produce complete, trustworthy and reliable analysis. The author has seen how a lack of familiarity, perhaps due to the software's simple calculation processes and quickly available visual outputs, has seemingly enticed some researchers into short tracking their understanding, and to process and report potentially superficial or non-meaningful outcomes as a result. It therefore should be stressed that it is important not only to undertake appropriate training to become completely familiar with the metrics that Leximancer requires for a particular data set, but also to critically consider its outputs.

Leximancer also has its faults. The most significant of which is in relation to its network maps, in that the same texts can produce different network configurations. This problem is recognised by the company who sell the software, but, as yet, a solution has not been found. Thus, to produce a reliable network for any given text, it is necessary to undertake a number of runs through the calculation process, and to take the output that is considered the most common. In view of this difficulty, additional, manually constructed networks were produced for this thesis that showed each network's major concepts and their (percentage occurrence) linkages to other concepts above a pre-determined threshold. This visual data could be reliably produced for each study, as although the network maps the software produced were inconsistent, the numerical data on which they were based (and indeed that for the subsequent SA scores) were perfectly consistent.

Another issue in regards to Leximancer, and also the Agna software used to produce the SA scores for a group or an individual participant, are that the outputs cannot be complete or direct measures of Situation Awareness. The network 'maps' comprise of what a participant reports s/he is aware of, whereas the cohesion scores of Density and Diameter indicate good precursors *for* Situation Awareness.

There is little doubt that better organised and integrated perceptions will help in our comprehension of driving events, and in some cases our resulting driving performance (as younger participants showed with Hazard Perception). But as has been discussed above, this also has to be considered against the quality of the information being processed. So whilst there is no doubt that 'Think aloud' protocols, particularly when captured on actual roadways, will have real world validity, a related question is whether construct validity is then retained.

It is arguable, of course, whether any single method of measuring SA could accurately provide a better 'score' in isolation, and in real world contexts. Many claim that this is achievable through comparisons to expert testimony (e.g. SAGAT, as it has been shown to have good levels of sensibility, reliability, and predictive validity (Endsley & Garland, 2000)). However, Salmon et al. (2009) suggest SA measures are effectively measuring different aspects of SA. Thus SAGAT, being deterministic and linear in nature, is of most use when analysts can identify SA elements a priori. On the other hand, in complex real world activities like driving, where SA cannot meaningfully be defined beforehand, and where the outcomes are not easily predictable, Salmon et al. (2009) suggest alternative approaches may be required.

In on-road driving contexts, the use of SAGAT would, in any case, be problematic. Whilst stopping a car to undertake recall tasks is, of course, possible; it could also be impracticable on occasion, potentially dangerous, and would detract from ecological validity. However, the conclusions made from this series of studies would be strengthened, if, with more time and support, they could be confirmed by other SA measures. A relevant example could be eye-tracking in relation to, say, mirror checking behaviour - given the concepts mentioned in studies 1 & 3.

Additionally, although actual driving was the preferred environment to evaluate SA for this research, such a naturalistic approach does come at the cost of experimental control. Even simple factors, such as having an unfamiliar 'passenger' present in their vehicle might influence a participant's driving style and behaviour. It is also impossible to create exactly the same driving environment for each participant, as weather and traffic density can never be precisely repeated between trials. However, the SA driving studies in the literature have potentially more pressing difficulties with ecological validity, due to their use of rather rudimentary simulators and pc-based roadway representations.

In conclusion then, the principal methodological issue here in regards to this thesis was to match appropriate SA measurement to the task to be assessed, and to give due consideration to available resource - be it time, relevant expertise, and/or equipment. The methodological approach chosen for the thesis met those demands and produced SA-related driver perceptions that could be analysed by software, rather than subjectively by the researcher. Its particular strength would appear to be that it could highlight potential areas for further investigation from actual roadways, which may be more closely and accurately assessed by the use of modern day simulators (see below). Thus it is hoped that more SA research in the future will seek to measure the concept, at least initially, on actual roadways.

9.4. Future Research

As the 'Limitations' section above considers, it would be of benefit to have the important findings of this research confirmed by the use of additional measures, and, it should be added – with more participants. This would both increase confidence in asserting the conclusions made in this work, and advantageously allow better scope for matching within any age-groupings. As was proposed above, eye-tracking would seem the best supporting option within actual roadway research to achieve both of these aims. It was a concern at the time of running the studies that any hardware brought into a participant's car might be more likely to distract or change his or her driving behaviour. But this detriment now has to be considered against the advantages of, for example, validating a potential deficiency in rear view checking by the older drivers.

A further possibility, on-road, might be the recording of brain activity for different environments, to indicate which were the more taxing. If this could be achieved, and in a non-invasively manner (as today's equipment suggests, see Figure 9.1), then it would be possible to direct SA training to relevant cues in these environments, with the aim of reducing potentially dangerous excesses of information processing.

Figure 9.1: A modern brain activity monitor

Although the studies in this research advantageously utilised actual roadways to measure SA, as a result, consideration rightly had to be given to a participant's safety. Thus it was never possible to expose the driver to particularly dangerous conditions, which though rare, may be the very ones where we need to find "the few unsafe drivers that may need to be identified" (p.276) (Bolstad, 2001).

It therefore would be interesting to use a simulator with sufficient realism to evaluate older drivers in such environments. Figure 9.2, below, shows the potential. This simulator, based at the University of Leeds, UK, is far advanced even from the one utilised by Zhang et al. (and Kaber et al.) in 2009. It can, for example, produce 360-degree and 3D fields of vision, and replicate the kinetic characteristics of driving, such as braking, accelerating, cornering, and even road roughness.

Figure 9.2: Example of a 2016 car simulator

A simulator of this kind would thus be able to realistically confirm many of the findings from this thesis. For example, the contention, supported by Kaber et al. (2012), that older drivers would improve their detection of hazards if they were able to control the speed of their vehicle. Or whether a link between Situation Awareness and Hazard Perception performance could be established sufficient to lead to benefits in safer driving training.

In addition, in this thesis and in Kaber et al. (2012), more taxing/complex road environments appeared to enhance an older driver's SA at Level 1 (perception). However, Kaber et al. further contend that this enhancement will necessarily lead to a degrading of SA at Levels 2 (comprehension) & 3 (projection). This would be interesting to confirm as it is counter-intuitive, yet potentially important for explaining the quality of (particularly) an older driver's Situation Awareness.

In regard to more general, developmental, research, this series of studies suggests older drivers would benefit from additional in-car technology that could raise their awareness. This, in fact, was already evident in the older participant's vehicles: such as rear view cameras, and obstruction and/or parked car warnings. And to enhance more general on-road awareness and to keep to speed limits (particularly in 30 mile an hour zones), they additionally employed cruise controls.

However, in an ideal world, such aids could be further enhanced by technology that could evaluate a driving environment and produce indicators of required processing depth and simple attention related advice. This would appear to be a useful long-term endeavour, however, consideration should be given to the affects that overly automated vehicles can have for retaining SA. These perhaps merit further consideration here.

Today much is spoken about the safety of increasingly autonomous vehicles, due to their impact on a driver's Situation Awareness. It is an area that has and continues to attract much research interest (e.g. Bashiri & Mann, 2014; Gibson et al., 2016), and has perhaps particular relevance for older drivers as further car automation may allow this group to drive for an increasing number of years.

To explain its impacts on SA, Endsley's model can be taken as a useful starting point. It can be recalled that she views SA as a product of three hierarchically dependent levels. And, in order to accurately project an outcome at its highest Level (3), that it is firstly necessary to correctly interpret, or comprehend, the current environment (at Level 2), which itself is dependent on the perception and awareness of relevant environment elements (at Level 1). As a corollary, then, any interference with awareness at a lower level will affect those higher task functions. The reverse effect can also occur, and although not considered directly by Endsley, it can also be argued that a particularly strong schematic basis for how an environment might be - say for a familiar road in a village - may bring predisposed actions at her Level 3 SA. This, in turn, providing a false framework with which to interpret and comprehend the environment (at Level 2), which could then lead to a misperception of relevant specific elements or cues (at Level 1).

Thus if you automate one of these processes, you potentially, like cognitive laziness (in a feedforward manner) or preconceptions (in a feedback manner), deny the driver of necessary and timely information. Yet the argument for automated vehicles is that the driver need not actively sustain Situation Awareness, and that as a result, operating safety and comfort will be improved as it will reduce the driver's workload.

Such premises, though, are questionable, as arguably, taking the driver out of the SA process, 'out-of-the-loop', so to speak, could compromise his/her and others safety. For example, the effect of task automation on reducing operator Situation Awareness and performance has been researched for some years in the aviation sector (Edwards, 1977; Wiener, 1988). It has been found that there are numerous documented air accident case studies that indicate this 'out-of-the-loop' problem that automation brings as a pre-crash factor (Billings, 1991; Moray, 1986; Wiener & Curry, 1980).

The dangers of displacing a human for an automating system in this regard are evident, as if s/he has to be quickly reinstated to a task (e.g., due to a system failure or safety critical event outside the capacity of the system), this will be hampered by a lack of Situation Awareness. As such, there will be a dangerous transition to the reinstated manual operation, as due to a lack of expectation, time will be lost in perceiving the current situation, reorienting oneself appropriately to the task, and then resolving any problems.

Such difficulties could further be heightened if, say, a driver perceives that the introduction of an automated system has led to a decrease in driving task difficulty. If so, an underestimation of task demand might follow, leading to less processing and even further reduced awareness. Merat & Jamson (2009) have demonstrated this by showing that in highly automated vehicles: the driver's response was always slower to a critical event; that the minimum headway to a lead car was considerably shorter; and that anticipatory braking performance was poorer. They argue that their participants were placing too high a degree of trust on the performance of the automated system, which may well be detrimental in real driving situations due to a loss of Situation Awareness.

It should further be added here that although automated systems are felt, and indeed appear, to reduce driver workload, they can also potentially increase it. Much might depend upon the psychology of the individual driver, as some may feel that an automated system actually needs more, than less, monitoring. But even in such cases, this additional activity would still impact negatively on driving performance, Situation Awareness, and safety. This is because there would again be less time for that driver to consider, when required, an appropriate range of relevant road environment cues, process and understand them, and then take appropriate actions.

There is no doubt that if roadways could be fully automated - where autonomous vehicles could communicate with each other and with roadway infrastructure, that real benefits could accrue. Traffic would move more efficiently, parking issues would be resolved in urban areas, and ride-hailing programmes could reduce the number of vehicles a household might need. The difficulty would seem to be in the interim time, when both fully automated and manually driven cars might occupy the same roadway – and it is in such cases when Situation Awareness research will have a crucial role to play. There are clearly benefits for older drivers with fully automated vehicles, yet potentially a greater loss for the group in SA – due to the onset of age-related deficits. This is an area that therefore requires particular focus in order to ensure safety is retained at all times.

9.5. Reflections

This thesis has looked at Situation Awareness and how it might be affected by a driver's age. An academic reviewer of Studies 1 & 2 considered this objective to be "a very valuable research topic of traffic safety research". The thesis also utilised a new methodology to assess older driver SA (though not new in other transport contexts). This was commented on by a second reviewer of the work, who felt the qualitative approach "rather unusual in traffic psychology, but nevertheless valuable". These studies, in combination, have since been published in 'Transportation Research (Part F)':

Key CEJ, Morris AP, Mansfield NJ (2016). Situation Awareness: Its proficiency amongst older and younger drivers, and its usefulness for perceiving hazards. Transportation Research Part F: Traffic Psychology and Behaviour, 40:156-168.

Study 3 is presently awaiting publication in the same Journal, and again this work was seen by one reviewer as "Very valuable research using an often underestimated methodological approach":

Ref: TRF_2016_214. Title: A study investigating the comparative Situation Awareness of older and younger drivers when driving a route with extended periods of cognitive taxation. Journal: Transportation Research Part F: Psychology and Behaviour.

Situation Awareness is an interesting and challenging concept to research, as it is difficult to define and demonstrate. Some in fact have argued that it does not even exist, but is merely a product of working memory (e.g. Bell & Lyon, 2000). Many others do believe in its existence, but have defined it in a diverse number of ways (e.g. Sarter & Woods, 1991; Fracker, 1991b; Smith & Hancock, 1995; Moray, 2004; Dostal, 2007; Artman & Garbis, 1998). Its leading and best known researcher, Mica Endsley, whose model of SA still persists today, twenty years on, sees it as a product of linear information processing. But this has been challenged, most notably by advocates of a 'distributed' or 'systems' approach, who conceptualise and measure the construct somewhat differently (as discussed in Chapter 3).

Like others (e.g. Smith & Hancock, 1995; Salmon et al., 2009; Stanton et al., 2006), this thesis argues that SA is more likely to be an indistinguishable product *and* process of information. Older drivers, for example, may indeed *produce* SA from a more limited range of relevant information cues, due, perhaps, to age related decrements. But is this just from passive processing, or more from a *process* of selecting cues pre-consciously and/or consciously from a wealth of relevant driving experience?

The answer remains unclear, but it is important to know, as how we process information will ultimately determine how safely we drive.

9.6. Bullet point summary of the thesis's contribution

- Older drivers matched younger drivers in Situation Awareness scoring when driving a non-cognitively taxing route, but were found to be significantly poorer on a more cognitively taxing route.
- The Situation Awareness scores of younger drivers were significantly related to their scores for Hazard Perception.
- Younger drivers outperformed older drivers on a Hazard Perception task, particularly in regards to the speed of detecting a hazard.
- Participants produced significantly better Situation Awareness scores from watching video footage of a car journey, rather than when actually driving.
- Textual analysis of driver commentaries showed that older drivers were less aware of what was behind their vehicles and enunciated less safety-related concepts.
- Perceptions of task difficulty appeared to be an important influential factor for SA proficiency.

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Appendices

1. Instructions for Studies 1 & 3

How to undertake a Verbal (‘think aloud’) Protocol Analysis

A Verbal Protocol Analysis of driving sounds quite complex, but actually its very simple. All you do is ‘think aloud’ - talk about the task and the decisions that you are making while you are driving.

Sometimes these will be general thoughts i.e., perhaps relating to the volume of traffic on a particular roadway. So you may talk about: where you are placing your vehicle; the road environment and condition; the road signs and signals you encounter; other road users – cars, trucks, buses, cyclists, and what they are doing; and how that relates to you and what you are doing about it.

Sometimes your thoughts might be very specific i.e., I am watching that bus and giving it space as I think it might pull out in front of me. Other examples might include:

- I’m trying to work out if the car to the left of me is going to move into my lane.
- I’m checking the traffic lights/speed limit sign.
- I’ve just noticed that there is a cyclist/vehicle/bus behind me.
- I think that this traffic light is about to turn red so I’m speeding up a little.
- I can see that the car ahead is indicating so I know that they are about to slow down and turn left.
- The car in front is slowing down so I need to brake.
- I don’t know what the current speed limit is so I’m guessing based on the road that it’s 60
- I just noticed the pedestrian up ahead on the left so I’m keeping an eye on him as I think he is about to cross the road.
- I’m deciding whether I have enough time to make it through the lights.
- I think I need to be in the right hand lane here so I’m checking my mirror before moving over.

Please note, that it is important that you verbalise as much as you can as you go around the route. This includes, for example, when you are stopped at an intersection and are observing things and thinking about them (e.g. ‘I am keeping an eye on the traffic light or the traffic travelling in the opposite direction as I know when they stop I will be going’ or ‘I am keeping an eye on the traffic behind me’). Even if you think what you are thinking is irrelevant please still verbalise it.

Also, try to behave and think as you normally would do when driving, and to drive at your normal speed. I am interested in YOUR thought processes, so you cannot be wrong as you are providing a description of your thoughts as they relate to the driving task.

If for any reason you have to stop “thinking aloud” to complete a difficult manoeuvre, it is

important that you remain safe and in control of the vehicle. However, if something does happen to stop you talking I would be very interested in it, so please recap your thoughts once you are able to do so.

Finally, before you start on the route, you will get a chance to practice “thinking aloud” whilst driving around the Loughborough campus. We will start and come back to the University once the route is completed.

In summary then:
1. Please verbalise what you are thinking during your drive;

2. Try to do so as continuously as you can, regardless of whether you think your thoughts are relevant or not, though;

3. Behave and think as you normally would (do not make up verbalisations for the sake of the study).

Many thanks.

2. Instructions for Study 2

STUDY INSTRUCTION SHEET

This study will ask you to imagine that you are driving the car in the videos that you are shown. The videos will be of different lengths, with the longest lasting for about 6 or 7 minutes. I anticipate that the study will take around 45 minutes in total.

What I should like you to do is give me a running commentary (that I will record) relating to the things that you are aware of from each of the driving environments that you will encounter, and in particular those that you feel might impact on your safety. Examples might include the actions of other vehicles, pedestrians, and the road environment itself, but moreover it is what you think that is of relevance that counts.

Please note that it is also important to try and verbalise as continuously as you can. Even if you feel that what you are thinking is irrelevant, please still verbalise it - I am interested in your thoughts, so what you say cannot be 'wrong'.

I appreciate that it is a bit unusual to continually verbalise, so if there is a prolonged period of silence at any time I might prompt you to say a bit more. On the other hand, if at times you feel there is too much to report don't worry about conveying it a little after the event.

So in summary:

1. Try to imagine you are the driver in the journey.

2. Verbalise what you are thinking with an emphasis on what might impact on your safety.

3. Try to verbalise continuously regardless of whether you think your thoughts are relevant or not.

I hope this is all clear, but if you do have any questions by all means drop me an e-mail. There will also be an opportunity to clarify any aspect of the study on the day, and to have a practice run before the trial videos start.

Many thanks again for your help.

3. Typical information sheet and informed consent form

Main Investigator: Dr James Key (J.Key@lboro.ac.uk)

Supervisors: Prof. Andrew Morris *(Lead, Behavioural Safety Research Group)*
Prof. Neil Mansfield *(formerly, Associate Dean of Research, now at Imperial College, London).*

Loughborough Design School,
Loughborough University,
Loughborough,
Leicestershire,
LE11 3TU.

What is the purpose of the study?
This study undertakes an assessment of Situation Awareness through a Verbal (or 'think aloud') Protocol Analysis. The narratives that this method produces will be assessed to reveal their underlying structural properties.

The research is being conducted as part of a Postgraduate student research project supported and funded by Loughborough University.

Are there any exclusion criteria?
You must hold a valid Full UK Driving Licence as recognised by Loughborough University.

What will I be asked to do?
You will be directed around the route provided previously, and asked to verbalise your thoughts whilst driving - as explained in the 'Verbal Protocol Analysis' information sheet provided. Your responses will be recorded.

Once I take part, can I change my mind?
Yes, if at any time, before, during or after the study you wish to withdraw, please inform the investigator. You do not have to explain your reasons for withdrawing and your data will be destroyed.

Will I be required to visit the University?
Yes, you will be asked to meet the main investigator at the Loughborough Design School (LDS). During the study, you will be asked to drive a circular route from LDS around some roads in Leicestershire, returning to the University's main entrance car park off Epinal Way.

How long will it take?
This will vary depending on the speed you drive, but the expectation is around 30 minutes.

What personal information will be required from me?
You will be required to give your age and length of driving experience.

Are there any risks in participating?
You will be asked to drive on roads, and as such there are inherent risks in this activity. However you will be asked to drive at a quiet time of day, and merely to talk whilst driving.

What do I get for participating?
You will be paid £20 for your participation in this research.

Will my taking part in this study be kept confidential?
Yes. You will only be identified using a participant identification number, meaning that your name will not be associated with any of your data. Furthermore, the collected data will be stored on a password protected computer that only the main investigator has access to. Your consent form will be stored separately to further ensure that your name is not associated with any of this data, all of which will be destroyed on the study's completion. You will not be identifiable in the analysis and reporting of your data due to the use of participant identification numbers.

What will happen to the results of the study?
The results will be written in a Postgraduate thesis and will be used to guide further research in this area. Should the thesis be of a high enough standard, it may be published in a relevant peer-reviewed academic journal.

I have some more questions; who should I contact?
If you have any further questions, please contact the main investigator through the contact address/e-mail given above.

What if I am not happy with how the research was conducted?
If you are not happy with how the research was conducted, please contact Mrs Zoe Stockdale, the Secretary for the University's Ethics Approvals (Human Participants) Sub-Committee:

Mrs Z Stockdale, Research Office, Rutland Building, Loughborough University, Epinal Way, Loughborough, LE11 3TU. Tel: 01509 222423. Email: Z.C.Stockdale@lboro.ac.uk

The University also has a policy relating to Research Misconduct and Whistle Blowing which is available online at http://www.lboro.ac.uk/admin/committees/ethical/Whistleblowing(2).htm.

INFORMED CONSENT FORM

Loughborough University

The purpose and details of this study have been explained to me. I understand that this study is designed to further scientific knowledge and that all procedures have been approved by the Loughborough University Ethics Approvals (Human Participants) Sub-Committee.

I have read and understood the participant information sheet and this consent form.

I have had an opportunity to ask questions about my participation.

I understand that I am under no obligation to take part in the study.

I understand that I have the right to withdraw from this study at any stage for any reason, and that I will not be required to explain my reasons for withdrawing.

I understand that all the information I provide will be treated in strict confidence and will be kept anonymous and confidential to the researchers unless (under the statutory obligations of the agencies which the researchers are working with), it is judged that confidentiality will have to be breached for the safety of the participant or others.

I understand and agree to my responses being recorded.

I agree to participate in this study.

Your name

Your signature

Signature of investigator

Date

4. Example transcripts

i) Study 1

PPT19:

Checking my mirrors to see what the cars behind me are doing, see if they're turning as well. Indicating left, even though I don't know if I have to. Slowing down as there's a cyclist, let him pass first. Checking my mirrors, and going onto the dual carriageway. And then indicating right to overtake the cyclist. Having to twist around because I often check in my back window when I overtake, but that's steamed up, so. Using my wing mirrors as well. Checking my mirrors to see what's going on behind me - base my rearview mirror and the wing mirror on the right. And accelerate slightly less, 'cause, ah there's a bit of traffic ahead, but still a considerable distance away. Checking the traffic lights make sure they're still green. Still kind of maintaining a slightly slower speed than I normally would, because it's raining and there are cars up ahead. And starting to slow down because they're stopping at the traffic lights. Probably won't come to a full stop because I'm still a considerable distance away. Go straight ahead, and is that waiting here? Checking my, erm, wing mirror, because this lane starts merging, so, it's worth it to see if there's anyone trying to jump in front. Again I'm going considerably slower than I normally would because it's really wet. Okay so I'm checking my rearview mirror, as I'm about to start slowing down, coming up to roundabout, checking my wing mirror. And indicating to go right. Slowing down coming up to the roundabout and looking ahead to see what's coming, but then speeding up, 'cause nothing else is coming my way. Checking again in my mirrors. Going up to the traffic lights, so, slowing down. Having a look down over the bridge just to see how busy it is, is there any traffic. As we march the traffic lights. Checking to see what the van next to me is doing whereabouts they're going to turn off, and changing lanes to go to the exit. Stopping again at traffic lights, and checking my mirrors again. Okay, indicating to come off of the roundabout onto the M1. Turning off my indictors, and then easing in the slip road trying to get up enough speed so that I'm not slowing anyone else down and can comfortably come onto the motorway. I'm checking in my right mirror making sure nothing's coming. Slowing down slightly to get in between two cars. Oh hate driving in this. Normally I would, probably, um, accelerate out and overtake but because it's so, it's raining so heavily and there's a lot of spray, this is going to be quite difficult, and I don't like driving minor's particularly so, I'd rather stay down, and leave it more careful. Checking my mirrors to see what's happening, if there's anyone close behind me. Because I'm in the slow lane, erm, I'm less concerned about people coming up directly behind me. As we're coming up behind a lorry, I'm going to check over my shoulder and in my wing mirror and then indicate to overtake. Checking my speed, and all the, behind me. Turn my lights on fully rather than just having near side beams on because visibility is quite poor. Visibility my car up, more behind can see. Okay so I'm overtaking the larger vehicle, indicating left, checking in my rearview mirror to make sure I've got enough distance to go back in front of him. And then checking my right side mirror to see what's going on in middle lane. Constantly checking my rearview mirror and my wing mirror. Checking signs, reading the signs, for services. Just as they're there, not as I actually want them, but just trying to take notice of what they're saying. Checking my mirrors again. There's a van coming up on my right so rather than accelerate and overtake this lorry I'm gonna slow down slightly let him pass, there's not much behind these vans so, I'll now let him pass and then check over my shoulder and, indicate right into the other lane to overtake the two lorries right in front of me. Checking in my rearview mirror, seeing what's behind. And passing the second lorry so, checking my rearview mirror, my left side mirror, indicating, going back into the slow lane. Checking the signs to see which junction we're at. See whereabouts we are. I'm flying to East Midlands next, well going to East Midlands next week, so interested in those signs to see how far it take us to here. Taking notice of the junction countdown signs on the left. Indicating left for this junction. Checking my er right wing mirror. Slowing down slightly as I've er not really driven on these roads before so just making sure that I'm driving at a safe speed just in case there are any slip roads and things like that coming out. Taking notice of the signs. I'm not necessarily slowing down but making sure I'm not accelerating any further because there's cars coming off the slip road and checking my left wing mirror, see if there are further cars, and my rearview mirror. Okay so checking the sign erm of the roundabout and starting to slow down. Go into the middle lane as I don't want to turn directly left, and its coming to a stop at the roundabout. Accelerating to get in the way of that car, counting first exit and then indicating to come off at the second. Checking the signs, and merging, checking my left wing mirror to make sure there's nothing coming up behind me. There's a lorry on a road so I'm checking my right wing mirror to make sure that nothing's coming up behind me, and, pulling in slightly because there's a bus, slowing down and then accelerating 'cause it's clear so to get in front of the ban, van, then. Okay, so I'm looking at the signs, checking to see what's going on around the roundabout, slowing down, waiting to see if that car's indicating, but they've gone into the left hand lane so they've pulled off the roundabout. Indicated to come off the roundabout. I'm just having a look at the road ahead to see what's going on. Um, can't really see any road signs to see what speed it is, so, but it's not a built up area so I'm guessing more than 30 so I'm going at 40 just to be on the safe side, maybe a little bit more. Taking note of the signs, aware that's not far away, the airport, so that's nice. Traffic lights up ahead which are red so, starting to slow down but they've just gone green so, not particularly slowing down that much. Keeping an eye out for surrounding cars and also see if the traffic lights go back to red before I get to them. I now know where the airport is. And checking the signs again. So slowing down. So indicating and checking my mirrors, and, not necessarily using my brake but using my gears to slow down, and then using my brake because it's quite a tight corner. And going around the corner. And again, no speed signs, but, guessing this would be national speed limit. Checking in my rearview mirror again. Probably won't be going too fast because of, ah, there's no cycle path so there could be cyclists or there's um road signs of horses so going quite slow and now we're in a 30 so braking to slow down. The car coming so I won't accelerate any further. There's cars parked on the right so, not going too fast, checking to see if there's any cars ahead. Checking to see if there are any pedestrians on the pathways. Indicating right, checking my right mirror, slowing down to pretty much a stop because it's quite a blind turning erm in terms of cars coming towards me. Yet again not going particularly too quickly as it's quite a small road there's no road markings, erm, no cars coming ahead at the moment but, I suppose parked cars parking on, on the right, so, keeping an eye out for any cars coming towards me, any cars coming out of the junctions. See a car coming towards me but they are turning, their going, parking on my side of the road, so slow down a little bit, 'cause I can't actually see behind them, and I'll go quite slowly around them. People like that annoy me. Erm, going really slowly 'round tight corners, leaning forwards to see, to make it a little more visible what I'm seeing and what is 'round there. Again keeping an eye out for any pedestrians or anything around there, so. Coming up to a junction so start to slow down. Checking my mirrors again, and coming to a stop, because there's a stop line, and leaning forwards checking right and then left just before I pull out, and then checking my rearview mirror just to see if I had, in case there's anyone particularly coming up fast behind me now. Checking to see if any cars are coming towards the junctions that we are passing - the roads on the left. And checking the road signs, speed limits. Checking my rearview mirror. Again, the road signs. Hard to a place where we are now. National speed limits, and speeding up a little bit more, but, these roads are quite unfamiliar so, not going too fast and its wet and they're quite er tight corners as well. Looking for dog walkers or pedestrians, although it has just occurred to me that it is chucking it down with rain so there probably won't be that many walkers out. Speeding up a little bit on this straighter parts of the road but, er actually press my brakes a bit as I don't know how tight the corners are. Taking it, the road sign. What is that animal, is that a cow? Some kind of cattle, 'allo yeah it's a cow. Er just taking what the road sign that was. Mud on the road, so, not accelerating through here. Checking on the left as there's a couple of cars parked in a lay-by. Taking note of the next sign, horses. Checking my speed limit. Checking the road sign there. And slows to a 30 mile an hour speed limit so using my brake to slow down, to make sure I get down to the right speed. Changing down a gear, cause there's cars parked on the right, on the road, so could be keeping an eye out for any cars coming towards me. They may have to um come onto my side of the road. I notice this sign for, there's a hump in the road, about a hundred and thirty yards, okay. So, going quite slowly, slowing down for the speed bump, going down a gear for that. Having a look at the houses around here as they're really nice as well. Checking to see if there are any cars coming out of the er junction - there's a car reversing out of their driveway. Checking my rearview mirror. Overtaking a car that's on the side of the road. And accelerating a little bit. Again keeping an eye on any side roads where cars could come from, any pedestrians on paths, it's all quite quiet at the moment. Slowing down for a speed bump. Checking my rearview mirror as there is now a car behind me. There's cars parked on the left, so, moving out to the right to go past them. Checking ahead to make sure there's no cars coming my way. Lots of cars parked on the right again, so, won't be much space for two cars to pass down here - keeping that in mind. Checking my rearview mirror again to see what the cars behind me are doing. Another speed bumps. Er, a school safety zone, just making sure the lights aren't flashing 'cause that's when you have to go 20 miles an hour rather than 30, which they're not, so that's fine. Speed bump, didn't particularly slow down for that one, although I was going 25 miles an hour, so not too bad. Again checking the school safety zone, car park, er signs. Killer speed bump. And there's cars parked on the left just before a corner, so not going too fast around these. Thinking of this van, then going back in, then back out here 'cause there's further cars. Noticing that bus stops have got bright yellow. And no more cars parked on the side so we're going slightly quicker up to 30 miles an hour. Checking my mirror, indicating, and slowing down, making sure there are no cars coming up ahead of me so turning right. Checking my mirrors again, and looking ahead to see what's coming there's a past parked car. Cars parked on the right, so, keeping an eye out what's happening - there's a Postman getting back into his van. Noticing that there's a massive tree in the middle of the road, so, going 'round that. It would be quite tight if we were going around the other side by the looks of things, but got quite a nice wide road here. Checking my mirrors and indicating, and coming to a stop at the junction. It's not a great deal of visibility to the right, so we come out quite slowly, and, check to see what the speed limits are around here, um assume this is a 30 'cause it's a built up area of lights, and, just seen a 50 sign coming in to the, as we leave the built up area. Checking in my rearview mirror, there's a van coming quite fast behind me, but, I'm not going particularly slowly at the moment. And also another sign reinforcing the 50 mile an, mile per hour speed limit. Checking my rearview mirror to see what that lorry's doing, and they're not so far, and not so close behind me anymore. And got tight corner signs, so, just being mindful of those, I'm not particularly slowing down as I'm not going 50 I'm going 40 at the moment, and then accelerating out of the corner. Noticing there's a there's a 40 mile an hour speed limit just up ahead so, taking my foot off the accelerator. Closing those traffic lights up ahead, and the, er road signs, going into the right hand lane and indicating right whilst checking my rearview mirror. Er checking the traffic lights, they're green and slowing down, changing down a gear 'cause it's quite a tight turn, and seeing what all the other cars are doing, making sure no one is coming from either the right or the left, now, or coming out of any car parks. Checking for speed limits, it's 40. Seeing what these road signs are - yellow one with an arrow in a square, not sure what that means, but, um, I don't think it's very relevant to what we're doing. So into 30 mile an hour zone. Traffic lights ahead have just about turned red, so, not, not braking very hard, just really slowly 'cause I'm still quite considerable distance away and knocking it into neutral, just die down. Making sure I'm in the right lane for where I need to go – just straight ahead, rather than right. And then checking in my rearview mirror. Handbrake is not um always very good, so keep me foot on the brake a lot of the time – making you feel really safe now ha ha. Okay, so checking my mirrors, see what's happening behind me. Checking ahead to see if there are any pedestrians crossing, where the traffic lights were beforehand. Urm there's cars and vans parked on the left although the road is very wide. So, not so slowing down a considerable amount to erm compensate for this. There's a car coming from the right, but just checking there's enough space, which there is. Making sure I'm keeping to the 30 mile an hour speed limit. Checking my mirrors again. Checking to see if any cars are coming out of junctions that we pass. Checking the traffic lights remain green as I pass them. Checking the traffic from the right. Van slow, way too slow from to the right there, just ch, seeing if he's going to turn. So coming up to a 50 mile an hour zone, so, accelerate a bit more. And got 50, check my rearview mirror, it's quite a wide road, although, there is only room for one car, there's only one lane, so, just making sure no one's being an idiot trying to overtake. Making note of the bendy road signs and the fact that we're now coming to a part of grevel there's no barrier in between. Making note of the 30 mile an hour sign and another straight yellow sign. Checking my speed. Making sure I'm a, a considerable distance away from the car ahead, particularly because it's wet. And cars braking due to the lorry coming out, although it's reversing, so just being aware of that. Checking the um traffic lights and slowing down 'cause a van was turning left. Checking that there's a car in front of me that wants to turn left as well. Checking the road signs, what's going on around me. Checking my rearview mirror, just to make sure that the cars behind me are okay. Taking note of the cameras that are up there. Oop being careful of the puddles. Taking note of the speed camera sign although, but at the same time being aware that there is no speed camera down here that I know of. That means we're going to break the speed limit. So indicated to make sure I'm in the right hand lane, which is a bit confusing because they've changed the road markings here, which is quite new. Er, 30 mile an hour speed limit coming up to the roundabout, so slowing down, indicating to go into the right hand lane and slowing down because there's traffic lights which are red. And then coming to a stop, and accelerating again quite quickly because the lights have gone green. Checking my mirrors to see what the cars behind me are doing, counting the exits – one, two, one, and then, oh slowing down because there's a car that's coming, a couple of cars in front, and indicating to come off left. Slowing down because there's a car in the right lane but, erm, needing to turn. Realising that I'm in the wrong lane, so checking my er side mirror and indicating left, and slowing down slightly as the cars turning in front of. Also notice the bus wants to come out as well. Checking for a speed limits down here, erm there don't seem to be any signs. Slowing down here, to go in there. Okay. Being careful 'cause there's cars either side so I'm having to drive in the middle of the road, here. Checking for pedestrians 'cause it's quite a built up area. Lots of cars parked on either side of the road, so, being quite mindful of that as well. There's a car coming, towards me, erm but they're indicating left so, I'll let them go first, I'll flash them to let them go through, I don't think she's seen it so I'll do it again. So that's caused me to stop behind some parked cars which is fine. Keeping an eye on cars coming towards me with parked cars on their side of the road. Lorries coming up there, the road. I'll just slow down rather than completely stop for them, as I was kind of half way between him and a parked car, so, stopping wouldn't really have made a difference. Checking my mirrors, and coming to a stop. Checking right and then left. There's quite poor visibility to the left but to the right it's clear so, come out quite slowly, now checking in my rear view mirrors, my side mirrors, more cars parked either side of the road, so, just keeping an eye on that. Slowing down a little bit because I can't quite see around the cars. Checking just like the general strip around me. So checking my mirror, there's a car right ahead but it's ahead of where I'm turning, so. Cutting in this man walking in the middle of the road, so, slowing down, to make sure he gets to the path, before I get any closer. Checking my rearview mirror to see what he's doing 'cause he's just come back into the middle of the road, and and driving more in the middle of the road here, erm 'cause there's no road markings and there's cars parked on either side, though some of them are on the path, erm, a bit strange, but, there's no cars coming ahead, so, driving in the middle of the road. Checking my mirrors and slowing down, and stopping 'cause there's cars coming to the right. And moving out, checking left and right 'cause it's quite a busy road. Accelerating. Checking to see where other cars are coming out. Trying to place where we are 'cause I live on this road, and now I know where we are – s'not come out of that road before. Erm, so I know it's 30 down here, but only 'cause I live here, otherwise I wouldn't know. I'd assume it was a 40, er because it's quite a wide road although it is a built up area, so. There's a cyclist er wanting to cross, but because there's cars coming towards me as well, me stopping wouldn't be very helpful. If it was clear on the other side of the road I would have stopped, let her go through, so. Checking my mirrors. Oh because the cycle path is so close, checking particularly to see if there are any cyclists coming down the side of me, and slowing down, but not stopping at the roundabout 'cause there's nothing coming, and turning off. Checking the traffic lights, make sure they're still green, and checking to my left to see if they're any cars coming down the slip road out of Russell Todd. There's cars coming out of the road to my er right, so, slowing down slightly for them. Checking traffic lights are still green. Okay so checking my mirrors and indicating right. Checking the traffic lights, and slow down quite sharply - squeaky brakes - 'cause traffic lights have turned red. Checking around, we'll see whose on the roundabout, how busy it is. And traffic lights have turned green so, starting off again. Just checking to my right even though the traffic lights are red their side but it's just liking force of habit, checking who's going on what lane in roundabout and indicating left to come off. Checking the traffic lights are still green, and that no one's crossing, making sure that this Nissan is not going to change its mind, and indicate right, slowing, going quite slow, braking to turn right, seeing how fast this lorry's going ahead but, this car has stopped to let me out so thanking him, and indicating to my right to the university. Ah barriers up, which is always nice, hopefully it won't erm charge me. Slowing down for the speed bump here, it's quite harsh.

ii) Study 2

<u>Standard drive</u>

Okay so there's, there's cars kind of in front of me, turning in. I'd be aware of whether they were turning off of that road or coming towards me - and at what speed as well. Erm, I'm getting eventually when he pulls off, I'd be looking in the, erm, mirrors to see if there is anything coming from behind. Any pedestrians or cyclists maybe coming around the outsides of the cars. There's a pedestrian up ahead but they're turning off onto the road from the side. There's a car coming from the side of the road but it's not coming towards me. And another one. And just keeping an eye out for anything else, but, because we're not moving I wouldn't be too worried. Okay, so there's another car coming towards me, so I'd be aware of kind of where I am on the road, and where they are. And then I'd be checking in my er side mirror. Wing mirrors. And I'm coming 'round, erm, it's a kind of a bit of a blind corner there, so I'd be waiting out for cars making sure they, they can see me. Turning into the side road, so making sure there's no traffic coming across me. Overtaking the cars that are parked on the left. So making sure there's nothing erm ahead of me. Because there's a lot of trees as well, make sure I can, I could see any pedestrians. Coming up to a 'T' junction, so slowing down, obviously checking left and right. So there's a bit, a fair bit of traffic. Er across some traffic lights, which are green. There's pedestrians on the other side of the road. Erm, I think there's a, is that a lorry parked on the opposite side of the road, so there's cars coming around it. So, there's one coming towards me that's not going to stop, so I'm slowing down, to let them past. There's pedestrians next to me on the road. There's more cars parked to the side of the road as well, although they're in parking bays so it's not an issue. More pedestrians and a petrol station mean that things could come out, a cars. A side roads. There's no traffic really is, erm, traffic lights that are at red, so I'm slowing down – and stopping. That kid's on his own, on his own, that's not very good. Erm, just waiting for traffic and pedestrians. Being aware of the fact that clueless is a crossing, so people could be crossing at the same time, as when it's green, but they're not. So it goes green and I go. Go left. Er, there's a car parked in front of me on the left, on my side of the road, so I'm checking to see whether anything coming towards me, and pulling out. And there's quite a few so I'm staying kind of in the middle of the road. I would probably go a little bit faster than this guy is purely because it's quite a long clear road, so you can see that nothing is coming at the moment. If there was a closer bend I would go a bit slower. Which is coming up but now the cars are. Oh it's a 'T' junction not a bend. So there's no cars parked there, so slowing down. Checking for traffic. I'd see if there's anything coming my way, and then pulling out. And it's, more parked cars on there, it's quite a thin road, so I'd go a bit slower, and it's quite a tight corner as well, so. Although it's one way, so that's okay. Er, coming up to another junction, and continuing on a one way road, so, there's less to worry about. Cars on the left, making sure that there's no one getting out of the cars, so there's no doors opening, things like that. No one crossing or any animals coming out from underneath cars as well, like cats. Coming up to another junction. Checking for traffic. There's. Oh no there was a car coming, so, not he didn't pull out then. And another one. I'm pulling out. This one's quite a busy road, so, I'm not going too fast. 'Cause there's no pathway or anything, so, straight on to a kind of like a bridge. Just taking it, quite. I'd take it quite slowly here 'cause it's not a very wide road. There's quite a bit of traffic. Some houses on the left, I think. Erm, traffic lights. There's someone at the traffic lights, and they've gone red, so I'm stopping. Can't see the traffic lights now but, I once there be flashing orange I'd make sure no one was on the, crossing, before I started to pull off again. Nice bit of a wider road now, so probably could do a little bit safer. There's people on bikes and things but there on the other side of the road. There's a car parked on the left, but again it's on the path, so it's not really a hazard. Just kind of making a note of it. Just keep an eye across the road. There's cars pulling out from the junction in front of me on the left. Erm, and that's because the traffic lights are red, but they've just turned green, so, would slow down a bit but not much. And turn in to the junction. Another quite tight road, so, slowing down a little bit. Quite tight bends with cars coming, with car, erm, roads either side as well, so, anything could be coming out of those. A few blind corners. There's no paths, so if there are any pedestrians, I'd have to kind of go 'round them, so that would be aware of that as well. Wouldn't go too fast around these corners. Is it another junction? He seems to be slowing down so I'm guessing he's going to turn right. Checking to see if there are no pedestrians crossing the road. It's as though it's a school sign. Just being aware of small children running around, which there are on the right. There's a car parked on the left, so, I'm looking ahead to see if there's anything coming. There's not, so I'm pulling out onto the other side of the road. And now there's a car coming, so, get back onto my side of the road, and turn left. More cars parked on the left, so, again, there's a car coming, so I am slowing down and stopping to let them past, until there's enough room for me to go 'round. There's another car coming but it's further away and not even turning down that road, so. Again, getting out the way of that car. Being aware of the pedestrians which are, are just crossing the road. Where there is no crossings as well so that's a bit dangerous. Turn it 'round. Again checking to see if there are any pedestrians because this is quite a built up area. Looks like a kind of estate, so there might be kids playing. Pulling out past the van. There's lots of cars parked on both sides, so, being aware of that. And, pulling up apparently.

More complex drive

So, that's kind of a blind summit of a hill, so wouldn't go too fast over that. There's a pedestrian in the middle of the road. Cars parked, kind of either side, so, making sure there's nothing coming towards me from their side kind of pulling out. Erm, they're quite wide roads, so, I reckon I could fit two cars down the middle even if you were – yeah they're kind of bays, on the side, so, not too worried about having to slow down to pass those. Although, the layout of the road seems to change. So there's a lot of cars parked and pedestrians - it's busy. So I'm keeping an eye out, for, all sorts really. And then the traffic lights have obviously gone red, and just turned green, so I'm slowing down, to allow the two cars in front of me to pass. This looks like a one way road, so, this is okay. Traffic lights, making sure they stay green. Pedestrians, on both sides of the road, and a cyclist. Keep, being aware of those. There's cars, pulling out. There's traffic lights. There's cars parked. There's lots of things to be aware of: roadworks and signs, and temporary traffic lights. Being aware of, kind of, cars passing me, and cars being parked on the left so I'm kind of having to pull out, here. So, I would have checked in my mirrors, to make sure, there's nothings coming. There's a zebra crossing, that no one's waiting at. Erm, knowing that it's twenty miles an hour down here, so, erm, taking my time. Ll, again, lot's of cars parked on th, either sides , but, they're in bays. There's a bus, park, er, waiting to pull out by the looks of things. Erm, more traffic lights, oh lots of pedestrians, it's roadworks going on. Passing on cars on the left that are parked in bays, that's not a problem. Further roadworks and kind of, cones, and, barriers, so taking my time near those 'cause they could have blown over at some point, or. That's a hazard. Car in front of me is turning left, so I'm slowing down, particularly 'cause there's pedestrians crossing. More traffic lights which are green. God, loads of more roadworks. Coming up to, another junction so slowing down 'cause there's quite a few cars in front of me. I am also kind of in the middle of the road here, so, I'd be checking I'm not in anyone's way. Not that I could do anything about it if I was. Erm, coming up to traffic lights, but they're green. Quite a lot of visual noise around here, loads of traffic lights and stuff. This is better. Onto a dual carriageway, no more parked cars either side, but, it looks like it's quite busy, so, making sure that there's no one too close behind me as I go into the left hand lane. Traffic lights are green, and coming up to a roundabout, so slowing down - particularly because the traffic lights are red. Pulling off. Okay I, I'd check in my mirrors again just to make sure there's no one kind of in the wrong lane trying to cut me up or anything. I'd speed up here so I could join the, whatever that is, dual carriageway, at a decent speed, even though it's thirty. Um just so that I didn't cause any problems with cars either before or after me. And then join the dual carriageway. Erm, switch lanes, checking my mirrors. Okay, switching lanes again, so I'd be checking my mirrors. Keeping an eye on the traffic lights, see when they change, particularly 'cause there's a camera there. Um, yep, hoping that I'm in the right lane, 'cause it's busy. Following this 'round. There's another camera, so, checking the traffic lights again. That's not worth the risk. And another camera. And more traffic lights. With pedestrians there as well, so it would be extra careful. Following it around, more traffic lights. Another pedestrian waiting. Probably keep an eye on that lorry as well, I don't like passing lorries in roads this small. We're going into the right hand lane. Checking the traffic lights are slowing down, 'cause there's traffic at the red traffic lights. Be checking that sign to make sure I'm on the right, erm, in the right lane and going in the right direction. Following it 'round. Watching out for that bus and the lorry, and slowing down, but not much, 'cause the lights going green. Switching lanes. Here, be in, okay. Then I'd be indicating. And, pulling off. The traffic lights are green, and no one waiting at them, but there's someone's stood there now. More parked cars and pedestrians. There's a guy on the left, on the path. Traffic lights – one set are green, and one set are red, so, make sure I was going in the right direction. More traffic lights, of which at green. There's cars around, there's er, woah, there's a van pulling out, only a little bit too far over to my side just in case I was, not in the middle of the road. There's a lorry parked on the left, so I wouldn't get too close to that. Probably try and get a happy medium between far enough away from the lorry but not in the, right hand lane. This guy looks like he just hasn't caught up, alongside it. Ah, it's a police car on the right. Erm, so that's obviously why that Mercedes has pulled 'round. Just rather be keeping an eye of where that was going to go, in my mirrors. Going around the road blockages. Erm, making sure there was no oncoming traffic. There's more cars parked on the left. Erm, so, going 'round those slowly. There's traffic lights which are, which are red - oh right okay so there's a little green arrow. Erm, keep an eye out for further cars and pedestrians. There's road blockages on the left, so, particularly as that's a bus coming I'd be careful I wasn't pulling out too far. With that cyclist as well going 'round the parked cars. And, there's traffic, so, slowing down. At this point, yeah, probably keep an eye out as to where that cyclist was going 'cause I past it before. And now, yeah, letting it go in front of me because of the, traffic on the left. Okay, but because they can now safely go in the bus lane, I would, not overtake them, 'cause there's traffic lights which are red. This quite a tight road again, there's cars parked on the other side and there's lots of kind of big heavy vehicles going through, so I'd be aware of that. In terms of my erm placement of the car. Okay, past the traffic lights. There's pedestrians at the crossing but the lights are green. But notice the police car, probably. Er, green traffic lights. Want to keep going around. Er have we checked, oh, there's a pedestrian taking him time. Checking traffic lights again. Following this 'round. So there's cars parked on the right, it looks like quite a wide road. There's a car coming towards me. Er, yeah, there's enough space there.

iii) Study 3

Alright, so I'm going to slow down a little bit for the traffic lights, but not too much because they've just turned to green, so, hoping I won't have to use my brakes. It's quite busy because all the students are back, and, however, the lights are green, so, it's very unlikely that anyone will be crossing the road. Looking at a car to my left, just making sure that they don't pull out. I can see a cyclist through the er back window of the car ahead, erm, they're not going to go across, that's okay. There's people on the path, but there not of any concern really. Nowhere near the road. Traffic lights up ahead, and there's people waiting either side, so they're likely to change, but, they haven't, so that's good, oh, just got through them. And then a red light up ahead, so I'm slowing down. Checking my rear view mirror to make sure anyone who's behind me is slowing down as well. I can't see the traffic lights, so, I'm going to have to rely on the vehicles ahead of me. And there's a vehicle coming up behind on the left. I'm just making sure I've left them enough space. Okay, so, vehicles ahead of me moving forwards. Keeping an eye on the traffic lights, make sure they stay green. Jumping through that one. Okay. Again, just keeping an eye on the two sets of traffic lights ahead. Checking in my right, rear view, er right, wing mirror, as two lanes merge into one. So I'm just making sure no one's trying to overtake. Keeping an eye out for, cyclists on the road, as there's no cycle path. Lots of pedestrians on the pathway. There's more traffic lights coming up ahead, and they're green at the moment, and it doesn't, there's nobody on the crossing, so. Okay, slowing down 'cause the car ahead of me is braking. Coming up to a roundabout. There's a learner coming 'round. There's another car, however, in need of indicating to come around in front of me, going. Indicating to turn off the roundabout. There's traffic lights up ahead, so I'm Just making sure that, they're staying green at the moment, and also keeping an eye on the vehicles, a couple of cars ahead of the one in front of me. Just to kind of pre-empt any stops. I'm slowing down, and checking, right, to see if there are any oncoming vehicles, which there aren't, so I'll go. And indicating to go off the roundabout. Just checking the car to the right of me. Think that's doing. Again traffic lights ahead, but they're really green. There's a car to my left about to pull out. Just checking in my rear view mirror, see if there's anything behind. There's no traffic behind at all, as the, lights have just gone red, so. Nice and clear, green lights at the crossing. Again, just slowing down a little bit, 'cause there's a roundabout coming up. And although the car hasn't braked in front of me yet, it, likely to soon. Slowing down considerably, as it's a bit of a blind corner 'til now. And this is, there's no cars around, so, crossing the roundabout. Checking that site entrance to make sure there's no cars coming out of it. And indicating to come off the roundabout. Checking my rear view mirror, still no one behind. And checking my speed dial as well. And I know there's another roundabout coming up soon, so I'm just kind of monitoring, the distance between my car and the car in front. Okay, so, veering slightly to the right, going to the right hand lane, and slowing down. As the car in front of me is also slowing down. It's a busier roundabout, so, kind of turn, almost stop. There's a car coming. I can get out before it. Okay, following this car around, keeping to the right. Checking my left wing mirror, to make sure there's no traffic coming. And signalling to come off the roundabout. Checking my speed dial. And checking both sides of the road because that was a cycle crossing. There's a car on my right, but it won't pull out because there's traffic on, the right hand side of the road, at the moment. Okay I'm slowing because there are traffic lights ahead, and the vehicles ahead of me are slowing down and braking. Slowing to a stop and checking my rear view mirror as well 'cause there's now a car behind me, which is going into the right hand lane. The car in front of me is indicating left, which means I'll probably take off slightly slower. So I'll bear that in mind when I, pull away as well. Okay, the lights have gone green. So I'll give the Land Rover in front a bit more space, 'cause he'll be slowing down to turn. There's a pedestrian about to cross the road, but it's my right of way. Checking my speed dial. And again, keeping an eye out for pedestrians and cyclists - we're entering a village - and there's a cycle path on the left. There's pedestrians around, and there's also vehicles parked on the left, so, I'm making sure there's no oncoming traffic that could potentially cause a hazard, create a hazard. Bike, er, the bus in front is braking. There's a mini roundabout, and I'm making sure there's nothing coming on the right, from the roundabout, so we can go straight over. Speed bump. Okay, it's quite busy by the bus stop, and the bus is going to stop there as well, to pick up the, er, people. So, I'm slowing down, and I can see a truck, or a, a van coming, on the right hand side. I'm gonna indicate right, and wait for this vehicle to pass. And then, overtake the bus. Probably accelerating slightly quicker than I normally would because there was a car a fair distance away.

Checking the pedestrians on my left. Slowing down for the speed bumps. Checking my rearview mirror, make sure there's nothing going on behind. There's some pedestrians on the sidewalk, and they're crossing each other, so, slow down a little bit. Okay, traffic lights are green. Okay, checking on the right, the mini roundabout, there's nothing there. Checking my speed dial. There's a cyclist, he's on the other side of the road. There's cars parked, however they're set back from the road, so, it's not too much of a hazard. There's three pedestrians walking abreast on the path. Keeping my eye on the speedometer. Here there's more cars parked on the side of the road this time so having to go around them. There's an oncoming bus but I've got time to go around them. Also there's no cars behind me so I didn't indicate to go around them. Okay, so I'm slowing for the mini roundabout. There's nothing coming from the right, so I'm turning. There's a cyclist coming up ahead. Just checking in my rear view mirror again. It's a bit of a blind corner, so, I'm going slightly slower. And this car's parked on the side, so, that'll mean I'll go a bit slower as well. Okay. It's a nice open road. Nice and quiet down here. Again, checking my rear view mirror. Again it's gone up to a national speed limit, however, there are some, real blind corners, so, take my time 'round here. I got lost 'round here last week, I've just recognised that. It's quite a blind corner, I guess, I'm just taking it a bit slower. And w,will checking my rear view mirror to make sure there's no one behind me. A bit of a blind hill as well, so taking care for potential cyclists. And braking around another blind corner, and another. There's also some kind of, debris on the road, so that's making me go a little bit slower as well, just because of the skid risk. And, there's a construction site entrance sign, so, taking care, part that entrance. And there's an oncoming car, so I'm slowing down a little bit as it's on a corner. And slowing down again due to the blind corner. Bit bright, so I'll put the sun visor down, might compromise my vision. Here's another car coming, although it's nice wide stretch of road. It's another tight corner 'cause there's a sign, saying so, so I'm not going to go too fast around this one. It's mad that this is a, national speed limit zone. Slow around another corner, and, accelerating a bit 'cause we're on a straight. I am slowing down again for another corner, this one's quite a tight one as well. The weather is obviously making this a little bit harder as well 'cause we've got some really bright patches of sunshine which are, causing some glare for the windscreen. Okay so make sure there's no oncoming traffic. There's a car coming out of the right, but it was slowing down, as it's quite a er a narrow road, so, wasn't enough space for the two of us. There's a pedestrian in the road, ah, but he's on the right, so, we'll, drive past slowest in case there's any oncoming traffic which I cannot see, because of the blind dip. So, I'll go a bit slower, but there's nothing coming. Okay, it's a bit of a blind corner here. The roads are much more narrow, so, I've got to go, much slower, and then, it opens up a bit. Yes, slowing down, just coming to a bit of a blind dip again. And, a very tight corner. Almost looks like a dead end it's so tight. Okay, taking it really slow around the corner, just in case anything was coming. And again, got another, very tight corner coming up, with quite a lot of debris of, twigs and things in the road, so, I'll take it nice and slowly. If a car was coming along, it would be pretty tight, so. There's three pedestrians walking in the middle of the road, erm, so, hoping, yep, they're go over to the right. Risky. Okay, there's another blind corner, so, I'll take this nice and slowly. And another one. Okay, it's come here for a little while, for, another corner a few yards up ahead. Okay, then it opened out a little bit, so, go a tiny bit faster. Checking my speed dial to see how fast, and then slowing down again, it's really another tight corner. Checking my rear view mirror to see if there's any traffic behind, which there isn't. I'm going slowly around, the corners up ahead. There's no pedestrians at the moment. Oh, there's one, and there's dogs which are off of leads, so, gonna go quite slowly. They've got them to sit down, so, say thank you. And then a really tight corner, so I'm gonna go really slowly around here, as I have to come outwards a bit to have to turn the corner. I see some cars parked up ahead on the road, which makes it, a little more difficult. So before we go past them just making sure there's nothing, coming, ahead of me - which there isn't. It's a nice, straight, bridge, over the reservoir, so, go a little bit faster. And it's a nice view.

Okay, so there's a car parked on my side of the road, so I'm just gonna check my wing mirror to make sure there's nothing coming behind me, if there was I would have signalled. Okay, so I'm making sure there's nothing coming that way, or ahead of me, or behind me, so I can do my turn. And I'm checking the mirrors, just to make sure there's nothing coming up that lane that I'm reversing into. And then, I'm coming, out, having turn 'round. Okay, so, making sure there's nothing coming the other way now, which there isn't. Checking in my rear view mirror to make sure there's no traffic behind me. And slowing down a little bit, just to make sure there's no traffic coming towards me. Passing the parked cars on my right. And then slowing down considerably, for the tight corner over the bridge. At least I know there are some pedestrians on this road, so, I'll be taking these corners, particularly slow, particularly as the dog, as the dogs are off the leads, so. Just in case they're running in the road at all. Trying to keep, erm, a fair bit to the left, as it's a very narrow road. Okay, so the pedestrians are crossing the road, so they're on my right. Just, slowing down, 'cause the dogs are running around. Being careful around these blind corners again. Checking my rear view mirror, just to make sure the pedestrians aren't, huh, aren't chasing me - the dogs aren't running up behind. And, try again, trying to just keep to the left, on the, corners, just in case there's any oncoming traffic. I know there are some more pedestrians coming up, relatively soon, so, be keeping, being mindful of them. Particularly as they were walking in the middle of the road beforehand, so. Hopefully they'll be able to hear my car first as they will be facing the other way. Okay, so another blind corner. I'm slowing down again, the road gets a little narrow. Okay, so there's quite a few pedestrians in front, facing me. So he's on my side so I'm gonna have to go off to the right making sure there's no traffic coming towards me. And, the pedestrians have moved over to the left - thank you. Okay, so I've safely crossed them, and then I'm moving back over to the, left hand side of the road, driving up to quite a tight corner. So, I'm slowing down considerably, and keeping as far to the left as I can. Oo, okay, and it's clear for me for quite a while. Checking my rear view mirrors, make sure there's nothing coming behind. There's a gate on my right and left, just making sure there's nothing coming out of those. Okay, so there's a blind, hill, coming up. So I'll just slow, slow down slightly coming up to that. And then there's a driveway, there's nothing coming out of there. There's some more house here, so I'm more aware of the fact that vehicles could come out of erm the driveways and any of these cars. Any of these driveways, yes, the cars will come out of the driveways. Okay so I'm slowing 'cause we're coming up to a junction. Oo, it's a bit of a blind one. There's nothing coming to my left, however there's a car coming to my right, so, just double checking again, right and then left, and right before I go. Okay, I can see the change in speed limits, so, just checking my, speedometer. Make sure I don't keep to the correct speed. There's an opening on my right, so making sure no vehicles coming from there. It's there, checking my rearview mirror, have to make sure that nothings coming from behind, signalling, and turning left. Another quick check in my, wing mirror to make sure there's no cyclists. Okay, so there are some cyclists in the road up ahead, riding, two or three abreast by the looks of things. So hopefully they will, move. It's quite a wide road though, so, if there's, there's plenty of space. I'm slowing down nevertheless, because they're never quite wide. Checking in my wing mirrors, there's, a pedestrian coming out on my right. Slowing down, just to make sure there's nothing coming up on my right hand side for the roundabout. And going straight over. There's a pedestrian up ahead, he's crossing the road, but, they're way ahead, so, no need to slow down at this moment. Oh, is she stopping in the road. And there's an oncoming van. Checking in my rear view mirror, there's still no vehicles behind. There's a junction on the left, from that road on the left, so making sure no one's coming out of that. So a car coming out from the junction on the left, so just slowing down a little bit. Okay so they're braking now, although not signalling, so, slow down a little bit for them. There's cars parked on the left, although, that car was considerably on the kerb, so, wasn't too much of a hazard. There's several cars now parked on the left hand side of the road, so, I'm checking in my rear view mirror and my right wing mirror to make sure there's nothing oncoming. There's a car coming towards me but the car I'm about to pass, on my left, is on the pavement, so it's not too bad, however there are some parked cars on the left. Checking the rear view mirror, to make sure there's no cars behind. Stopping at the junction 'cause there's a car on my right and a pedestrian who's a little behind me. Having a quick check to the left just to make sure no one's on the wrong side of the road. Okay, checking my wing mirror and my rear view mirror again. Car ahead is braking and signalling right, but they would have turned by the time I get there. Oh, they're doing er, not sure what they're doing, stopping on the side. Checking, the, junction, and there's a car on the right hand side, so the car, the oncoming car is slowing down to be passed. There's a cat in the road, so, yeah okay, I, had that had been further in the road I would have probably slowed down, a lot more, considering, how spontaneous they can be. And it's safely on the pathway. So car coming on my right. It's quite, a little bit of a tight corner, I'm slowing down. There's cars parked on my right, and there's an oncoming car. So it's my right of way, so we'll see what, see what it does, and it's not going to stop at all. Thank you very much, cheers. It's my right of way. Er, there's more cars parked on the right, and no oncoming traffic. Indicated. Check in my mirror. Lots of pedestrian on the road. Nothing coming from the right, so, signalling I'm turning, and, in my, left, wing mirror I've just seen there's a car coming behind as well, so be mindful of that. Traffic lights are green. Cars parked on the left, however they are in bays, so, that's not too much of a hazard, and there's no oncoming traffic. Okay, so there's a car behind me now. I'm just checking in my rear view mirror. The car ahead's braking for the speed bumps, so I'm doing the same. Ensuring that I'm maintaining a safe distance away from the car in front, just in case, they brake suddenly, 'cause we're in quite a, a small little village. Then a speed bump, and there's a bus wanting to pull out, so, I'll stop and let them go. So I'm flashing to let them go. There's cars parked on the right hand side which is what they're, passing. And there's a car behind passing. Just thanking that Audi for waiting. There's a car behind. Okay, so it's quite a narrow road here, so I'm taking it quite slowly. And reading the signs about oncoming vehicles in the middle of the road. And it's a bit of a blind corner, so, another car coming, so I'm just going to pull over to the left to make sure they've got space. There's two cars coming. Oh my goodness, it's a really narrow bridge. Okay then I take it quite slowly. And there's nothing. Oh I can see cars in the, reflection, so, I'll take it slowly I'm right over the bridge. Check in my rear view mirror, to make sure there's nothing, no traffic behind. Okay, so I'm slowing down, checking in my rear view mirror, for cars behind, and turning. That's fourth gear not second. It's a, tight corner, but a, wide road, so, not slowing down too much, and coming onto the dual carriageway, so braking a little bit. There's a car coming. And signalling to join the dual carriageway. Checking in my wing mirror and rear, rear view mirror, to, make sure cars around me are being safe as well. Checking my speedometer. And coming up to a roundabout, so, not braking just yet. Just took my foot off the accelerator, and now I'm braking. There's a little bit of, a queue on the roundabout, so, I'll brake a little bit prematurely, although if the cars have gone now, so, just slowing down a little bit. Okay, braking, looking ahead to see if there's any, cars coming from the right. Slowing down, just double-checking, and, crossing the roundabout. Checking in my, wing mirror, to make sure there's no, outside traffic. Checking my speedometer. And, coming up quite close to the car in front, so just going to overtake them. Signalling. Checking my wing mirror. Overtaking this car. There's a car parked in a layby, so I'm just keeping an eye on it, to make sure it's not gonna pull out. Checking my wing, er rear view mirrors, to make sure I've left enough distance to get back into the left hand lane. And, checking my wing mirror on the right, just to keep an eye on the traffic that's passing me. Checking my speed dial, and looking in the rear view mirror as well, just to check the cars behind. Okay, so I'm getting a bit close to the car off in front, however there's a car, coming up on my right, so just slowing down a little bit, and then signalling to overtake the car in front of me – whose turning left anyway. So, I'll wait for him to turn and then signal to go into the left hand lane again. So I'm checking in my rear view mirror, there's a car coming from the junction on the left, off the slip road, so, I won't signal just yet. Just making sure in my rear view mirror they've got enough space, and signalling to go back into the left hand lane. Okay, so it's fifty miles an hour now, so I'm just checking that I've slowed down to the correct speed. And got signs for the roundabout coming up ahead, so, just being aware of the traffic and the junction as well. Checking my rear view mirror, before I slow down. And heading for the, left hand lane. Checking to my right, to see what's coming from, that side of the roundabout. And there's traffic coming from the right, so, I've just stopped. And there's nothing coming, so, crossing the roundabout, and signalling left to turn off. Again, checking my rear view mirror, and, left, wing mirror, to make sure I'm not gonna hit anything.