A COMPARISON BETWEEN STATIC AND KINETIC VISUAL ATTENTION AS A MEANS OF DETECTING AGE-RELATED DETERIORATION OF THE VISUAL SYSTEM AND DRIVING PERFORMANCE

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A COMPARISON BETWEEN STATIC AND KINETIC VISUAL ATTENTION AS A MEANS OF DETECTING AGE-RELATED DECLINE IN THE VISUAL SYSTEM AND DRIVING PERFORMANCE

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SUMMARY

The aim of this research project was to determine whether static or kinetic visual attention tests provide the best means of detecting age-related deterioration of the visual system and driving performance.

A critical review of previous research revealed that visual attention tests, such as the Useful Field of View (UFOV) test, provided the best means of detecting age-related changes to the visual system that could potentially increase crash risk. However, the question was raised as to whether the UFOV, which was regarded as a static visual attention test, could be improved by inclusion of kinetic targets that more closely represent the driving task.

A computer program was written to provide more information about the derivation of UFOV test scores. Although this investigation succeeded in providing new information, some of the commercially protected UFOV test procedures still remain unknown. Two kinetic visual attention tests (DRTS1 and 2), developed at Aston University to investigate inclusion of kinetic targets in visual attention tests, were introduced.

The UFOV was found to be more repeatable than either of the kinetic visual attention tests and learning effects or age did not influence these findings.

Determinants of static and kinetic visual attention were explored. Increasing target eccentricity lead to reduced performance on the UFOV and DRTS1 tests. The DRTS2 was not affected by eccentricity but this may have been due to the style of presentation of its targets. This might also have explained why only the DRTS2 showed laterality effects (i.e. better performance to targets presented on the left hand side of the road). Radial location, explored using the UFOV test, showed that subjects responded best to targets positioned in the horizontal meridian. Distraction had opposite effects on static and kinetic visual attention. While UFOV test performance declined with distraction, DRTS1 performance increased. Previous research had shown that this striking difference was to be expected. Whereas the detection of static targets is attenuated in the presence of distracting stimuli, distracting stimuli that move in a structured flow field enhances the detection of moving targets. Subjects reacted more slowly to kinetic compared to static targets, longitudinal motion compared to angular motion and to increased self-motion. However, the effects of longitudinal motion, angular motion, self-motion and even target eccentricity were caused by target edge speed variations arising because of optic flow field effects.

The UFOV test was more able to detect age-related changes to the visual system than were either of the kinetic visual attention tests. The driving samples investigated were too limited to draw firm conclusions. Nevertheless, the results presented showed that neither the DRTS2 nor the UFOV tests were powerful tools for the identification of drivers prone to crashes or poor driving performance.

Key Words: Motion, Visual attention, Age, Driving performance, Crash risk.

To

Ruth and Keith Phelps

my parents.

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“The art of driving is looking at the right place at the right time”.

Hills (1980)

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CHAPTER ONE

INTRODUCTION

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1.1 Purpose

The aim of this research project was to determine whether static or kinetic visual attention tests provide the best means of detecting age-related deterioration of the visual system and driving performance. Ageing of the visual system could increase the risk of drivers being involved in road crashes. This chapter critically reviews previous research that has explored the relationship between age, deterioration of the visual system and crash risk. Methods of screening older drivers are discussed, and an outline of the chapters that follow is provided.

1.2 Age and driving accidents

Older drivers constitute the most rapidly expanding proportion of drivers on the road and it could be stated that the Western World is developing into an "ageing society on wheels" (Schlag, 1993). The predicted increase of older drivers, both per head and in annual mileages (Owsley, 1997), could have a serious impact on road safety (Barr, 1991; Stamatiadis & Deacon, 1995) as they are the most likely group to be involved in a traffic accident or road crash (Dissanayake et al., 1999). Older drivers are also involved in different types of crashes compared to their younger counterparts (McGwin & Brown, 1998; Ryan et al., 1998).

1.2.1 Older drivers and statistics

There are currently 31.6 million drivers in the UK of which 4.1 million (approximately one in eight drivers) are over the age of 65 years (Focus on Personal Travel, 1997/99). However, as many as one in four could be over the age of 55 years (O'Neill, 1992). In 1994, there were 15.7 million drivers over the age of 70 years in the US alone (Rogers & Fisk, 1999). Yassuda et al. (1997) have predicted that there will be 50 million drivers over the age of 65 years by the year 2020 in the US, of which almost 50% will be over 75 years (Graham, 1995). Similarly, in the US, it is anticipated that as many as one in four drivers will be over the age of 65 years by the year 2024 (Ball et al., 1993) and as many as one in three by the year 2030 (Gutheil, 1996).

Currently the numbers of older drivers on the road is relatively low, especially for women (Schlag, 1993; Hakamies-Blomqvist & Wahlstrom, 1998), and it should not be assumed that all older people would stop driving just because they are ageing. Jette and Branch (1992) found older adults continue to drive well into their 80's and 90's. As life expectancies increase, the mean age of drivers over the age of 65 will also increase. Furthermore, functional and chronological ages become increasingly dissociated as we continue to live longer. For this reason the over 65's should not be considered as one group (Kosnik et al., 1990; Ball, 1997) and other functional abilities should be taken into consideration rather than age (Pauzie et al, 1999).

1.2.2 Older drivers and road safety

A U-shaped curve (see figure 1.1) is observed when crash rates per mile are plotted as a function of age (Burg, 1967a; Bloomfield, 1999). The curve shows that crashes occur more often in the youngest and oldest drivers (Doherty et al., 1998; Dunne et al., 1998; Goode et al., 1998; McGwin et al., 1998; Kim et al., 1998; Ryan et al., 1998). In the US drivers over the age of 70 make up only 9% of the driving population, yet they contribute to 13% of driving fatalities (Rogers & Fisk, 1999). Younger drivers are likely to have more crashes due to inexperience and recklessness (Burg, 1975; Taylor, 1995; Cobb & Coughlin, 1998; McGwin & Brown, 1999). On the other hand, older drivers are likely to have more crashes because of the effects of ageing (Davison, 1985; Shinar & Schieber, 1991; Owsley et al., 1994, 1998a; Levy et al., 1995; Wood, 1999; Mantyjarvi et al., 1999; McGwin & Brown, 1999).

Along with higher crash rates, there are two further factors that are specific to older drivers (Hakamies-Blomqvist, 1993). Firstly, older drivers are more likely to be severely or fatally injured compared to their younger counterparts with similar injuries because of increased fragility (Evans, 1988a, 1991; Hakamies-Blomqvist, 1993; Brouwer & Ponds, 1994). Secondly, older drivers are more likely to have caused the crash (Cooper, 1990; Hakamies-Blomqvist, 1993; McGwin & Brown, 1999).

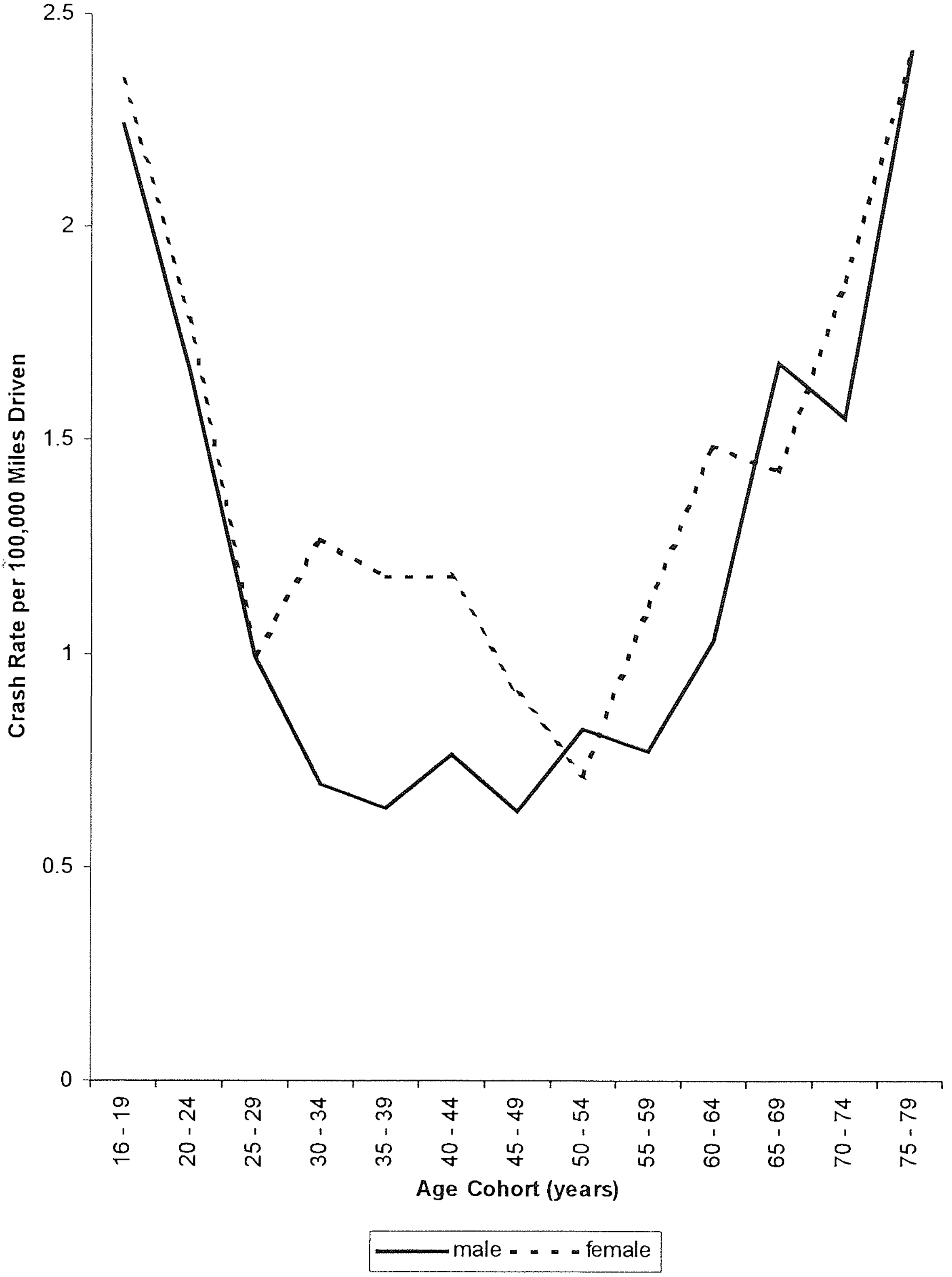


Figure 1.1: Mean crash frequencies per 100,000 vehicle miles plotted for male drivers (solid line) and female drivers (broken line) as a function of age (after Burg, 1967a).

1.2.3 Views on the safety of older drivers

The views on whether older drivers are a risk to other drivers are mixed. Graham (1995) stated that older drivers were "some of the safest drivers on the road" and Schlag (1993) suggested that older drivers might be less of a risk because their annual mileages were typically lower and subsequently reduced their exposure to the dangers of driving. However, National Travel Survey statistics, for the years 1989/91 and 1997/99, have shown that drivers are travelling further than ever before and in particular older drivers (http://www.statistics.gov.uk, 2001). The annual mileage of drivers aged between 60 – 64 years has increased by 7.4%, during this period, compared to an increase of only 2.4% for drivers of all ages. Spolander (1991) looked at the number of crashes compared to the number of driving licence holders. She found that older drivers had the lowest crash rates because of compensatory driving behaviour. Consequently the Swedish Parliamentary Committee concluded there was no requirement for extra safety measures with respect to older drivers. Stutts & Martell (1992) analysed the population and crash involvement trends of drivers during the period 1974 to 1988. They found an increase in the number of older drivers, particularly females. They also found that crash rates for all drivers over the age of 55 years had dropped in comparison to younger drivers. Moreover, the largest reduction in crash rates was found for drivers over the age of 65 years, both per mile driven and per capita. Brouwer & Ponds (1994) point out that cars were only widely available to the masses, in Europe, from the 1960's. This suggests that an 80-year-old in 2000 would have a maximum of only 40 years of driving experience. Yet, an 80-year-old in 2020 may have up to 60 years experience. Perhaps the extra 20 years of driving experience may make a difference, since as Waller (1991) pointed out experience makes drivers safer. They will also have more experience of driving faster and more sophisticated cars that could present problems to the 80 year old of 2001 who is more accustomed to simpler vehicles.

In contrast, Hakamies-Blomqvist (1993) suggested older drivers were more of a risk as they experienced higher crash rates per mile driven (see also figure 1.1). Stewart (1975) found crash rates were inversely proportional to the number of miles driven for all age groups. This was concluded from the fact that young and older drivers had the highest number of crashes and the lowest annual mileages. General slowing and increased reaction times are thought to contribute to the poorer performance of the elderly when driving (Wolffelaar, 1991). Carr et al. (1992) looked at the effect of age on driving skills alone. They found that driving skills, relating to single-tasks (i.e. driving with no distraction), were well preserved in older drivers (65+ years) compared to both middle age (25 – 35 years) and younger drivers (18 – 19 years). Conversely, Dingus et al. (1997) found older drivers (65+ years) had a higher incidence of errors related to safety when dual-task performance (i.e. driving and navigating) was assessed. Ranney & Pulling (1990) also found older drivers made errors in understanding instructions, route selection, gap execution and vehicle control. They were also slower to make decisions. Yet, they showed no difference in response speed to emergency situations, indicating that driving skills are maintained in older drivers for simple tasks but they deteriorate as the demands become more complex.

1.2.4 Older drivers and types of crashes

Crashes can either be active or passive. An active crash occurs when the driver hits another vehicle and a passive crash occurs when the driver is hit by another vehicle (West, 1993). As the age of the driver increases, they are more likely to be involved in an active type crash (Parker et al., 2000) and less likely to be involved in a passive type crash. They are also more likely to be involved in a multi-vehicle collision than a single vehicle crash (Ranney & Pulling, 1990).

Generally, crashes involving older drivers occur in complex situations (Ranney & Pulling, 1990). These types of crashes involve divided attention and decision making (Wolffelaar et al., 1991) particularly at junctions and intersections (Schlag, 1993). McFarland et al. (1964), amongst others, found older drivers were over-represented in crashes due to failure to give right of way, improper turning, ignoring stop signs and incorrectly manoeuvring. Mantyjarvi et al. (1999) studied the location of crashes involving drivers of all ages. Of 56 crashes, 36% were at an intersection, 32% in parking places, 18% were rear-shunts and 14% were reversing incidents.

1.3 Vision and ageing

It is well documented that deficits of age alone are not sufficient to account for the increased crash risk of older drivers. For example, many older drivers are involved in crashes that occur under conditions of optimum visibility, for example during daylight hours and in good weather (McGwin & Brown, 1999). Many research projects have concentrated on deficits in visual aspects, as the underlying cause of crashes. It is often cited that upto 90% of the sensory information received when driving is visual in origin (Sivak, 1996). Visual aspects can be divided into basic and higher functions and there is a distinction between the two (Taylor, 1987; North, 1988; Ball et al., 1990c; Shinar & Schieber, 1991; Dunne et al., 1995; Charman, 1996).

1.3.1 Basic visual functions and ageing

Basic visual functions relate to attributes of the eye as a sensory organ. These functions include visual acuity, contrast sensitivity and visual field sensitivity and many of them decline with age (see table 1.1) but physiologically these functions change at a different rate to biological age (Ordy et al., 1991; Waller, 1991; Haegerstrom-Portnoy et al., 1999). The deterioration in these functions is associated with two age-related changes in the structure of the eye (Fozard et al., 1977; Owsley et al, 1993). The first changes occur between 35 and 45 years of age and the second between 55 and 65 years. The earlier changes are lenticular in origin and constitute presbyopia. The later changes affect the retina and these include macula degeneration and cataracts for example. These changes are evident in visual field losses and increased sensitivity to both reduced lighting levels and flicker.

Visual acuity declines after 60 years of age (see figure 1.2) but dynamic visual acuity declines earlier and faster (Burg, 1964, 1966, 1967, 1968a, 1971; Elliott & Whittaker, 1991; Klein, 1991;

Shinar & Schieber, 1991). Media opacities develop in old age leading to problems with disability glare, contrast sensitivity and colour discrimination (Owsley et al., 1991, 1998; Mantyjarvi et al., 1998, 1999; Owsley & McGwin, 1999; Mantyjarvi & Tuppurainen, 1999). Ageing also leads to longer glare recovery times (Burg, 67; Collins, 1989; Carter, 1994; Rubin et al., 1994; Anderson & Holliday, 1995; Bichao et al., 1995). Pupil miosis with age leads to reduced retinal illumination that must influence vision under the mesopic light levels experienced at night (Sloane et al., 1988; Koch et al., 1991; Sheedy & Bailey, 1993; Owsley et al, 1993; Winn et al., 1994; Chauhan & Charman, 1995; Jackson et al., 1999). Tritan colour vision defects emerge with old age (Weale, 1965; Ruddock, 1993; Wood & Troutbeck, 1994). Age related macular degeneration leads to reduced visual acuity, particularly at low light levels (Klein, 1991). Diseases such as closed angle glaucoma (Burg, 68b; Johnson & Keltner, 1983; Jaffe et al., 1986; Potamitis et al., 1994; Jones et al., 1995; Owsley et al., 1998a) and diabetes (Cox et al., 1993; Brouwer & Ponds, 1994; McGwin et al., 1999; Owsley & McGwin, 1999) increase with age leading to visual field restriction, however, they are also prevalent from middle age. Cerebro-vascular accidents increase with age and they can also cause visual field restriction (Szlyk et al., 1993a; Schanke et al., 1999).

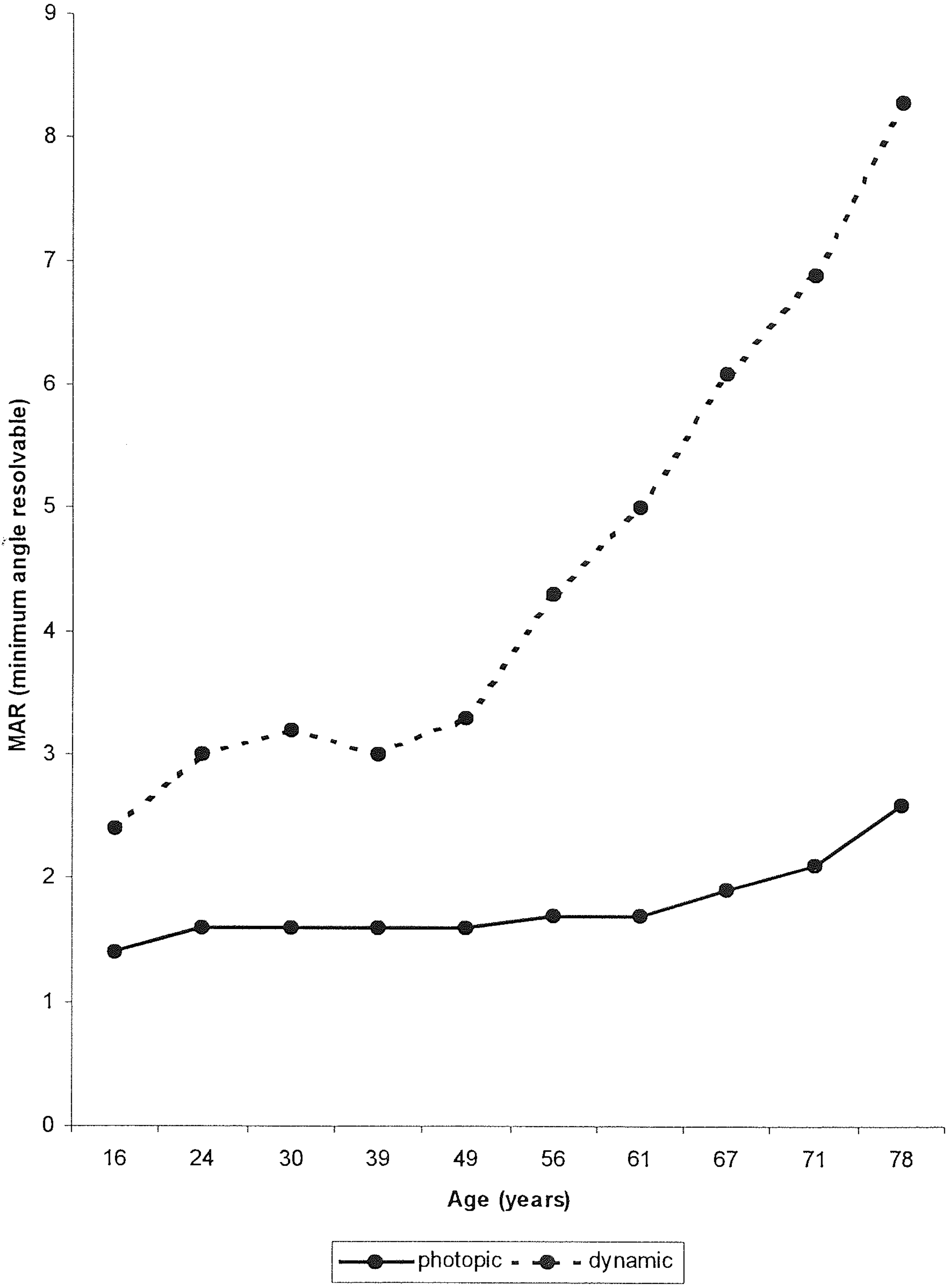


Figure 1.2: The decline of static (solid line) and dynamic (broken line) visual acuity with age (after Shinar & Schieber, 1991).

1.3.2 Higher-order visual functions and ageing

Higher order visual functions relate to attributes of the whole visual system including the eye and brain. These functions show more deterioration with age than do basic visual functions (see table 1.1). Visual attention is a higher order visual function (Owsley et al., 1994; Owsley, 1994). The Useful Field of View (UFOV) test measures processing speed, divided attention and selective attention (Ball et al., 1990a). Only selective attention deficits tend to occur in the young (Brouwer & Ponds, 1994; Sekuler & Ball, 1986). Ageing then brings about additional losses in divided attention and processing speed (Owsley et al., 1998b). Older drivers also have increasing difficulty judging speed and motion (Kosnik et al., 1990).

Test	Prior crash involvement	Age
UFOV	0.52 *	0.60 *
Mental status	0.34 *	0.47 *
Central visual field	0.28 *	0.28 *
Peripheral visual field	0.26 *	0.40 *
Contrast sensitivity	0.24 *	0.40 *
Visual acuity	0.23 *	0.27 *
Ocular media	0.17 *	0.24 *
Night glare	0.16 *	0.31 *
Colour discrimination	0.11	0.25 *
Day glare	0.10	0.12

Table 1.1: Correlation's (Pearson's correlation coefficient) between various tests versus prior crash involvement (294 drivers aged between 56 and 90 years; Owsley, 1994) and age (53 drivers aged between 57 and 83 years; Owsley et al., 1991). An asterisk denotes statistical significance at the 95% level.

1.3.3 Mental status and age

From the table above (see also figure 1.3), mental status correlates highly with both crashes and age. Lundberg et al. (1998) investigated the relationship between cognitive functions and crashes in older drivers with and without moving traffic violations. They found that older drivers in both groups, who were crash involved, were more likely to be cognitively impaired. Similarly Stutts et al. (1998) found older drivers showing early signs of dementia were over represented in crashes. Further, Perryman and Fitten (1996) found many older drivers had mild dementia that affected their driving performance.

Owsley et al. (1998a) suggested that older drivers with dementia were unable to self-regulate their driving patterns and consequently exposed themselves to higher risk situations. Also cognitively impaired drivers are highly likely to have normal visual acuity and visual fields (Rizzo et al., 2000). In contrast Vincenzi (1999) found older drivers who remained in employment were able to offset the general effects of ageing due to increased mental and physical workload.

It has been found that 16.8% of people over 65 years of age have cognitive impairment with no dementia (Graham et al, 1997) and between 20% (Retchin et al., 1988) and 47% (Evans et al., 1990 cited in Bylsma, 1997) of people over the age of 85 may be impaired. Brouwer and Ponds (1994) estimated that 4% of older drivers have signs of dementia.

1.4 Vision and driving

Literature reviews have been carried out by Burg (1975), McKenna (1982), Davison (1978, 1985), North (1985), Taylor (1987), Ball et al. (1990b), Shinar & Schieber (1991), Owsley et al. (1991), North (1993) Charman (1996) and others. A brief summary of the research is provided here. For a full review of vision and driving see the Department of the Environment, Transport and Regions' (DETR) website on road safety (http://www.roads.detr.gov.uk/roadsafety/).

1.4.1 Basic visual functions and driving

Basic visual functions, such as visual acuity and visual fields, tend to be weakly related to crashes (Hills & Burg, 1977; Keltner & Johnson, 1987; Wallace & Retchin, 1992; Mantyjarvi et al., 1998; see also table 1.1). Stronger relationships have been found between more complex basic visual functions such as dynamic visual acuity (Burg, 1967) and crashes.

1.4.2 Higher-order visual functions and driving

Higher order functions, such as visual attention, exhibit the strongest relationships with crash rates (Owsley et al., 1991; Ball et al., 1993; Owsley, 1994; see also table 1.1). Structural equation models (see figure 1.3) have revealed that basic visual functions may only be indirectly related to crash rates through their influence upon higher order visual functions (Owsley, 1994; Owsley & Ball, 1998).

Evidence is growing regarding the ability of the UFOV test to detect age-related changes (Dunne et al., 1995), prior crashes (Ball et al., 1991; 1993; 1994) future crashes (Owsley et al., 1998), crashes in a simulator (Rizzo et al., 1997), crashes related to neurological disease (Rizzo & Dingus, 1996), situational awareness (Chaparro et al., 1999) and driving performance (Wood, 1995; De Raedt & Ponjaert-Kristoffersen, 1998).

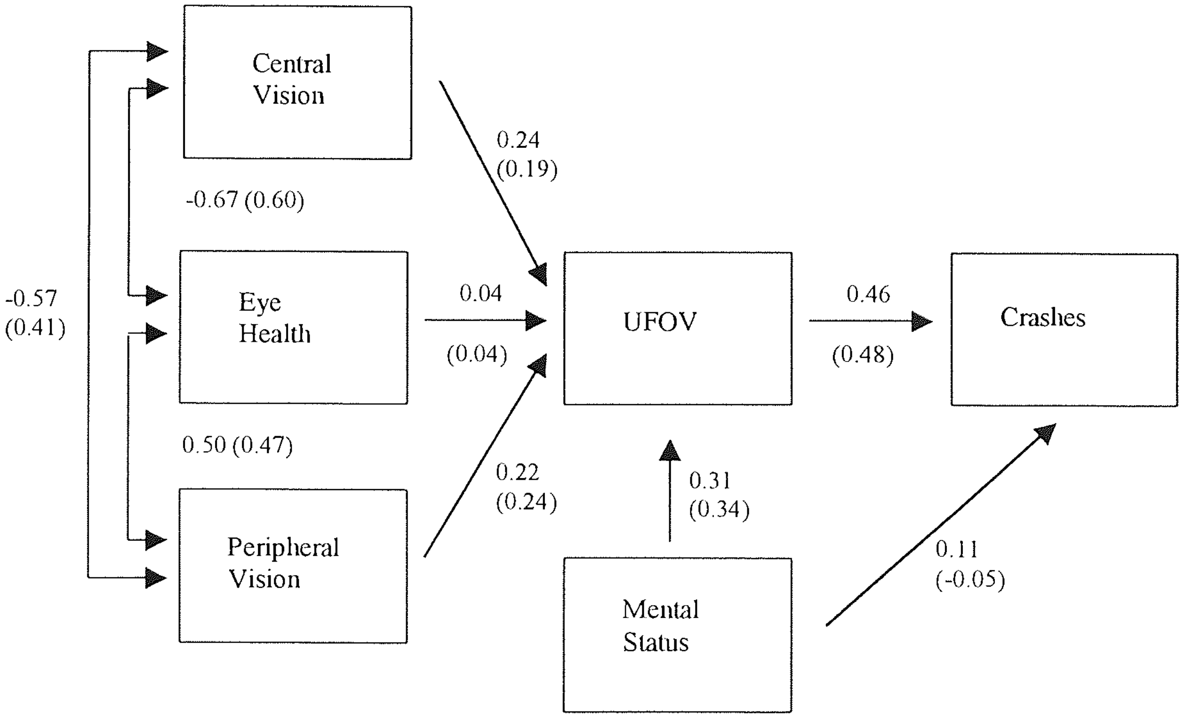


Figure 1.3: Structural equation model showing the relationship between visual functions and crash rate. Figures represent correlation coefficients for prior and future (in brackets) crashes (after Owsley, 1994).

1.4.3 The problems of driving research

Exploring the correlation between vision and driving has several problems (Munton, 1995; North, 1993 and others). Driving performance can be divided into two areas, driving skill and fitness to drive (Brouwer & Ponds, 1994). Driving skill is dependent on learning and experience and refers to the smoothness and safety of the ride. The level of skill applied when driving relies on the efficient use of knowledge, abilities and resources. Fitness to drive relates to the mental and physical abilities of the driver, along with access to the necessary resources required to drive safely and without interference to other drivers. To truly assess whether an individual is fit to drive then it would be essential to assess all areas relevant to driving (Carr, 1993; Owsley, 1997).

Research often relies on self-reported crash rates, which are known to be inherently unreliable (Ball & Owsley, 1991; Owsley et al., 1991; Ball et al., 1993; Goode et al., 1998; Withaar, 2000). Vision is only one of a number of factors involved in driving. Shinar and Schieber (1991) concluded that only a weak link would be found between lower-order visual factors and crashes because:

- Crashes are rare and multi-factoral
- Unreliable and gross vision data has been collected in many large-scale studies
- Legislation excludes drivers with severe visual defects
- Self-restriction of drivers with visual problems
- Road systems are forgiving and compensate for human error
- Attentional or higher-order perceptual failings are often cited as causes of crashes
- Higher-order visual functions have **not** been included in large-scale studies

1.4.3.1 Self-recorded versus State crash records

Crash records can also be obtained from official or state records. When a comparison is made of both these types of records a discrepancy is often found. The number of crashes reported by drivers, particularly young men, is generally underestimated (Ball & Owsley, 1991; Owsley et al., 1991; Ball et al., 1993; Marottoli et al., 1997; Goode et al., 1998). There are several other reasons why the records show conflicting data (Marottoli et al., 1997; Owsley, 1997):

- Individuals often make mistakes
- Individuals are uneasy about giving full details of all crashes
- Minor events are frequently not reported by the Police
- Inefficient Police reports
- Not all crashes are brought to the attention of the Police

1.4.3.2 Crashes are rare and multi-factoral

Crashes are rarely caused by one specific factor; they are a combination of several factors (Davison, 1985; Hills, 1980; Lovsund et al., 1991). Shinar et al., (1978) suggested there were three broad classes into which these factors could be placed, human, environmental or vehicular. Quimby and Watts (1981) analysed the causes of 2,000 crashes and concluded that human factors contributed to 95% of these crashes and were the sole cause of 65% of them. Hakamies-Blomqvist (1993) compared the factors that contributed to self-caused crashes during a five year period (1984 – 1989) in older drivers (over 65 years) and younger drivers (26 – 40 years) in the safest age group (see figure 1.1). Of 353 fatal crashes she found that 99% of them were related to human factors. Environmental factors tend to play only a small role in contributing to crashes in the older driver, as these drivers tend to avoid driving in extreme weather conditions (McGwin & Brown, 1999). Vehicular factors relate to mechanical faults, such as faulty brakes or worn tyres.

Research needs to pinpoint the exact human factors that cause specific types of crashes. De Raedt (2000) found that detailed analysis of specific types of crashes yielded better predictions than when all types of crashes were grouped together. Crash predictability was found to increase from 62.9% (all crash types) to 73.8% for crashes that occurred where "traffic from the left has right of way, and when making left turns". In the UK, this would be the equivalent of traffic from the right having right of way, and when making right turns.

Crashes occur infrequently and research has suggested that a link with vision would only be found if the sample sizes were large enough and included sufficiently high numbers of crashes (Goldstein, 1964; Hofstetter, 1976; Davison, 1985; Ball & Owsley, 1991; Colsher & Wallace, 1993). However, Johnson and Keltner (1983) measured visual field losses in 10,000 pairs of eyes and they failed to find a link with driving performance. Ball and Rebok (1994) suggested that the performance of older drivers was characterised by individual differences and a link between vision and crashes would only be found by examining individual drivers. Others have suggested that no link would be found and that it is more important to look at the human factors in terms of specific skill deficiencies (Duncan et al., 1991).

1.4.3.3 Unreliable data

Early, large-scale projects measured visual acuity using commercially available screeners that are known to be relatively inaccurate (Burg 1964; Burg, 1971; Council & Allen, 1974; Hills & Burg, 1977; Cole, 1979; Johnson & Keltner, 1983; Davison, 1985). Wild & Hussey (1985) argued that static visual acuity (Snellen) was unreliable for measurements of spatial resolution because it uses an ordinal scale with unequal steps. Similarly, Haegerstrom-Portnoy et al. (1999) found that high-contrast tests of visual acuity, that optimally measure vision, underestimated the degree of visual function loss suffered by older individuals under conditions of low illumination (see also Johnson & Casson, 1995). Scialfa et al. (1988) reported on multiple methods for the measurement of visual sensitivity and perhaps different tests would be more appropriate to driving (see also Ivers et al., 1999). Visual acuity is but one test and contrast sensitivity is another. The latter has been shown to be diagnostically more superior (Ginsburg et al., 1981; Ginsburg et al., 1983; Owsley et al., 1983, 1999; Shinar & Gilead, 1987). This could explain why studies using more accurate measurements of visual acuity using high contrast targets, have still failed to find a link between driving ability and vision (Davison, 1985; Hebenstreit, 1984; Hofstetter, 1976; Humphriss, 1987).

Annual mileages are also used as an assessment of crash risk. Yet self-reported annual mileages are inherently unreliable (Ranney & Pulling, 1990; Ball et al., 1991, 1993; Owsley et al., 1991; Owsley, 1997; Trobe, 1998) and incomparable to mileages in the UK (Charman, 1996).

1.4.3.4 Legislation and visual standards (visual acuity and fields)

Only individuals with good acuity are allowed to drive. Charman (1996) suggested that this was insupportable as higher crash rates occur in other European countries, as well as Australia, Canada, New Zealand and the US (Davison, 1985), despite them having a stricter legal visual requirement for driving than in the UK. Szlyk et al. (1993b) assessed the performance of drivers with juvenile macular degeneration on a driving simulator and recorded self-reported and state crash records. Drivers with central visual loss (visual acuity between 6/12 and 6/21) were at no greater risk of crashes when driving in daylight conditions only, compared to drivers with normal vision. Yet Gresset and Meyer (1994b) found higher incidents of crashes in drivers who failed the visual standard required for driving and who had binocular vision deficits. Sheedy and Bailey (1993) suggested that any relationship between vision and crash rates would be diluted by the restriction of drivers to only those with good visual acuity. Results are mixed and more evidence is required before visual acuity restriction can be considered a true factor in reducing crash rates.

Similarly, mixed conclusions are found when visual fields are taken into consideration. Lovsund et al. (1991) determined that visual field losses were instrumental in the cause of some crashes. However, they also suggested that no large-scale studies would be able to find a relationship between field losses and crashes. Szlyk et al. (1992) found patients with field losses due to retinitis pigmentosa were more likely to be involved in self-reported crashes and to encounter crashes on a driving simulator compared to subjects with normal fields. Yet, Wood et al. (1993), found no detrimental effect on driving skills, when horizontal visual fields were restricted to 90° maximum in the horizontal. Ball et al. (1990a) measured visual fields in older adults and found standard visual field assessments were unable to detect peripheral visual problems experienced in real life.

Also Casson and Racette (2000) found a link between the size of a visual field loss and driving performance, but not with its location.

1.4.3.5 Self-restriction

Older drivers with visual problems are often aware they have a problem (Kosnik et al., 1990) and they are thought to voluntarily restrict their driving habits (Munton, 1995). Older adults are frequently retired, drive fewer miles and consequently they are able to decide when to make their journeys in order to avoid slippery roads, rush hour and night driving (Retchin et al., 1988; Schlag, 1993; Eberhard, 1996; Duchek et al., 1997; Hakamies-Blomqvist & Wahlstrom, 1998). Owsley et al. (1998) found drivers who restricted their driving to fewer than 7 days a week were less of a crash risk than those who drove every day.

Hakamies-Blomqvist (1994) looked at the effects of compensatory strategies on crash rates. She found that older drivers who drove more slowly were involved in fewer crashes for example when driving at night and in poor weather conditions. Older drivers are known to drive more slowly to compensate for slower reaction times (Li et al., 1998).

Slade & Dunne (1999) questioned 7254 drivers from the UK on their self-reported driving habits and crash histories. Only those drivers with high contrast visual deficits, independent of age, were found to restrict their driving strategies. Further support for the theory was found by analysing a subset of drivers (961 drivers, 31 – 35 years old). The subset was further divided into two groups, "no driving restriction" and "driving restriction". Those drivers with reduced visual acuity who had been involved in a crash were over represented in the "no driver restriction" group (Slade & Dunne, 1997).

While it can be seen that some individuals with visual problems adopt new driving strategies, it cannot be guaranteed that all drivers will follow this path (Stutts, 1998). Some drivers may be unaware of changes in their visual acuity and visual fields (Shinar et al., 1978). Stutts (1998) recommended that health professionals should evaluate fitness to drive in older patients and Cairney (1997) suggested that medical practitioners should advise older drivers to restrict their driving to avoid having their licenses revoked if driving skills were felt to be inadequate.

Waller (1991) mentioned that changes in driving behaviour had both positive and negative attributes. She reported that crash research had shown that increased annual mileages were associated with reduced crash risk. However, she recommended that it should not be taken for granted that the characteristics of older drivers' behaviour, at this present time, would remain unchanged in the future.

Research has led to the development of various models of driving behaviour. Michon (1985) has theorised a hierarchical model of car control and this model may help to explain the compensatory driving strategies of older drivers with visual impairment.

Michon's model is useful for researching driver-traffic integration. The model has three time-related interacting levels of driver behaviour:

- strategic
- tactical
- operational

When high level decisions are made, for example in the "strategic" and "tactical" levels, they guide the lower more automatic "operational" level.

At the "strategic" level, changes include the choice of driving conditions. These decisions are knowledge based and they take place before driving commences, for example avoidance of high stress situations such as driving at night (Ysander & Herner, 1976; Planek & Fowler, 1971). This type of decision is time independent as the driver is able to change strategies when not involved in a driving situation.

Changes in the "tactical" level affect manoeuvres made by older drivers and they include increased headway (Brookhuis et al., 1991), reduced speed (Case et al., 1970; Rackoff, 1975 Rackoff & Mourant, 1979), and the use of anticipatory behaviour (Schlag, 1993; Stelmach & Nahom, 1992). These decisions are rule based and they are made when the driver is on the road and they are influenced more by the pressure of time. Driving is self-paced and controlled by the demands placed on the driver. This would explain why older drivers tend to drive more slowly.

The "operational" level is the most time-dependent since instantaneous responses are required to both the changing road conditions and the actions of other drivers. Changes made at the operational level are skill based. Older drivers have been shown to need more time to make this type of decision when driving (Stelmach & Nahom, 1992; Wolffelaar et al., 1991).

De Raedt (2000) assessed the compensatory driving strategies of older drivers who received poor on-the-road assessment scores. He found that compensatory behaviour was more likely to be adopted by those drivers with no crash history. Similarly, Szlyk et al., (1995) found those drivers who did not restrict their driving were more likely to have crashes.

1.4.3.6 Roads are forgiving

Hills (1980), suggested that drivers often rely on experience for making judgements whilst driving. This is particularly important in complex or hazardous situations, for example when overtaking, merging into high-speed traffic or crossing a main road. Safety margins are more often than not included within these decisions, but inevitably an error will be made. Nevertheless, not all errors result in crashes because of allowances built into the road system (Shinar et al., 1978). Examples include hard shoulders, wide lanes, and additional safety time of red traffic lights between phases as well as the compensatory behaviour of other drivers.

1.4.3.7 Higher-order perception and driving

Driving performance is subject to much more than just visual performance. Driving involves the interaction between man and the environment and it is often considered to be a "system" (Panek et al., 1977). This system also involves perceptual skills, decision making skills and divided attention (Charman, 1996) and it has been suggested that the visual functions required for driving would be better explained by visual perception (Panek et al., 1977) as a whole. Munton (1997) considered perception to be "at least as important as vision in driving". Attention has also been considered particularly important for driving (Parasuraman & Nestor, 1993). McKnight & McKnight (1993) suggested that attentional resources have a greater impact on safety than on the control of a vehicle, and that aspects of attention or inattention were the most likely cause of crashes. Previous research has determined three main areas of anomalous driver behaviour that result in unsafe driving and ultimately crashes (Reason et al., 1990). They are violations, lapses and errors.

Violations, in contrast to both errors and lapses, are intentional (Parker et al., 2000). It is a deliberate action performed by a driver that may have safety implications both for the driver concerned and other road users. Violations are associated with taking risks and they are statistically related to crash involvement (Parker et al., 1995). Violations are not predictive of either active or passive type crashes (Parker et al., 1995). Violations can be further divided into aggressive violations (driving too close to the car in front) and non-aggressive violations (disregarding the speed limit). Older drivers are less likely to cause road violations since they take fewer risks and they do not normally act aggressively (Parker et al., 2000).

Lapses are non-intentional mistakes resulting from a failure of attention that can predict both active and passive type crashes (Parker et al., 2000). However, Parker et al. (2000) suggested a lapse of attention to be an unlikely cause of crashes and more a cause for embarrassment. Older drivers are more likely to experience a lapse of attention such as misreading sign-posts or getting into the wrong lane when approaching a roundabout or junction (Parker et al., 2000).

Errors are non-intentional mistakes that maybe potentially dangerous. They are predictive of active type crashes (Parker et al., 2000) and they are often related to inexperience (Aberg & Rimmo, 1998). Parker et al. (2000) stated that errors were "the failure of a planned action to achieve the desired consequences". An example of an error is underestimating the speed of an approaching car when overtaking. Treat (1980) suggested that errors could be divided into four main groups:

- Recognition errors
- Decision errors
- Performance errors
- Others

1.4.3.7.1 Recognition errors

Recognition errors constitute the predominant cause of crashes (Rumar, 1990) and generally occur because of improper lookout, excessive speed, inattention, false assumption, improper manoeuvre, improper evasive action or internal distraction. Treat et al. (1977) looked at the causes of crashes and they found 56% were the result of recognition failure. The two major causes of recognition failure were "improper lookout" and "inattention" making up 23% and 15% respectively, of this total. Staughton & Storie (1977) visited the scenes of 2036 crashes. Analysis revealed 44% of the crashes were due to perceptual errors when the driver was considered at fault. Shinar et al. (1978) found that drivers with reduced vision were three times more likely to be involved in an crash involving "improper look out" compared to drivers with normal vision. Visual or perceptual errors are often cited as the cause of crashes, such as "the looked but failed to see" type (Sabey & Staughton, 1975; Staughton & Storie, 1977) along with cognitive errors such as " failed to detect until it was too late" type (Rumar, 1990). Perceptual and cognitive errors are the two main categories used to define late detection errors (Rumar, 1990). It has been estimated that 69 – 80 % of accidents at intersections are as a result of a late detection error by one of the drivers involved (Cairney & Catchpole, 1996). These types of errors could be reduced if drivers concentrated more on their actions, placing more reliance on focussed attention. However, focussed attention requires more effort and is often less effective. Driving is a well-learned skill and many actions are performed automatically rather than relying on expectations. A fine balance exists between the over use of either automatic or controlled (i.e. focussed attention) processes. Crashes can occur if too much reliance is placed on automatic skills because hazards can be missed or because of fatigue following high levels of focussed attention.

1.4.3.7.2 Decision errors

A decision error could also be considered an error in judgement (Hills, 1980). An example of a decision error would involve a mis-judgement in the gap between moving vehicles when pulling on to a main road or a gap between two parked cars. These errors are made because the driving situation is complex and involve variations in speed and judgement of distances (Ranney & Pulling, 1990).

1.4.3.7.3 Performance errors

Performance errors include the improper execution of an action that was appropriately decided (Treat et al., 1979). A performance error would be due to lack of skill in the safe control of a vehicle. An example of a performance error would be lane drifting (Mackie & O'Hanlon 1977).

1.4.3.7.4 Others

Other types of errors include falling asleep and blackouts (Treat et al., 1979). This category is the smallest of all (Rumar, 1990) and contains all crashes other than recognition, decision or performance errors. A crash of this type would include technical errors. Mackie & O'Hanlon (1977) defined a technical error as 'a failure on the part of the driver to perform certain acts of courtesy associated with highway safety and, indeed, required by law and the commission of certain technical violations of the law'. An example of a courtesy error would be failure to make the appropriate signal when turning and an example of a violation would be tailgating.

1.4.4 Should vision be screened with one test or a test battery?

Recent research supports a link between higher-order visual functions and crashes (Owsley, 1994). Higher-order functions are better predictors of crashes, because they put demands on the visual system that are more realistically related to the demands of driving (Shinar & Schieber, 1991) and they are more sensitive to age-related decline (Ball et al., 1990c; Sekuler & Ball, 1986; Scialfa et al., 1987).

However, research has shown that different types of crashes are the result of deficiencies in different cognitive functions (Withaar, 2000). The presence of one type of deficiency is rarely the cause of crashes, it is more likely to be due to changes in two or more functions (McKenna et al., 1986). Therefore, a battery of tests has the advantage of examining a wider range of functions (Rubin et al., 1995). It has been suggested that a battery of tests would be most beneficial for detecting those drivers most at risk of crashes (Brabyn et al., 1994; Buyck et al., 1988; Decina & Staplin, 1993; De Raedt, 2000; Henderson, 1975; Lundberg et al., 1998; Marottoli et al., 1998; McKenna, 1982; Schneck et al., 1994; Owsley, 1997; Sims et al., 2000: Withaar, 2000). McKnight & McKnight (1999) found a battery of tests to be more sensitive and more reliable for assessing driver performance than an on-the-road assessment. Owsley et al. (1998) recommended that the UFOV test should be included in a functional test battery to evaluate the skills relevant to driving performance and to enhance classification of crash-risk drivers. Owsley (1997) also idealised that the screening battery should be quick and easy to administer, low in cost and should have a high level of sensitivity and specificity.

1.5 Visual and sensory information

The majority of information that is required for driving is visual in origin (Hills 1980; Sivak, 1996). Drivers are able to concurrently perform multiple tasks, but they can only focus attention on one task at a time (Tijerina & Kantowitz, 1994) and this is usually visual in origin. Research has been unable to provide an accurate numerical estimate (Sivak, 1996) of the amount of visual information actually required to drive safely. Sivak gives two reasons why this figure remains illusive:

- lack of data
- lack of a definitive measurement system

No one would dispute that vision is an essential part of driving, as without a visual input we would not know where to steer, accelerate or brake and almost certainly crash (Stewart, 1988). Senders et al. (1967) carried out a study where subjects wore a helmet, whilst driving, in either an open or closed state. The open state gave a normal field of vision whilst the closed state occluded all details of the car and road ahead. All subjects, when occluded, found they could drive for only a few seconds.

Vision is but one of our senses. There are four further senses (auditory, tactile, olfactory and taste) that may be relevant to driving, along with kinaesthetics (Ohta & Komatsu, 1991; Conchillo et al., 1997). For example the perception of speed is considered to be an integration of multiple sensations (Gibson, 1954) collating information from visual, auditory, tactile, kinaesthetic, vestibular and proprioceptive sensations. Vision, hearing, touch and kinaesthetics are all relevant to driving and together they provide all the information required to drive safely. McKnight and Adams (1970) carried out a comprehensive evaluation of driving and classified 1500 different driving behaviours. Eighty-nine of these behaviours were considered critical to driving; of these 82% were visual, 11% based on kinaesthetic information, 6% tactile and 1% auditory.

1.5.1 Kinaesthesis and driving

Kinaesthesis or proprioception is the sensation of body position, body weight, muscle tension and the perception of movement. These sensations help us move around under the pressures of gravity. Information regarding linear and rotary movement is obtained from the vestibular apparatus (Gibson, 1968). Kinaesthesis helps in the maintenance of body posture and the control of acceleration and deceleration for both spatial displacements and turning. However, these sensations are modified from normal everyday experiences when we drive, because of the presence of suspension in vehicles (Sivak, 1985). Blaauw (1982), researching the validity of a fixed based driving simulator, found that perception of lateral transformations while driving were diminished due to the absence of kinaesthetic feedback. McLane and Wierwille (1975) found driving performance on a driving simulator deteriorated when yaw, roll and pitch movements were removed. The lack of these types of movements in some driving simulators is thought to be the cause of "simulator sickness" (Barrett et al., 1969).

1.5.2 Tactile information and driving

Touch is relatively important when we are driving; it helps us keep control of the vehicle by continually monitoring the friction between the tyres and the road. If the road conditions are wet or icy there is less friction between the tyres and the road, resulting in more movement of the steering wheel. This increased movement warns of possible danger and the need to slow down. For example, in France, the maximum speed limit is reduced on wet days (Edwards, 1998).

Car or motion sickness is restricted to passengers, because they are unable to gain feedback regarding the cars motion, information that is only available to the driver through contact with the controls (Barrett & Thornton, 1968).

1.5.3 Auditory information and driving

Sound has some importance to driving (Panek et al., 1977; Nilsson & Alm, 1991; Schlag, 1993; Charman, 1997). For example we need to be able to hear car horns (Panek et al., 1977), emergency service sirens (Fidell, 1978; Caelli & Porter, 1980), engine noises and screeching tyres (Matthews & Cousins, 1980). However, profoundly deaf individuals are legally allowed to drive in the UK (http://www.dvla.gov.uk) and they do not need to report any hearing loss until the age of 70 years, except in the case of a vocational license. Kahneman et al. (1973) compared drivers with and without crash histories on an auditory selective-attention task. They found that those drivers who failed the test were more likely to have a history of crashes.

Ivers et al. (1999) found that drivers with a moderate hearing loss, particularly in the right ear, were more susceptible to crashes. McCloskey et al. (1994) researching the effects of sensory impairment found that drivers wearing hearing aids were twice as likely to have a crash resulting in injury. However, research has more often failed to find a link between hearing and driving performance (Mihal & Barrett, 1976; Gresset & Meyer, 1994a). Results are mixed but auditory functions are known to deteriorate with increasing age along with visual decline. It has been estimated that 70% of the population over 50 years of age have a hearing loss of some type (Anderson et al., 1969).

Perrott et al. (1991) examined visual search performance with and without sound effects. They found visual search performance was more efficient when sound was present, both when the sound was related to a visual stimulus and when it was more general. Sound can also help with restricting speed for varying road conditions. Research by de Waard et al. (1995) on road noise found that driver's speeds were lower and driving was safer on noisy roads. Horswill and McKenna (1999), using a driving simulator, found that preferred speed reduced as cabin noise increased, implying the perceptual effects of hearing on the estimation of speed. This effect could be translated to wet or icy conditions when drivers reduced their speeds because of increase road noise, resulting in far fewer crashes. Eighty percent of all crashes occur in dry conditions (Road

Crashes Great Britain, 1999), though Cooper et al. (1995) suggested this might be because there were more dry or good days than wet or bad ones and because speeds increase on dry roads.

Sound may act as a distraction, both from outside and inside the vehicle (McKnight & McKnight, 1993; Panek et al., 1977; Bruce, 2000). All vehicles are fully enclosed and act as a sound barrier to keep out unwanted noise. Not all noise is detrimental as many drivers are quite capable of holding a conversation or listening to the radio whilst driving safely (Brown, 1965). This skill may be related to driving experience (Eysenck, 1993; Wikman et al., 1998). Radeborg et al. (1999) suggested that holding a demanding conversation while driving relied on the availability of sufficient attentional resources and the ability to divide attention optimally between the two tasks. It has been recommended that auditory rather than visual information displays should be fitted in cars wherever possible to avoid over loading the visual system (Bruce, 2000). Research has found a negative link between driving performance and phone conversations (Brown et al., 1969; McKnight & McKnight, 1993; Nilsson & Alm, 1991; Violanti & Marshall, 1996; Violanti, 1997 and 1998; Wikman, et al., 1998). Alm and Nilsson (1995) compared choice reaction times of young and older drivers whilst using a mobile phone. Reaction times were longer in both age groups. Moreover the effect was accentuated in the older group.

1.5.4 Summary

Sensory information of all origins is required to drive safely but driving is highly dependent on the sense of vision alone. Visual sensory input is considered to be the dominant sense over all the other senses (Avolio et al., 1985) and it has been suggested that a visual attention test should be used to predict driving performance. In particular Avolio et al. (1985) suggested that a visual selective attention test should be included in a test battery (see section 1.4.4) to fully assess driving abilities.

1.6 When is an older driver no longer fit to drive?

The UK is the only member in the EC that relies on the driver to report health problems to the Driver and Vehicle Licensing Agency or DVLA (White & O'Neill, 2000). Individuals, who experience health problems that may be detrimental to driving, are legally bound to inform the DVLA of these problems (http://www.dvla.gov.uk) particularly if they are advised to do so by their GP (Morgan & King, 1995).

The sanction to drive is a civil liberty, but not a fundamental right (Munton, 1993) and everyone has the choice to drive providing they meet the requirements set by the State. Currently, legislation fails to detect those older drivers at risk of crashes, but how and when should it be decided that an individual is no longer fit to drive? It could be suggested that driving licenses should expire for all drivers when they reach 65 or 70 years of age (Rogers & Fisk, 1999). Legally, however, older drivers cannot be stopped from driving just because they are old (Waller, 1991; Goode et al., 1998). Also, research has revealed that age has a weaker relationship than cognitive function (i.e. UFOV) with either crash risk or simulated driving performance (Ball & Rebok, 1994). Therefore, who should decide when an older driver is no longer fit to drive? Should the decision be left entirely to the individual, or as a result of failing a medical examination relating to health and vision, or by failing newly developed screening methods that assess the skills required to drive? In all cases, a reliable assessment of fitness to drive is crucial to maintain safe mobility of older drivers (Ranney & Pulling, 1990) and it should be based on empirically derived criteria (Lundberg et al., 1997).

1.6.1 What influences an individual's decision to stop?

Driving is becoming a more valued part of living and consequently older drivers will want to stay mobile for longer. Owning a car is often regarded as a status symbol and more reliance is placed on having a car and remaining mobile into old age than ever before. Yassuda et al. (1997) found older American drivers were more interested in ways to become safer drivers than to cease driving altogether. Driving is important because; it helps maintain freedom and independence, improves the quality of life for older people and prevents depression brought on by immobility (Brouwer & Ponds, 1994; Cairney, 1997). Moreover, older drivers are more likely to have disabilities that restrict them from using public transport (Morgan & King, 1995). Unfortunately research has revealed that older drivers overestimate their own abilities and those of other drivers (Rebok et al., 1990; Maratolli & Richardson, 1998; Kruger & Dunning, 1999) and consequently they do not know when they should give up driving (Holland & Rabbitt, 1994; Rabbitt et al., 1996).

Research groups have tried to find the factors that influence older drivers in their decision to cease driving. Older drivers often experience pressure from family members to refrain from driving if they become hazardous to themselves and other road users (Cairney, 1997). Questionnaires have shown that older people stop driving because of increased costs (Morgan et al., 1995) and because of loss of confidence (Brayne et al., 2000). Women drivers tend to stop driving at an earlier age than men do because driving is of less importance to them (Hakamies-Blomqvist & Wahlstrom, 1998). However, these are all extrinsic factors. There are two other factors that are predominant in the decision to stop driving. These factors are intrinsic and they are due to eye and health related problems.

1.6.1.1 Eye related problems

The effect of age on basic visual functions was introduced in section 1.3.1 and researchers have tried to establish the impact of these changes to the older driver. Visual decline can be assigned to changes in five visual functions: visual processing speed, light sensitivity, dynamic vision, near vision and visual search (Kline et al., 1992). These visual problems are reported to be five times greater in older drivers than in younger drivers (Kosnik et al., 1988). The resulting effects on driving performance are little understood, but the problems generally experienced by older drivers can be divided into five major categories: unexpected vehicles, vehicle speed, dim displays, windshield problems and sign reading. Kosnik et al. (1990) surveyed the visual problems reported by elderly drivers who had recently stopped driving. The problems reported included, for example, loss of visual quality, inability to read small print, difficulties locating and reading signs embedded in clutter, difficulty reading adverts on passing buses and difficulty reading in dim light or at night. Individuals that had stopped driving had experienced visual problems with increased frequency and severity compared to those still driving (Kosnik et al., 1990). In the majority of cases a combination of these problems, rather than a single factor, induced older individuals to stop driving. Interestingly, the inability to read adverts on passing buses (dynamic visual acuity) showed the highest correlation with the decision to stop driving (Kosnik et al., 1990). Gallo et al. (1999) found that older drivers with visual impairment, compared to those with normal visual acuity, were more likely to cease driving or alter their driving strategies by driving less or even stopping driving altogether.

1.6.1.2 Health related problems

With increasing age come changes in the status of general health. Researchers have looked at the impact of health changes on driving in the elderly. Forrest et al. (1997) found the prevalence of medical problems, these being most often heart disease and diabetes, to be higher in individuals that had stopped driving than in those still driving. Gallo et al. (1999) also found that people that had stopped driving were more likely to be diabetic and that current drivers with heart disease or arthritis were more likely to have lower annual mileages and to avoid long trips. Hakamies-Blomqvist and Wahlstrom (1998) carried out a population-based study on all drivers born in 1922 and they found the main reason for driving cessation in this cohort was heart disease.

1.6.2 Medical screening of older drivers

Currently the screening of drivers is limited to visual acuity and visual field examinations (http://www.dvla.gov.uk/) and there is no annual 'MoT' for drivers, unlike that carried out on cars (O'Neill, 1992). Davison & Irving (1980) suggested that it would be better for individuals to have regular eye examinations and be made aware of detrimental changes than to be subjected to strict testing regimes. Particularly since research has found that 16% of drivers screened routinely on the roadside failed the British visual standard required to drive and 97% of drivers surveyed were unable to recall the exact distance specified in the number-plate test (Taylor, 1997). A survey of British drivers found a strong reluctance for regular car licence renewal involving a medical check (AA Foundation, 1988). Hakamies-Blomqvist et al. (1995) investigated the effect of a Finnish driver-screening program on road safety. The compulsory screening of older adult drivers was introduced in Finland, but not in the neighbouring country of Sweden. The screening of Finnish drivers has proved to be a very costly experience and of little benefit to the driving Finnish community (Hakamies-Blomqvist et al., 1995) since the Swedish drivers, who were not screened, had a lower risk of crashes than their Finnish counterparts. The medical screening of older drivers is complex and consequently it will be expensive (Owsley, 1997). It is often considered cheaper to restrict older drivers than to screen them (Cobb & Coughlin, 1998).

1.6.3 Alternative methods for screening older drivers

Older drivers experience more undue burden because of the effects of ageing and they find it harder to make decisions. Two approaches can be considered to detect those drivers at risk of having a crash (Schiff, 1996):

- cognitive components approach
- critical driving components approach

1.6.3.1 Cognitive components approach

The first approach assumes that the increased risk of motor vehicle crashes is due to declining sensory and cognitive functions with increasing age (Schiff, 1996). This approach is popular with both scientists and clinicians because the tests are cheap and easy to administer in a medical environment (De Raedt, 2000; Marottoli et al., 1998).

Ranney & Pulling (1990) found performance on laboratory test showed more variation than performance on specific driving tasks. Schlag (1993) also found that the performance of older drivers on laboratory tests was far worse than that of young drivers, yet he found their driving habits to be very similar. He also suggested that alterations in the behaviour of older drivers, as a result of impairment, were only statistically significant in extreme situations. He added, that laboratory tests might be less relevant to driving as they test individuals to the limit, which is not possible for on road assessment. Also driving is a highly learned and automated task, whilst laboratory tasks are unfamiliar to drivers and need to be learned. This could explain why the older drivers are worse at these tests than younger drivers, but their driving skills are comparable. One example of a test using the cognitive approach is the UFOV test developed by Sekuler & Ball (1986).

1.6.3.2 Critical driving components approach

This approach examines the performance of drivers in critical driving situations that involve increased risk of collisions (Schiff, 1996) to identify those most at risk of a crash (Odenheimer, 1993; Rebok et al., 1994). Assessments of this style are more costly as they are more time consuming and they involve the use of driving simulators (Cox & Taylor, 1999; Rizzo & Dingus, 1996). The relative cost of different simulators can be found in table 1.2 below. Assessments can also be carried out on closed-road test tracks (Wood, 1999) or on the road (De Raedt, 2000; Withaar, 2000), but these are more dangerous.

Type of Simulator	**Cost (million £)**
Desk top simulator	0.002
UFOV *	0.015
Part-cab mock-up and simple tasks	0.02
Leeds University simulator	0.5
Moving base simulator	2
VTI moving base with lateral movement	5
NADS system in USA	30

Table 1.2: The relative costs of various driving simulators found worldwide that assess driving performance using the cognitive (denoted with an asterisk) and the critical component approach. Figures supplied from data held at the Department of Psychology, Leeds University.

Assessments of the critical component type are often used to validate tests that use the cognitive approach (Arthur et al., 1994; Schiff, 1996). However, the true value of driving simulators has not yet been proven with respect to measuring driving performance (Watts & Quimby, 1979; Quimby & Watts, 1981; Hughes & Cole, 1986; Lovsund & Hedin, 1986; Szlyk, 1992, 1993b) and an on-the-road assessment may be more realistic or ecologically valid (Goode et al., 1998). On-the-road assessments can take place either on the open road or on a closed test circuit. The former is less valid due to varying conditions (i.e. weather and traffic density) whilst the latter is less valid as it does not represent the real world of driving (Odenheimer et al., 1994).

1.6.3.3 Cognitive versus critical driving components approach

Carr (1993) suggested that there were three skills required for safe driving, perception, cognition and execution. Using these guidelines there is room for both types of screening method in the assessment of older drivers. Recently, Janke and Eberhard (1998) recommended the introduction of three-tier testing for older drivers. Initially drivers would be screened for deficits in basic visual functions (i.e. perception). Passing the test would lead to re-issue of driving licenses and failure would lead to the need for further assessment. The cognitive approach would act as the next stage in a screening device for older drivers (De Raedt, 2000). Failure here would lead to a final screening stage that would consist of a test using the critical driving approach, using either a driving simulator or an actual on-the-road assessment (i.e. execution).

1.6.4 The future of driver screening

There are three possible methods that can be considered for the retirement of older drivers from the road. The first relies on self-restriction (see section 1.4.3.5). This has its benefits, as older drivers can decide for themselves when they are no longer safe to drive. Unfortunately drivers overestimate their own abilities (see section 1.6.1). A recent study by Wood and Mallon (2001) found that older drivers do not always self-regulate. They found that 19% of older drivers who took part in their study, who had ocular pathology and who continued to drive, were considered to be unsafe during an on-the-road assessment. Self-restriction should therefore be considered as unreliable. The second involves screening by current legislative measures (i.e. visual acuity and visual fields). Unfortunately screening of this type has failed to detect drivers of increased risk of crashes (see section 1.4.3.4) and it too can be considered as unreliable. The third method involves more specialised assessment of driving skill and fitness to drive using both the cognitive and critical component approaches (see section 1.6.3.3).

A three-stage assessment procedure has recently been introduced in the Netherlands and it is performed on all drivers when they reach the age for license renewal (Withaar, 2000). The first stage is a type of medical 'MoT' performed by the medical department of the national licensing authority (CBR). If there is any doubt of driver safety then the candidate is sent for a specialist evaluation. The driver then undergoes the second stage of medical screening that involves a series of cognitive tasks and the medical team produces a report. If there is still doubt of driver safety then the candidate is sent for an on-the-road assessment (third stage).

Passing the first, second or third stage results in the renewal of the driving licence for a further five years. Restricted or suspended licences are only issued after completing the final stage.

If the future lies in cognitive and critical component approaches the development and evaluation of promising tests like the UFOV test is indicated.

1.7 Recommendations of the Secretary of State's Honorary Advisory Panel on Driving and Visual Disorders

The UFOV test is currently the only commercially available instrument for measuring visual attention. This test appears to be most capable of detecting age related visual deterioration (section 1.3.2, table 1.1) and crash risk (section 1.3.2, table 1.1). It is for this reason that the UFOV test is to be investigated in this research project. The Secretary of State's Honorary Advisory Panel on Driving and Visual Disorders, that advises the DVLA on visual standards for British drivers is also keen to carry out a thorough investigation of the UFOV test and has visited Aston University for that purpose.

There are some problems with the UFOV test. Firstly, the UFOV research has been carried out almost entirely by its inventors, though corroborative evidence is available (Wood, 1995; De Raedt & Ponjaert-Kristoffersen, 1998; Chaparro et al., 1999). Secondly, there is little known of the algorithm used to derive UFOV scores. This information is commercially protected but needs to be known if investigation of this test is to be thorough. Finally, the Panel observed that whilst the UFOV test records responses to briefly presented static stimulus arrays (i.e. the UFOV test may be referred to as a static visual attention test), the driving task involves responding to moving stimuli. Driving takes place in a continually changing environment where objects continuously move in a flow field. Therefore, it would seem logical that the development of a kinetic visual attention test might improve crash prediction and be more ecologically valid (see section 2.2.5).

1.8 Scope of thesis

This thesis was designed to pursue development of a kinetic visual attention test as recommended in section 1.7. Chapter 2 provides a description of the static (UFOV) and kinetic (DRTS, Driver Reaction Time Simulator) visual attention tests and the experimental methods designed to investigate them. The UFOV algorithm is examined in chapter 3. The repeatability of static and kinetic visual attention tests are compared in chapter 4. Determinants of static and kinetic visual attention are explored in chapters 5 (target position), 6 (clutter) and 7 (target motion). Static and kinetic visual attention tests are compared in terms of their ability to detect age-related changes in the visual system (chapter 8) and to predict crash risk and driving performance in both older and police drivers (chapter 9). The outcomes of this research project and avenues for further research are summarised in chapter 10.

CHAPTER TWO

STATIC AND KINETIC VISUAL ATTENTION TESTS AND RESEARCH METHODS

NB For a full key see page -7-.

2.1 Introduction

The aim of this chapter is to introduce the concepts that underpin the static and kinetic visual attention tests used in this study and to outline the experimental methods adopted for this research project.

2.2 Static visual attention test: Useful Field of View (UFOV)

The UFOV measures an area called the functional field of view and it is a static visual attention test. Attention is the system often considered as the first stage of information processing (Eysenck, 1993). Visual information is initially obtained using visual search and then attended to using a two-process model (Ball et al., 1990). The concept of the two-process model arose from the observation that some objects are conspicuous and easily detected whilst others are more inconspicuous and less easily detected. Many two-process models have been proposed with varying terminology for example; parallel and serial, diffuse and focussed, ambient and focal and automatic and effortful (Hartley, 1999). Ball et al. (1990), the developers of the UFOV test, selected the terminology adopted by Neisser (1967, 1976) and later Julesz (1981) and they refer to the "pre-attentive" and the "attentive" processes.

Visual attention is known to decline with age leading to a restriction in the size of the functional field. Visual attention processes can be assessed in many ways including the use of precues, dual tasks, visual search and interference or facilitation procedures (Hartley, 1999). The UFOV test is a visual search paradigm that includes all these methods (see section 2.2.5).

2.2.1 The functional field of view

The functional field of view can be interpreted as the area around fixation within which a stimulus must be recognised or identified (Mackworth, 1976; Rantanen & Goldberg, 1999). It covers a visual angle of 1° - 4°, and is equivalent in size to the field that projects onto the fovea. Grandjean (1969) referred to this as the area of "maximum focus" and it has a visual angle in the vertical meridian of 1°. Williams (1982) referred to this area as the "foveal" functional field of view (FFoV) and he found that the size of the FFoV constricted from 4° for a low cognitive task to 2° for a more complex task. Williams (1982) also found that subjects' performance on a peripheral task declined when the stimuli were located more than 3° – 3.5° from fixation.

Sanders (1970) defined the functional field as the "spatial area or visual field extent that is needed for a specific visual task". The measurement of this functional visual field is based on the presentation of peripheral targets whilst performing a central task (Leibowitz & Appelle, 1969). The term functional implies that the level of performance depends not only on the sensitivity of the peripheral field but also on the complexity of the central task (Ikeda & Takeuchi, 1975). The size of the functional field of view is determined by performance in the peripheral field but its size is unrelated to that of the sensory visual field that is measured using perimetry. Perimetry measures the sensitivity of peripheral retina while the subject fixates a central target (Harrington, 1971).

Sanders (1970) suggested that the functional field could be made up of three parts: the stationary field, the eye field and the head field.

The stationary field is the extent of the functional field in the absence of eye movements; it extends to approximately 30°, in the horizontal meridian, from the fovea and is limited by visual acuity alone.

The eye field is the extent of the visual field in the presence of eye movements and extends to at least 68° (Sanders, 1970). According to Sanders (1970), eye movements are initiated when stimuli fall between 20° and 40° from the fovea. The eye field is also called the middle field (Grandjean, 1969), and has a maximum visual angle of 40° in the vertical meridian. Visual acuity declines at these eccentricities, but motion and high contrast stimuli are still detected (Grandjean, 1969;

Whitaker et al., 1992; Latham & Barrett, 1998) to enable quick glances to objects located in this area.

The head field, or outer field (Grandjean, 1969) is the extent of the functional field with both eye and head movements. Head movements are initiated when stimuli fall between 80° to 90° from the fovea and the head field extends to approximately 105°, but these values are task dependent (Sanders, 1970). Facial features, such as eyebrows, limit the head field so that it has a visual angle of only 40° - 70° in the vertical meridian (Grandjean, 1969). Visual acuity is degraded by a factor of 6 at 30° and approximately 10 at 60° (Johnson & Leibowitz, 1976). These values correspond closely to degradation in motion perception and suggest that visual acuity and motion perception are related.

More recently the stationary field has been referred to as the functional field of static view or FFSV and both the eye and head field, together, make up the functional field of dynamic view or FFDV (Pottier, 1999).

Scheerer (1978) criticised the theory of the functional field stating that this field was variable. Indeed the functional field varies in size between individuals (Johnson & Leibowitz, 1974), between tasks (Engel, 1977), with practice (Weltman & Egstrom, 1966; Barca & Fornaro, 1980) and according to the complexity of the task (Ikeda & Takeuchi, 1975; Withaar, 2000). For example, the functional field shrinks when a single task is replaced with a dual task (Greve, 1972; Ikeda & Takeuchi, 1975; Ball, 1986; Ball et al., 1988), when the presentation time is reduced (Walsh & Prasse, 1980; Bergen & Julesz, 1983; Ball, 1986; Scialfa et al., 1987), when distractors are added (Mackworth, 1965; Bouma, 1970; Drury & Clement, 1978; Sekuler & Ball, 1986; Ball et al., 1988) and when the target and distractors become more similar (Bloomfield, 1972; Engel, 1977; Treisman & Gelade, 1980; Bergen & Julesz, 1983). There are two views that can explain the shrinkage of the functional visual field (Crundall et al., 1999; van de Weijgert & van de Klok, 1999) in perceptual narrowing. The first suggests a "tunnel vision" effect where attention is taken away from the periphery to concentrate centrally, whilst the second refers to "general interference" where peripheral attention is spread more diffusely to compensate for the increase in central demand (Holmes et al., 1977).

2.2.2 Visual attention

Attention is a dynamic and complex processing system. Information processing starts with the onset of a sensory stimulus and culminates with a response or action. The interim consists of a series of decisions that aid interpretation of the sensations, development of a perception and finally instigation of the action. These decisions involve filtering and prioritising the available information and they constitute an "executive function" (De Raedt, 2000; Rizzo & Dingus, 1996; Wickens, 1984).

Attention is the system that aids perception, it is only activated when a multiple of sensory stimuli are available and it can be divided into several dimensions serving different functions:

- selective attention
- divided attention
- switched attention
- sustained attention

2.2.2.1 Selective attention

Selective attention relates to the processing of information from one stimulus when two or more distracting stimuli are present (Hartley, 1999). Selective attention is the process that controls our awareness of specific events in the environment. The ability to select information is a pre-requisite for efficient behaviour, particularly with respect to driving. Individuals must be able to attend to the relevant information and yet ignore the irrelevant. Research has revealed that selective attention tests are good predictors of crash-risk (Mihal & Barrett, 1976; De Raedt, 2000). Selective attention is known to decline with age irrespective of being in good health (Perryman & Fitten, 1996) and this decline is thought to start from approximately 30 years of age (Panek et al., 1977).

Visual search tasks designed to assess selective attention in drivers have found deficits in older drivers and it has been suggested these deficits are due to an inability to ignore irrelevant information (Rabbitt, 1965). Madden (1992) also found that older adults were slower to allocate attention than younger adults were, and he suggested that this slowing would not be restricted to selective attention tasks. An example of this type of test can be found in part three of the UFOV test (see section 2.2.5.3).

2.2.2.2 Divided attention

Divided attention relates to the processing of information from two or more stimuli presented at the same time (Hartley, 1999). The success rate for completing both tasks depends on the component tasks. Hartley (1992) suggested that age-related difference in divided attention tasks, between young and older drivers, would be detected because of the effects of age on the component tasks. The ability to divide attention is also pertinent to driving. For example individuals must be able to allocate attention to two sources of information when merging onto a main road from a side road. Divided attention ability for a specific task is known to improve with experience. For example, an experienced driver is able to hold a conversation whilst driving which a novice would find difficult. Sekuler & Ball (1986) also demonstrated that divided attention tasks could be performed to the same standard by both young and older subjects and performance was only slightly worse for the divided attention task than for the component tasks. Parasuraman & Nestor (1991) found crash rates were more weakly related to divided attention than they were to switched attention (see section 2.2.2.3). A divided attention task has been incorporated in the UFOV test (see section 2.2.5.2).

2.2.2.3 Switched attention

Switched attention occurs when attention is alternated between one source and another (Hartley, 1999). In a dynamic environment this involves switching attention from one location to another and is highly relevant to driving. Yet little research has been carried out in this area with respect to driving or ageing. This type of attention is usually assessed using tasks that assess either visuo-spatial locations or task switching. These type of tests involve recognition and reproduction and include the paper-folding test or clock drawing task (De Raedt, 2000). Parasuraman & Nestor (1991) found the relationship between accident rates and measures of attention was best for switched attention. This type of attention is not assessed using the UFOV test.

2.2.2.4 Sustained attention

Sustained attention or vigilance occurs when attention is consistently maintained on one source of information with the aim of observing any changes over time (Hartley, 1999). This is particularly relevant to driving yet research in this area is minimal (De Raedt, 2000). Several studies have failed to detect any age-related changes in vigilance, only a decline in all age groups with fatigue (McDowd & Shaw, 1999). Parasuraman and Nestor (1991) found a weak link between accident rates and sustained attention. Vigilance is assessed in the first part of the UFOV test (see section 2.2.5.1).

2.2.3 Visual search: Pre-attentive and attentive processes

Pre-attentive visual search uses rapid parallel processing to gather information automatically over a large spatial area and it guides us to where an object is located in the periphery (Treisman & Gelade, 1980). The similarity between a target and its background determine how easily it is seen (Bergen & Julesz, 1983). For example, if a target has a single feature (e.g. colour, orientation, size, motion, stereoscopic depth, curvature, pictorial cues for depth, and surface properties) then it can be selected pre-attentively (Burton-Danner et al., 2001) and it is said to "pop-out" from the display (Treisman & Gelade, 1980). This system is considered by some to be limited by the sensory visual field (Ball et al., 1990). The UFOV test is a visual search paradigm that examines pre-attentive processes by measuring the spatial area within which an individual can be quickly alerted to visual stimuli within a single glance (Sanders, 1970; Ball et al., 1990).

Attentive processes bring about a concentration of resources within a small spatial area (Treisman & Gelade, 1980). The attentive system uses serial processing of information to discern and group the features of the stimulus for the purpose of identification (i.e. pattern recognition).

2.2.4 Visual search and age

There are four hypotheses that have been developed to explain the decline in visual search with age (Ball et al., 1990);

- The general slowing hypothesis
- The spatial localisation hypothesis
- The perceptual window hypothesis
- The useful field of view hypothesis

2.2.4.1 General slowing hypothesis

The general slowing hypothesis is a theory of general ageing (Hartley, 1999). It states that older adults require more time to process information as a result of general slowing in cognitive processes with advancing age (Birren, 1965; Cerella, 1985b; Salthouse, 1985). The slowing of information processing with advancing age results in less information being processed (i.e. smaller quantity), but the quality of the information is not affected (Plude & Doussard-Roosevelt, 1989). The processing of information can be divided into two aspects, peripheral (i.e. visual pathway) and central (i.e. central nervous system) processing (see figure 2.1). Age-related slowing in the peripheral processes is thought to affect feature search and age-related slowing in the central processes is thought to intensify the problems associated with pattern recognition (Plude & Doussard-Roosevelt, 1989). Madden and Allen (1991) found older subjects were slower to extract information from a scene. The central processes are known to decline more with advancing age than the peripheral processes (Cerella, 1985b), though there is still much uncertainty as to whether the slowing is sensory or motor based (Porciatti et al., 1998).

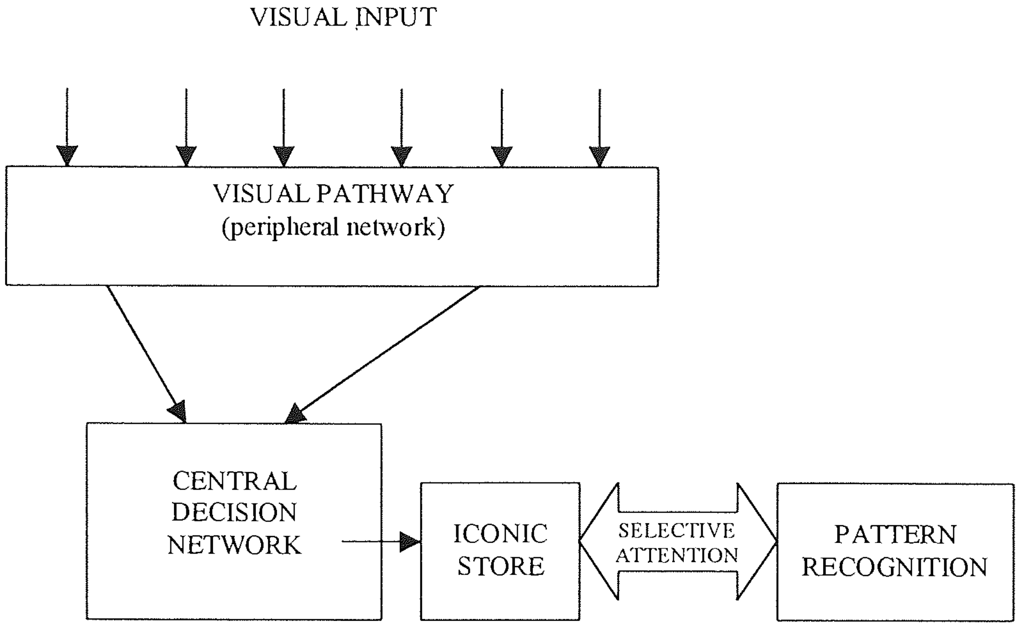


Figure 2.1: Diagrammatic representation of a model of visual information processing (after Walsh, 1982).

The central processes consist of a decision stage in the processing of the output from the visual pathway (see figure 2.1). This occurs simultaneously (pre-attentively) with the peripheral perceptual processing (Walsh, 1982). The central stage does not identify the visual input, but rather synthesises its context-dependent features, creating higher-level sets of visual features. These higher-level features are then used in higher-level processes of pattern recognition. The output of the central stage is saved in a sensory store, termed "iconic memory" (Neisser, 1967). The capacity of iconic memory is large but the information is rapidly and irreversibly lost within 250 msec of the onset of the stimulus (Walsh, 1982).

Visual pathway peripheral perceptual processes are assumed to operate in parallel (Turvey, 1982) and they are initiated when light falls on the eye. Peripheral processes cover both the input of the information and the output of a response. The speed at which the information is processed depends on the features of the information.

The general slowing hypothesis can be divided into two versions, a strong theory or a weak theory (Salthouse, 1993; Hartley, 1999). A strong theory describes an anatomical mechanism for slowing and it is based on evidence that the slowing is caused solely by a general speed factor. An example of a strong theory is given by Birren (1974) who states that slowing is due to a slowing of synaptic transmissions in the nervous system. In contrast a weak theory is based on evidence that slowing is the result of other factors in addition to a general speed factor. It attempts to define a function that explains the differences between younger and older adults.

Sekuler & Ball (1986) dismissed the idea that age-related slowing effects were general. A study comparing the responses of young and older subjects, on the selective attention part of the UFOV test, found no difference between the groups.

2.2.4.2 Spatial localisation hypothesis

It has been thought for some time that objects are located and selected pre-attentively (Ball et al., 1990). Attention is then focused towards selected objects to identify or recognise their relevance to the task being undertaken. The spatial location hypothesis (Plude & Hoyer, 1985) states that there is a decline in the selectivity of visual attention with age, due to the reduced ability to locate and identify the relevant information or an inability to ignore the irrelevant information (Rabbitt, 1965).

Plude & Hoyer (1985) found that visual search deficits were present in older adults and that they were not related to the decline of visual acuity with age. However, they were unable to specify the precise origin of the deficit, but concluded that these deficits had one of two possible causes. The first was that aging resulted in an inability to accurately locate targets (Walsh & Prasse, 1980; Plude & Hoyer, 1985), particularly when they contained a multiple of the features mentioned in section 2.2.3 (Treisman & Gelade, 1980). The second cause was that there was a more general reduction in either the capacity or the speed of visual processing (Cerella et al., 1980).

2.2.4.3 Perceptual window hypothesis

Studies have also looked at the size of the visual field within which information can be located and identified. This has led to the perceptual "window" hypothesis (Ball et al., 1990), stating that older adults have a smaller functional visual field than younger adults do. Evidence for this hypothesis emerges from the observation that older adults tend to make several times more fixation eye movements (Cerella, 1985a; Scialfa et al., 1987) and they also experience increased saccadic latencies (Carter et al., 1983) unlike their younger counterparts to locate objects. Thus older adults take more time per glance and take in less information, independent of time restraints, than younger adults do.

Morgan (1988) provided a good example of a constricting perceptual window in his account on the effects of age on vision:

> "I have the impression that my working fields, in contrast to my clinically measured fields (which are normal), are somewhat reduced... Objects coming from my right that I missed on causal observation sometimes suddenly appear in my field. I think I have to make a greater effort than before to perceive objects in the periphery of my field. If I give my full attention to detecting peripheral objects, as in visual field testing, my performance is excellent. But when my attention is divided, as in driving, I think that there has been a decrease in the size of my visual fields."

Plude and Doussard-Roosevelt (1989) provide three suggestions that could explain the reduced perceptual window experienced by older adults. The first is a strong theory (i.e. supported by psychophysical evidence) and it proposes a restriction due to age-related effects of "lateral masking" in older adults (Hoyer & Plude, 1982). Lateral masking is the loss of sensitivity (i.e. reduced acuity) in the peripheral visual field (Brenton & Phelps, 1986) and limits the quantity of information available in a single glance. The second is a weak theory (i.e. not supported by psychophysical evidence) and it compares the perceptual window to a zoom lens. Consequently, the field of focus is elastic and dependent on the density of objects within the display area. The more densely populated the display, the narrower the focus and the less densely populated the display, the wider the focus. The final interpretation relates to selective attention deficits that increase demand on the central processes and would thus limit peripheral processes. Research by Plude and Doussard-Roosevelt (1989) failed to find evidence to support the first two theories. They found that visual acuity could not be a limiting factor as restriction was found in both young and older adults. The density of objects was not the limiting factor as restricted fields were only found when the density related to the number of features in the targets and not to the number of targets. They rejected these theories in favour of the third suggestion. They concluded that the restriction in the perceptual window would only be seen when selective attention was required.

2.2.4.4 Useful field of view hypothesis

This hypothesis is not an attention-based hypothesis as such (Hartley, 1999), but more a conceptual link between different tasks and the components of driving. Research by the Transport Research Board, in 1988, revealed that the driving task was composed of a sequence of four components (Visual Resources Inc., UFOV manual):

- visual stimuli are detected and stored at a sensory level
- stimuli are recognised, identified and located
- once recognised, a decision of action is made
- finally resulting in the execution of a motor response

The useful field of view hypothesis considers the detection, localisation and identification of supra-threshold targets (i.e. high contrast) in complex backgrounds (Ball et al., 1991, 1993). It states that four independent attentive processes play a role in the reduction of the useful field of view with age (Ball et al., 1990; Ball & Rebok, 1994):

- poor vigilance
- reduced speed of visual processing (general slowing hypothesis)
- reduced ability to divide attention (spatial localisation hypothesis)
- reduced selective attention (perceptual window hypothesis)

2.2.5 Description of the UFOV test

The UFOV test measures functional binocular vision by utilising a random radial localisation task (Sekuler & Ball, 1986). The test involves the detection of targets that are both highly visible and embedded in clutter to remain consistent with the driving environment (Ball et al., 1990). This follows the concept of "ecological validity" introduced by Neisser (1967) where a test is only valid if it has face validity. Localisation of a target was chosen as it is unaffected by memory, learning or recognition processes (Cerella et al., 1987). Ball et al (1988) also selected the radial pattern because the array is unaffected by luminance levels (Leibowitz et al., 1955), image blur (Leibowitz et al., 1979), refractive error (Post & Leibowitz, 1980), visual acuity (Ball et al., 1988) or pupil miosis (Sloane et al., 1988). The targets are viewed using a tachistoscopic presentation and they are only visible for a brief amount of time to prevent eye movements (Ball et al., 1988) and to minimise fluctuations in fixation (Kosnik et al., 1986). Several parameters, which are affected by age, are manipulated during the test (processing speed and target conspicuity) to generate a test score that relates to the size of the functional field of static view. There are three sub-tests that sequentially assess processing speed (vigilance), divided attention and selective attention. All of these processes function independently but their effects are additive (Ball et al., 1988). The UFOV score is expressed as a percentage loss of a functional field of static view that has a maximum radius of 35° (Ball et al., 1990). The minimum radius of this field is 5°, equivalent to the size of the central target, and corresponds to a maximum total UFOV loss of 90%. Each sub-test makes an equal contribution of up to 30% of the final functional field loss. In the case of visual processing speed task, the percentage loss increases from 0% (no problem) to 30% (great difficulty) as the processing speed increases. For the divided and selective attention tasks, all scores between 0% and 30% are calculated from the linear relationship between eccentricity and errors of localisation. The size of the useful field of view, despite being measured using static targets, is considered to be a "dynamic measure" (Ball et al., 1993) and it is defined as "the eccentricity at which observers can localise peripheral targets 50% of the time". The score is thus calculated at the point when 50% of the peripheral targets are correctly localised (see section 3.4).

The UFOV test is designed for use on a PC and the size of the field (35°) is only limited by the size of the monitor (Ball & Owsley, 1992). The viewing distance is set at 23.5 cm, for a 19" monitor, to ensure the peripheral targets are located at the correct eccentricities.

There are various training versions of the UFOV test available that are not used for driver screening. These include versions with simpler central tasks (present or absent), more complex central tasks (happy or sad faces), wider screen (up to 50° radius), exchanging the central task for an auditory task (3 ascending or descending tones), the addition of an auditory task (along with the identification and localisation task), changing the colour of the peripheral targets (blue, red, green, yellow or white), increased target salience (dim distractors) and various training strategies (eg restricted eccentricities or field areas). None of these options were available on the UFOV test used in this study.

Once a test run has been completed a printout of the results is generated. For the commercially available test equipment this printout only supplies a record of the final score for each of the sub-tests and a total score (i.e. percentage loss). However, the printout for the UFOV test used at Aston University is different from the commercially available test (see appendix 1a). This printout reports all the responses (i.e. raw data) made by the subject for each presentation made during both the divided and selective attention tasks of the test and they are shown as follows:

i) N = no mistakes
ii) P = peripheral mistake
iii) C = central mistake
iv) B = both central and peripheral mistakes

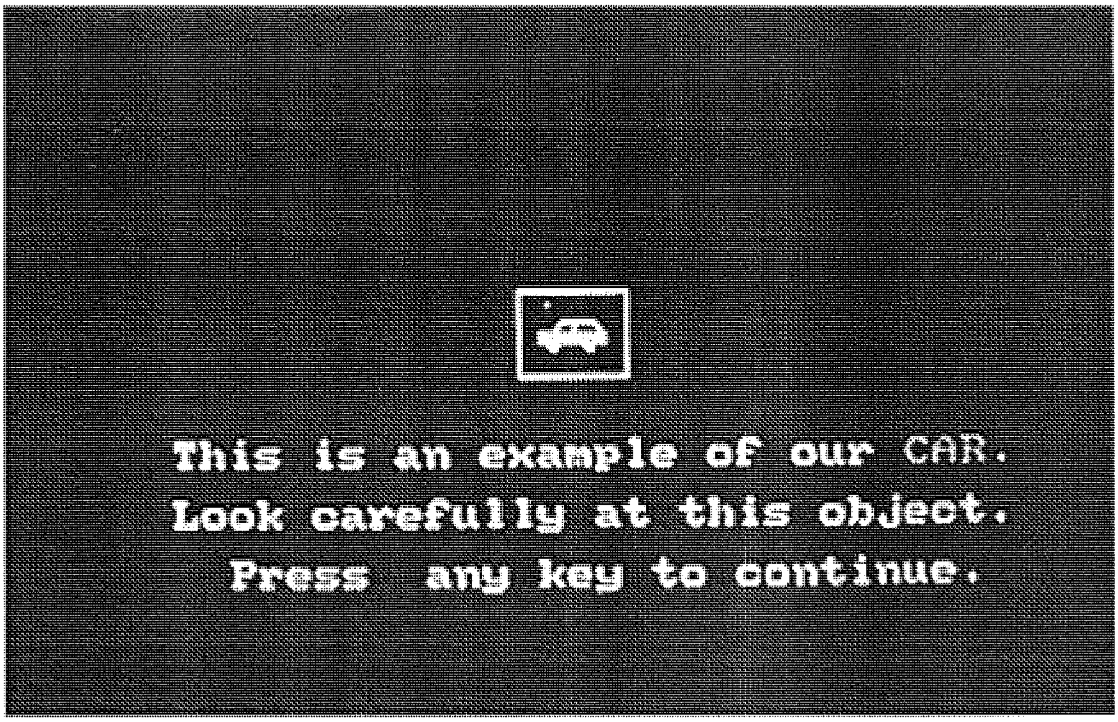
The raw data and its uses will be described in more detail in chapter 3.

2.2.5.1 Processing speed

This is the speed at which a task is attended to and processed and it is a measure of the minimum length of time (ms) required to identify a target. Processing speed is dependent on the task itself.

For example, a highly practised simple task will take far less time to complete than a novel complex task (Hoyer & Plude, 1982). Information processing rates for sensory-motor speed, perceptual speed and reaction time speed are known to decline with age (Earles & Salthouse, 1995) and a U-shaped curve is observed when processing speeds are plotted as a function of age (Cerella & Hale, 1994). The ability to process information rapidly is an important part of driving and its relevance is apparent in the "emergency stop" procedure carried out during a driving test.

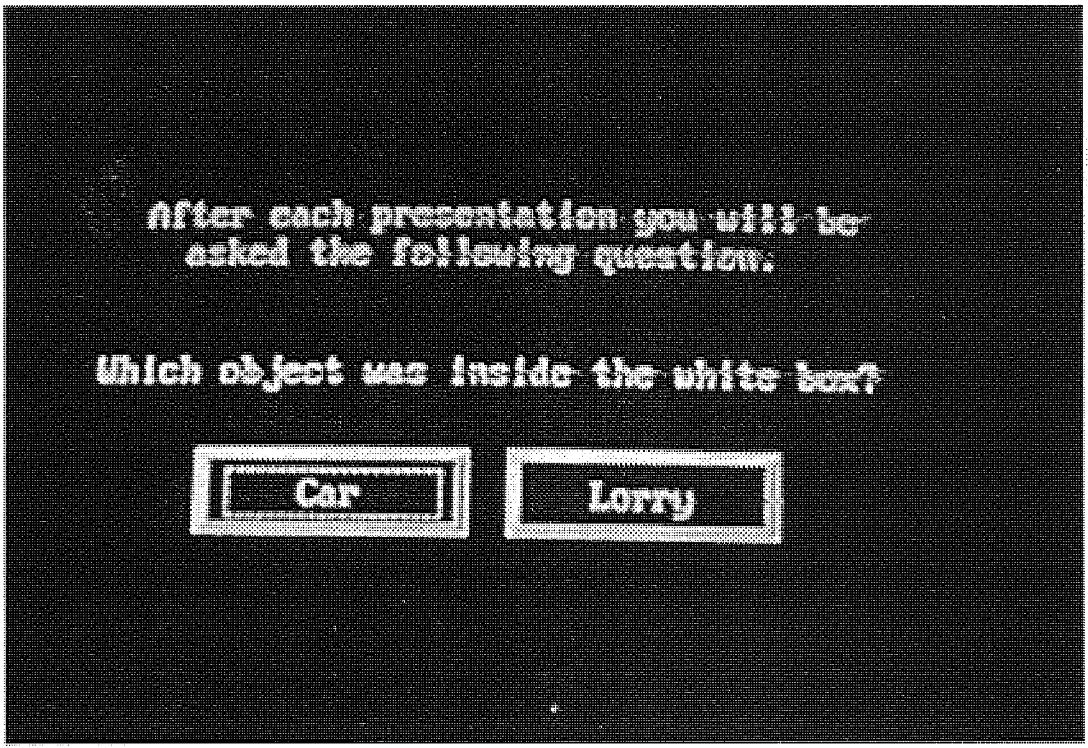
The central task is first used on its own to assess vigilance (see section 2.2.2.4) and to estimate processing speed (see figure 2.2). The task involves identification of a static silhouette of a car or lorry in a fixation frame (8° x 9°). The fixation frame acts as a precue as it appears 1 second prior to the appearance of the silhouette (Ball et al., 1988). Previous research by Owsley et al. (1995) revealed that, subjects with a visual acuity worse than 6/15 consistently failed this part of the test.



This is an example of our CAR.
Look carefully at this object.
Press any key to continue.

Figure 2.2: The central processing speed task of the UFOV test, showing the silhouette of a car in the central fixation box.

All observers are given four practice trials, which can be repeated until the task is fully understood. When the test begins the stimulus is initially visible for 240 ms. All stimuli are immediately followed by a masking stimulus (see section 2.2.5.4.4) that lasts for 750 ms (Ball et al., 1988) to prevent afterimages. The subject is then asked to identify the central target and a selection is made without a time constraint (see figure 2.3). Using a method of limits (see section 2.2.5.4.1), the stimulus duration is reduced after two correct responses and increased after one incorrect response. The incremental changes made to stimulus duration (17 - 50 ms) depend on the number of errors made during practice runs. Eight reversals from correct-incorrect are recorded and the threshold duration is calculated as the mean of the last five reversals. The processing speed is thus calculated when the subject correctly identifies 75% of the central targets (Ball et al., 1990).



After each presentation you will be asked the following question:

Which object was inside the white box?

Figure 2.3: The UFOV test question used for central identification task.

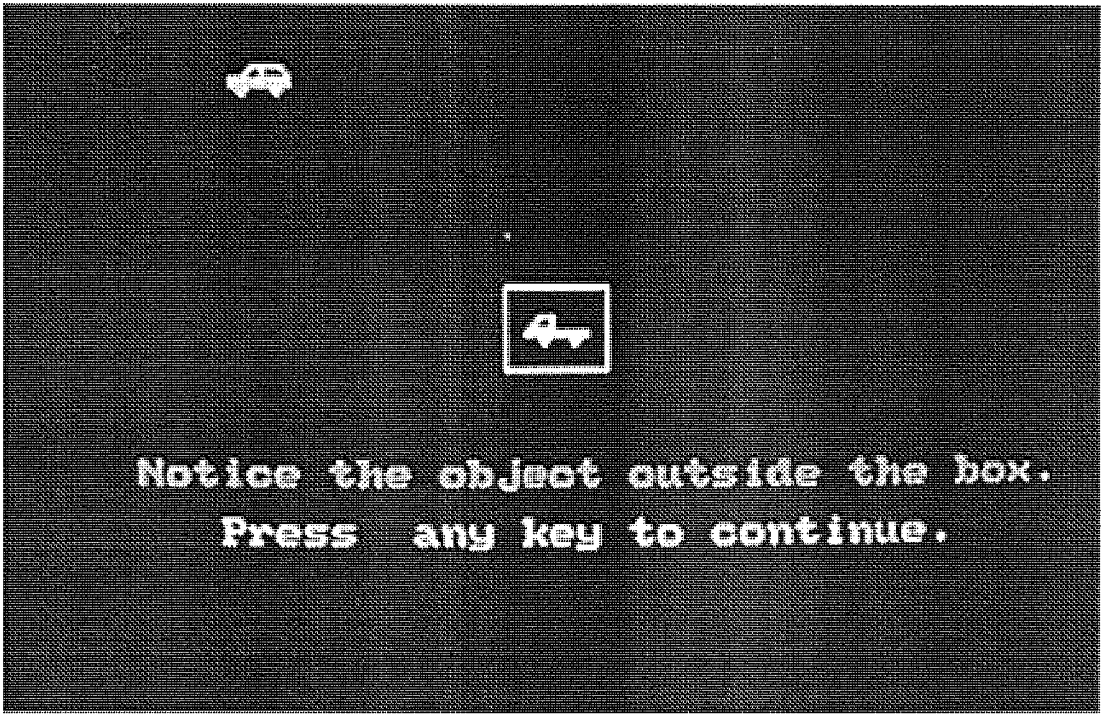
2.2.5.2 Divided attention

Divided attention was introduced in section 2.2.2.2. The UFOV test measures divided attention by presentation of a central and a peripheral target (see figure 2.4). The peripheral target is located in one of 24 positions around the central target, at any one of 3 eccentricities (10°, 20° or 30°) along any one of 8 spokes radiating from the centre of the screen at 45° intervals. The angular location of each spoke can be found in table 2.1 (see also figure 2.5).

Spoke	1	2	3	4	5	6	7	8
Location	90°	45°	0°	315°	270°	225°	180°	135°
	UP		RIGHT		DOWN		LEFT	

Table 2.1: The location of each of the eight spoke positions of the UFOV test, where 0° is located at the positive horizontal.

The location of the peripheral target is selected randomly, but equally often, for each of the 24 possible positions. The central and peripheral targets appear simultaneously for a brief duration followed by the masking stimulus.



Notice the object outside the box.
Press any key to continue.

Figure 2.4: The divided attention task of the UFOV test, showing the central silhouette in a box (lorry) and the peripheral target (car) at spoke 8.

Observers are asked to first identify the central target, to ensure fixation, and then the spoke along which the peripheral target was located (see figure 2.5). There are no time constraints to these responses and both the identification question and the radial spoke pattern remains on the monitor until a decision has been made. Divided attention is determined from the number of errors made in locating the peripheral target for different stimuli durations. The initial presentation time depends upon the previously estimated processing speed. All presentation times are brief to avoid the initiation of a saccade to locate the peripheral target. If all central targets are correctly identified and more than 50% of the peripheral targets are correctly located, then the duration is reduced in 40 ms increments to a minimum stimulus duration of 40 ms. If error rates of more than 50% occur in the first instance, then the duration increases in 40 ms increments to a maximum of 240 ms. If large numbers of errors are made in identifying the central target then the test is termed inconsistent and therefore becomes invalid.

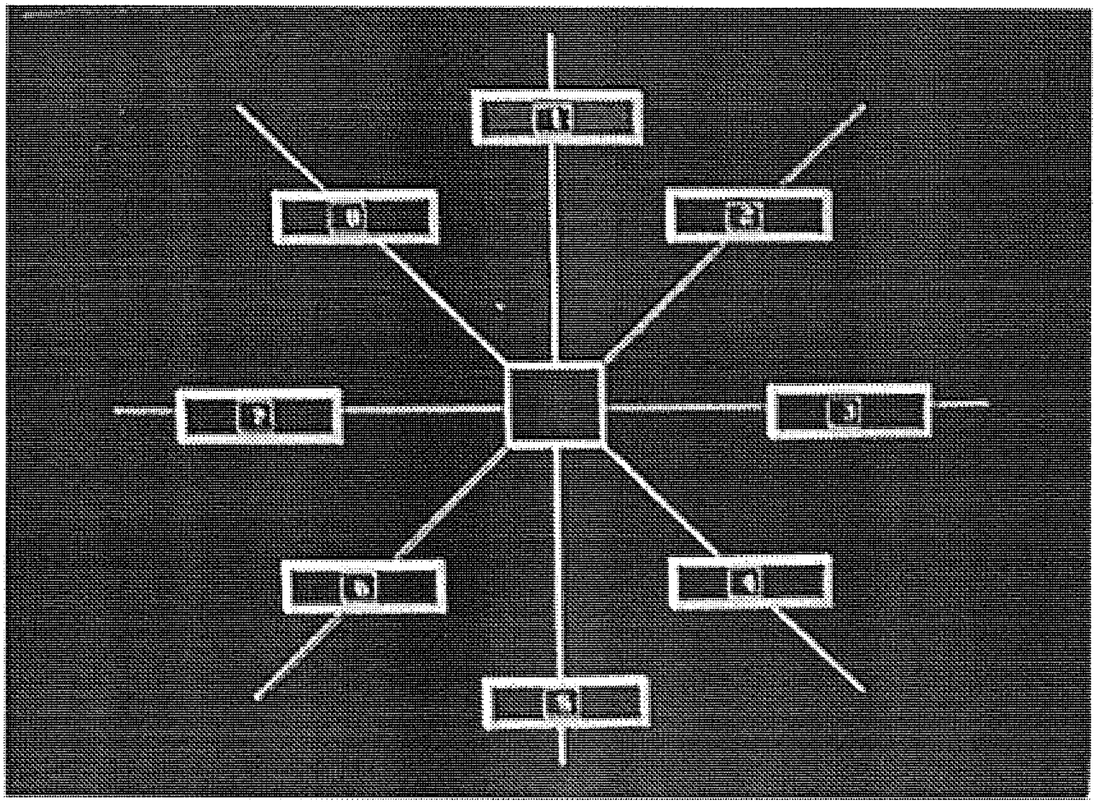
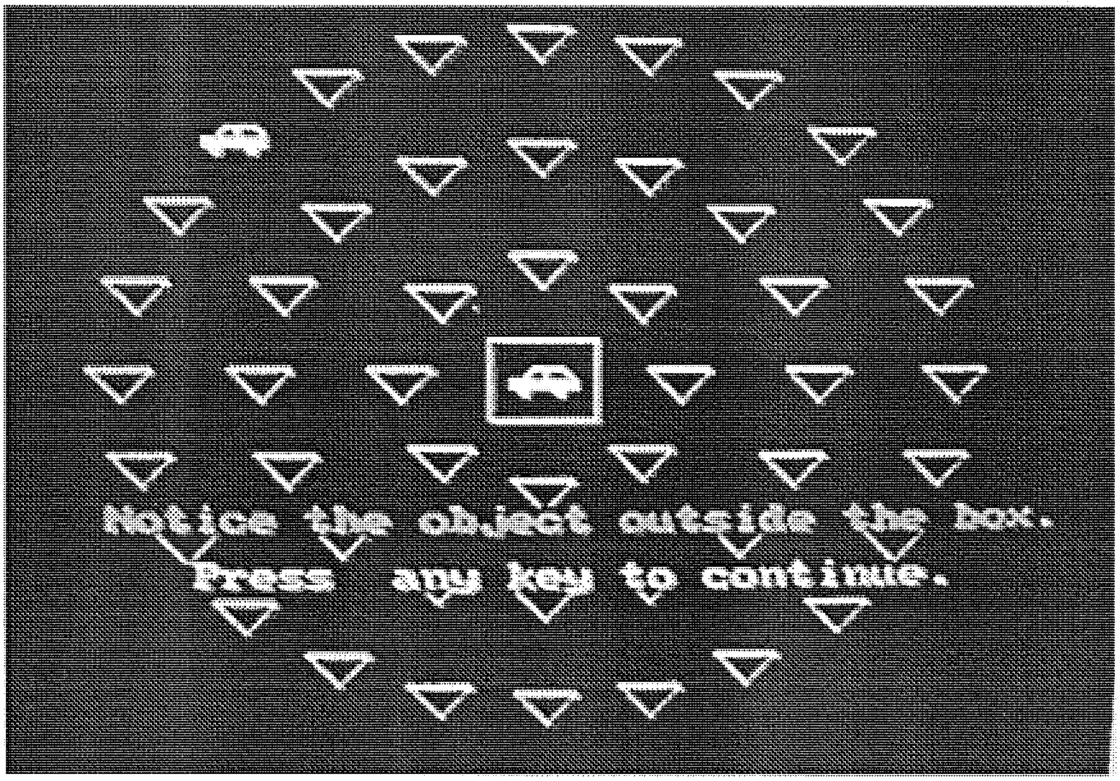


Figure 2.5: The UFOV test radial spoke pattern question for locating the peripheral target.

2.2.5.3 Selective attention

Selective attention was introduced in section 2.2.2.1. The UFOV test measures selective attention by introducing distractors (see figure 2.6). The level of distraction is known to have a detrimental effect on visual search (Scialfa et al., 1987). However, for the UFOV test increasing the number of distractors from 12 to 47 has no effect on performance (Ball et al, 1988) indicating that targets are selected in a pre-attentive fashion from amongst the distractors.

For the selective attention sub-test there are 47 distractors located at three eccentricities along 16 spokes radiating from the centre of the screen at 22.5° intervals. This part of the test incorporates both the central identification task and the peripheral location task, but with the peripheral target embedded in distractors. The stimulus array is presented at varying durations, ranging from 40 ms to 240 ms in steps of 40 ms, followed by the masking stimulus. The initial presentation time is dependent on the final presentation time for the divided attention part of the test. Selective attention is determined from the number of errors made in locating the peripheral target at each eccentricity, for each presentation time. If correct responses are recorded for all central targets and for at least 50% of the peripheral targets, then the stimulus duration is reduced, as for the divided attention task, until more mistakes are made in the peripheral location task. If error rates of more than 50% occur in the first instance for the peripheral location task, then the stimulus duration increases, until correct responses occur or the maximum duration of 240 ms is reached. As for the divided attention task, when a central error is made, the peripheral response is ignored and the eccentricity is repeated and if large numbers of errors are recorded then the test becomes invalid. Also, once the sub-test is completed a percentage loss is calculated with a range from 0% (no problem) to 30% (great difficulty).



Notice the object outside the box.
Press any key to continue.

Figure 2.6: The selective attention task of the UFOV test, showing the central silhouette.

2.2.5.4 Psychophysical procedures used in the UFOV test

The UFOV test makes use of two mathematical approaches to measure thresholds or points on a psychometric function (Treutwein, 1995). Processing speed is measured using two variations of the method of limits (staircase and two alternative forced choice procedures) along with backward masking.

2.2.5.4.1 Method of limits

The method of limits is used to measure the threshold of a sensory stimulus (Gescheider, 1985). It is a highly efficient and quick method and for this reason it is the most frequently used. The method of limits can be used to measure both absolute thresholds to single stimuli and difference thresholds to pairs of stimuli. The threshold is obtained by varying the value of the stimulus in ascending or descending steps for a defined interval starting from either the lower or upper limit of the interval respectively. The procedure is reversed when the upper or lower limit of the interval is reached. The threshold is the stimulus intensity that would be detected for a chosen percentage (e.g. 50%).

2.2.5.4.2 Staircase method

The staircase or up-and-down method is a variation of the method of limits and there are several algorithms that can be employed (Meese, 1995). The standard staircase consists of a sequence of stimuli that increase or decrease in value according to the response. When the response changes, the stimulus level is recorded and the direction in which the value changes is reversed until the response changes once more. The UFOV test uses a hybrid staircase as the stimulus duration is reduced after only two correct responses (Meese, 1995). From the data a psychometric function is produced that shows the relationship between the stimulus level and the percentage of correct responses. For the UFOV processing speed sub-test Ball et al. (1986) selected the point on the function where 75% of responses were correct, corresponding to the point when five reversals from correct to incorrect were recorded. However, Wetherill & Levitt (1965) devised a method to determine the percentage point for a given number of reversals called the Up-and-Down Transformation Rule (UDTR). Using the hybrid staircase selected by Ball et al. (1986), they estimated that thresholds were being tested at a level corresponding to 70% correct detection (rather than 75% correct detection as quoted by Ball et al., 1990).

2.2.5.4.3 Two alternative forced choice procedure

The two alternative forced choice procedure (2AFC) is another variation on the method of limits. Here a stimulus is briefly shown that has one of two possible configurations. The stimuli can be presented either sequentially (temporal forced choice) or simultaneously (spatial forced choice). Following the presentation, the subject is forced to decide which of the configurations was displayed. A response is required whether the subject is certain or not of what was viewed (i.e. forced choice). The UFOV test adopts sequential presentation of stimuli.

2.2.5.4.4 Backward masking

Masking is a form of perceptual interference, where two stimuli are presented in quick succession resulting in an impairment of one of the stimuli (Turvey, 1973). The rapid appearance of a masking stimulus following a leading stimulus is termed "backward masking" (Walsh, 1982). Backward masking occurs when the first stimulus is impaired by the second stimulus. The origin of masking can either be in the peripheral visual pathway or in the central visual mechanism and is dependent on the duration and intensity of the stimulus (i.e. target energy) and the time interval between the stimuli. The longer the interval the longer time there is for the first stimulus to be processed. Two hypotheses (Kahneman, 1968) have been suggested that could result in the impairment, the first is an interruption hypothesis (i.e. disrupts the processing of the first stimulus) and the second is an integration hypothesis (i.e. the two stimuli fuse together).

The UFOV test uses a masking stimulus that consists of a spatially random masking noise made up of vertical and horizontal lines of varying intensity. This is consistent with the type of mask required to assess pre-attentive processes for binocularly presented targets (Turvey, 1973). Turvey (1973) stated that a peripheral mask has different characteristics to a central mask and that a peripheral mask is defined by the following three characteristics:

i) it is an energy-dependent phenomenon

(the radiant light energy of the mask must exceed the energy of the target)

ii) target energy is related to the inter-stimulus duration to escape masking

iii) the figural characteristics of the mask are non-critical

The backward mask has several benefits and predominantly prevents an after image from remaining on either the monitor or in the eyes. This is particularly important for older individuals who are more susceptible to visual persistence (Kline & Schieber, 1982) where stimuli remain longer in the visual system (Botwinick, 1978; Coyne et al., 1979; Breitmeyer et al., 1982). It also interferes with the perception of the leading stimulus, thereby allowing only central processing of the information to take place (see section 2.2.4.1).

Although this section has briefly introduced the theory behind the UFOV test and its different sub-tests, the precise algorithm used to derive a UFOV score from the raw data has never been described. Research carried out to explore this algorithm is provided in chapter 3.

2.3 Kinetic visual attention test: Driver Reaction Time Simulator (DRTS)

The DRTS represents the pilot attempt at developing a kinetic visual attention test for drivers. The prototype, DRTS1, was developed in the Department of Vision Sciences at Aston University. A second version, DRTS2, was developed by Vauxhall Motors as part of their Glow Power Campaign to promote road safety, in 1998.

2.3.1 Rationale for a kinetic visual attention test

The impetus for developing the DRTS1 stems from recommendations made by the Secretary of State's Honorary Advisory Panel for Driving and Visual Disorders (see section 1.7). The DRTS1 was designed to investigate the parameters that influence the reaction time or "thinking time" component of car stopping distances (see figure 2.7). The DRTS1 incorporates the key features of the UFOV (i.e. divided and selective attention tasks) in addition to stimuli that move in a flow field (i.e. as roadside objects do). An optic flow field is defined as the movement of light in a stream either towards or away from an observer due to relative movement between the observer and the environment (Bruce et al., 1996).

2.3.1.1 Thinking times

Car stopping distances, found on the Department of the Environment, Transport and Regions' (DETR) website (see http://www.roads.detr.gov.uk/roadsafety), are divided into two parts, a thinking distance and a braking distance. The thinking distance is based upon a thinking time (671 ms) that is constant for all travelling speeds. A quote from Hills (1980) relating to thinking times states

> "This value clearly refers to optimum driving conditions, i.e. to an alert driver who is expecting a clearly visible signal that is unambiguous in nature and for which there is no uncertainty as to the appropriate response."

However, the thinking time should be based on the "stopping sight distance" used in the design of roadways (Olson & Sivak, 1986). The sight distance, is a measure that will ensure that drivers are given sufficient time to respond to a hazard and it is determined by a driver's perception-response time. Olson and Sivak (1986) found that drivers needed 1.6 sec to respond to an unexpected hazard. This is 0.9 sec. longer than the thinking time used to calculate thinking distances in the UK and 0.9 sec. shorter than the perception-response time of 2.5 sec (West et al., 1993) employed in the US at that time. Work by Johansson and Rumar (1971) derived a brake reaction time of 0.9 sec for a known event. However, this time increased to 1.2 sec for an unexpected event and is 0.5 sec longer than the published thinking time used today.

2.3.1.2 Perception-response times

A perception response time is a reaction time and it is a measure of the speed of information processing. Perceptual motor reaction times are good predictors of crash-risk (Barrett et al., 1977; Panek et al. 1977; Pen et al., 2000) and more relevant to the driving environment (Ball & Sekuler, 1980). Reaction times increase with increasing task complexity (Wierwille et al., 1985) and they are also known to increase with advancing age (Welford, 1977; Olson & Sivak, 1986).

Reaction times involve four information processing stages according to Wickens (cited in Panek et al., 1977):

i) the pre-perceptual stage

ii) the perceptual analysis stage

iii) the decision stage

iv) the response execution stage.

The pre-perceptual stage involves receiving visual information about the environment. The capacity of the pre-perceptual stage is known to decline with advancing age and therefore less information is provided for processing. Less information can lead to misjudgements and ultimately crashes, especially if there is insufficient time to gain more information. The perceptual analysis stage provides an evaluation of the information to locate and identify the stimulus. Once identified, the third stage is reached in which a decision is made as to whether to respond to that stimulus and what type of response is required. The final stage involves the execution of the desired motor response.

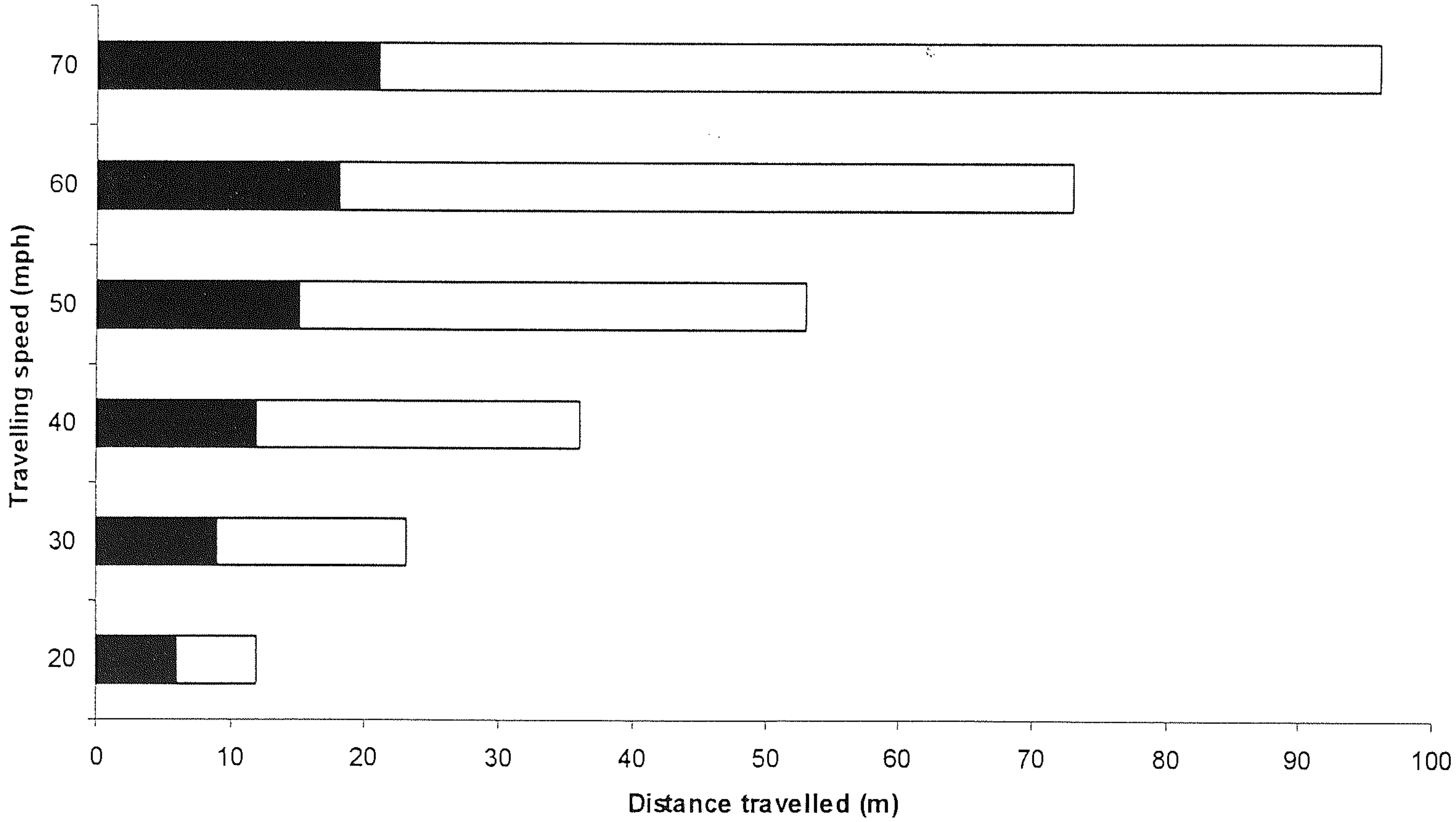


Figure 2.7: Graph showing the thinking (black bars) and braking (white bars) distance, in metres, for various travelling speeds (mph) based upon figures published by DETR.

All reaction times are a measure of the time lapse between the stimulus onset and the motor response. They are dependent on the number of stimuli present and the response required (Barrett et al., 1977) for a particular task. There are three types of reaction times tasks:

- simple
- choice
- complex

2.3.1.2.1 Simple reaction times

This is the time taken to respond to a single stimulus that suddenly appears. Barrett et al. (1977) measured the simple reaction time for the sudden appearance of a single red disc (static stimuli) that appeared 10 times. The subjects were divided into two groups (young and older drivers) and responses were made via a foot-pedal. Simple reaction times were equal for each group (see table 2.2).

Type of reaction time	Younger drivers	Older drivers	Significance level
Simple	0.40 (± 0.04) sec.	0.41 (± 0.04) sec.	NS
Choice	0.49 (± 0.05) sec.	0.53 (± 0.05) sec.	0.001
Complex	0.75 (± 0.08) sec.	0.85 (± 0.15) sec.	0.001

Table 2.2: The mean (± standard deviation) simple, choice and complex reaction times, measured in seconds, for young (N = 36, age 25 to 41 years) and older (N = 34, age 43 to 64 years) drivers (After Barrett et al., 1977).

2.3.1.2.2 Choice reaction times

This is the time taken to respond to one of several different stimuli that suddenly appear. Barrett et al. (1977) measured the choice reaction time for the sudden appearance (static stimuli) of one of three stimuli: a single red disc (brake response), a green left turn arrow (turn steering wheel to left) or a green right turn arrow (turn steering wheel to right). Each symbol was randomly presented five times. Choice reaction times for each group were longer than the simple reaction times. The older drivers had longer reaction times than the younger drivers did and the results were statistically significant (see table 2.2).

2.3.1.2.3 Complex reaction times

This is the time taken to respond to a single stimulus embedded in complex background. Barrett et al. (1977) measured the complex reaction time using visual search. Subjects were given a photograph (static stimuli) of a driving scene. They were asked to locate and respond to a traffic signal or sign embedded in the clutter. The signs and responses were the same as those used in the choice reaction time task. Complex reaction times were much longer than both the simple and choice reaction times for both age groups (see table 2.2). Older drivers had longer complex reaction times and greater variance than the younger drivers did and the difference was statistically significant (see table 2.2).

2.3.1.2.4 Simple, choice and complex reaction times versus driving performance

Barrett et al. (1977) showed that reaction times varied with the number of stimuli present and the response required. From this simple study it was clearly shown that reaction times vary greatly, depending on the amount of information presented to the subject. Further, Johansson and Rumar (1971) stated that not only do reaction times vary with the task but also with the sensory demands of the task and between individuals. They also determined that on average a reaction time to an unknown task would be 1.35 times longer than a reaction time to a known task.

Research has shown no relationship between simple reaction times and crash rates (De Raedt, 2000). Perhaps this is because young drivers (25 years) are at their peak with regard to reaction times and visual acuity (Brown, 1939), yet they have one of the highest accident rates (see section 1.2.2), and other factors are more important for safe driving. However, choice and complex reaction times rely on higher-order cognitive functions and they are more relevant to driving (De Raedt, 2000) as they predict crash involvement (Mihal & Barrett, 1976). However, the reaction times measured in this study are for static stimuli and even longer reaction times may be recorded for kinetic stimuli that move in a complex scene.

2.3.1.3 Motion

Objects that are moving are easily detected against a stationary background (Bruce et al., 1996). However, when driving the background is no longer stationary. The objects that are moving are now also moving in a flow field and subsequently they become harder to detect (Bruce et al., 1996). The peripheral visual field is designed to detect motion without the need to fixate what is moving (Falkmer et al., 2001). Also, the detection of motion in the central visual field is known to be harder when performing a simultaneous peripheral motion detection task (Probst et al., 1986).

Motion detection is easy to perform under controlled experimental conditions, but when driving the movement of an object is sometimes unpredictable (Ball & Sekuler, 1981). Ball and Sekuler (1981) termed the unpredictable nature of targets as "stimulus uncertainty". Stimulus uncertainty affects the detection (Ball & Sekuler, 1980) and visibility of a moving target (Sekuler & Ball, 1977). The direction and the speed of the motion are directly linked to the detectability of a target (Ball & Sekuler, 1981). Work by Driver et al (1992) revealed that changing the speed of a target had no effect on its detectability but changing the direction off motion did, suggesting that speed is more discriminating than the direction of motion. However, increasing speed is known to increase reaction times both when driving in a simulator (Santos, 1999) and on-road (Probst et al., 1987).

Motion perception (i.e. detection and identification) has been found to be related to driving performance (Henderson & Burg, 1974; Hills, 1975; Shinar, 1977) along with motion detection (Scialfa, 1987). It has been suggested that the detection of movement when driving is more important than discrimination of what is moving (Santos, 1998; Ball et al., 1983). There are two types of motion that can be experienced when driving:

- Angular motion
- Longitudinal motion

2.3.1.3.1 Angular motion

Angular or tangential motion occurs when a vehicle crosses the visual field at a tangent (Hills, 1980). The vehicle remains at a constant distant from the observer and consequently its visual size remains constant. Driving requires not only the detection of angular movement but also the detection of direction and the rate of movement. Bogard (1974) found that older drivers were less able to perform a task involving angular motion than younger drivers. However, there is only a weak link between the detection of angular movement and accident rates (Shinar, 1977).

2.3.1.3.2 Longitudinal motion

Longitudinal motion or motion in depth occurs when a vehicle is travelling directly towards or away from an observer (Hills, 1980). The vehicle remains in one position but its size alters, either increasing or decreasing depending on its direction of travel relative to the observer. Longitudinal motion is useful for judging speed and this ability declines with age (Cremer et al., 1990; Johansson & Lundberg, 1997; Kosnik et al., 1990; Scialfa et al., 1987, 1991).

2.3.1.3.3 Angular versus longitudinal motion

Hills (1980) suggested that angular motion was easier to detect than longitudinal motion. This could be explained by considering the areas of the visual system that are used in each case. Angular motion detection generally involves peripheral vision, which is known to be more sensitive to movement whilst longitudinal motion generally involves central vision, which is known to be better at resolving detail than detecting movement (Hills, 1980).

2.3.2 The requirements of a kinetic visual attention test

The kinetic visual attention test needed to include the following features relevant to driving, as identified in the research literature (Ball & Owsley, 1991; Ball et al., 1993; Ball & Rebok 1994):

- movement in visually cluttered environments
- simultaneous use of central and peripheral vision
- execution of primary and secondary tasks
- uncertainty of when or where important visual events occur

The UFOV test examines pre-attentive processes (see section 2.2), as targets are visible for a maximum of 240 ms. However, the DRTS represents road conditions in which objects do not suddenly appear or disappear. Instead, objects move in the flow field and they are present for more than 240 ms so that both pre-attentive and attentive processes operate.

2.3.3 DRTS1: Description

The DRTS1 test was designed for use on a laptop or desktop computer (see figure 2.8). The QuickBasic program written for the test can be found in appendix 2. The following description relates to its default settings – which can be, optionally, varied. A viewing distance of 50 centimetres is adopted. The computer monitor depicts the driver's view down the middle of a straight road of 7 metres wide. The road disappears over the horizon 400 metres away from the driver. Distracting lampposts, 20 centimetres wide and 5 metres high, are positioned opposite each other on the right and left hand sides of the road and at 100 metre intervals along the road. The simulator speed is set at 50 mph. Motion is simulator by presenting a new frame every 111ms (9 Hz refresh rate). The central task comprises a leading car, 2 metres wide and 1.5 metres high, positioned 100 metres in front of the subject and travelling at the same speed. This car may suddenly stop and its movement represents longitudinal motion (see section 2.3.1.3.2). When this happens, the subject is required to press the spacebar of the laptop keyboard as quickly as possible and a reaction time is recorded. Peripheral tasks comprise three rows of pedestrians, 0.75 metres wide and 1.8 metres high, positioned on the right and left hand sides of the road in line with each set of lampposts. Any one of the pedestrians can cross the road at a speed of 7.5 mph. This only happens after the leading car has passed the pedestrian. The movement of the pedestrians represents angular motion (see section 2.3.1.3.1). Inner, middle and outer pedestrians, on both sides of the road, cross at emergent eccentricities of 2.5°, 5.0° and 7.5°, respectively, from the subjects viewpoint. Again, the subject is asked to press the spacebar as soon as one of the pedestrians moves and a reaction time is recorded. The computer only allows these events to occur one at a time. The order in which each event (braking of the leading car or crossing of a pedestrian) takes place is randomised and consequently the driver's attention must be directed at the whole screen at the same time. This requires good divided attention. Roadside lamppposts and non-crossing pedestrians serve as distractors so that good selective attention is required. Each event is programmed to occur three times yielding an estimate of the mean and standard deviation of the reaction times for each event.

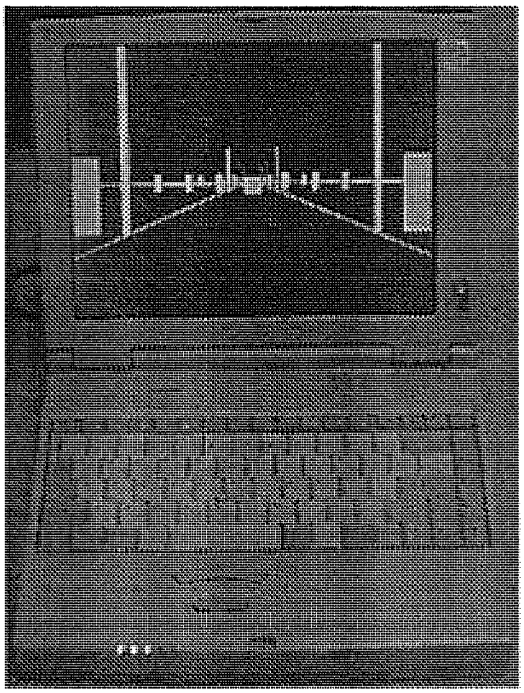


Figure 2.8: A scene depicting the default setting of the DRTS1 kinetic visual attention test presented on a laptop computer.

The UFOV test incorporates supra-threshold targets, white stimuli against a black background. The DRTS1 test was originally designed to include the same type of target. However, because of the type of screen used (LCD type) an uncomfortable level of target flickered occurred. To overcome this, the screen contrast was reversed so that the targets appeared as dark grey stimuli on a light grey background. This dramatically reduced the amount of flicker. A comparison of reversed and non-reversed display of targets was carried out in a pilot study (see appendix 3) on 36 observers and indicated that there was no significant difference in reaction times measured in each condition (see appendix 3a). The reverse contrast condition was, therefore, adopted for comfort.

2.3.4 DRTS2: Description

The DRTS2 test was designed to overcome some of the limitations of DRTS1. It is also presented via a laptop or desktop computer (see figure 2.9). The kinetic visual attention test program was written by NetComms Limited, using JavaScript. Macromedia Flash 3.0 was used to produce graphical 3D modelling. This is an animation tool and was used to design colourfully rendered car dashboard, background scenery and moving objects. Observers responded to stimuli using the mouse and space bar.

Both of these controls were mapped, using JavaScript, to a Visual Basic script that controlled events triggered within the animation. This improved computer program removed the uncomfortable monitor flicker experienced using the DRTS1.

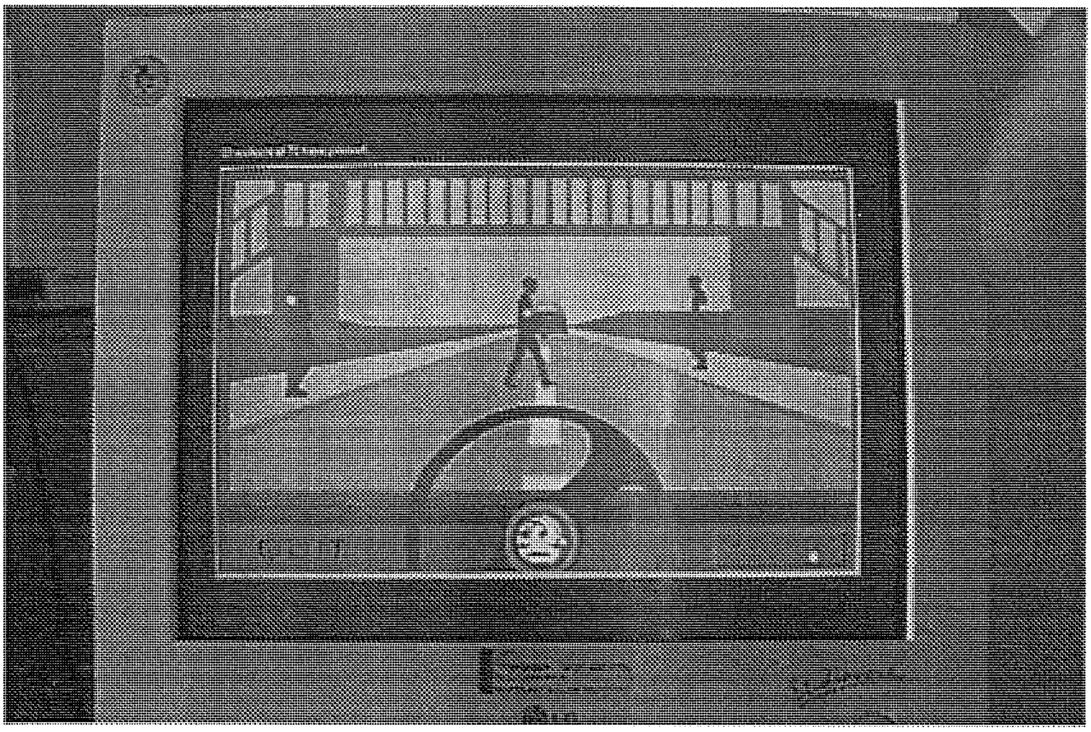


Figure 2.9: A scene from the DRTS2 kinetic visual attention test presented on a PC.

The computer monitor depicts the driver's view down the middle of a straight road that disappears over the horizon. As for the DRTS1, the central task comprises of a leading car positioned in front of the subject that may suddenly brake. When this happens, the subject is required to respond by clicking the left mouse key. This differs from the DRTS1 in that the central task takes place continuously so that it is a true primary task. No reaction time is recorded for this event but failure to perform this task leads to termination of the test.

Roadside pedestrians appear randomly, only some of which cross the road. Pedestrians only cross when they reach one of three emergent eccentricities on either side of the road (2.5°, 3.9°, and 5.5°). At least two pedestrians are always in view so that the observer remains uncertain as to when or where a pedestrian will cross from. When a pedestrian crosses the observer is required to press the spacebar on the keyboard as quickly as possible. The reaction time is automatically saved. All reaction times are written to a text file using Visual Basic.

Distractors include lampposts, bridges, houses, road signs and non-crossing pedestrians.

For reasons that go beyond the scope of this study, the DRTS2 depicts daytime and nighttime road conditions. Pedestrians are also equally divided into those with and without reflective DayGlow armbands. However, pilot studies (see appendix 3) on 36 observers revealed that neither day nor nighttime conditions (see appendix 3b) or presence of day-glow armbands on pedestrians (see appendix 3c) exerted any statistically significant effects upon reaction times recorded. In total 36 pedestrian crossing events occurs in each scene, giving a total of 72 events. Reaction times for each of these events are captured in a database. Should the user fail to react to five pedestrians in a row the application automatically terminates.

2.3.5 Comparison between DRTS1 and DRTS2 tests

The DRTS1 and DRTS2 tests vary slightly in the way they satisfy the requirements of a visual attention test for drivers (see section 2.3.2). This section compares both tests.

2.3.5.1 Movement in a cluttered environment

DRTS1 and DRTS2 both satisfy this requirement by showing moving stimuli in flow fields relevant to driving. Both tests incorporate visual clutter. However, it was anticipated that the DRTS2 would have greater perceived face value than the DRTS1 due to its colourfully rendered road scenes.

2.3.5.2 Simultaneous use of central and peripheral vision

Although the DRTS1 requires subjects to simultaneously attend to central and peripheral events, these events never take place simultaneously. The DRTS2 overcomes this limitation by providing a continuous central task that takes place at the same time as peripheral events.

2.3.5.3 Execution of primary and secondary tasks

Strictly speaking, the DRTS1 involves carrying out one task (i.e. responding) to two different types of event (central and peripheral). The DRTS2 overcomes this limitation by requiring subjects to attend to the central task through one control at the same time as attending to the peripheral task through another control.

2.3.5.4 Uncertainty of when or where events will occur

The DRTS1 and DRTS2 both fulfil this requirement as all events occur randomly and pedestrians can emerge from one of the three eccentricities on both sides of the road.

2.3.5.5 Test parameters

Unlike DRTS1, the test parameters of the DRTS2 program were not specified as these could vary with computers of different processor speed. In order to compare the two tests it was necessary to have a measure of all events. DRTS2 test parameters were checked by taking measurements from a video recording of one main run that had been carried out on a Pentium 233 PC.

To fully evaluate the DRTS2 test parameters, it was necessary to assume the width of the road and the width of the leading car. The working distance was kept constant at 50 cm. Multiple readings were taken for each test parameter and error analysis performed in order to establish a mean and standard error for each value. The final parameters are shown in table 2.3 and the error analysis can be found in appendix 4. The high standard error recorded for DRTS2 travelling speed revealed that the moving scene would frequently speed up or slow down as the density of the scenery varied.

	DRTS1	DRTS2	
Test parameter	Mean	Mean	Standard error
Assumed working distance (m)	0.5	0.5	-
Assumed road width (m)	7	3.6	-
Road length (m)	400	246	2.2
Travelling speed (mph)	50	58	7.3
Assumed width of central car (m)	2	2.0	-
Distance to central car before braking event (m)	100	129	0.6
Distance to central car after full braking event (m)	-	50	0.3
Height of child pedestrian (m)	1.8	1.2	0.003
Width of child pedestrian (m)	0.75	0.19	0.003
Eccentricity #1 of crossing pedestrians (°)	2.5	2.5	0.009
Eccentricity #2 of crossing pedestrians (°)	5.0	3.9	0.009
Eccentricity #3 of crossing pedestrians (°)	7.5	5.5	0.006
Pedestrian crossing speed (mph)	7.5	2.9	0.03

Table 2.3: Parameters of the DRTS1 (default setting) and DRTS2 kinetic visual attention tests.

2.4 Description of apparatus and driving sample

This section describes the apparatus and driving sample used in this study. Detailed research methods are provided in chapters 3 to 9.

2.4.1 Apparatus

All tests were carried out in a darkened room to prevent distracting monitor reflections. This is consistent with the normal driving environment when drivers are exposed to varying levels of luminance. Each program was performed using a different computer and the test equipment is outlined in sections 2.4.1.1 to 2.4.1.3.

2.4.1.1 UFOV test equipment

The UFOV test was carried out on a Dell System 325P (Texas) personal computer, with a 23" monitor (Goldstar, Korea), keyboard (Dell, Ireland), mouse (Dell, Taiwan) and printer (Hewlett Packard Desk-jet 600, Spain). A chin rest was also used to ensure that subjects were kept at the correct working distance (22.5 cm). This was necessary as subjects otherwise tended to pull away from the screen because of its very short working distance.

2.4.1.2 DRTS1 test equipment

The DRTS1 test was carried out on a Toshiba 4000CDS (Japan) Satellite laptop computer. The program could only be run on this type of computer for two reasons. Firstly, to set up the test a "function" key (see appendix 2) was required that was only available on this type of computer. Secondly, a LCD screen was required to reduce screen flicker (see section 2.3.3). Responses were made via the integral keyboard. No head restraint was used for this test, as the working distance was more accommodating. The subjects were asked to make themselves comfortable and the laptop was positioned at the correct distance. No further measurements of the working distance were taken, however the subjects sitting position was monitored and adjusted as required.

2.4.1.3 DRTS2 test equipment

The DRTS2 program was performed on a Pentium-MMX 233 personal computer (Tempus Computers, Birmingham) with a 12" monitor (Studioworks, Korea), keyboard (Key Tronic, Mexico) and mouse (Logitech, China). As for DRTS1, no headrest was used.

2.4.2 Sample

Three groups of subjects were used to examine the variations in performance on static and kinetic visual attention tests with age (see section 2.4.2.1) and the prediction of driving performance (see section 2.4.2.2).

2.4.2.1 Static and kinetic visual attention – variations with age

Chapters 3 to 8 provide a description of results arising from 36 subjects (see appendix 6a, subject-group 1), age range 20 – 79 years, with no ocular pathology and with binocular visual acuities of at least the number plate standard (Drasdo, 1981; http://www.dvla.gov.uk). Subjects were divided equally into young (18 – 20 years), middle (30 – 55 years) and older (65 + years) age groups. Each age group comprised 6 male and 6 female subjects. Analysis of the data revealed there were no statistical differences between male and female subjects (see appendix 3a) for all three visual attention tests. For all future analyses the data collected for male and female subjects will be pooled. Table 2.4 summarises the mean ages of each group.

Age Group	N	Mean Age
Young	12	20 ± 0
Middle	12	35.2 ± 4.5
Older	12	71.8 ± 4.9
All	36	42.3 ± 22

Table 2.4: Table showing the number of subjects and the mean (± standard deviation) ages (years) per age group and for all ages.

2.4.2.2 Static and kinetic visual attention – prediction of driving performance

Chapter 9 provides a description of results arising from two different subject groups.

The first sample (see appendix 6b, subject group 2) was recruited in collaboration with Dr N Ward of the Department of Psychology at Leeds University. They comprised of 19 drivers aged 62 – 80 years (mean ± standard deviation: 71 ± 5 years).

The second sample (see appendix 6c, subject-group 3) was recruited from Sussex Police Force. They comprised of 25 police drivers aged 29 – 62 years (mean ± standard deviation: 42 ± 9 years).

2.5 Data analysis

Initial examination revealed that data for all tests were not normally distributed. Transformation of the data was thus necessary so that powerful and versatile parametric statistical tests could be applied to the results of this study.

2.5.1 UFOV transformation

The standard transformation that is used for a percentage is the inverse sine of the square root of the value to be transformed (Ball et al., 1990). The UFOV is collected as a percentage loss and percentage of peripheral target location errors; however, the majority of subjects obtained a 0%

score which would result in a transformed score of infinity. Subsequently, for this analysis the percentage scores were modified (see appendix 5a for details).

The degree of normality of the transformed data were examined using a method described by Sachs (1992) which states:

i) The median divided by the mean should fall between 0.9 and 1.1
ii) The mean should be more than three times the standard deviation

If these conditions are satisfied then the data is approximately normal. It is well known that in practice it is unlikely to get ideal normality from a sample (Snedecor, 1989). The formulae and table to confirm that the transformed data are normally distributed can be found in appendix 5a.

2.5.2 DRTS1 and DRTS2 transformations

For the DRTS1 and DRTS2 tests it was necessary to experiment with various transformations in order to determine the best one for a normal distribution. To this end reaction times for all trials were pooled and transformed by raising them to a power (n), where n varied from 2 to –3 in 0.5 steps.

The degree of normality of the transformed data were examined using the methods described in section 2.5.1. The formulae and table to confirm that the transformed data are normally distributed can be found in appendix 5b.

CHAPTER THREE

AN INVESTIGATION OF UFOV TEST PROCEDURES

NB For a full key see page -9-.

3.1 Introduction

The aim of the research presented in this chapter was to understand how the UFOV test results were derived from the raw data collected on individual subjects. This approach was necessary, as a literature search had failed to fully explain how UFOV tests results were derived.

3.2 Methodology

As previously explained in section 2.2.5, the UFOV test used to collect the data presented in this thesis had been modified by Visual Resources Inc. (the developers of the UFOV test) to provide a detailed printout of the raw data collected from each subject in addition to the final UFOV test results. A precise description of the raw data is provided in later sections of this chapter.

Eighty-two UFOV printouts were analysed. Of these, 72 arose from two repeat UFOV tests carried out on each of the 36 subjects described in section 2.4.2.1. In addition to these, 10 arose from UFOV tests carried out on patients exhibiting more severe UFOV losses.

This analysis revealed the procedures used to convert the raw data into final UFOV test results. To ensure that these procedures had been correctly identified, a BASIC computer program (see appendix 1b) was written that incorporated each procedure so that raw data entered for each subject would yield the correct final UFOV results. This program yielded the correct final UFOV results for all 82 of the printouts analysed.

Taking the above as confirmation that all UFOV procedures had been correctly identified, the remainder of this chapter provides an explanation of each procedure using the raw data from an example UFOV printout. This printout is shown in appendix 1a. The author generated the printout by making purposeful mistakes during the UFOV test in order to demonstrate key features of each procedure. Extracts of this printout are reproduced in various places in this chapter to aid understanding of each procedure.

3.3 Description of the UFOV printout

For the purpose of this explanation the printout (see appendix 1a) has been divided into three parts:

- UFOV assessment
- Sub-test summary
- Trial by trial listing

3.3.1 UFOV assessment

The UFOV assessment section of the example printout is shown in figure 3.1. An internal validation check, referred to later (see section 3.3.2), was used to determine whether the test was valid or inconsistent. The test time was also recorded. This was followed by the degree of reduction of the UFOV, which amounted to 55% in this case. Under the title "basis of loss" was a breakdown of what part processing speed losses (10%), divided attention losses (20%) and selective attention losses (25%) contributed to this figure. As previously explained (see section 2.2.5), the total UFOV reduction was simply the sum of processing speed, divided attention and selective attention losses.

```
-------------------------------- UFOV ASSESSMENT ---------------------------------
TEST RESULTS:            VALID                     TEST TIME       12.17 MIN

Degree of Reduction of the Useful Field of View:   55.00%

BASIS OF LOSS:
            Processing speed loss:     10.00%
            Divided attention loss:    20.00%
            Selective attention loss:  25.00%
-----------------------------------------------------------------------------------
```

Figure 3.1: Extract of example UFOV printout (appendix 1a) showing UFOV assessment section.

3.3.2 Sub-test summary

The next section of the example printout did not have a title but is referred to here as the sub-test summary (see figure 3.2). The threshold duration (47ms) is shown first and was derived during task 1, the processing speed task, involving identification of a central target (see section 2.2.5.1).

This is followed by a summary of the results of task 2, the divided attention task, involving identification of a central target and location of a peripheral target (see section 2.2.5.2). Finally a summary is provided of task 3, the selective attention task, involving identification of a central target and location of a peripheral target embedded in distractors (see section 2.2.5.3). It is apparent from figure 3.2 that although tasks 2 and 3 can be carried out at durations of 40ms to 240ms in 40ms steps, all of these durations were not tested. Next to all of the durations tested is a UFOV value and a count of centre misses. The UFOV value can vary between 5° (i.e. the size of the central target) and 35° (i.e. the radius of the field over which the UFOV took place). The UFOV values were used to determine divided and selective attention losses (also shown in the sub-test summary) but a description of the procedures used follows later (see sections 3.4.2 and 3.4.3). The centre misses refer to the number of times that the central target was incorrectly identified and it is the number of centre misses that are used as an internal check of the validity of the UFOV test. In this sense, centre misses served as a fixation monitor, and the test becomes invalid when a certain number of misses are recorded.

```
--------------------------------------------------------------------------------------------
Threshold duration – task 1:          47 msec
Task 2 – Divided attention
duration            UFOV              centre misses
240                 not tested
200                 not tested
160                 22.5              0
120                 5                 0
80                  not tested
40                  not tested
Divided attention loss:               20
Task 3 – Selective Attention
duration            UFOV              centre misses
240                 12.5              1
200                 5                 0
160                 not tested
120                 not tested
80                  not tested
40                  not tested
Selective attention loss:             25
--------------------------------------------------------------------------------------------
```

Figure 3.2: Extract of example UFOV printout (appendix 1a) showing subtest summary.

3.3.3 Trial by trial listing

The trial by trial listing of the example printout (see appendix 1a) consists of 5 columns of raw data. The first column identifies the sub-test: divided attention task (task 2) or selective attention task (task 3). Raw data for the processing speed task (task 1) is not shown. The second column shows the test duration. The third column indicates the subject's response in terms of the type of errors made. Here, there may be no errors at all (N), a central target identification error (C), a peripheral target location error (P) or errors relating to both central target identification and peripheral target location (B). The fourth column relates to the spoke upon which the peripheral target was located. Spoke orientations (otherwise called radial locations) corresponded to 90° (spoke 1), 45° (spoke 2), 0° (spoke 3), 315° (spoke 4), 270° (spoke 5), 225° (spoke 6), 180° (spoke 7) and 135° (spoke 8) where 0° is positive horizontal. The last column indicates the eccentricity at which the peripheral target appeared. Targets could appear at eccentricities of 10°, 20° and 30°. These raw results were presented in the order in which they were presented to the subject. The spoke orientation of each peripheral target was selected randomly, but its eccentricity was generally selected in sequence; either increasing (10° then 20° then 30°) or decreasing (30° then 20° then 10°).

3.4 Description of the UFOV processes

The UFOV test consists of three sub-tests (see section 2.2.5) and each sub-test score is generated in a slightly different manner. This section describes how the scores are calculated for each sub-test.

- Processing speed
- Divided attention
- Selective attention

3.4.1 Derivation of processing speed loss

Processing speed loss (%)	Threshold duration (ms)	Number of subjects that achieved threshold duration
0	16	51
	20	7
	23	5
	27	2
5	37	7
10	47	2
	49	2
15	56	1
20	63	2
25	78	1
30 (test terminated)	88 (maximum score 325)	1

Table 3.1: Processing speed losses that resulted from the threshold durations of 82 subjects

Threshold duration (see figure 3.2) was derived by a staircase method that was described in the previous chapter (see section 2.2.5.4.2). Table 3.1 shows the processing speed losses that resulted from different threshold durations. This table also shows the number of subjects that achieved each threshold duration. It can be seen that processing speeds ranging from 16 to 88ms resulted in processing speed losses that ranged from 0 to 30%. One subject performed very poorly on this task and gained a threshold duration of 325 ms. Here, a processing speed loss was not recorded. Instead, the UFOV test was terminated and an overall UFOV reduction of 90% was given. Another subject, not shown in table 3.1, received a 5% processing speed loss for a threshold duration of 16ms. According to the results shown in table 3.1, a processing speed of 0% should have arisen. However, this subject had divided and selective attention losses of 30%. It, therefore, appears that poor performance in divided and selective attention tasks can result in elevation of the processing speed losses.

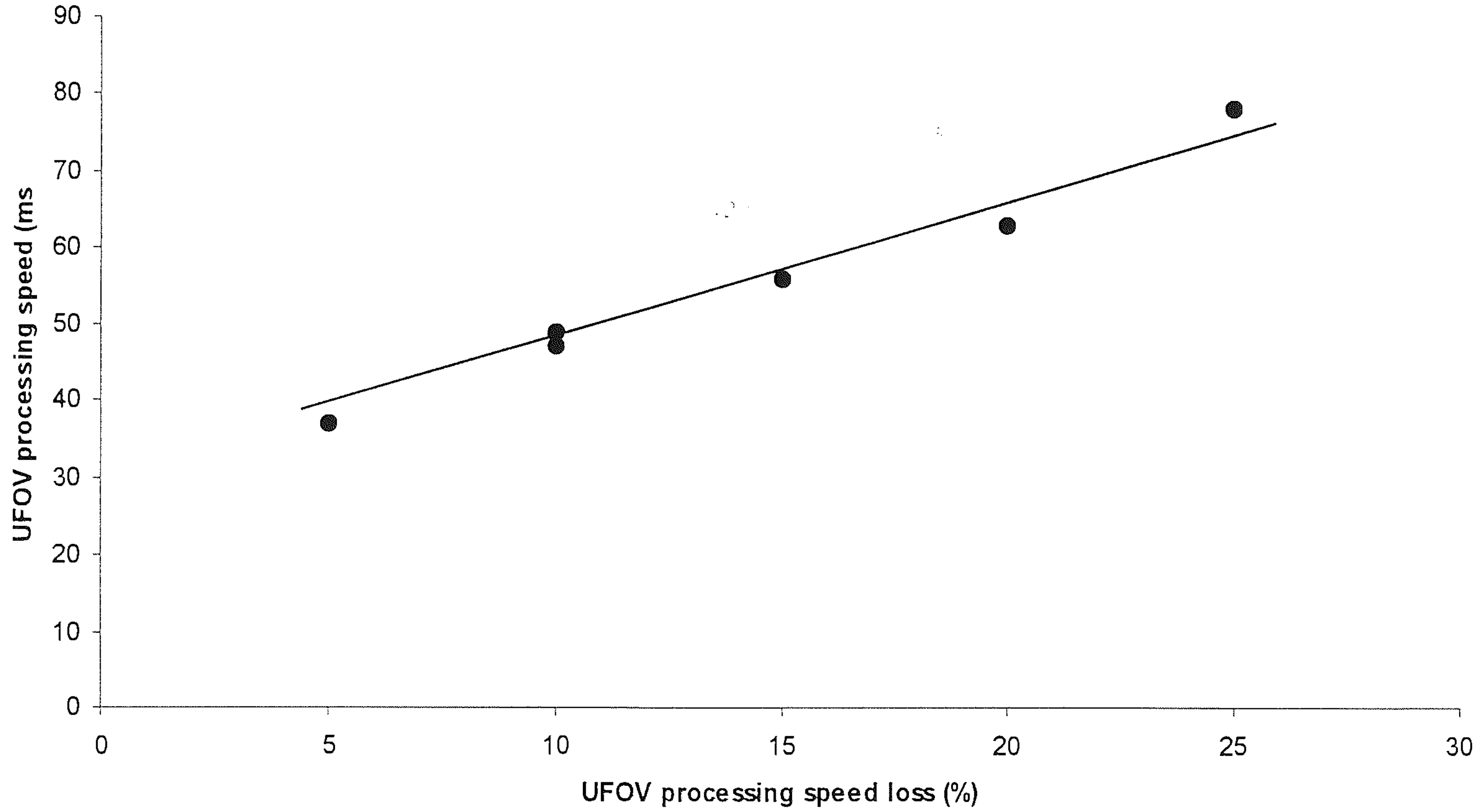


Figure 3.3: The relationship between processing speed duration (ms) and processing speed loss (%). Data relating to 0% processing speed losses and the very poor threshold duration that resulted in termination of the UFOV test have been removed. The regression line reveals a linear relationship (Processing speed loss = [0.521 x threshold duration] – 14.378, $r^2 = 0.985$). Datum points (solid circle) are taken from table 3.1.

Processing speed losses are linearly related to threshold durations but this relationship breaks down for processing speed losses of 0% and in situations where a very poor threshold duration results in termination of the UFOV test (Sekuler and Ball, 1986). Figure 3.3 confirms this by illustrating the linear regression between threshold duration and processing speed loss after removal of processing speeds of 0% and the single threshold duration of 325ms.

Table 3.1 and figure 3.3 lack the data to provide the precise threshold duration limits that define each level of processing speed loss. Nevertheless, one could speculate from table 3.1 and the regression shown in figure 3.3 that threshold durations of up to 30ms correspond to a 0% processing speed loss. Thereafter, an increment in threshold duration of 10ms corresponds to a 5% increment in processing speed loss. As mentioned earlier, the recorded processing speed loss may be increased by 5% should the subject perform poorly in divided and selective attention tasks.

Subjects with processing speed losses of less than 30% proceed to the divided and selective attention tasks of the UFOV test. For those with processing speed losses of 30% or very poor threshold durations, the UFOV test is terminated. In this case, a loss of 30% is automatically assigned to both divided and selective attention. This, presumably, reflects the notion that failure of the relatively easy processing speed task indicates that a subject would inevitably fail the more demanding divided and selective attention tasks.

In keeping with the above, extracts from the UFOV sample printout (figures 3.1 and 3.2) show that the threshold duration was 47ms and that this equated to a 10% processing speed loss.

3.4.2 Derivation of divided attention loss

A description of the divided attention task is provided in section 2.2.2.2. It was mentioned in section 3.3.2 that, although this task can be carried out at durations of 40ms to 240ms in 40ms increments, not all durations are tested. This is presumed to be an attempt to reduce the overall time taken to perform the UFOV test. Instead, the starting duration tested depends on the previously obtained processing speed loss. Table 3.2 shows the relationship between processing speed loss and the divided attention starting duration deduced by examination of 82 UFOV printouts.

Divided attention starting duration (ms)	Processing speed loss (%)
80	0 5
120	10 15
160	20 25
Test terminated	30

Table 3.2: Relationship between processing speed loss and the divided attention starting duration deduced from 82 UFOV printouts.

Again, in keeping with the above, extracts from the UFOV sample printout (see figures 3.1 and 3.2) and the trial by trial listing (see appendix 1a) show that the 10% processing speed loss lead to a starting divided attention task duration of 120ms.

At whatever duration is tested, between 3 and 5 repeat presentations are made at each eccentricity, depending upon the number of response errors made by the subject. Here, the radial location and eccentricity of peripheral targets is randomised. In the case of a central target identification error, then the eccentricity associated with that error is repeated but usually at a different radial location. The percentage of peripheral target location errors is calculated for each eccentricity. There are then three possible outcomes:

i) An error rate of 0% for all three eccentricities results in a UFOV value of 35° for that duration. The task is then repeated at a shorter duration (reduced by 40ms);

ii) An error rate of below 50% for at least one eccentricity results in a UFOV value of less that 35°, but greater than 5°. It was not possible to determine the procedures used to derive the precise UFOV value but this did not matter, as the UFOV value does not influence the outcome of the test. The simple fact that the UFOV value falls between 5 and 35° means that the task is repeated at a shorter duration (reduced by 40 ms);

iii) An error rate of above 50% or more for all three eccentricities results in a UFOV value of 5°. In this case the task is repeated at a longer duration (increased by 40 ms);

The divided attention task continues to repeat, at longer or shorter durations (as dictated by outcomes i to iii above) until an endpoint is reached. This endpoint is defined as the longest duration for which a UFOV value of 5° occurs.

The divided attention loss then depends upon this endpoint duration. Table 3.3 shows the relationship between the endpoint duration and the divided attention loss as deduced by examination of 82 UFOV printouts. Reading this table from bottom to top, it can be seen that an endpoint duration of 240ms results in the maximum divided attention loss of 30%. The divided attention loss then falls for successively shorter endpoint durations. In cases where the peripheral target location error rate is less than 50% for all eccentricities tested at 40ms duration, a new set of rules apply. Subjects making three or more errors, when the errors for all three eccentricities are summated, receive a 5% divided attention loss while those with less than three errors all receive a 0% loss.

Divided attention loss (%)	Endpoint duration (ms)
0	Less than 3 peripheral target location errors across all eccentricities at 40ms duration
5	Three or more peripheral target location errors across all eccentricities at 40ms duration
10	40
15	80
20	120
25	160
27.5	200
30	240

Table 3.3: Relationship between the endpoint duration and the divided attention loss deduced from 82 UFOV printouts.

The procedures described above are, again, illustrated in the trial by trial listing (see appendix 1a) and sub-test summary (see figure 3.2) of the UFOV sample printout. At a starting divided attention task duration of 120ms, error rates of over 50% occurred at all eccentricities so that a UFOV value of 5° was assigned. The task was then repeated at a longer duration of 160ms. At this duration, error rates of less than 50% occurred at eccentricities of 10° and 20°. Because error rates fell below 50% for at least one eccentricity, a UFOV value of greater than 5° but less than 35° was assigned (22.5°). At this point, the endpoint, being the longest duration for which a UFOV value of 5° occurs, was known to be 120ms. In accordance with table 3.3, this endpoint duration resulted in a 20% divided attention loss.

3.4.3 Derivation of selective attention loss

The derivation of selective attention loss is very similar to that of divided attention. The selective attention starting duration is governed by the previously determined divided attention loss (see table 3.4). Table 3.4 shows that starting durations for the selective attention task are longer than those of the divided attention task (see table 3.2). This could be due to the relative severity of the selective attention task compared to the divided attention task. As for divided attention, selective attention is not measured if the divided attention loss amounts to 30%. In this case, the UFOV test is terminated and a selective attention score of 30% is automatically assigned.

Selective attention starting duration (ms)	Divided attention loss (%)
160	0 5
200	10
240	15 20 25 27.5
Test terminated	30

Table 3.4: Relationship between divided attention loss and the selective attention starting duration deduced from 82 UFOV printouts.

The endpoint duration of the selective attention task is defined and sought in the same manner as that of the divided attention task. However, the allocation of selective attention loss to endpoint duration does differ and is summarised in table 3.5.

Selective attention loss (%)	Endpoint duration (ms)
0	Peripheral target location error rate below 50% for at least one eccentricity at 40ms duration
7.5	40
12.5	80
17.5	120
22.5	160
25	200
30	240

Table 3.5: Relationship between the endpoint duration and the selective attention loss deduced from 82 UFOV printouts.

The procedures described above are, once again, illustrated in the trial-by-trial listing (see appendix 1a) and sub-test summary (see figure 3.2) of the UFOV sample printout. In accordance with Table 3.4, the 20% divided attention loss lead to a selective attention starting duration of 240ms. At this duration, an error rate of below 50% occurred at 10° eccentricity. Because the error rate fell below 50% for at least one eccentricity, a UFOV value of greater than 5° but less than 35° was assigned (12.5°). The task was then repeated at a shorter duration of 200ms. At this duration, error rates of over 50% occurred at all eccentricities. A UFOV value of 5° was thus assigned. At this point, the endpoint, being the longest duration for which a UFOV value of 5° occurs, was known to be 200ms. In accordance with table 3.5, this endpoint duration resulted in a 25% selective attention loss.

3.5 Summary

A computer program (see appendix 1b) was written, based upon the author's understanding of the procedures used to derive final UFOV scores as deduced from examination of 82 sets of raw data. This program was subsequently tested on all sets of raw data and yielded the correct final UFOV scores in each case. This outcome was taken as confirmation that the UFOV procedures had been correctly understood.

It was deduced that the overall UFOV reduction was the sum of percentage losses derived from the processing speed, divided attention and selective attention tasks. The endpoint of the processing speed task was a threshold duration that was linearly related to processing speed loss. The endpoint of both the divided and selective attention tasks was the longest test duration for which peripheral target location errors exceeded 50% at all target eccentricities. Divided and selective attention losses were then assigned according to the endpoint duration found.

Although this investigation has revealed some of the internal workings of the UFOV test, there are still several important aspects of this test that remain unknown. A full understanding of the internal validation check (see section 3.3.2) carried out during the UFOV test could not be deduced as very few of the subjects tested in this study had inconsistent performances. Conversion of the endpoint of each task to a particular percentage loss (see tables 3.1, 3.3 and 3.5) is based upon data owned by the developers of the UFOV test (Ball et al., 1993). This information is, understandably, commercially protected. Nevertheless, this information is important and its absence prevents comprehensive scientific evaluation of the UFOV test. Interestingly, one of the purposes for which the UFOV test was developed was the determination of fitness to drive. However, it may be that failure to carry out a full independent scientific evaluation of this test may forever bar its use for such a purpose.

CHAPTER FOUR

FACTORS THAT INFLUENCE STATIC AND KINETIC VISUAL ATTENTION TESTS: REPEATABILITY

NB For a full key see page -9-.

4.1 Introduction

This chapter describes the results of experiments designed to compare static (UFOV) and kinetic (DRTS1 and 2) visual attention tests in terms of their repeatability.

4.2 Methods

Repeat measurements were taken from 36 subjects divided equally into young, middle and older age groups (see section 2.4.2.1). Each subject performed all three visual attention tests on two separate sessions. The order of tests carried out in each session was counterbalanced (see appendix 6a). The interval between sessions can be found in table 4.1.

Age Group	Interval between sessions / days
Young	85 ± 27.8
Middle	89.7 ± 41.4
Older	45.9 ± 20.7

Table 4.1: The interval (mean ± standard deviation) between the first and second experimental sessions.

4.2.1 Static visual attention: UFOV

The elements of the UFOV test (section 2.2.5) that were assessed (see tables 4.2 to 4.4) included processing speed losses (processing speed), divided attention losses (divided attention), selective attention losses (selective attention) and the overall UFOV reduction (total UFOV). The total UFOV score is derived from the addition of scores from the processing speed, divided attention and selective attention sub-tests (see section 2.2.5).

4.2.2 Kinetic visual attention: DRTS1

Elements of the DRTS1 test that were assessed (see tables 4.2 to 4.4) included reaction times recorded when the central leading car sudden stopped (leading car), when pedestrians suddenly crossed the road at emergent eccentricities of 2.5° (inner pedestrian), 5° (middle pedestrian) and 7.5° (outer pedestrian) in addition to pooled reaction times for all of these events (all events).

Reaction times to inner, middle and outer pedestrian events that took place on the right and left hand sides of the road were averaged.

4.2.3 Kinetic visual attention: DRTS2

Elements of the DRTS2 test that were assessed (see tables 4.2 to 4.4) included reaction times recorded when pedestrians suddenly crossed the road at distances from the subject of 41 m (distant pedestrian), 26 m (intermediate pedestrian) and 19 m (near pedestrian) in addition to pooled reaction times for all of these events (all events). The effective emergent eccentricities of distant, intermediate and near pedestrians were 2.5°, 3.9° and 5.5°, respectively (see table 4.1). Again, reaction times to pedestrian crossing events that took place on the right and left hand sides of the road were averaged.

4.2.4 Data analysis

All test scores were transformed for the purposes of statistical analysis (see sections 2.5.1 and 2.5.2). Transformations were carried out in such a manner that a high score represented better test performance than a lower score. Repeatability was determined by examining the bias and limits of agreement (Bland & Altman, 1986, 1996) calculated from data collected during the two experimental sessions described above. Kendall's correlation was also used to rank each test in terms of its relative repeatability.

The bias (see table 4.2) was calculated by subtracting the data collected during the first session from that collected during the second session. This meant that a positive bias would indicate that test performance improved when repeated (i.e. a learning effect). One sample 2-tailed t-tests were applied to determine whether the bias exhibited a statistically significant departure from zero. Statistical significance was tested at the 95%, after applying Bonferroni's correction for multiple comparisons (Katz, 1997). As 52 analyses were carried out (13 tests x 4 age groupings: young, middle, older and pooled), Bonferroni's correction dictated that statistical significance at the 95% level corresponded to a probability of less than 0.0009.

The limits of agreement (see table 4.3) were calculated by multiplying the standard deviation of the bias by 1.96 (Bland & Altman, 1986, 1996). The reasoning behind the use of limits of agreement now follows. Chapters 5 - 7 examine the determinants of visual attention. Here, reference is made to variations in test performance that result from alteration of various factors (i.e. target position, clutter and motion). The influence of a given factor upon test performance is tested for statistical significance. However, a distinction must be drawn between statistical significance and clinical significance. A statistically significant effect can be observed even when the same effect is not clinically observable. The way to determine whether a statistically significant difference is clinically observable is to compare the former to the calculated limits of agreement of a test. For example, let us say that a factor altered the DRTS1 reaction time by 10 ms and that this effect was found to be statically significant. This 10 ms difference would only be clinically observable if the limits of agreement of that test were less than 10 ms.

Kendall's correlation (see table 4.4) was carried out on untransformed data collected during both sessions. It was necessary to use non-parametric correlation coefficients as there was considerable variation in the range of scores arising from each of the tests examined and because different units were used to measure static and kinetic visual attention. Parametric correlation coefficients would have been influenced by these factors and would thus give rise to misleading information about the relative repeatability of each test; in other words, a test with a wide range of scores would tend to yield a higher correlation coefficient than an equally repeatable test with a narrower range of scores. Non-parametric correlation coefficients, on the other hand, are based upon the degree to which the rank order of subjects, ranked in terms of test performance, remained the same in both experimental sessions. Each correlation coefficient was tested for statistical significance at the 95% level after Bonferroni's correction (i.e. the probability needed to be less that 0.0009 because 52 analyses were carried out).

Repeatability was assessed for each age group separately and after pooling subjects of all ages so that the influence of age upon repeatability could be examined.

4.3 Results and discussion

Table 4.2 shows the bias calculated from repeat measurements. One-sample 2-tailed t-tests revealed that none of the values achieved statistical significance at the 95% level. No age-related trends in the bias thus emerged.

Table 4.3 shows the limits of agreement arising from repeat measurements. The limits of agreement of all UFOV sub-tests consistently increased with age. No consistent trends emerged for kinetic visual attention (DRTS1 and DRTS2) sub-tests.

Table 4.4 shows Kendall's correlation coefficients for repeat measurements. Statistically significant correlations arose for nearly all sub-tests when results for subjects of all ages were pooled. Therefore, sub-tests were ranked in terms of these results. The highest ranking test was the total UFOV reduction. This illustrated that addition of processing speed, divided attention and selective attention losses to give a combined UFOV score had the effect of increasing the repeatability of the UFOV test. It also showed that the UFOV test was more repeatable than either of the kinetic visual attention tests (DRTS1 and DRTS2). Averaging reaction times for all events increased the repeatability of the DRTS2 test, but not the DRTS1 test. Due to the fact that correlation coefficients derived for individual age groups were not statistically significant, except for one instance, it was not possible to draw any conclusions about age trends. The poor repeatability of DRTS1 scores relative to those of DRTS2 may have arisen because each subject had sat the DRTS1 test 4 times, in order to explore factors influencing kinetic visual attention (see chapters 5-7), prior to taking part in the experimental sessions described in this chapter. This may have reduced their alertness to the DRTS1 test due to a state of boredom. Also the DRTS2 test could be considered a more ecologically valid test and consequently responses are more consistent.

Task	Age group	Bias			
		Young	Middle	Older	All subjects
Test	Sub-test	N = 12	N = 12	N = 12	N = 36
UFOV	Processing speed	0.000	<0.001	-0.002	-0.001
	Divided attention	0.000	<0.001	0.001	<0.001
	Selective attention	<0.001	0.002	0.001	0.001
	Total UFOV	<0.001	0.002	0.004	0.002
DRTS1	Center	0.014	0.052	-0.025	0.014
	Inner	-0.023	0.011	0.002	-0.003
	Middle	0.022	0.026	0.061	0.036
	Outer	0.021	0.035	0.101	0.052
	All	0.008	0.031	0.035	0.025
DRTS2	Distant	0.006	-0.032	0.025	<0.001
	Middle	-0.005	-0.038	0.025	-0.006
	Near	-0.006	-0.059	0.022	-0.014
	All	-0.002	-0.043	0.002	-0.007

Table 4.2: The bias (transformed test scores) arising from repeat measurements taken during two experimental sessions. Negative values indicate test performance reduced when repeated. All other values indicate that test performance did not alter or improved when repeated. One-sample 2-tailed t-tests revealed that none of the values achieved statistical significance at the 95% level after Bonferroni's correction for multiple comparisons was applied.

Task		Limits of agreement (transformed test scores)			
	Age group	Young	Middle	Older	All subjects
Test	Sub-test	N = 12	N = 12	N = 12	N = 36
UFOV	Processing speed	0 (0)	0.002 (1.4)	0.016 (17.1)	0.008 (8.7)
	Divided attention	0 (0)	0.002 (2.2)	0.016 (16.9)	0.008 (8.7)
	Selective attention	0.006 (6.5)	0.008 (8.7)	0.014 (13.3)	0.010 (13.8)
	Total UFOV	0.006 (6.5)	0.008 (8.6)	0.065 (54.5)	0.037 (37.0)
DRTS1	Center	0.14 (355)	0.41 (1359)	0.39 (2914)	0.33 (1233)
	Inner	0.20 (166)	0.19 (143)	0.10 (113)	0.17 (151)
	Middle	0.18 (158)	0.24 (215)	0.17 (278)	0.20 (215)
	Outer	0.25 (313)	0.31 (391)	0.24 (808)	0.27 (456)
	All	0.15 (383)	0.22 (545)	0.17 (788)	0.18 (545)
DRTS2	Distant	0.12 (131)	0.15 (180)	0.13 (235)	0.14 (186)
	Middle	0.13 (131)	0.13 (145)	0.15 (254)	0.14 (173)
	Near	0.13 (136)	0.18 (205)	0.14 (238)	0.16 (202)
	All	0.10 (104)	0.14 (160)	0.12 (206)	0.13 (164)

Table 4.3: The limits of agreement (transformed test scores) arising from repeat measurements taken during two experimental sessions.

Task	Age group	Kendall's correlation coefficient			
		Young	Middle	Older	All subjects
Test	Sub-test (**rank**)	N = 12	N = 12	N = 12	N = 36
UFOV	Processing speed (**12**)	0.000	0.000	0.122	0.296
	Divided attention (**3**)	1.000*	0.000	0.383	0.682*
	Selective attention (**2**)	0.572	0.192	0.525	0.750*
	Total UFOV (**1**)	0.621	0.257	0.528	0.763*
DRTS1	Center (**13**)	0.473	0.030	-0.273	0.240
	Inner (**10**)	0.168	0.394	0.515	0.548*
	Middle (**8**)	0.462	0.260	0.727	0.567*
	Outer (**7**)	0.212	0.333	0.667	0.569*
	All (**11**)	0.485	-0.091	0.303	0.492*
DRTS2	Distant (**5**)	0.229	0.303	0.485	0.591*
	Middle (**9**)	0.198	0.333	0.485	0.556*
	Near (**6**)	0.443	0.545	0.667	0.580*
	All (**4**)	0.290	0.485	0.485	0.627*

Table 4.4: Kendall's correlation coefficients for repeat measurements taken during two experimental sessions. Negative values indicate inverse relationships between repeated measurements. All other values indicate that direct relationships between repeated measurements. Asterisks indicate values that were statistically significant at the 95% level after Bonferroni's correction for multiple comparisons was applied. Sub-tests were ranked according to the magnitude of the correlation coefficients determined for all subjects.

Previous research by Ball et al (1990) during the development of the UFOV test looked at repeatability. This study included 86 participants divided into three age groups; young (<40 years), middle (41 –59 years) and older (>60 years). They found the total UFOV score to have good test-retest reliability. The values for the correlation coefficient (r) found by Ball et al (1990) and the values found in this study for the UFOV test are shown in table 4.5.

Test	r value
N = 86 (after Ball et al., 1990)	
UFOV	0.92
N = 36	
Processing speed	0.83
Divided attention	0.78
Selective attention	0.95
Total UFOV	0.90

Table 4.5: The r values for the UFOV repeatability performed by Ball et al and the results from this study.

The results indicate that the UFOV is highly repeatable, as the results are very similar for both studies.

4.4 Summary

The results presented in this chapter show that:

- Age exerted no clear influence upon repeatability described in terms of bias, limits of agreement or correlation coefficients,
- The absence of statistically significant bias (table 4.2) indicated that there were no learning effects for any of the sub-tests investigated,
- The limits of agreement presented in table 4.3 are referred to in chapter 8 (age effects) as a means of distinguishing between statistically and clinically significant effects,
- The correlation coefficients shown in table 4.4 indicate that the UFOV test is more repeatable than either of the kinetic visual attention tests.

CHAPTER FIVE

COMPARISON OF STATIC AND KINETIC VISUAL ATTENTION TESTS: POSITIONAL EFFECTS

NB For a full key see page -10-.

5.1 Introduction

This chapter provides an account of the research carried out on target position as a determinant of static (UFOV) and kinetic (DRTS1 and 2) visual attention.

The primary aim of this research was to examine target eccentricity. It is well known that the human eye is less sensitive to perimetric stimuli presented in the periphery compared to those presented at the fovea (Harrington, 1976). As the targets of the UFOV, DRTS1 and DRTS2 appeared at various eccentricities, it was possible to determine whether a similar reduction of sensitivity occurred for visual attention tests.

The question of target laterality also arose. All three of the visual attention tests presented targets in the right and left visual field. Could the fact that we drive on the left-hand side of the road in the UK influence our sensitivity to targets emerging from either side of the road? For instance, the UFOV test presents peripheral targets that represent silhouettes of cars or lorries (see section 2.2.5.1). Subjects might be more sensitive to vehicular targets being presented in their right visual field, as vehicles travelling towards us on the opposite side of the road will tend to be seen to our right. On the other hand, pedestrian targets are presented during tests carried out on the DRTS1 (see section 2.3.3) and DRTS2 (see section 2.3.4). Subjects might then be more sensitive to targets presented in the left visual field, as we may be more alert to the likelihood of pedestrians crossing from the left (nearside) kerb.

Finally, the UFOV presents targets at any one of eight radial locations (see section 2.2.5). This provided an opportunity to investigate this aspect of target position. Interestingly, the inventors of the UFOV test claimed that radial location did not influence the ability to correctly locate peripheral targets (Sekuler & Ball, 1986) while a later study claimed that targets presented in the right or left visual fields were more accurately located than targets presented in the superior and inferior visual fields (Pauzie et al., 1998).

5.2 Methods

Data were collected from 36 healthy subjects divided equally into three age groups (see section 2.4.2.1).

Position	Definition of position	Interaction factors		
		Eccentricity	Distraction	Age
UFOV (peripheral target location errors)				
Eccentricity	10°, 20°, 30°	-	✓	✓
Lateral	Left or right	✓	✓	✓
Radial location	Spoke 1 – 8	✓	✓	✓
DRTS1 (reaction times)				
Eccentricity	2.5°, 5°, 7.5°	-	✓	✓
Lateral	Left or right	✓	✓	✓
DRTS2 (reaction times)				
Eccentricity	2.5°, 3.9°, 5.5°	-	-	✓
Lateral	Left or right	✓	-	✓

Table 5.1: Summary of the target positions and interactions investigated using each visual attention test. Ticks indicate interactions investigated. Dashes indicate interactions that were either not appropriate or could not be investigated.

Table 5.1 summarises the target positions, type of data analysed and the interactions that were investigated using each visual attention test. For the UFOV test, the percentage of peripheral target location errors for each eccentricity (10°, 20°, 30°) and radial location (spoke 1 - 8, see section 3.3.3) were calculated from each subject's trial by trial listing (section 3.3.3). Reaction times to pedestrian crossing events were analysed in the case of the DRTS1 and DRTS2 tests. For the DRTS1 test, this included reaction times recorded when pedestrians suddenly crossed the road at emergent eccentricities of 2.5, 5° and 7.5°. For the DRTS2 test, this included reaction times recorded when pedestrians suddenly crossed the road at distances from the subject of 41 m, 26 m and 19 m. The effective emergent eccentricities of these pedestrians were 2.5°, 3.9° and 5.5°, respectively (see table 2.1).

All test scores were transformed for the purposes of statistical analysis (see sections 2.4.5 and 2.4.6). Transformations were carried out in such a manner that a high score represented better test performance than a lower score. Effects and interactions were tested for statistical significance at the 95% level using factorial ANOVA's followed by Bonferroni/Dunn post-hoc tests (Abacus Concepts, 1996; Katz, 1997). The interactions examined included eccentricity, clutter and age.

The interactive effects of clutter could only be examined for the UFOV and DRTS1 tests. For the UFOV test, the peripheral target location errors for the divided attention task served as the "no clutter" condition as, for this task, only the peripheral target would appear in the visual field (see section 2.2.5.2). The selective attention task served as the "clutter" condition as, for this task, the peripheral target was embedded in a field of 47 distracting symbols (see section 2.2.5.3); giving rise to a target : distractor ratio of 1:47. For the DRTS1 test, data collected from two modified versions of this test were analysed (a more detailed description of these is provided in section 6.2). The ratio between target and distractor pedestrians was varied from 1:6, for the "low clutter" condition, to 1:30 for the "high clutter" condition. Both versions were run in counterbalanced order (see section 6.2).

5.3 Results

5.3.1 Eccentricity effects

Eccentricity influenced UFOV peripheral target location errors ($F_{2,1388} = 78.766$, $P<0.0001$) and exhibited an interaction with clutter ($F_{2,1388} = 44.156$, $P<0.0001$) but not age ($F_{4,1388} = 2.307$, $P = 0.0562$). Analysis of the interaction between eccentricity and clutter revealed that peripheral target location was only influenced by eccentricity in the presence of clutter ($F_{2,827} = 99.504$, $P<0.0001$). Here, peripheral target location became less accurate as eccentricity increased (see figure 5.1). Post-hoc analysis (Bonferroni/Dunn) revealed that peripheral target location errors differed for all eccentricities ($P<0.0001$ in each case).

Eccentricity also influenced reaction times measured using the DRTS1 test ($F_{2,396} = 19.894$, $P<0.0001$) but no interactions were found with clutter ($F_{2,396} = 1.054$, $P = 0.3497$) or age ($F_{4,396} = 1.208$, $P = 0.3068$). Figure 5.2 shows that subjects reacted more slowly as eccentricity increased. Post-hoc analysis revealed that reaction times recorded for outer targets differed from those measured for inner ($P<0.0001$) and middle ($P = 0.0015$) targets. The difference between reaction times measured for inner and middle targets did not achieve statistical significance. Interestingly, target eccentricity had no statistically significant influence upon reaction times measured using the DRTS2 ($F_{1,198} = 2.237$, $P = 0.1094$).

5.3.2 Laterality effects

Laterality did not exert a statistically significant influence upon either the UFOV ($F_{1,347} = 2.062$, $P = 0.1520$) or DRTS1 ($F_{1,396} = 3.485$, $P = 0.0626$) test results. It did, however, influence reaction times measured using the DRTS2 test ($F_{1,198} = 5.277$, $P = 0.0226$), although no interactions were found with eccentricity ($F_{2,198} = 0.204$, $P = 0.8155$) or age ($F_{1,198} = 0.005$, $P = 0.9995$). Figure 5.3 shows that subjects responded more quickly to pedestrian targets emerging from the left.

5.3.3 Radial location effects

Peripheral location errors made on the UFOV test were influenced by radial location ($F_{7,1388} = 6.659$, $P<0.0001$). Both eccentricity ($F_{14,1388} = 2.022$, $P = 0.0136$) and clutter ($F_{7,1388} = 2.978$, $P = 0.0042$) interacted with radial location. However, no statistically significant interaction was found with age ($F_{14,1388} = 1.022$, $P = 0.4283$). Analysis of the interaction between eccentricity and radial location revealed that peripheral location errors were only influenced by radial location at the 20° target eccentricity ($F_{7,502} = 3.458$, $P = 0.0013$). Post-hoc analysis revealed that responses to the lower target (spoke 5) were less accurate than those recorded for targets to the left (spoke 7, $P = 0.0004$) and upper-left (spoke 8, $P = 0.0003$). Analysis of the interaction between clutter and radial location showed that peripheral location errors were only influenced by radial location in the presence of clutter ($F_{7,822} = 5.068$, $P<0.0001$). In this case, Post-hoc analysis showed that the peripheral location was less accurate for the lower target (spoke 5) compared to targets located to the right (spoke 3°, $P<0.0001$), lower-right (spoke 4, $P = 0.0006$), lower-left (spoke 6, $P = 0.0009$), left (spoke 7, $P=0.0004$) and upper-left (spoke 8, $P = 0.0008$).

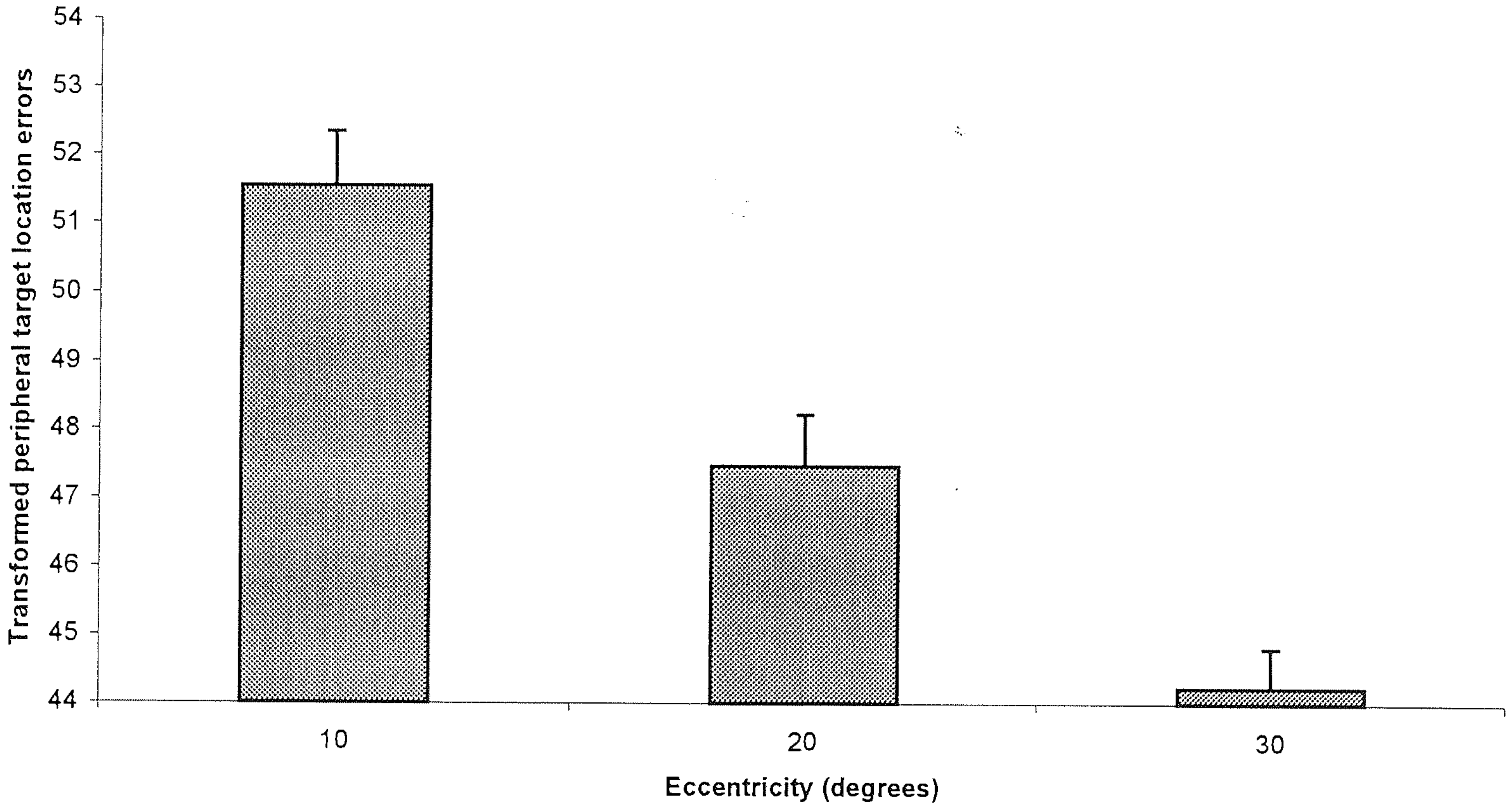


Figure 5.1: Transformed peripheral target location errors (mean and upper 95% confidence limit) measured using the UFOV test in the presence of clutter and plotted as a function of eccentricity. Results for all age groups and radial locations were pooled for this graph.

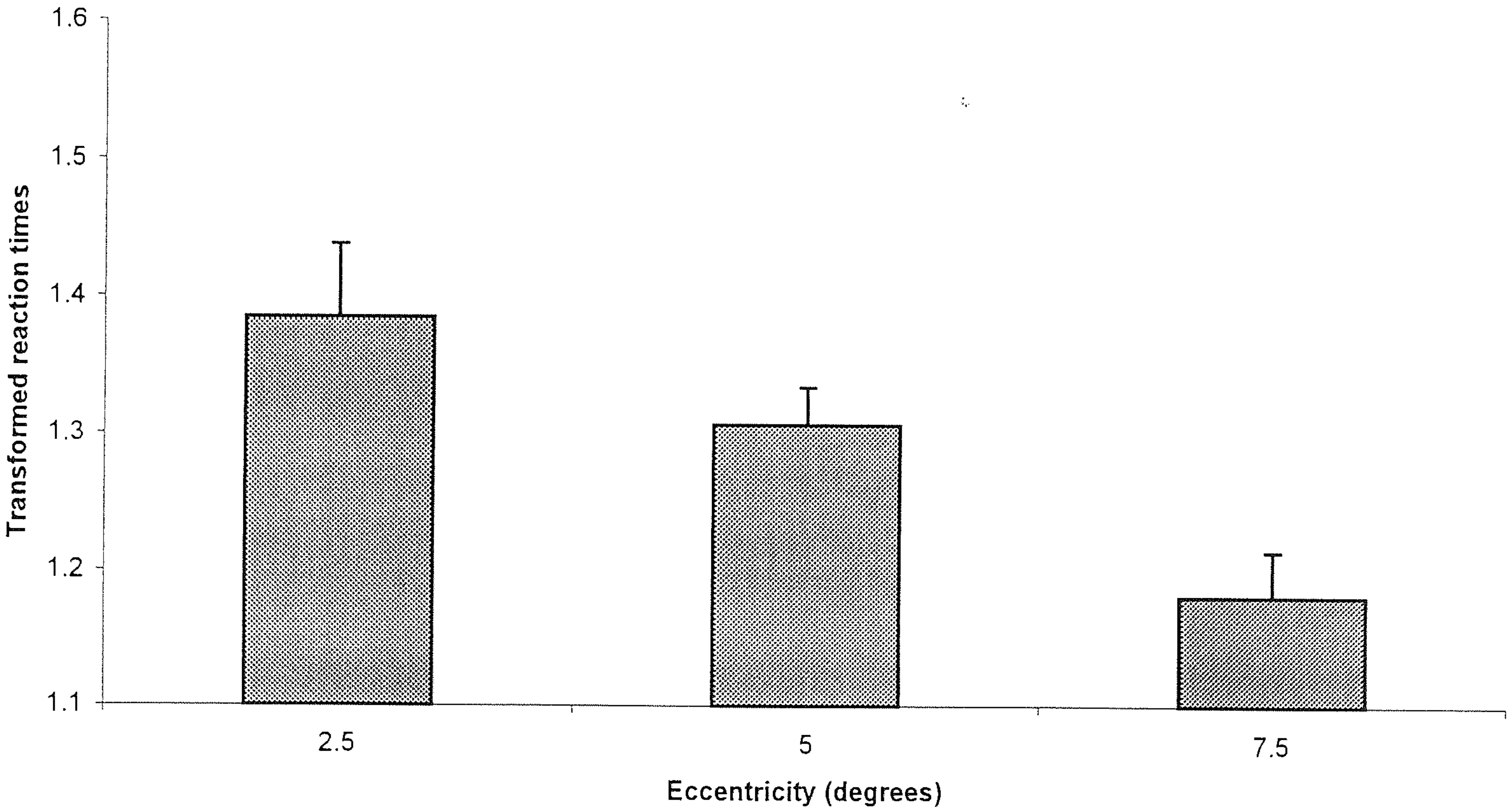


Figure 5.2: Transformed reaction times (mean and upper 95% confidence limits) measured using the DRTS1 test. All age groups, levels of clutter and laterality were pooled for this graph.

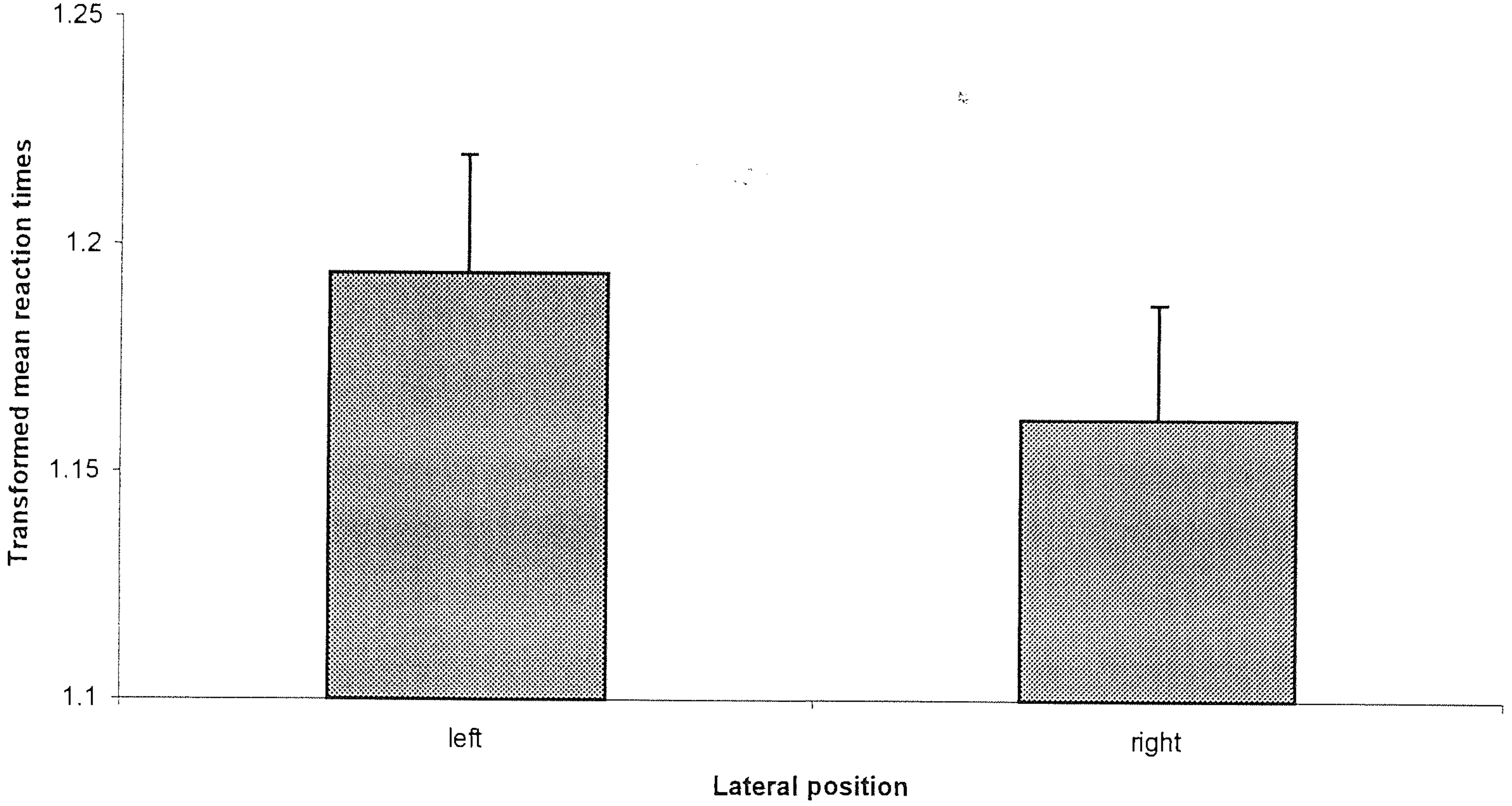


Figure 5.3: Transformed reaction times (mean and upper 95% confidence limits) measured using the DRTS2 test for targets presented to the left and right visual field. All age groups and target eccentricities were pooled for this graph.

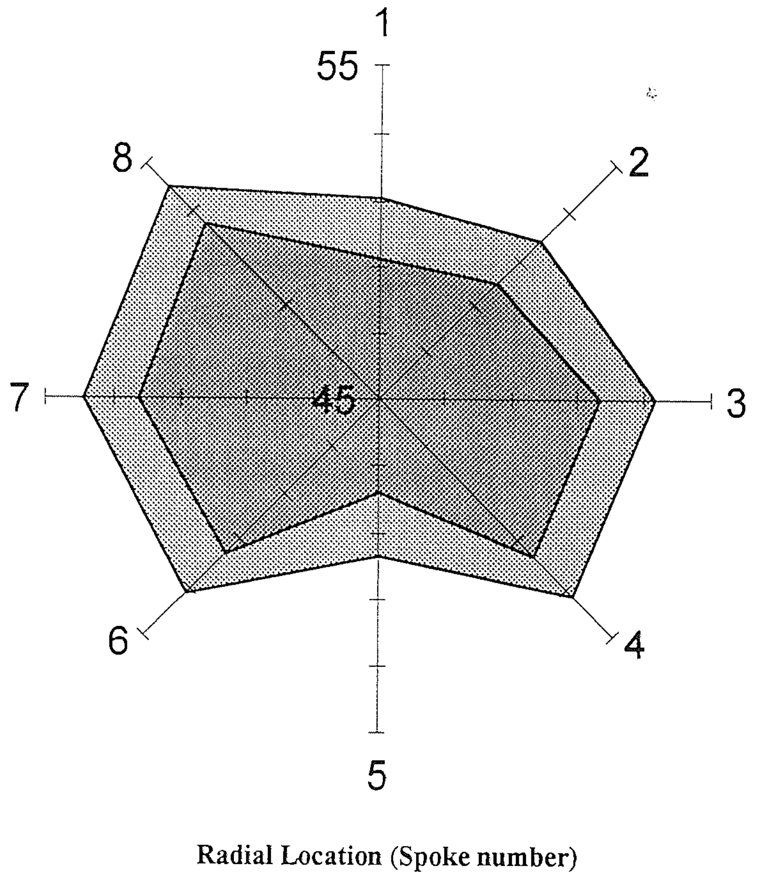


Figure 5.4: Transformed peripheral target location errors (mean; dark grey area and upper 95% confidence limits; light grey area) for the eight radial locations of the UFOV test measured for the 20° eccentricity. All age groups and levels of clutter were pooled for this graph. Note the radial locations that correspond to right (spoke 3), left (spoke 7) upper (spoke 1) and lower (spoke 5). Scale 45 – 55 transformed units.

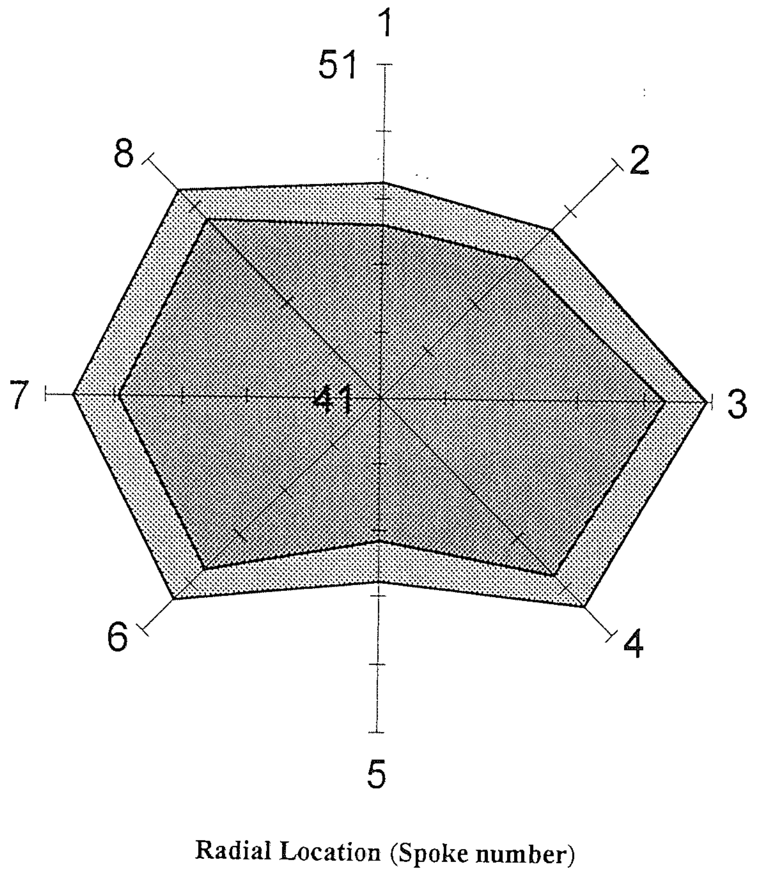


Figure 5.5: Transformed peripheral target location errors (mean; dark grey area and upper 95% confidence limits; light grey area) for the eight radial locations of the UFOV test measured in the presence of clutter. All age groups and eccentricities were pooled for this graph. Note the radial locations that correspond to the right (spoke 3), left (spoke 7), upper (spoke 1) and lower (spoke 5) targets. Scale: 41 – 51 transformed units.

5.4 Discussion

A strong eccentricity effect was found for both the UFOV (figure 5.1) and DRTS1 (figure 5.2) tests, which is consistent with previous research (Cerella, 1985; Scialfa et al., 1987; Szlyk et al., 1993; Owsley et al., 1994; Wood, 1995; Crundall et al., 1999). No such result was found for the DRTS2. There are two possible explanations for this. Firstly, the DRTS2 test had a very different style of presentation than either of the other tests. The road scene was more realistically rendered and pedestrian targets were located at the edge of the kerb at varying distances away from the subject. Although this meant that targets emerged from different eccentricities, other target parameters may have confounded the eccentricity effect. For example, the most distant target emerged at the lowest eccentricity. Although the low eccentricity of this target should have elicited the quickest reaction time, this target will also have been smaller than closer targets emerging from greater eccentricities. This variation in size may have confounded the eccentricity effect. In contrast, no such size variation occurred for UFOV and DRTS1 targets emerging from different eccentricities were. Secondly, the eccentricities examined using the DRTS2 test were smaller (maximum = 5.5°) than those used in the DRTS1 (maximum = 7.5°) and UFOV (maximum = 30°) tests. The eccentricity effect may not be evident for such small eccentricities. Indeed, results of the DRTS1 test (Figure 5.2) support this as no statistically significant difference arose for targets at eccentricities of 2.5° and 5°.

The observation, relating to the UFOV test, that the eccentricity effect is only apparent in the presence of clutter is consistent with previous research (Brouwer & Ponds, 1994; Scialfa et al., 1987; Sekuler & Ball, 1986). That the eccentricity effect was evident when the DRTS1 test was run at both low (1:6) and high (1:30) target : distractor ratios also has support in the literature; Ball et al (1988) found a similar effect for the UFOV test when the target : distractor ratio was increased from 1:12 to 1:47. This may serve as evidence that static and kinetic targets are located in a pre-attentive (parallel search) fashion (see section 2.2.3).

Laterality did not exert a statistically significant influence upon the UFOV and DRTS1 tests. Yet again, this was at variance with the DRTS2 test for which laterality was statistically significant. Here, subjects responded more quickly to pedestrians emerging from the left (see figure 5.3). This difference may have arisen because the DRTS2 test, being more realistically rendered than the UFOV or DRTS1 tests, elicited subject responses that were more akin to natural driving behaviour.

The finding that radial location influenced peripheral location errors measured using the UFOV test (see figure graph 5.1) contradicts the work of Sekuler and Ball (1986) who stated that there was no such effect, though they provide no statistical evidence to support their statement. The results presented in figure 5.1 provide evidence that subjects are more able to locate targets presented in the horizontal meridian (i.e. to the left and right) than in the vertical meridian (i.e. above and below). Support for this emerges from research carried out by Pauzie and Gabaude (1998) on their version of a visual attention test that presented static targets in the periphery with a kinetic central task.

5.5 Summary

The results presented in this chapter show that:

- The well known reduction of retinal sensitivity to perimetric targets presented at progressively larger eccentricities was reflected in both static (UFOV) and kinetic (DRTS1) visual attention tests. The DRTS2 test did not exhibit such an effect but this may have been due to the style of presentation of its targets and the limited eccentricities examined.
- Only one of the kinetic visual attention tests (DRTS2) exhibited a laterality effect. This may also have been due to the style of presentation of its targets.
- Radial location influenced peripheral target location errors measured using the UFOV test.

CHAPTER SIX

FACTORS THAT INFLUENCE STATIC AND KINETIC VISUAL ATTENTION TESTS: DISTRACTION EFFECTS

NB For a full key see page -10-.

6.1 Introduction

This chapter provides an account of the research carried out on distraction (i.e. clutter) as a determinant of static and kinetic visual attention. The influence of field width on kinetic visual attention was also examined as it was considered that its effects might be similar to that of clutter.

Clutter is an integral part of visual attention tests (see section 2.3.2). It also represents one of the fundamental differences between visual attention tests and perimetry, as perimeters lack clutter. Yet, increased levels of clutter have a detrimental effect on the size of the functional field (Bloomfield, 1972; Drury & Clement, 1978; Williams, 1983; Sekuler & Ball, 1986; Scialfa et al., 1987; Ball et al., 1988, 1990a) particularly for drivers (Lee & Triggs, 1976; Miura, 1986; Crundall et al., 1999). Older drivers are more easily distracted by clutter (Rabbit, 1965; Tipper, 1991; Sauer et al., 2001) and have greater difficulty locating road signs that are embedded in clutter (Kosnik et al., 1990; Wood & Troutbeck, 1994a, 1994b) particularly when they are moving (Kosnik et al., 1988). Crash rates are also more closely related to performance on visual tasks that include clutter (Avolio et al., 1986).

Field width relates to the area over which targets may appear. Clutter and field width may have similar effects on visual attention. Whereas clutter draws attention away from the target by presenting the visual system with the burden of having to isolate the target from numerous similar objects in the field, field width may do the same by broadening the area over which the visual system needs to search in order to locate potential targets.

6.2 Methods

Data were collected from 36 healthy subjects divided equally into three age groups (see section 2.4.2.1). Table 6.1 summarises the clutter and field width parameters and interactions that were investigated using static (UFOV) and kinetic (DRTS1) visual attention tests. For the UFOV test, the percentage of peripheral target location errors was calculated from each subject's trial by trial listing (section 3.3.3). For the DRTS1 test, reaction times to pedestrian crossing events were analysed. It was not possible to vary the clutter or field width of the DRTS2 test, so this test was not used in this investigation.

Parameters		Interactions		
		Radial location	Eccentricity	Age
CLUTTER				
Test	Target:distractor ratios			
Static visual attention (UFOV)	1:0 and 1:47	✓	✓	✓
Kinetic visual attention (DRTS1)	1:6, 1:18 and 1:30	-	✓	✓
FIELD WIDTH				
Test	Target areas			
Kinetic visual attention (DRTS1)	5°, 10° and 15°	-	-	✓

Table 6.1: Summary of clutter and field width parameters and interactions investigated using static and kinetic visual attention tests. Ticks indicate interactions investigated. Dashes indicate interactions that could not be investigated. The DRTS2 was not used in this investigation.

As previously explained (see section 5.2), two levels of clutter were examined for the UFOV test. The divided attention task represented the "no clutter" condition (target : distractor ratio = 1:0) while the selective attention task served as the "clutter" condition (target : distractor ratio = 1:47). The UFOV is a standard test, which means that the order of sub-tests is pre-fixed. In all trials of the UFOV subjects performed the low clutter condition before the high clutter condition.

Although a brief explanation of how clutter was varied for the DRTS1 test was provided in the last chapter (see section 5.2), a more detailed explanation now follows. Section 2.3.3 has described how pedestrians were organised in rows of 6; 5 of these being distractor pedestrians and one, chosen at random, being a target pedestrian that moved out of the flow field (i.e. crossed the road). The distance between roadside lampposts governed the separation of each pedestrian row. At the default setting of 100m, 4 rows of pedestrians would be seen by subjects at one time; as the road was 400m long. Thus the ratio of target : distractor stimuli (including the leading car) was 24:1. At a lamppost setting of 400m, only 1 row of pedestrians would be seen at any moment and this ratio would drop to 6:1. Similarly lamppost settings of 133m and 80 m gave rise to 3 and 5 rows of pedestrians, respectively, leading to ratios of 18:1 and 30:1, respectively. Each subject was tested at target : distractor ratios of 6:1, 18:1 and 30:1, representing progressively increasing levels of clutter. The order of treatments was counterbalanced to avoid unwanted bias (see appendix 6a).

It was only possible to examine the effect of field width on kinetic visual attention (DRTS1). In its default mode, DRTS1 pedestrians' crossed the road at eccentricities of 2.5° (inner), 5° (middle) and 7.5° (outer). In this mode, subjects had to spread their attention over a field of 15°. The DRTS1 program offered the option of "switching off" the outer and middle pedestrian crossing events, thereby reducing the field to 10° and 5°, respectively. In these modes, outer and middle pedestrians would still be visible in the field but would never cross. This also meant that the target : distractor ratio remained unchanged. The rationale behind this part of the study was to determine how field width influenced reaction times. Reaction times were pooled for leading car and inner pedestrian events, as these were the only events tested at all field widths. Each subject was tested with the DRTS1 set for field widths of 15°, 10° and 5°. In all cases, the target : distractor ratio was 1:24. The order of treatments was, again, counterbalanced to avoid unwanted bias (appendix 6a).

All test scores were transformed for the purposes of statistical analysis (see sections 2.5.1 and 2.5.2). Transformations were carried out in such a manner that a high score represented better test performance than a lower score. Effects and interactions were tested for statistical significance at the 95% level using factorial ANOVAs followed by Bonferroni/Dunn post-hoc tests (Abacus Concepts, 1996; Katz, 1997). Interactions examined included eccentricity (10°, 20° and 30° for UFOV; 2.5, 5° and 7.5° for DRTS1), age and radial location (spokes 1 - 8, see section 3.3.3).

6.3 Results

6.3.1 Clutter effects

Clutter influenced UFOV peripheral target location errors ($F_{1,\ 1388}$ = 722.530, P<0.0001) and exhibited interactions with radial location ($F_{7,\ 1388}$ = 2.978, P = 0.0042), eccentricity ($F_{2,\ 1388}$ = 44.156, P<0.0001) and age ($F_{2,\ 1388}$ = 196.364, P<0.0001). Clutter reduced the accuracy of peripheral target location at all radial locations, eccentricities and for all age groups (see table 6.2). This effect became more pronounced for upper (spoke 1) and lower (spoke 5) radial locations compared those to the right (spoke 3) and left (spoke 7) (see figure 6.1), as eccentricity increased (see figure 6.2) and for middle aged drivers (see figure 6.3).

Interaction with clutter	Statistical significance
Radial location (spoke number)	
1 (up)	$F_{1,192}$ = 84.551, P<0.0001
2	$F_{1,186}$ = 65.716, P<0.0001
3 (right)	$F_{1,190}$ = 53.421, P<0.0001
4	$F_{1,194}$ = 44.815, P<0.0001
5 (down)	$F_{1,191}$ = 86.850, P<0.0001
6	$F_{1,187}$ = 28.958, P<0.0001
7 (left)	$F_{1,189}$ = 43.092, P<0.0001
8	$F_{1,187}$ = 62.130, P<0.0001
Eccentricity	
10°	$F_{1,513}$ = 45.560, P<0.0001
20°	$F_{1,508}$ = 171.952, P<0.0001
30°	$F_{1,505}$ = 379.994, P<0.0001
Age group	
Young	$F_{1,516}$ = 157.186, P<0.0001
Middle	$F_{1,510}$ = 304.829, P<0.0001
Older	$F_{1,500}$ = 152.910, P<0.0001

Table 6.2: The statistical significance of the effect of clutter on UFOV peripheral location errors for each radial location (spoke number), eccentricity and age group.

Clutter also influenced reaction times measured using the DRTS1 test ($F_{2,\ 297}$ = 43.047, P<0.0001) and exhibited interactions with eccentricity ($F_{4,\ 297}$ = 89.743, P<0.0001) and age ($F_{4,\ 297}$ = 3.823, P = 0.0048). Clutter only had a statistically significant effect at the 5° eccentricity ($F_{2,\ 105}$ = 3.349, P<0.0001). Here, curiously, post-hoc tests (see also figure 6.4) revealed that reaction times recorded for target : distractor ratios of 1:6 were worse than those recorded for target : distractor ratios of 1:18 (P=0.0004) and 1:30 (P=0.0030). Clutter also only affected younger ($F_{2, 105} = 6.192$, P = 0.0029) and middle aged ($F_{2, 105} = 7.532$, P = 0.0009) drivers but not the older age group ($F_{2, 105} = 1.696$, P = 0.1885). As before, post hoc tests (see also figure 6.5) revealed that reaction times recorded for low amounts of clutter were worse than those recorded for higher amounts of clutter in the case of both younger (P = 0.0018 for 1:6 versus 1:18; P = 0.0051 for 1:6 versus 1:30) and middle aged (P = 0.0006 for 1:6 versus 1:18) drivers.

6.3.2 Field effects

Disappointingly, field width did not influence reaction times measured using the DRTS1 test ($F_{2, 197} = 0.240$, P = 0.7870).

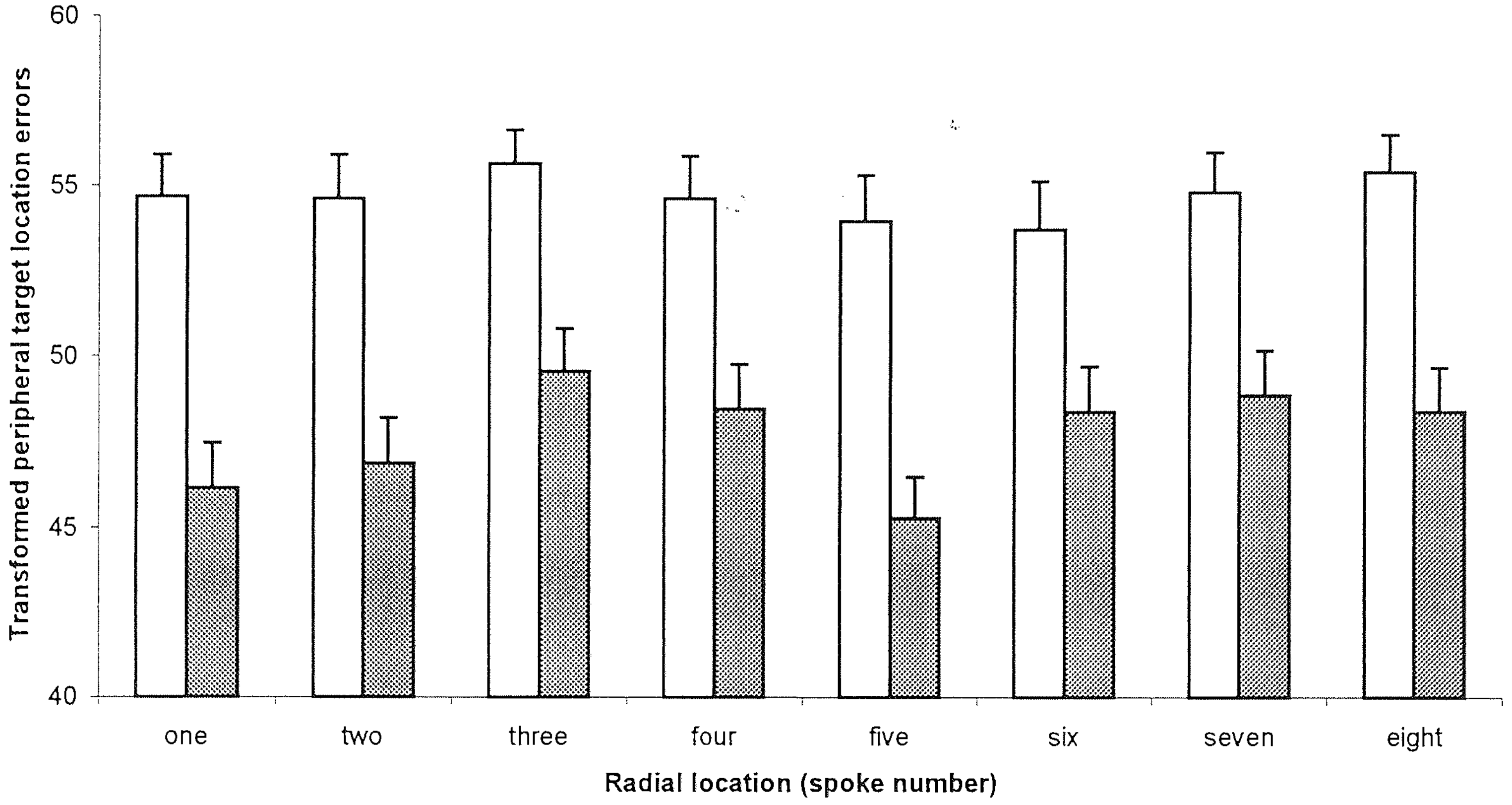


Figure 6.1: Transformed peripheral target location errors (mean and upper 95% confidence limit) for the eight radial locations of the UFOV test measured without clutter (white bars) and with clutter (grey bars). All age groups and eccentricities were pooled for this graph. Note the radial locations that correspond to right (spoke three), left (spoke seven), upper (spoke one) and lower (spoke five) targets.

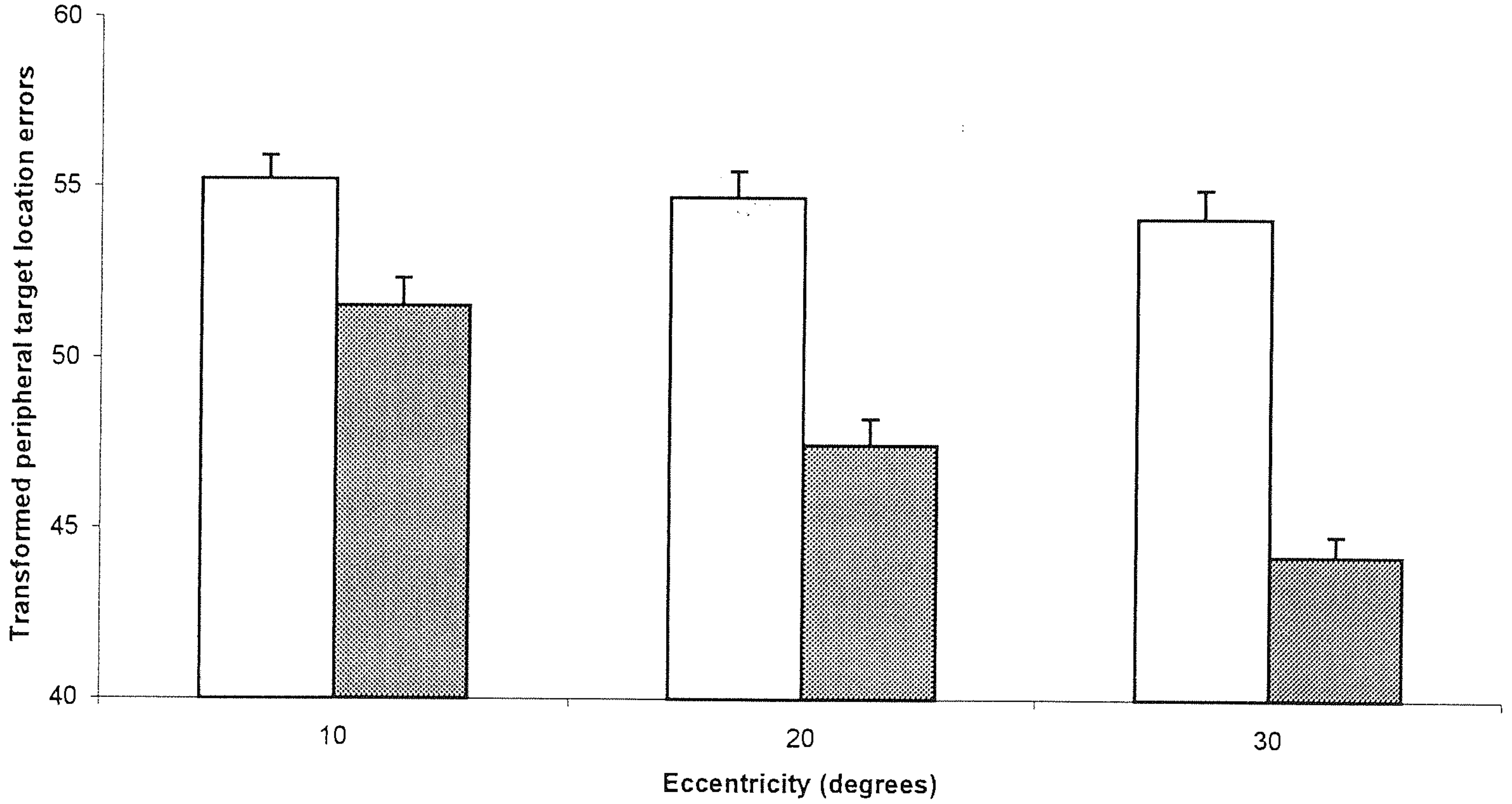


Figure 6.2: Transformed peripheral target location errors (mean and upper 95% confidence limit) for the three eccentricities of the UFOV test measured without clutter (white bars) and with clutter (grey bars). All age groups and radial locations were pooled for this graph.

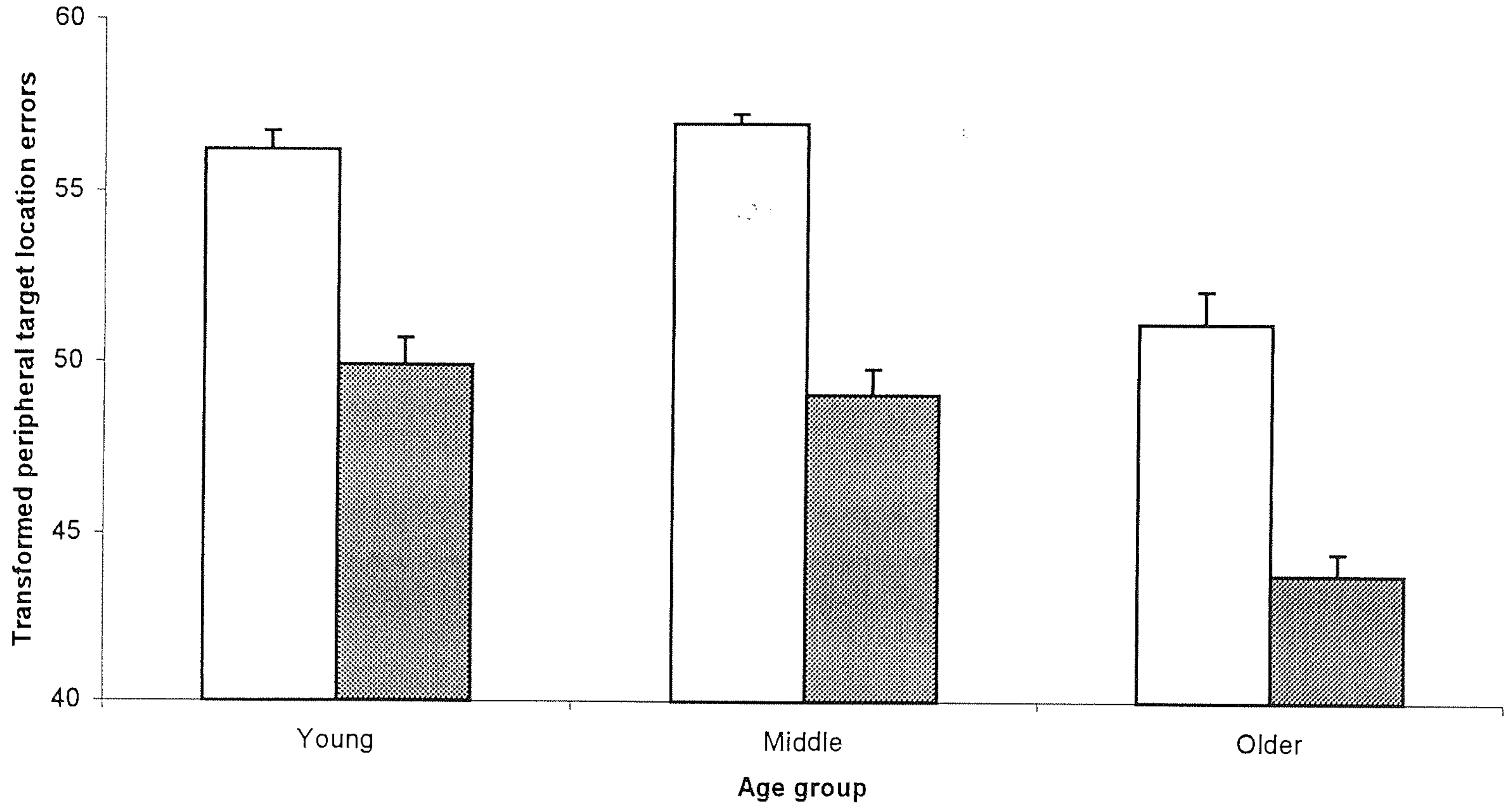


Figure 6.3: Transformed peripheral target location errors (mean and upper 95% confidence limit) for UFOV tests carried out on young, middle and older subjects without clutter (white bars) and with clutter (grey bars). All radial locations and eccentricities were pooled for this graph.

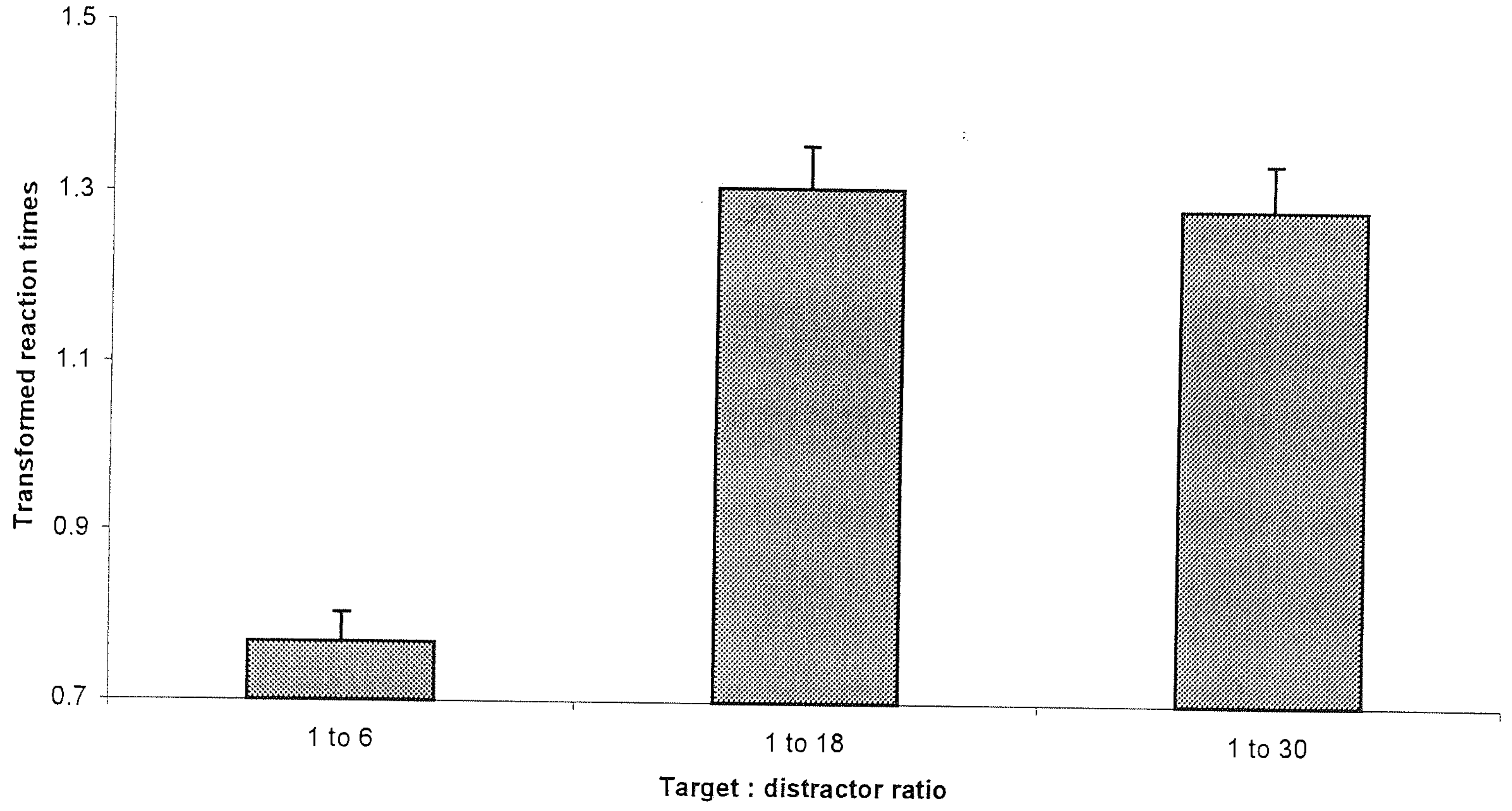


Figure 6.4: Transformed reaction times (mean and upper 95% confidence limit) for DRTS1 pedestrian targets that emerged at an eccentricity of 5° under three levels of clutter; target : distractor ratios of 1:6, 1:18 and 1:30.

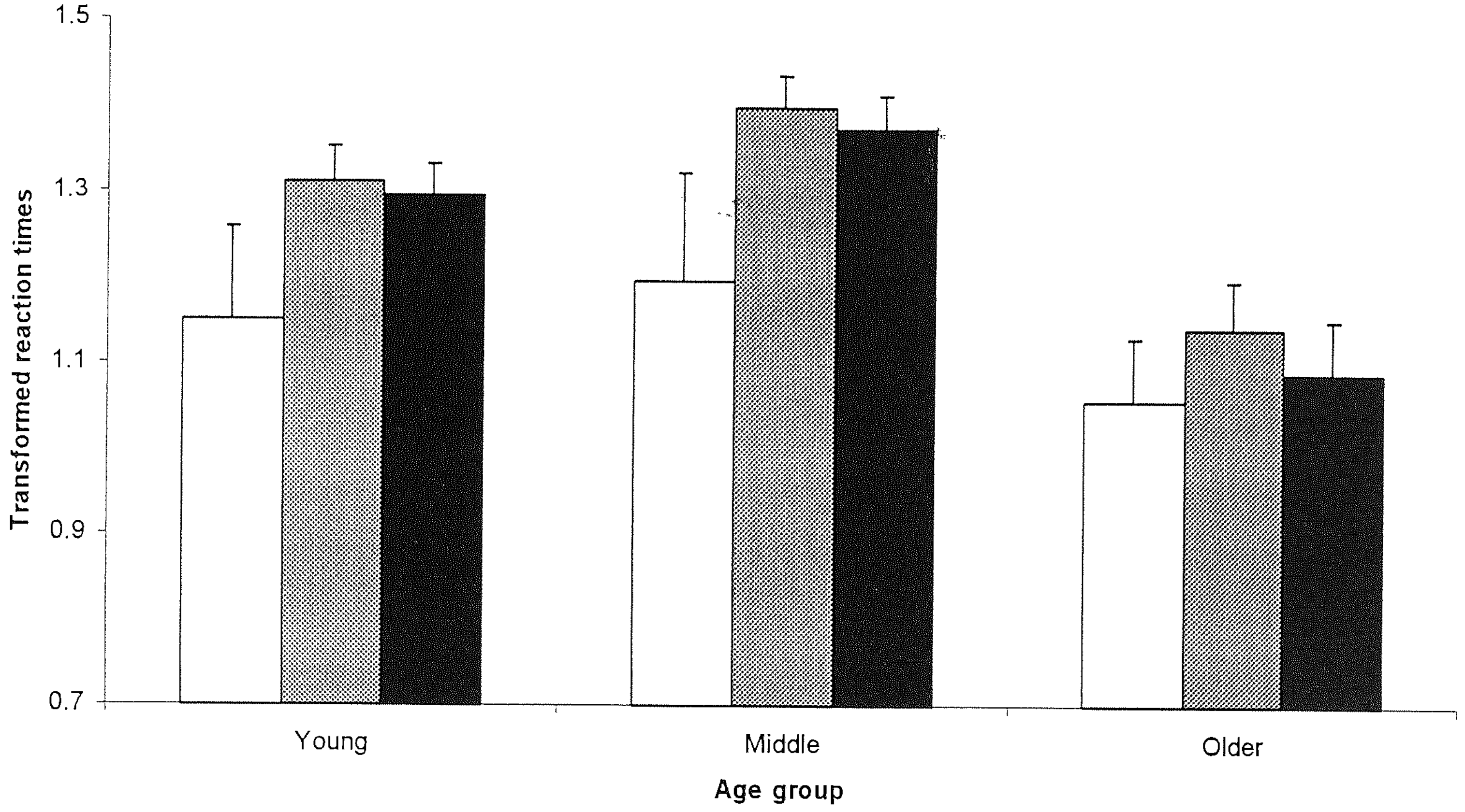


Figure 6.5: Transformed reaction times (mean and upper 95% confidence limit) for the DRTS1 test carried out on young a middle-aged drivers under three levels of clutter; target : distractor ratios of 1:6 (white bars), 1:18 (grey bars) and 1:30 (black bars).

6.4 Discussion

For static visual attention (UFOV), the presence of clutter reduced the accuracy of peripheral target localisation. The severity of this effect increased for targets located above and below fixation (see figure 6.1), as eccentricity increased (see figure 6.2) and for middle-aged drivers (see figure 6.3). That radial location influenced the clutter effect (see figure 6.1) contradicts the findings of Sekuler and Ball (1986) who claimed that radial location had no influence on peripheral target location. The results presented in this chapter do, however, lend some support to the work of Leibowitz et al. (1955), Pauzie and Gabaude (1998), Fine (2000) and Sauer et al. (2001), each of whom claimed that radial location did influence target location.

For kinetic visual attention (DRTS1), the presence of clutter improved reaction times; quite the opposite effect to that observed for static visual attention. This effect was only statistically significant for pedestrians that crossed the road at emergent eccentricities of 5° (see figure 6.4) and for young and middle-aged drivers (see figure 6.5). One explanation for this may be that the lack of clutter gave rise to a state of inattention so that, through reallocation of attentional resources, reaction times slowed down. The reason why this did not occur for the static visual attention test may have been that the UFOV test presents stimuli very briefly (maximum duration = 240 ms), so that subjects remain alert. Target pedestrians of the DRTS1 test, on the other hand, remained on the screen for several seconds, so that subjects may have allowed their attention to wander. Another surprise finding was that clutter did not influence reaction time for the older age group. Previous research has revealed that older subjects have smaller functional fields of view (Cerella, 1985; Scialfa et al., 1994; Kosslyn et al., 1999), are less able ignore distraction (Rabbitt, 1965; Tipper, 1991; Sauer et al., 2001) and often need to recheck the presence of a target, thereby increasing their reaction times (Plude & Doussard-Roosevelt, 1989). It is, of course, possible that the above effects caused such variation in the data for older subjects that any clutter effects were completely masked.

The absence of a field width effect was unexpected but may have been due to the fact that subjects were not told that only certain pedestrian targets would cross. For example, as explained in section 6.2, middle and outer pedestrians would remain in the field as clutter even if it were only the inner pedestrians that were programmed to cross the road. Therefore, subjects may have tended to spread their attention over the entire field of distractor pedestrians regardless of the fact that target pedestrians would only have emerged from more central locations. The outcome of this experiment might also have changed had the pedestrians that had been "switched off' (see section 6.2) as potential target pedestrians been removed from the field altogether. This will have meant that the target : distractor ratio would no longer remain constant but would have changed from 1:24 for a 15° field width, through 1:16 for a 10° field width, to 1:8 for a 5° field width.

6.5 Summary

The results presented in this chapter show that:

- Clutter influenced static visual attention (UFOV). The accuracy of peripheral target location declined in the presence of clutter and this effect became more pronounced as eccentricity and for middle aged drivers. This effect was also influenced by radial location.
- Clutter had the opposite effect on kinetic visual attention (DRTS1). Reaction times improved in the presence of clutter. This effect only achieved statistical significance for pedestrians that emerged from the 5° eccentricity and for young and middle-aged drivers.

CHAPTER SEVEN

COMPARISON OF STATIC AND KINETIC VISUAL ATTENTION TESTS: MOTION EFFECTS

NB For a full key see page -11-.

7.1 Introduction

This chapter provides an account of the research carried out to investigate the influence of motion upon static and kinetic visual attention. Four aspects of motion were investigated:

- static versus kinetic target presentation
- angular versus longitudinal target motion
- self-motion (travelling speed)
- optic flow field effects, target edge speed and eccentricity

Motion detection is a fundamental property of the human visual system (Conchillo et al., 1997; Gray, 1999; see also section 2.3.1.3) and is an ecological requirement, for example, the detection of movement will have enhanced the hunting skills and ensured the survival of our ancestors (Rosenholtz, 1999). Today, the accurate detection of moving objects is vital for everyday events such as driving (Porciatti et al., 1998). Henderson and Burg (1974) considered the detection of angular and longitudinal motion to be more important for driving than either the size of the useful field of view, attentive fixations or dynamic visual acuity.

Investigation of static versus kinetic target presentation was of interest as these modes of target presentation represent the primary differences between the static and kinetic visual attention tests used in this study. Further, fitness to drive is assessed using perimetry that involves the detection of stimuli that suddenly appear in the visual field (see section 1.6.2). While static visual attention tests made use of sudden onset stimuli, kinetic visual attention tests involved stimuli that were present for extended periods of time before suddenly moving. Responses to the latter stimuli are arguably more relevant to driving (Porciatti et al., 1998, Santos 1998; see also section 2.3.1.3). In static scenes it is the salience of an object that makes it detectable but for kinetic scenes motion is the defining feature (Milanese et al., 1995) suggesting that it is a pre-attentive feature (McLeod et al., 1988).

Investigation of angular versus longitudinal target motion was of interest as both types of motion were included in the kinetic visual attention tests used in this study. Crossing pedestrians represented angular motion and sudden braking of the leading car represented longitudinal motion (section 2.3.1.3). Hills (1980) pointed out that a target moving with longitudinal motion would take longer to detect than one travelling at the same speed but with angular motion. This is because the former would exhibit less lateral displacement than the latter. Also, the ability to detect longitudinal motion was shown to decline at a faster than angular motion with advancing age. Hills (1980) added that our relative inability to detect longitudinal motion could lead to errors in judging the motion of vehicles travelling towards or away from us. He supported this by citing an earlier report (Mackie, 1972) showing that 42% of accidents were the result of head-on collisions.

Investigation of self-motion (travelling speed) was of interest as this is known to alter our perception of moving objects and may influence reaction times (Santos, 1998). Interestingly, published vehicle stopping distances are based upon the assumption that the reaction time component does not vary with travelling speed but remains constant (see section 2.3.1.1).

Finally, investigation of optic flow field effects was of interest as these may also alter our perception of moving objects (Santos, 1998). To understand this, optic flow field effects must first be explained. As we approach a stationary object that is positioned in the centre of the road directly in front of us, it appears to increase in size (i.e. it appears to have longitudinal motion). At a long distance from us its size increases slowly but this speeds up, as we get closer. In other words, it appears to accelerate towards us. Now, let us consider a second stationary object placed some distance to the side of the first. As we approach this object, it both increases in size (the longitudinal motion component) and moves laterally (the angular motion component). Again, as we move closer, its longitudinal and angular motion components appear to accelerate. A third object, placed at a greater eccentricity than the second, would appear to move in a similar fashion but would exhibit greater angular acceleration as it was approached. If either of the eccentrically placed targets were to move towards the centre of the road, the previously described optic flow field effects would alter their apparent motion. In both cases, the apparent lateral motion due to the optic flow field effect would counteract the actual movement of the targets towards the centre of the road. Both targets would thus appear to move more slowly than their true speeds and this effect would be more pronounced as target eccentricity and self-motion (i.e. travelling speed) increased. Research has shown that reaction times increase as the speed of a stimulus reduces (Ball & Sekuler, 1980; Porciatti et al., 1998; Burr et al., 1998). Therefore, two questions arose. First of all, could any observed change in reaction time with self-motion be attributed to the optic flow field effects described above? Secondly, could optic flow field effects account for the increase in reaction times with increasing eccentricity observed in chapter 5?

7.2 Methods

Data were collected from 36 healthy subjects divided equally into three age groups (see section 2.4.2.1) using the DRTS1 kinetic visual attention test. This test was used as its parameters could be altered to investigate the four aspects of motion outlined in section 7.1.

The DRTS1 was run in static and kinetic mode for the investigation of static versus kinetic target presentation. In static mode, the pedestrian and leading car events were not continuously present. They would, instead, suddenly appear on the screen, one at a time. Subjects had to respond as quickly as possible. In kinetic (default) mode, all events were continuously present with pedestrian targets moving in a flow field. In this case, subjects had to respond as soon as a pedestrian moved out of the flow field or the leading car braked. The order of the treatments was counterbalanced to avoid learning effects (see appendix 6a) that would otherwise confound the results.

Investigation of angular versus longitudinal target motion was carried out by comparing reaction times recorded for pedestrian crossing events (representing angular motion, section 2.3.1.3.1) and central car braking events (representing longitudinal motion, section 2.3.1.3.2).

Investigation of self-motion was carried out by running the DRTS1 at travelling speeds of 30, 50 (default) and 70 mph. These travelling speeds represented those commonly encountered on British roads. The order of treatments was, again, counterbalanced to avoid learning effects (see appendix 6a).

To determine whether changes in reaction time with self-motion or eccentricity could be attributed to the optic flow field effects described in section 7.1, vertical edge speeds were calculated for pedestrian crossing events at all eccentricities (2.5°, 5°, 7.5°) and travelling speeds (30, 50 and 70 mph) (see table 7.1). DRTS1 edge position algorithms (appendix 2b) were used for this purpose. These algorithms simulated optic flow field effects so that targets appeared to accelerate towards the subject. By definition, an accelerating target does not have a constant edge speed that can be expressed as a single figure. Yet single figure edge speeds were required for this analysis. This problem was overcome by plotting edge position (degrees) over a time interval (seconds) that was small enough for the graph to appear approximately linear. The gradient of this graph, determined by linear regression, then provided a single figure representing the mean edge speed (in degrees per second) over that time interval. As most reaction times fell within 1 second of the onset of each stimulus (i.e. the point at which each pedestrian target started to cross the road), a 1 second time interval was used. It is worth pointing out here that all DRTS1 pedestrians were programmed to cross towards the centre of the road at a fixed speed of 7.5 mph. The variation in edge speeds shown in Table 7.1 is the resulted of optic flow field effects simulated by the DRTS1 test. For a travelling speed of 0 mph, each pedestrian would have had a constant edge speed of 1.92 degrees per second, regardless of eccentricity. However, the optic flow field effects bought about by self-motion have resulted in a reduction in the apparent edge speeds of all targets, the magnitude of which increases with eccentricity and travelling speed (as explained in section 7.1). This has occurred to such an extent that, to a driver approaching at 70mph, a pedestrian target crossing the road from an emergent eccentricity of 7.5° does not even appear to be walking towards the centre of the road but instead appears to be moving outwards with the flow field. By correlating reaction times with vertical edge speeds corresponding to each of the pedestrian targets shown in table 7.1, it was possible to determine whether target edge speed influenced reaction times.

Eccentricity (degrees)	Travelling speed (mph)	Edge speed (degrees per second)
2.5°	30	1.76
5°	30	1.36
7.5°	30	0.95
2.5°	50 (default)	1.65
5°	50 (default)	0.93
7.5°	50 (default)	0.19
2.5°	70	1.45
5°	70	0.3
7.5°	70	-0.8

Table 7.1: Calculated mean vertical edge speeds (degrees per second) of DRTS1 pedestrian crossing events for each eccentricity and travelling speed. Positive and negative edge speeds indicate that the pedestrian would appear to travel, respectively, towards and away from the centre of the road. Pedestrians were programmed to cross towards the centre of the road at a fixed speed of 7.5 mph (1.92 degrees per second). The variation in edge speeds are the resulted of optic flow field effects simulated by the DRTS1 test. Mean vertical edge speeds relate to a time interval of 1 second after the onset of a crossing event. Vertical edge speeds are not constant because optic flow field effects cause targets to accelerate.

Further investigation into the influence of edge speed upon eccentricity involved observing the variation in reaction times recorded for pedestrian targets that emerged at each eccentricity with and without correction for optic flow field effects. Optic flow field effects were corrected by adjusting the crossing speeds of the inner (to 5.3 mph) and outer (to 9.8 mph) DRTS1 pedestrian targets so that they appeared to cross at the same speed as the middle pedestrian targets (i.e. all pedestrians edge speeds were equal to 0.92 degrees per second). This treatment allowed eccentricity effects to be observed in the absence of confounding edge speed variations. If reaction times showed no variation with eccentricity, it could be concluded that the eccentricity effects observed in chapter 5 were solely due to edge speed variations arising from optic flow field effects. If, on the other hand, the variation of reaction times with eccentricity matched those observed without optic flow field correction (i.e. using the DRTS1 in its default mode), it could be concluded that the eccentricity effects observed in chapter 5 were independent of edge speed variations arising from optic flow field effects. Data, for this investigation, were collected from 4 young adults (see appendix 6d, subject group 4). Each subject took part in three trials. The first trial was carried out with the DRTS1 test set at default settings and served as a familiarisation run. The two remaining trials were carried out using the DRTS1 test with and without correction of optic flow field effects, as described above. The order of treatments was, once again, counterbalanced to avoid learning effects (see appendix 6d)

Reaction times for all investigations were transformed for the purposes of statistical analysis (section 2.5.2). Transformations were carried out in such a manner that a high score represented better test performance than a lower score. Effects and interactions were tested for statistical significance at the 95% level using factorial ANOVAs followed by Bonferroni/Dunn post-hoc tests (Abacus Concepts, 1996).

7.3 Results

7.3.1 Static versus kinetic target presentation

Target presentation (i.e. static or kinetic) influenced reaction times ($F_{1, 262} = 484.690$, $P<0.0001$) and exhibited an interaction with event type ($F_{3, 262} = 70.020$, $P<0.0001$) but not age ($F_{2, 262} = 0.620$, $P = 0.5386$). Here, subjects reacted more quickly to static targets than kinetic targets. This was the case for all events types (i.e. the leading car braking event, $F_{1, 70} = 176.904$, $P<0.0001$; the middle pedestrian crossing event, $F_{1, 69} = 222.765$, $P<0.0001$; and the outer pedestrian crossing event, $F_{1, 70} = 36.269$, $P<0.0001$) except inner ($F_{1, 69} = 0.057$, $P = 0.8116$) pedestrian crossing events (see figure 7.1). Interestingly, the observations made in chapter 5, that reaction times slowed down as pedestrian target eccentricity increased (see figure 7.1), only held true for kinetic targets ($F_{3, 140} = 56.057$, $P<0.0001$) and not for static targets ($F_{3, 138} = 2.292$, $P = 0.0809$). Post-hoc tests revealed that reaction times were different at all eccentricities ($P<0.0001$) except for the leading car (0°) and middle (5°) pedestrian crossing event ($P = 0.8629$).

7.3.2 Angular versus longitudinal target motion

The type of target motion (i.e. angular or longitudinal) influenced reaction times ($F_{3,132} = 83.941$, $P<0.0001$) and exhibited an interaction with age ($F_{6,132} = 2.546$, $P = 0.0230$). Figure 7.2 illustrates the responses of each age group. Subjects of all ages reacted more quickly to angular motion (i.e. pedestrian crossing events) than longitudinal motion (i.e. the leading car braking event). Statistical analysis of these effects is summarised in table 7.2.

Age group	Effect of target motion	Post-hoc comparisons of reaction times measured for longitudinal (i.e. leading car) and angular motion (i.e. crossing pedestrian) at three emergent eccentricities		
		2.5°	5°	7.5°
Young	$F_{3,44}=70.146$ $P<0.0001$	$P<0.0001$	$P<0.0001$	$P<0.0001$
Middle	$F_{3,44}=28.933$ $P<0.0001$	$P<0.0001$	$P<0.0001$	$P<0.0001$
Older	$F_{3,44}=19.167$ $P<0.0001$	$P<0.0001$	$P<0.0001$	$P<0.0001$

Table 7.2: Statistical significance (P-values) of the effect of target motion on DRTS1 reaction times for each age group.

7.3.3 Self-motion

Self-motion (travelling speed) influenced reaction times ($F_{2,389} = 5.442$, $P = 0.0047$) and exhibited an interaction with event type ($F_{6,389} = 6.151$, $P<0.0001$) but not age ($F_{4,389} = 0.891$, $P = 0.4691$. More detailed analysis showed that only the leading car and outer (7.5° emergent eccentricity) pedestrian crossing events exhibited statistically significant effects (table 7.3). Figure 7.3 shows that self-motion had most effect upon reaction times recorded for the outer pedestrian crossing event. Here, faster travelling speeds gave rise to slower reaction times.

Event type	Effect of self-motion	Post-hoc comparisons of reaction times measured for the three travelling speeds investigated		
		30 versus 50 mph	30 versus 70 mph	50 versus 70 mph
Leading car	$F_{2,104} = 3.688$ $P = 0.0284$	NS	NS	NS
Pedestrian crossing from 7.5°	$F_{2,99} = 5.897$ $P = 0.0038$	NS	$P = 0.0009$	NS

Table 7.3: Statistical significance (P-values) of the effect of self-motion (travelling speed) on DRTS1 reaction times for event type.

7.3.4 The influence of edge speed on reaction times

Table 7.4 shows the mean transformed reaction times of subjects in the young, middle and older age groups for target edge speeds corresponding to each travelling speed and pedestrian target emergent eccentricity investigated (see also table 7.1). For each age group, Pearson's correlation coëfficients are shown for the regression between target edge speed and reaction time. The magnitude of these (0.87 – 0.91) indicated that reaction times were strongly dependent upon target edge speed. Here, faster target edge speeds resulted in faster reaction times. It follows that the reduction of target edge speed that accompanies increased self-motion (travelling speed) and pedestrian target emergent eccentricity, due to optic flow field effects (see table 7.1), may be the main cause of the increased reaction times observed with increased self-motion (see figure 7.3) and eccentricity (see chapter 5).

Target edge speed (degrees/second)	Transformed reaction time		
	Young	Middle	Older
1.76	1.330	1.440	1.189
1.36	1.282	1.421	1.123
0.95	1.222	1.344	0.989
1.65	1.359	1.472	1.172
0.93	1.338	1.411	1.064
0.19	1.192	1.264	0.888
1.45	1.369	1.446	1.132
0.30	1.300	1.355	0.986
-0.80	1.000	1.101	0.912
Correlation coefficient	***0.87***	***0.95***	***0.91***

Table 7.4: Mean transformed reaction times of subjects in the young, middle and older age groups for edge speeds corresponding to each travelling speed and pedestrian target emergent eccentricity investigated. Pearson's correlation coefficients for the regression between target edge speed and transformed reaction time are also shown.

7.3.5 The relative influences of edge speed and eccentricity upon reaction times

Figure 7.4 shows transformed reaction times recorded for pedestrian targets with emergent eccentricities of 2.5°, 5° and 7.5° presented with and without correction for optic flow field effects. Increased eccentricity lead to slower reaction times when optic flow field effects remained uncorrected, so that target edge speeds decreased as eccentricity increased ($F_{2,9} = 15.168$, $P = 0.0013$). Post-hoc tests revealed that the outer events had the longest reaction times ($P = 0.0020$ for 7.5° versus 5°; $P = 0.0006$ for 7.5° versus 2.5°).

However, eccentricity had no statistically significant effect upon reaction times when optic flow field effects were corrected, so that target edge speeds remained constant at each eccentricity ($F_{2,9} = 1.230$, $P = 0.3372$). This suggests that the eccentricity effects observed in chapter 5 were attributable to target edge speed variations arising from optic flow field effects.

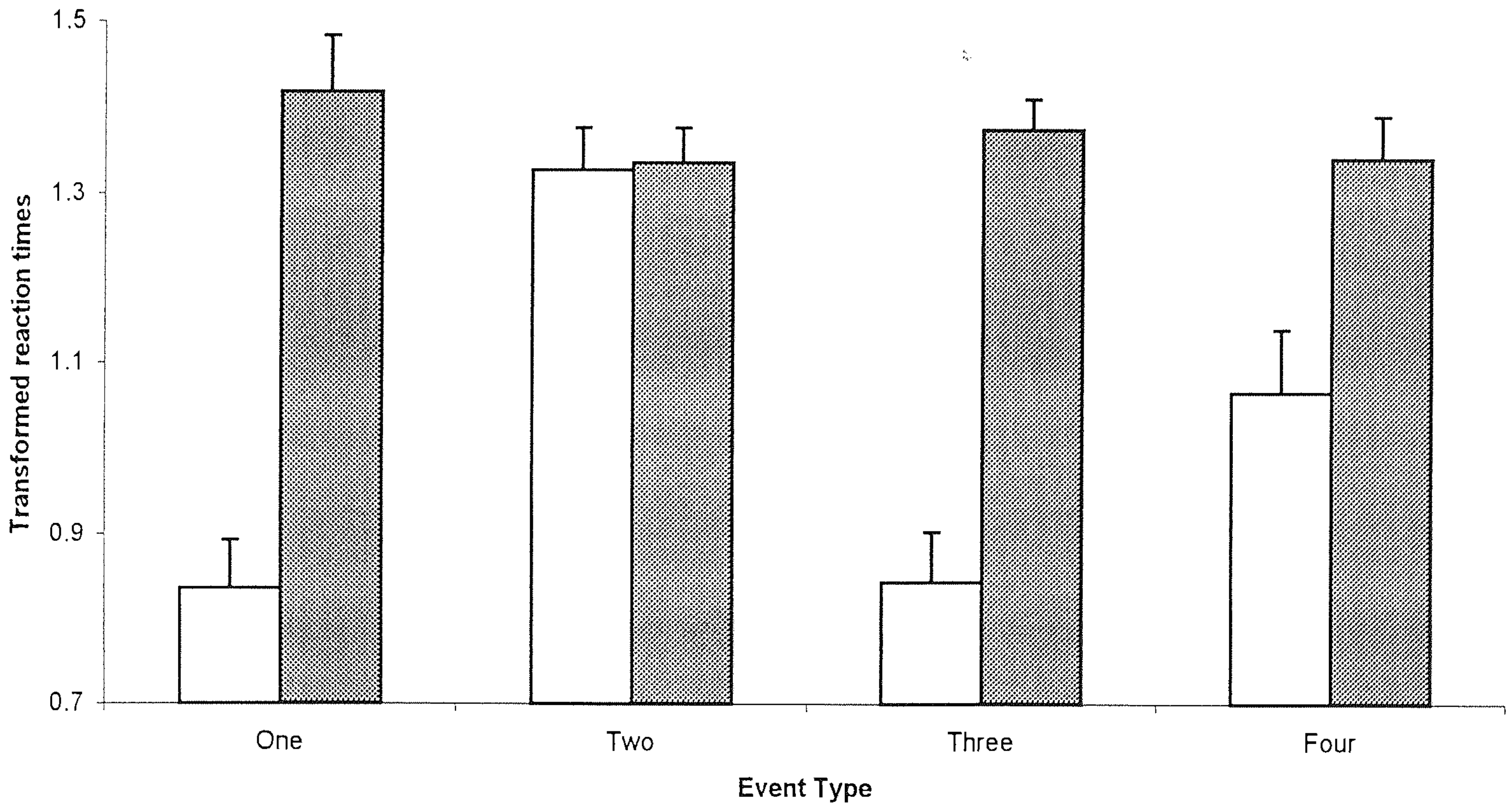


Figure 7.1: Transformed reaction times (mean and upper 95% confidence limit) for DRTS1 kinetic (white bars) and static (grey bars) presentation of each event type (1 = leading car braking event, 2 = pedestrian crossing at 2.5° emergent eccentricity, 3 = pedestrian crossing at 5° emergent eccentricity, 4 = pedestrian crossing at 7.5° emergent eccentricity).

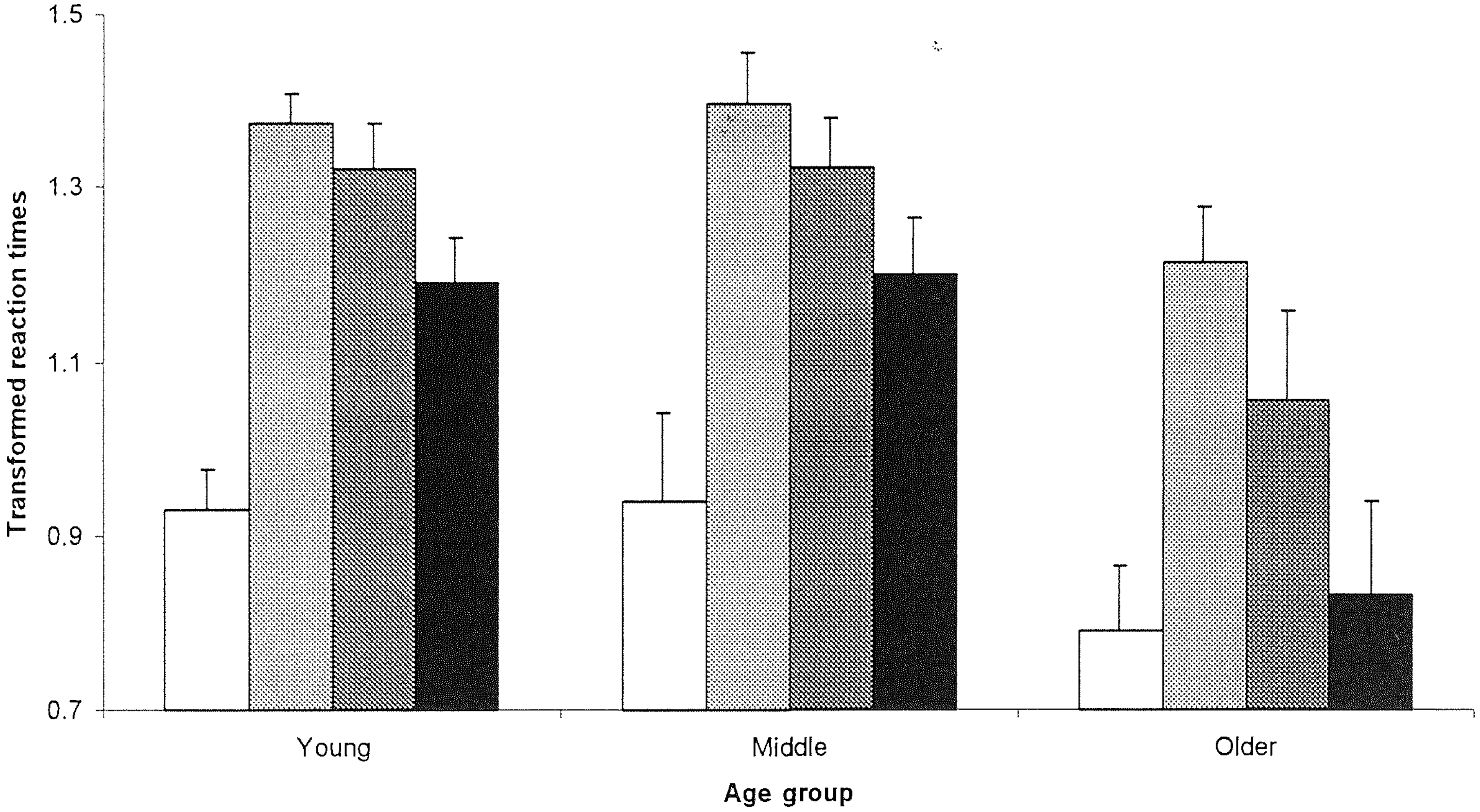


Figure 7.2: Transformed DRTS1 reaction times (mean and upper 95% confidence limit) of young, middle and older age groups targets that moved with longitudinal motion (white bars) or angular motion (light grey, medium grey and black bars represent angular motion at emergent eccentricities of 2.5°, 5° and 7.5°, respectively).

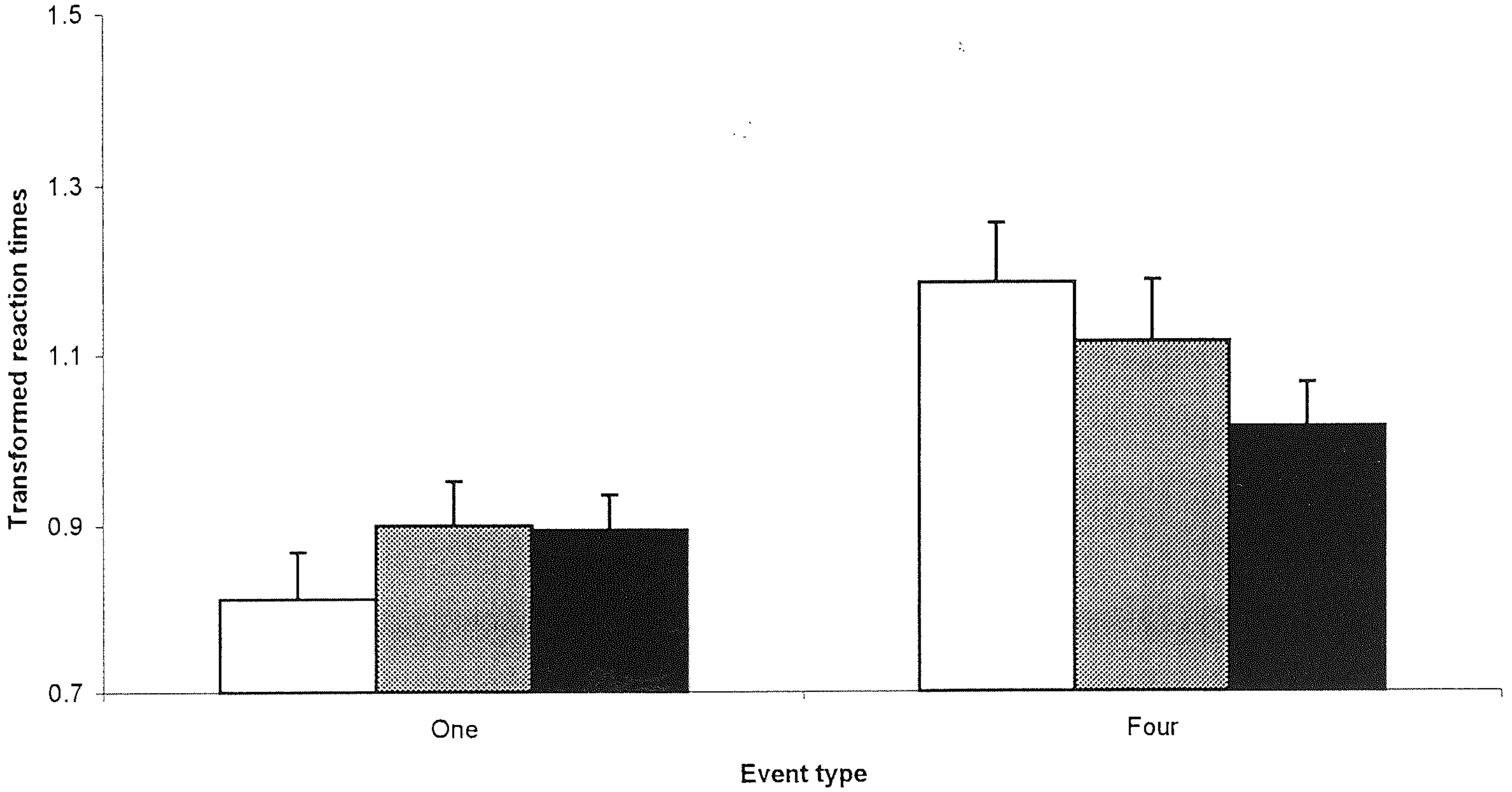


Figure 7.3: The mean transformed reaction times for the 0° (Event One) and 7.5° (Event Four) eccentricities of the DRTS1 test for speed, showing the upper 95% confidence limit. White bars represent 30 mph, grey bars represent 50 mph and black bars represent 70 mph. The mean transformed reaction times were pooled for age.

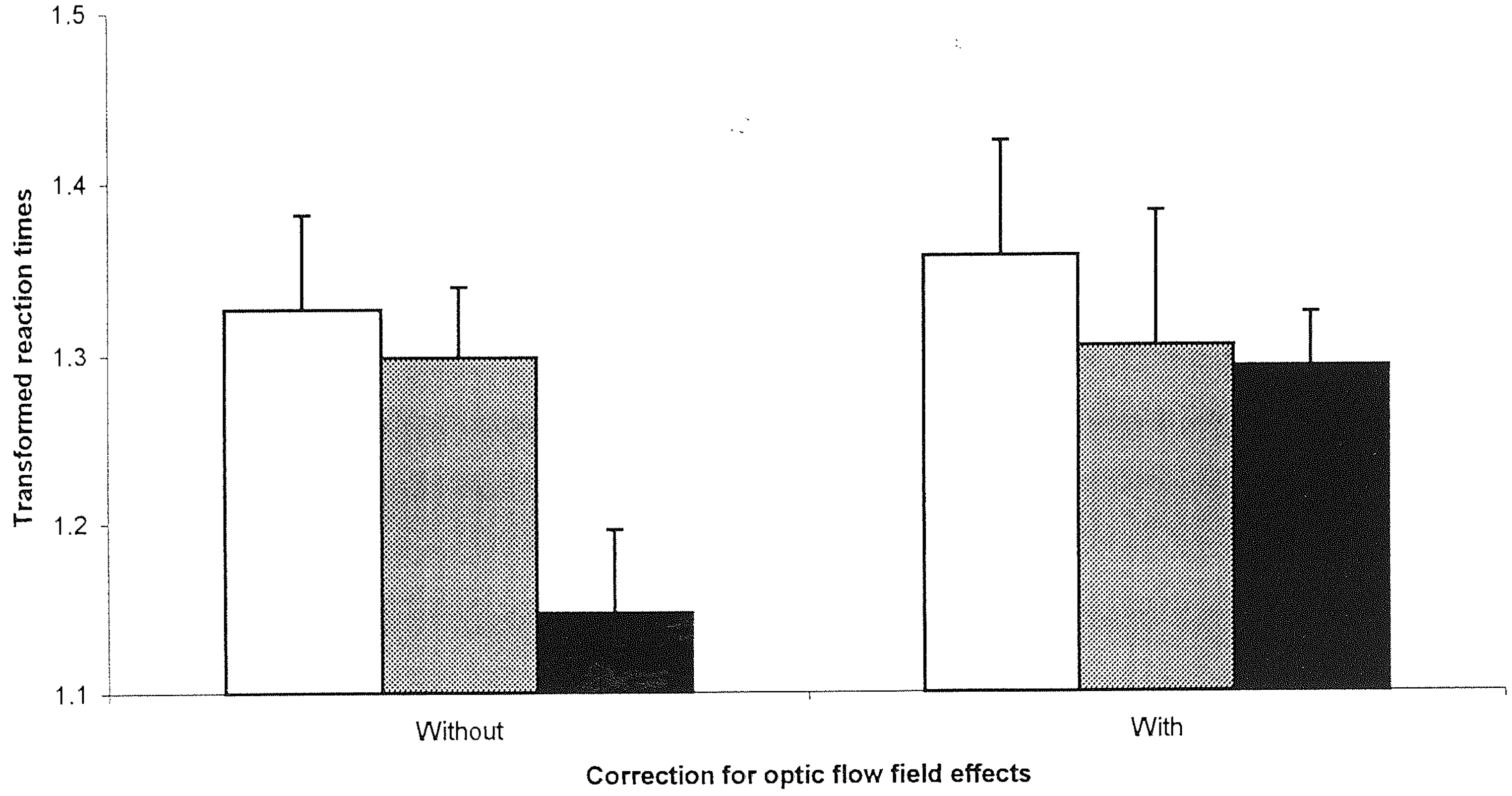


Figure 7.4: Transformed DRTS1 reaction times (mean and upper 95% confidence limit) recorded for pedestrian targets with emergent eccentricities of 2.5° (white bars), 5° (grey bars) and 7.5° (black bars) presented with and without correction for optic flow field effects.

7.4 Discussion

Static versus kinetic target presentation represented the primary differences between the static and kinetic visual attention tests used in this study. The results presented in section 7.3.1 showed that subjects tended to react more quickly to static targets than kinetic targets. Interestingly, reaction times slowed down as pedestrian target eccentricity increased for kinetic targets but not for static targets. This suggested that the eccentricity effect described in chapter 5 did not really exist but was only an artefact of target motion.

Investigation of angular versus longitudinal target motion was of interest as both types of motion were included in the kinetic visual attention tests used in this study. In agreement with previous research (Hills, 1975, 1980; Lappe and Krekelberg, 1998), the results presented in section 7.3.2 showed that subjects of all ages reacted more quickly to angular motion than longitudinal motion.

Santos (1998) proposed that self-motion altered perception of moving objects and could influence reaction times (Santos, 1998). Probst et al. (1986, 1987) stated that it was harder to detect object motion when involved in self-motion and that this effect increased with increasing self-motion. The results presented in section 7.3.3 showed that self-motion did, indeed, influence reaction times. Here, faster travelling speeds gave rise to slower reaction times. While some researchers have also shown that self-motion influences reaction times measured using driving simulators (Santos, 1999) and real driving (Probst, 1986; Probst et al., 1987) others have either not any effect (Driver et al., 1992) or have found, contrary to the results presented in this chapter, that reaction times speed up as self-motion increases (Ivry & Cohen, 1992). More research is needed in this area given that published vehicle stopping distances are currently based upon the assumption that reaction times remain constant for all travelling speeds (see section 2.3.1.1).

Santos (1998) also suggested that optic flow field effects might alter perception of moving objects. Table 7.1 was used to illustrate how optic flow field effects reduce target edge speeds as self-motion and target eccentricity increase. Observations by several other researchers (Ball & Sekuler, 1980; Porciatti et al., 1998; Burr et al., 1998), that reaction times increase as stimulus speed reduces, raised the question as to whether the slower reaction time that accompanied increased self-motion and eccentricity could be attributed to optic flow field effects. Results presented in section 7.3.4 showed that faster target edge speeds resulted in faster reaction times. This immediately suggested that the effects of self-motion and eccentricity could be attributed to optic flow field effects upon target edge speed. Further support for this was provided in section 7.3.5 which showed that the effects attributed to eccentricity, in chapter 5, were removed if variations in target edge speed, caused by optic flow field effects, were removed. As pointed out by Hills (1980), edge speed variations are also most likely to be the cause of differences in reaction time to targets moving with longitudinal and angular motion, described in section 7.3.1.

7.5 Summary

The results presented in this chapter show that:

- Subjects reacted more quickly to static targets than kinetic targets. Interestingly, static presentation removed the influence of target eccentricity upon reaction times.
- Subjects reacted more quickly to angular motion than longitudinal motion.
- Increased self-motion gave rise to slower reaction times.
- Target edge speed variations, often arising because of optic flow field effects, strongly influenced reaction times and were likely to be the cause of variations in reaction times recorded for longitudinal and angular target motion, self-motion and target eccentricity.

CHAPTER EIGHT

COMPARISON OF STATIC AND KINETIC VISUAL ATTENTION TESTS: AGE

NB For a full key see page -11-.

8.1 Introduction

This aim of the research presented in this chapter was to compare static (UFOV) and kinetic (DRTS1 and 2) visual attention tests in terms of their ability to detect age related changes in the visual system.

8.2 Methods

Data were taken from 36 healthy subjects divided equally into three age groups (see section 2.4.2.1, for details of each age group) using the three visual attention tests. Scores measured during the first repeat session described in section 4.2 (see also appendix 6a) were analysed.

Elements of the UFOV, DRTS1 and DRTS2 tests that were compared in terms of their ability to detect age-related changes to the visual system (tables 8.1 to 8.3) were also described in section 4.2. DRTS1 test variants (described in chapters 5 to 7) were then compared (table 8.4) in order to determine whether any of them enhanced this test's ability to detect age-related changes.

All test scores were transformed for the purpose of statistical analysis (see section 2.5.1 and 2.5.2). Transformations were carried out in such a manner that a high score represented better test performance than a lower score. Differences in test scores found for each age group were tested for statistical significance (table 8.1) at the 95% level using 1-way factorial ANOVAs followed by Bonferroni/Dunn post-hoc tests (Abacus Concepts, 1996; Katz, 1997). These differences were also compared to the limits of agreement of each test (previously shown in table 4.3) derived from the pooled results of all age groups (table 8.2). As explained in chapter 4, differences that exceeded the limits of agreement were deemed to be clinically significant. Tests were also ranked in terms of their ability to detect age-related changes to the visual system using Kendall's correlation coefficients (tables 8.3 and 8.4).

Task		Statistical significance	Post-hoc analysis		
Test	Sub-test		Young : Middle	Young : Older	Middle : Older
UFOV	Processing speed	$F_{2,33} = 3.038$, $P = 0.0615$*	NS	NS	NS
	Divided attention	$F_{2,33} = 11.550$, $P = 0.0002$	NS	0.0003	0.0001
	Selective attention	$F_{2,33} = 37.976$, $P<0.0001$	NS	<0.0001	<0.0001
	Total UFOV	$F_{2,33} = 29.885$, $P<0.0001$	NS	<0.0001	<0.0001
DRTS1	Leading car	$F_{2,33} = 4.281$, $P = 0.0222$	NS	NS	0.0138
	Inner pedestrian	$F_{2,33} = 13.177$, $P<0.0001$	NS	0.0002	<0.0001
	Middle pedestrian	$F_{2,33} = 15.959$, $P<0.0001$	NS	<0.0001	<0.0001
	Outer pedestrian	$F_{2,33} = 28.547$, $P<0.0001$	NS	<0.0001	<0.0001
	All events	$F_{2,33} = 26.439$, $P<0.0001$	NS	<0.0001	<0.0001
DRTS2	Distant pedestrian	$F_{2,33} = 22.452$, $P<0.0001$	NS	<0.0001	<0.0001
	Intermediate pedestrian	$F_{2,33} = 25.049$, $P<0.0001$	NS	<0.0001	<0.0001
	Near pedestrian	$F_{2,33} = 21.301$, $P<0.0001$	NS	<0.0001	<0.0001
	All events	$F_{2,33} = 13.627$, $P<0.0001$	NS	<0.0001	<0.0001

Table 8.1: The statistical significance of the effect of age on UFOV, DRTS1 and DRTS2 transformed scores for 36 people. Asterisks indicate the sub-tests that were not statistically significant. Post-hoc analysis indicates the values that were not statistically significant (NS) and those that were statistically significant (p value).

Task		Limit of agreement for all subject from table 4.3	Mean difference between transformed reaction times		
Test	Sub-test		Young : Middle	Young : Older	Middle : Older
UFOV	Processing speed	0.008	0	2.461*	2.461*
	Divided attention	0.008	0.354*	4.685*	5.039*
	Selective attention	0.010	1.758*	11.867*	10.109*
	Total UFOV	0.037	0.53*	7.185*	6.655*
DRTS1	Leading car	0.33	0.008	0.138	0.146
	Inner pedestrian	0.17	0.024	0.158	0.182*
	Middle pedestrian	0.20	0.003	0.263*	0.266*
	Outer pedestrian	0.27	0.009	0.359*	0.368*
	All events	0.18	0.003	0.266*	0.263*
DRTS2	Distant pedestrian	0.14	0.014	0.205*	0.191*
	Intermediate pedestrian	0.14	0.021	0.209*	0.188*
	Near pedestrian	0.16	0.004	0.195*	0.199*
	All events	0.13	0.010	0.203*	0.193*

Table 8.2: The limits of agreement and the mean difference between transformed reaction for the three age groups for each sub-test of the UFOV, DRTS1 and DRTS2 visual attention tests. Asterisks indicate the values that were clinically significant.

Task		Kendall's correlation coefficient
Test	Sub-test (**rank**)	All subjects N = 36
UFOV	Processing speed (**12**)	0.396
	Divided attention (**4**)	0.510
	Selective attention (**2**)	0.600
	Total UFOV (**1**)	0.609
DRTS1	Leading car (**13**)	0.211
	Inner pedestrian (**9**)	0.463
	Middle pedestrian (**8**)	0.472
	Outer pedestrian (**10**)	0.411
	All events (**5**)	0.506
DRTS2	Distant pedestrian (**11**)	0.407
	Intermediate pedestrian (**7**)	0.480
	Near pedestrian (**3**)	0.534
	All events (**6**)	0.488

Table 8.3: Kendall's correlation coefficients for scores and age. The values indicate direct relationships with age. All values were statistically significant at the 95% level after Bonferroni's correction for multiple comparisons was applied. Sub-tests were ranked according to the magnitude of the correlation coefficients determined for age.

Task		Kendall correlation coefficients	
		Tau	Rank
Test	Sub-test		
DRTS1	Static versus kinetic		
	Static (3)	0.346*	3
	Kinetic (1)	0.451*	1
	Speed		
	30 mph (7)	0.293*	7
	50 mph (2)	0.373*	2
	70 mph (8)	0.154	8
	Clutter (target : distractor ratio)		
	1:6 (4)	0.343*	4
	1:18 (5)	0.336*	5
	1:30 (6)	0.302*	6

Table 8.4: The Kendall correlations coefficients and ranking for optionally changed parameters of the DRTS1 test measured on 36 subjects. Asterisks indicate the values that were statistically significant at the 95% level after Bonferroni's correction for multiple comparisons was applied. Reaction times were pooled for event (all).

8.3 Results and discussion

Table 8.1 shows that all visual attention tests, except for the UFOV processing speed sub-test, exhibited statistically significant variations with age. Post-hoc tests revealed that the test scores did not differ for young and middle age groups. For the majority of tests, however, the older age group performed worse than both the young and middle age groups. Table 8.2 indicates those tests for which a clinically significant difference was found between age groups. Most of the highly statistically significant findings ($P<0.0001$) were also clinically significant. Interestingly, there were also some instances where a clinically significant finding did not achieve statistical significance. Table 8.3 shows that the total UFOV test was most able to detect age-related changes to the visual system. The rank order of the remaining tests was similar to that shown in table 4.3, relating to relative repeatability. This is, perhaps, not surprising as a more repeatable test is likely to be more able to detect fluctuations in test performance arising from factors such as age. The

DRTS1 seemed, overall, to be least able to detect age-related changes. Table 8.4 also shows that none of the DRTS1 test variants were able to improve its ability to detect age-related changes. This analysis was restricted to reaction times pooled across all events as this treatment of DRTS1 data was ranked the best in table 8.3.

8.4 Summary

The results presented in this chapter show that:

- The UFOV test is the best predictor of age-related changes,
- The addition of motion to a reaction time test improves its ability to detect age-related changes,
- The default setting of the DRTS1 test shows the best predictions of age.

CHAPTER NINE

COMPARISON OF STATIC AND KINETIC VISUAL ATTENTION TESTS: PREDICTION OF CRASH RISK AND DRIVING PERFORMANCE

NB For a full key see page -11-.

9.1 Introduction

The aim of the research presented in this chapter was to compare static and dynamic visual attention tests as a means of predicting crash risk and driving performance.

9.2 Methods

Two samples of drivers were investigated. The first sample comprised 19 older drivers (9 females and 10 males) whose ages ranged from 61 to 79 years (mean ± standard deviation: 70 ± 5 years). The second sample included 25 police drivers (all males) whose ages ranged from 29 to 62 years (mean ± standard deviation: 42 ± 9 years).

The first sample had previously taken part in a research project carried out by Dr Lily Read in the Psychology Department at Leeds University. The self-reported at-fault crash history of each driver had been established. Each driver had also been assessed on the Institute of Transport Safety's driving simulator (Read, 2001). Here, driving tasks were performed in an instrumented car. A simulated road environment was projected onto screens that allowed the driver realistic views through the windows of the instrumented car. Drivers were required to follow a leading car during which (a) headway distance from the leading car and (b) lateral position on the road was continuously monitored. Research has revealed that older drivers' have poor lane keeping and following distance skills than younger drivers (Wood & Mallon, 2001).

The standard deviation of lateral position (lane position task) served as a measure of how well each driver maintained a steady position on the road. The standard deviation of headway distance (following task) served as a measure of how accurately each driver could follow the leading car. Because drivers may have tended to concentrate on the leading car, it could be argued that this served as a central task while maintenance of lane position, possibly involving peripheral awareness of road markings and kerbsides (Crundall & Underwood, 1998), may serve as a peripheral task. The ability to perform both tasks simultaneously in the midst of cluttered driving simulator scenery might, therefore, be related to measures of static or kinetic visual attention.

Therefore, arrangements were made to recall each driver to take the UFOV and DRTS2 tests. No data were collected on the DRTS1 test because of time restrictions.

The second sample was recruited from Sussex Police Force. Crash histories were obtained from police records making them more reliable than self-reported data. Driving performance was also based upon a percentage examiner-rated open-road driving score, which again, may be more relevant than driving simulator performance. It must be borne in mind, however, that police drivers encounter more difficult road conditions and receive better driving tuition than typical private motorists do. Therefore, the findings of this sample may not be transferable to the general driving population. Randomly selected police drivers took the UFOV and DRTS2 tests. Again, no data were collected on the DRTS1 test because of time restrictions.

Statistical analysis of both driving samples involved splitting them into sub-samples of above or below average visual attention and driving performance. Crash histories were already dichotomised (i.e. drivers either did or did not have crashes). This dichotomous data was arranged into a series of 2x2 contingency tables (Hatch, 1998; Katz, 1997). The statistical significance of each association was determined using Fisher's exact probability test for 2x2 contingency tables. Relative risks were calculated and used to compare static (UFOV) and kinetic (DRTS2) visual attention tests and sub-tests in terms of their ability to predict crash involvement and driving performance.

Task		Crashes		Driving Simulator			
				Following task		Lane position task	
Test	Sub-test	RR	P	RR	P	RR	P
UFOV	Processing speed	2.1 (1.9-7.5)	0.47	0.0 (0.0-5.4)	0.47	0.0 (0.0-5.4)	0.47
	Divided attention	0.3 (0.2-11.9)	0.10	1.4 (1.3-9.4)	0.68	0.8 (0.7-8.8)	>0.99
	Selective attention	1.1 (0.9-7.2)	>0.99	0.9 (0.7-7.0)	>0.99	0.6 (0.4-7.1)	0.37
	Total UFOV	1.1 (0.9-7.2)	>0.99	0.6 (0.7-7.0)	0.37	0.6 (0.4-7.1)	0.37
DRTS2	Distant pedestrian	0.7 (0.6-6.9)	0.66	0.9 (0.7-7.0)	>0.99	1.4 (1.2-7.6)	0.66
	Intermediate pedestrian	1.1 (0.9-7.2)	>0.99	2.2 (2.1-9.2)	0.18	0.6 (0.4-7.1)	0.37
	Near pedestrian	0.5 (0.3-7.4)	0.18	1.4 (1.2-7.6)	0.66	0.6 (0.4-7.1)	0.37
	All events	1.7 (0.6-6.9)	0.66	1.4 (1.2-7.6)	0.66	1.4 (1.2-7.6)	0.66
Driving simulator	Following task	0.5 (0.3-7.4)	0.18				
	Lane position task	0.5 (0.3-7.4)	0.18				

Table 9.1: Comparison between static (UFOV) and kinetic (DRTS2) visual attention tests as predictors of self-reported at-fault crash involvement and driving simulator performance (following and lane-position tasks) in 19 older drivers. Values shown refer to relative risks, RR (lower and upper 95% confidence limits), and Fisher's exact probability, P. Statistical significance at the 95% level corresponds to $P<0.0019$ after correction for multiple comparisons (Katz, 1997).

Task		Crashes		Driving score	
Test	Sub-test	RR	P	RR	P
UFOV	Processing speed	No variation	-	No variation	-
	Divided attention	4.2 (4.1-12.9)	0.24	0.0 (0.0-8.3)	>0.99
	Selective attention	2.6 (2.5-12.0)	0.23	0.5 (0.4-11.7)	0.59
	Total UFOV	2.6 (2.5-12.0)	0.23	0.5 (0.4-11.7)	0.59
DRTS2	Distant pedestrian	0.5 (0.4-7.4)	0.64	1.5 (1.3-6.5)	0.43
	Intermediate pedestrian	2.2 (2.0-9.0)	0.38	1.5 (1.3-6.5)	0.43
	Near pedestrian	1.1 (0.9-7.4)	>0.99	1.5 (1.3-6.5)	0.43
	All events	1.1 (0.9-7.4)	>0.99	1.5 (1.3-6.5)	0.43
Driving score		0.5 (0.4-7.4)	0.64		

Table 9.2: Comparison between static (UFOV) and kinetic (DRTS2) visual attention tests as predictors of crash involvement from police records and examiner-rated open-road driving scores in 25 police drivers. Values shown refer to relative risks, RR (lower and upper 95% confidence limits), and Fisher's exact probability, P. Statistical significance at the 95% level corresponds to P<0.0033 after correction for multiple comparisons (Katz, 1997).

9.3 Results and discussion

The results shown in tables 9.1 and 9.2 show that none of the visual attention tests or sub-tests exhibited statistically significant associations with either crashes or driving performance. The following comparison of relative risks arising from each association can, therefore, only be taken as potential trends rather than concrete research findings.

In the context of this chapter, a relative risk of 1 means that drivers with below average test results were no more likely of having crashes or exhibiting below average driving performances than drivers with above average test results. In other words, the test in question had no predictive value. Relative risks of less that 1 mean that below average test results tend to be found in drivers with fewer crashes and above average driving performance. Such a test also has no predictive value. On the other hand, a relative risk of greater than 1 means that below average test results tend to be found in drivers with more crashes and below average driving performance. Such a test has some predictive value.

The overall UFOV score (relative risk: older drivers = 1.1, police drivers 2.6) was better at identifying drivers with greater crash risk than was the overall DRTS2 score (relative risk: older drivers = 0.7, police drivers 1.1). However, the overall DRTS2 score (relative risk: older drivers = 1.4, police drivers 1.5) was better at identifying drivers that had below average performances on driving tasks than was the overall UFOV score (relative risk: older drivers = 0.6, police drivers 0.5).

Interestingly, both tests were better at identifying drivers with greater crash risk than was simulator or open-road driving performance (relative risk in all cases was 0.5). This raises the question as to why above average driving performance was associated with higher crash risk. One likely explanation relating to police drivers is that those with above average driving scores tended to be advanced level drivers that encountered more dangerous situations that those with below average driving scores that tended to be standard level drivers. In this sense, the mixture of advanced and standard police drivers served as a confounding variable. Nevertheless, the association between above average driving performance and greater crash risk was also observed in older drivers for whom this confounding variable was absent. Older drivers with below average driving performance may, however, have been aware of their poorer driving skills and, consequently, have modified their driving behaviour to reduce crash risk (as has been described in section 1.4.3.5). Another explanation, also mentioned in chapter 1 (see section 1.4.3.7), may be that crashes are most likely to be caused by errors of judgement and lapses of concentration. Such events may be spurious, the occurrence of which are not easily predicted during driving assessments. A further point of interest was that driving performance on an open-road and a driving simulator exhibited the same degree of association with crashes. This suggests, contrary to what was suggested in the methods section of this chapter, that the open-road driving performance might not be more relevant to driving safety than driving simulator performance.

In the light of the above, it may be that crash histories may be the only indicator of ability to drive safely. If this turns out to be the case, then any test that can identify crash involved drivers may be useful for driver vision screening. The results presented in this chapter indicate that the kinetic visual attention test (DRTS2) was less able to perform this function than was the UFOV test.

Research has shown that the UFOV test is able to predict driving performance (de Raedt, 2000) during an on-the-road assessment. Further, a literature study (Van Rijn & Volker-Dieben, 1999) has concluded that the UFOV test is a promising means of identifying crash involved drivers with published relative risks or odds ratios (both being equivalent for relatively rare events like crashes, Hatch, 1997) ranging from 2 to 17. The studies that were reviewed made use of state recorded crashes. These are known to be more reliable than the self-reported crashes of the older driver sample presented in this chapter and which yielded a relative risk, in relation to overall UFOV scores, of less than 2. It is interesting to note, however, that the more reliable recorded crashes of the police drivers, presented in this study in relation to overall UFOV scores, yielded a higher relative risk of nearly 3.

Finally, a note must be made of the relative risks found for UFOV and DRTS2 sub-tests. Processing speed and divided attention offered a better means of identifying crash involved older drivers and police drivers, respectively, compared to the overall UFOV score. Divided attention was also more able to identify older drivers with below average driving performance. Reaction times recorded for middle pedestrian events were also more predictive, than overall DRTS2 reaction times, of crashes in older drivers and police drivers.

9.4 Summary

The driving samples investigated in this study were too limited to draw firm conclusions. Nevertheless, the results presented in this chapter indicate that:

- neither the DRTS2 nor the UFOV tests were powerful tools for the identification of drivers prone to crashes or poor driving performance;
- attempts to improve upon the predictive power of the UFOV test by developing a kinetic visual attention test (DRTS2) did not succeeded.

CHAPTER TEN

COMPARISON OF STATIC AND KINETIC VISUAL ATTENTION TESTS:

SUMMARY

NB For a full key see page -11-.

10.1 Summary

Chapter 1 provided a critical review of previous research that had explored the relationship between age, deterioration of the visual system and crash risk. Research had revealed that visual attention tests provided the best means of detecting age-related changes to the visual system that could potentially increase crash risk. The UFOV was the most promising visual attention test. However, members of the Secretary of State's Honorary Advisory Panel on Driving and Visual Disorders pointed out that the UFOV, which could be regarded as a static visual attention test, could be improved by inclusion of kinetic targets that more closely represent the driving task.

Chapter 2 provided a detailed description of the UFOV test along with the DRTS1 and 2, developed at Aston University to investigate inclusion of kinetic targets in visual attention tests. An outline of experiments carried out on these tests was also provided.

Derivation of UFOV test score was investigated in chapter 3. A computer program was written, based upon the author's understanding of the procedures and yielded the correct final UFOV scores in all subjects. Although this investigation provided new information about some of the UFOV test procedures, several important (commercially protected) aspects of the test still remain unknown.

The repeatability of static and kinetic visual attention tests was compared in chapter 4. The UFOV was found to be more repeatable than either of the kinetic visual attention tests and learning effects or age did not influence these findings.

Determinants of static and kinetic visual attention were explored in chapter 5 (target position), chapter 6 (distraction) and chapter 7 (target motion). Three aspects of target position were explored in chapter 5; eccentricity, laterality and radial location. Increasing target eccentricity lead to reduced performance on the UFOV and DRTS1 tests. The DRTS2 was not affected by eccentricity but this may have been due to the style of presentation of its targets. This might also have explained why only the DRTS2 showed laterality effects (i.e. better performance to targets presented on the left hand side of the road). Radial location could only be explored using the UFOV test and showed that subjects responded best to targets positioned in the horizontal meridian. Results presented in chapter 6 showed that distraction had opposite effects on static and kinetic visual attention. While UFOV test performance declined with distraction, DRTS1 performance increased. Previous research had shown that this striking difference was to be expected. Whereas the detection of static targets is attenuated in the presence of distracting stimuli, distracting stimuli that move in a structured flow field enhances the detection of moving targets. Results presented in chapter 7 showed that subjects reacted more slowly to kinetic compared to static targets, longitudinal motion compared to angular motion and to increased self-motion. However, the effects of longitudinal motion, angular motion, self-motion and even target eccentricity were caused by target edge speed variations arising because of optic flow field effects.

Static and kinetic visual attention tests were compared in terms of their ability to detect age-related changes to the visual system (chapter 8) and to predict crash risk and driving performance (chapter 9). Results presented in chapter 8 showed that the UFOV test was more able to detect age-related changes to the visual system than were either of the kinetic visual attention tests. The DRTS1 test could not be improved upon, in this respect, by incorporating any of the variants examined in chapters 5 to 7. The driving samples investigated in chapter 9 were too limited to draw firm conclusions. Nevertheless, the results presented showed that neither the DRTS2 nor the UFOV tests were powerful tools for the identification of drivers prone to crashes or poor driving performance. Therefore, attempts to improve the predictive power of the UFOV test inclusion of moving targets had not succeeded.

10.1.1 How reaction times equate to "thinking times"

Reaction times recorded for the DRTS1 test operating with default settings ranged from 538 to 2419ms, which spans the 671ms thinking times used by the DETR (www.roads.detr.gov.uk). It must, however, be pointed out that thinking times will have been based upon drivers responding via a footbrake while DRTS1 reaction times were based upon responses made via the keyboard (i.e. hand control). An unpublished study by the developers of the DRTS1 test at Aston University showed, on 12 young healthy drivers, that faster reaction times (paired t-test: $T_{11} = 6.70$, $P<0.0001$) were recorded using hand controls on the DRTS1 test (mean reaction time = 809ms) compared to footbrake controls on the driving simulator (mean reaction time = 1191ms) used by the Transport Research Laboratory (Crowthorne, UK). This corresponds to a keyboard : footbrake reaction time ratio of 1:1.47. This is in general agreement with previous research (Ritcher & Hyman, 1974).

DETR's published thinking times and stopping distances					
		Speed (mph)	Thinking time	Total stopping distance	
		30	671ms	23m	
		50	671ms	53m	
		70	671ms	96m	
DRTS estimated reaction times and additional stopping distances					
Factor		Speed (mph)	Reaction time	Additional stopping distance	
				Keyboard	Footbrake
Target presentation	Kinetic	50	850 ms	4m (8%)	6m (11%)
	Static	50	547 ms	-3m (-6%)	3m (6%)
Speed (mph)	30	30	781 ms	1m (4%)	6m (26%)
	50	50	783 ms	3m (6%)	11m (21%)
	70	70	836 ms	5m (5%)	12m (13%)
Clutter (target : distractor ratio)	1:6	50	675 ms	0m (<0%)	7m (13%)
	1:18	50	698 ms	1m (1%)	8m (15%)
	1:30	50	727 ms	1m (2%)	9m (17%)
Motion	Longitudinal	50	1278 ms	13m (25%)	27m (51%)
	Angular	50	665 ms	<1m (<1%)	7m (13%)
Emergent eccentricity	2.5°	50	567 ms	-2m (-4%)	4m (8%)
	5°	50	635 ms	-1m (-2%)	6m (11%)
	7.5°	50	825 ms	3m (6%)	12m (23%)
Age	Young	50	792 ms	3m (6%)	11m (21%)
	Middle	50	742 ms	2m (4%)	9m (17%)
	Older	50	1159 ms	11m (21%)	23m (43%)

Table 10.1: Comparison of stopping distances as published by the DETR and as estimated using the DRTS1 test for each factor examined in this study.

Table 1 compares the DETR's published stopping distances to those calculated from mean reaction times measured using the DRTS test for each factor examined in this study. Differences in stopping distances, expressed in metres and percentages, are shown for responses made via a keyboard and, after multiplication by 1.47, a footbrake. Stopping distances increased by up to 51%. This figure arose for longitudinal motion suggesting that drivers may have particular difficulty detecting deceleration (without braking) of cars travelling in front of them. Another point worth mentioning is that older drivers typically exhibited a 43% increase in stopping distances. These findings suggest that the DETR's published stopping distances may need revision. Research on steering responses to roadside obstacles appearing at night (Summala, 1981) appears to support this notion.

In this context we have provided evidence that reaction times also increase with target presentation, travelling speed, clutter, angular compared to longitudinal target motion, target eccentricity and age. The finding that reaction times are nearly doubled for longitudinal motion (i.e. when a car that is being followed suddenly brakes) compared to angular motion (i.e. when a pedestrian crosses a road). This finding has been reported before by Hills (1980).

The influences of travelling speed and clutter upon reaction times were least noticeable in older drivers and for central targets. This may have occurred because the reaction times of older drivers were much slower than the other age groups. This would mean that pedestrian targets will have crossed further towards the centre of the road, away from distractor pedestrians, by the time the older drivers responded. Younger drivers, in contrast, responded more quickly so that crossing pedestrians were still in the midst of distractor pedestrians.

10.2 Future research

The relatively poor repeatability of kinetic visual attention tests relative to static visual attention tests was probably the cause of the former being less able to detect age-related changes to the visual system compared to the latter. Research presented in chapter 3 has shown that variations in UFOV scores for the divided and selective attention tasks were minimised by grouping them into discrete UFOV loss categories. However, the UFOV test is more multi-factorial than the DRTS and this grouping only emphasises the limits of the UFOV test as a tool for driver screening. It is possible that the predictive power of the kinetic visual attention tests could be enhanced if the same procedures were adopted. An alternative strategy would be to replace reaction times with target detection rates. Here, the subject would be required to respond within a defined time limit. This study has also not investigated the effects of target luminance and colour contrast on kinetic visual attention. These aspects are important as we drive in a colourful world under a wide range of luminance levels (i.e. day and night). Finally, it was only possible to investigate the influence of target radial location on static visual attention. Inclusion of radial targets in kinetic visual attention tests would lend itself to research on the optimum positioning of in-car information devices and for the visual screening of drivers with visual field impairments. A new kinetic visual attention test (DRTS3) has just been developed at Aston University, incorporating the above suggestions.

Further, in view of current research trends it would be interesting to add eye movement analysis to the study. The DRTS could be used in conjunction with an eye-tracker (e.g. SensoMotoric Instruments eye camera) to monitor fixations and saccades and perhaps determine whether it is necessary to attend to a target or not in order to be able to detect it.

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APPENDIX ONE

UFOV VISUAL ATTENTION TEST

1a.1 Introduction

The printout provides a hard copy of patient information (see section 2.2.5), UFOV assessment scores, the threshold duration for task 1 (processing speed sub-test) and all the responses (i.e. raw data) made by the subject for each presentation made during both the divided and selective attention tasks of the UFOV test. The responses are shown on the printout as follows:

1) N = no mistakes
2) P = peripheral mistake
3) C = central mistake
4) B = both central and peripheral mistakes

Appendix 1a

USEFUL FIELD OF VIEW
DIAGNOSTIC EXAMINATION

Visual Attention Analyser

Visual Resources Inc., 1733 Campus Plaza, Suite 15, Bowling Green, KY 42101

BACKGROUND INFORMATION

Name: N P

SSN: 100000001

Birth Date: 11--15--1964

Test Date: 02--01--199

UFOV ASSESSMENT

TEST RESULTS: VALID

TEST TIME: 12.17 MIN.

Degree of Reduction in the Useful Field of View: 55.00%

BASIS OF LOSS:

Processing speed loss:	10.00%
Divided attention loss:	20.00%
Selective attention loss:	25.00%

Threshold duration - task 1: 47 msec.

Task 2 - Divided Attention

duration	UFOV	center misses
240	not tested	
200	not tested	
160	22.5	0
120	5	0
80	not tested	
40	not tested	

Divided attention loss: 20

Task 3 - Selective Attention

duration	UFOV	centre misses
240	12.5	1
200	5	0
160	not tested	
120	not tested	

80	not tested
40	not tested

Selective attention loss: 25

TRIAL BY TRIAL LISTING

TASK	DURATION	TYPE ERROR	PERIPHERAL SPOKE	TARGET LOCATION ECCENTRICITY
2	120	P	8	10
2	120	P	1	20
2	120	P	8	30
2	120	P	6	20
2	120	P	3	10
2	120	P	5	30
2	120	P	2	10
2	120	P	5	20
2	120	P	1	30
2	120	P	4	30
2	120	P	3	20
2	120	P	1	10
2	120	P	6	10
2	120	P	4	20
2	120	P	7	30
2	160	N	5	10
2	160	N	8	20
2	160	P	2	30
2	160	N	7	10
2	160	N	7	20
2	160	P	6	30
2	160	N	4	10
2	160	N	2	20
2	160	P	3	30
2	160	N	1	10
2	160	P	4	20
2	160	P	8	30
2	160	N	5	10
2	160	P	7	20
2	160	N	7	30
3	240	N	2	10
3	240	P	6	20
3	240	B	2	30
3	240	N	7	10
3	240	P	3	20
3	240	P	7	30
3	240	P	8	30
3	240	N	5	20
3	240	N	5	10
3	240	P	6	30
3	240	P	8	20
3	240	P	3	10
3	240	P	4	10
3	240	P	7	20

3	240	P	5	30
3	200	P	2	30
3	200	N	3	30
3	200	P	4	20
3	200	P	6	10
3	200	N	1	30
3	200	N	1	20
3	200	N	1	10
3	200	P	8	10
3	200	P	2	20
3	200	P	4	30
3	200	P	2	20
3	200	N	7	10
3	200	P	8	30
3	200	P	8	10
3	200	N	1	20
3	200	P	6	30

N=NO ERROR, C=CENTER ERROR, P=PERIPHERAL ERROR, B=CENTER AND PERIPHERAL ERROR

Appendix 1b

1b.1 Introduction

The following program was written in Quick Basic. It was written, based upon the author's understanding of the procedures used to derive final UFOV scores as deduced from examination of 82 sets of raw data. This program was subsequently tested on all sets of raw data and yielded the correct final UFOV scores in each case.

Appendix 1b

```
'UFOV Algorithm
'copyright Nicola Phelps
'version 02/03/00
'used for Phd Thesis 2001

CLS
PRINT "enter task 2 (divided) data"
duration1:
sumn10 = 0: sumn20 = 0: sumn30 = 0
sump10 = 0: sump20 = 0: sump30 = 0
INPUT "duration 240, 200, 160, 120, 80, 40"; dur
IF dur = 240 THEN dur240 = 1
IF dur = 200 THEN dur200 = 1
IF dur = 160 THEN dur160 = 1
IF dur = 120 THEN dur120 = 1
IF dur = 80 THEN dur80 = 1
IF dur = 40 THEN dur40 = 1

dataentry1:
    INPUT "eccentricity (10, 20, 30)"; ecc
    INPUT "response (n, p, b or c)"; resp$
    IF resp$ = "b" THEN GOTO dataloop1
    IF resp$ = "c" THEN GOTO dataloop1
    IF resp$ = "n" AND ecc = 10 THEN sumn10 = sumn10 + 1
    IF resp$ = "n" AND ecc = 20 THEN sumn20 = sumn20 + 1
    IF resp$ = "n" AND ecc = 30 THEN sumn30 = sumn30 + 1
    IF resp$ = "p" AND ecc = 10 THEN sump10 = sump10 + 1
    IF resp$ = "p" AND ecc = 20 THEN sump20 = sump20 + 1
    IF resp$ = "p" AND ecc = 30 THEN sump30 = sump30 + 1

dataloop1:
    PRINT "more data for duration"; dur
    INPUT "yes(y) or finish(return)"; option$
    IF option$ = "y" THEN GOTO dataentry1
    percent10 = ((sump10 / (sumn10 + sump10)) * 100)
    percent20 = ((sump20 / (sumn20 + sump20)) * 100)
    percent30 = ((sump30 / (sumn30 + sump30)) * 100)
    sump = sump10 + sump20 + sump30
    IF dur240 = 1 THEN pt10240 = percent10
    IF dur240 = 1 THEN pt20240 = percent20
    IF dur240 = 1 THEN pt30240 = percent30
    IF dur200 = 1 THEN pt10200 = percent10
    IF dur200 = 1 THEN pt20200 = percent20
    IF dur200 = 1 THEN pt30200 = percent30
    IF dur160 = 1 THEN pt10160 = percent10
    IF dur160 = 1 THEN pt20160 = percent20
    IF dur160 = 1 THEN pt30160 = percent30
    IF dur120 = 1 THEN pt10120 = percent10
    IF dur120 = 1 THEN pt20120 = percent20
    IF dur120 = 1 THEN pt30120 = percent30
    IF dur80 = 1 THEN pt1080 = percent10
    IF dur80 = 1 THEN pt2080 = percent20
    IF dur80 = 1 THEN pt3080 = percent30
    IF dur40 = 1 THEN pt1040 = percent10
    IF dur40 = 1 THEN pt2040 = percent20
    IF dur40 = 1 THEN pt3040 = percent30
    IF dur40 = 1 AND sump > 2 THEN divloss = 5
    INPUT "another duration (y) or finish(return)"; option$
    IF option$ = "y" THEN GOTO duration1

'calculate divided attention score
    IF pt30240 > 49 AND pt20240 > 49 AND pt10240 > 49 THEN divufov240 = 5
    IF pt30200 > 49 AND pt20200 > 49 AND pt10200 > 49 THEN divufov200 = 5
    IF pt30160 > 49 AND pt20160 > 49 AND pt10160 > 49 THEN divufov160 = 5
    IF pt30120 > 49 AND pt20120 > 49 AND pt10120 > 49 THEN divufov120 = 5
    IF pt3080 > 49 AND pt2080 > 49 AND pt1080 > 49 THEN divufov80 = 5
    IF pt3040 > 49 AND pt2040 > 49 AND pt1040 > 49 THEN divufov40 = 5
```

Appendix 1b

```
'calculate divided attention loss
     PRINT "Divided Attention"
     IF dur240 = 1 AND divufov240 = 5 THEN divufov = 30
     IF dur200 = 1 AND divufov200 = 5 THEN divufov = 27.5
     IF dur160 = 1 AND divufov160 = 5 THEN divufov = 25
     IF dur120 = 1 AND divufov120 = 5 THEN divufov = 20
     IF dur80 = 1 AND divufov80 = 5 THEN divufov = 15
     IF dur40 = 1 AND divufov40 = 5 THEN divufov = 10
     IF dur40 = 1 AND divloss = 5 AND divufov40 = 0 THEN divufov = 5
     IF dur40 = 1 AND divloss = 0 AND divufov40 = 0 THEN divufov = 0
     PRINT "UFOV loss ="; divufov; "%"
     dur240 = 0: dur200 = 0: dur160 = 0: dur120 = 0: dur80 = 0: dur40 = 0

PRINT "enter task 3 (selective) data"
duration2:
sumn10 = 0: sumn20 = 0: sumn30 = 0
sump10 = 0: sump20 = 0: sump30 = 0
INPUT "duration 240, 200, 160, 120, 80, 40"; dur
IF dur = 240 THEN dur240 = 1
IF dur = 200 THEN dur200 = 1
IF dur = 160 THEN dur160 = 1
IF dur = 120 THEN dur120 = 1
IF dur = 80 THEN dur80 = 1
IF dur = 40 THEN dur40 = 1

dataentry2:
     INPUT "eccentricity"; ecc
     INPUT "response (n, p, b or c)"; resp$
     IF resp$ = "b" THEN GOTO dataloop2
     IF resp$ = "c" THEN GOTO dataloop2
     IF resp$ = "n" AND ecc = 10 THEN sumn10 = sumn10 + 1
     IF resp$ = "n" AND ecc = 20 THEN sumn20 = sumn20 + 1
     IF resp$ = "n" AND ecc = 30 THEN sumn30 = sumn30 + 1
     IF resp$ = "p" AND ecc = 10 THEN sump10 = sump10 + 1
     IF resp$ = "p" AND ecc = 20 THEN sump20 = sump20 + 1
     IF resp$ = "p" AND ecc = 30 THEN sump30 = sump30 + 1

dataloop2:
     PRINT "more data for duration"; dur
     INPUT "yes(y) or finish(return)"; option$
     IF option$ = "y" THEN GOTO dataentry2
     percent10 = ((sump10 / (sumn10 + sump10)) * 100)
     percent20 = ((sump20 / (sumn20 + sump20)) * 100)
     percent30 = ((sump30 / (sumn30 + sump30)) * 100)
     IF dur = 240 THEN pt10240 = percent10
     IF dur = 240 THEN pt20240 = percent20
     IF dur = 240 THEN pt30240 = percent30
     IF dur = 200 THEN pt10200 = percent10
     IF dur = 200 THEN pt20200 = percent20
     IF dur = 200 THEN pt30200 = percent30
     IF dur = 160 THEN pt10160 = percent10
     IF dur = 160 THEN pt20160 = percent20
     IF dur = 160 THEN pt30160 = percent30
     IF dur = 120 THEN pt10120 = percent10
     IF dur = 120 THEN pt20120 = percent20
     IF dur = 120 THEN pt30120 = percent30
     IF dur = 80 THEN pt1080 = percent10
     IF dur = 80 THEN pt2080 = percent20
     IF dur = 80 THEN pt3080 = percent30
     IF dur = 40 THEN pt1040 = percent10
     IF dur = 40 THEN pt2040 = percent20
     IF dur = 40 THEN pt3040 = percent30
     INPUT "another duration (y) or finish(return)"; option$
     IF option$ = "y" THEN GOTO duration2

'calculate selective attention score
     IF pt30240 > 49 AND pt20240 > 49 AND pt10240 > 49 THEN selufov240 = 5
     IF pt30200 > 49 AND pt20200 > 49 AND pt10200 > 49 THEN selufov200 = 5
```

```
    IF pt30160 > 49 AND pt20160 > 49 AND pt10160 > 49 THEN selufov160 = 5
    IF pt30120 > 49 AND pt20120 > 49 AND pt10120 > 49 THEN selufov120 = 5
    IF pt3080 > 49 AND pt2080 > 49 AND pt1080 > 49 THEN selufov80 = 5
    IF pt3040 > 49 AND pt2040 > 49 AND pt1040 > 49 THEN selufov40 = 5

'calculate selective attention loss
    PRINT "Selective Attention"
    IF dur240 = 1 AND selufov240 = 5 THEN selufov = 30
    IF dur200 = 1 AND selufov200 = 5 THEN selufov = 25
    IF dur160 = 1 AND selufov160 = 5 THEN selufov = 22.5
    IF dur120 = 1 AND selufov120 = 5 THEN selufov = 17.5
    IF dur80 = 1 AND selufov80 = 5 THEN selufov = 12.5
    IF dur40 = 1 AND selufov40 = 5 THEN selufov = 7.5
    IF dur40 = 1 AND selufov40 = 0 THEN selufov = 0
    PRINT "UFOV loss ="; selufov; "%"
    dur240 = 0: dur200 = 0: dur160 = 0: dur120 = 0: dur80 = 0: dur40 = 0

    END
```

APPENDIX TWO

DRTS1 PROGRAM

Appendix 2a

2a.1 Introduction

The DRTS1 program was written using Quick Basic

2a.2 The program

```
'DRIVER'S REACTION TIME SIMULATOR; APPROA30.BAS; TESTING PROTOTYPE
'copyright Mark Dunne
'version 14/7/97
'renamed DRTS
'used for elective studies 97/8

'value of PI for degree-radian conversions
CONST PI = 3.141592654#

'OPENING SCREEN
    CLS
    PRINT : PRINT : PRINT "          ********* DRIVER'S REACTION TIME SIMULATOR *********"
        'prompt the operator to press keys "Fn" + "F10"
        'this necesary for responses made via SPACEBAR
        'pressing these keys twice allows normal keyboard use
        'which is necessary to allow change of options
    PRINT : PRINT "    IMPORTANT - IF YOU HAVE JUST SWITCHED THE COMPUTER ON"
    PRINT "    YOU WILL NEED TO ACTIVATE THE SPACEBAR AS FOLLOWS"
    PRINT : PRINT "        Hold down Fn key, then press F10 key"
    PRINT "        Do this twice and then press RETURN"
    PRINT : INPUT "    YOU DO NOT NEED TO DO THIS AGAIN WHEN RE-RUNNING SIMULATOR"; xxxx
        'declare that KEY 15 is SPACEBAR
            KEY 15, CHR$(0) + CHR$(57)

    PRINT : INPUT "    STANDARD (press RETURN) or ENHANCED (press 1) monitor resolution"; resopt

        'screen mode
            IF resopt = 0 THEN SCREEN 2
            IF resopt = 1 THEN SCREEN 12
        'horizontal dimension of monitor in pixels
            hpix = 640
        'vertical dimension of monitor in pixels
            IF resopt = 1 THEN vpix = 480 ELSE vpix = 200

optscreen:
'OPTIONS SCREEN

CLS
PRINT : PRINT : PRINT "               ********* OPTIONS *********"

PRINT : PRINT "    IMPORTANT - THESE OPTIONS ARE HIERARCHICAL"

PRINT : PRINT "      1. option scenery complexity"
PRINT : PRINT "      2. option simulator characteristics"
PRINT : PRINT "      3. option monitor calibration"
PRINT : PRINT "      4. option events and repeats"
PRINT : PRINT "      5. option static/dynamic and speed"
PRINT : PRINT "      press RETURN to proceed straight away"
PRINT : PRINT : INPUT "      select option"; mainopt

        IF mainopt = 1 THEN GOSUB mainopt1
        IF mainopt = 2 THEN GOSUB mainopt2
        IF mainopt = 3 THEN GOSUB mainopt3
        IF mainopt = 4 THEN GOSUB mainopt4
        IF mainopt = 5 THEN GOSUB mainopt5

        IF mainopt > 0 THEN PRINT : INPUT "    more changes (press 1) or not (press RETURN)"; moropt
            IF moropt = 1 THEN GOTO optscreen
```

Appendix 2a

```
'** DEFAULT SETTINGS **

    IF mwd = 0 THEN mwd = .5
    IF eyeht = 0 THEN eyeht = 1.25
    IF vmph = 0 THEN vmph = 50
        'convert mph to m/s (1 mph = 0.447 m/s)
            vms = vmph * .447
        'braking distances at driving speed (m) - from DVLA figures
            brakdist = .6 - (.037 * vmph) + (.016 * (vmph ^ 2))
    IF dlimit = 0 THEN dlimit = 400
        'calculate initial angle of line of sight to road surface
            tananglimit = eyeht / dlimit
    IF rdwidth = 0 THEN rdwidth = 7
    IF dyndist = 0 THEN dyndist = 100
    IF koh = 0 THEN koh = 5
    IF kow = 0 THEN kow = .2

    IF lcarh = 0 THEN lcarh = 1.5
    IF lcarw = 0 THEN lcarw = 2
    IF foldist = 0 THEN foldist = 100
    IF sepopt = 1 THEN foldist = vms * foltime
    IF pedh = 0 THEN pedh = 1.8
    IF pedw = 0 THEN pedw = .75
    IF pedvmph = 0 THEN pedvmph = 7.5
        'convert mph-m/s (1 mph = 0.447 m/s)
            pedvms = pedvmph * .447
    IF pedang(1) = 0 THEN pedang(1) = 2.5
    IF pedang(2) = 0 THEN pedang(2) = 5
    IF pedang(3) = 0 THEN pedang(3) = 7.5
        'calculate pedestrian crossing parameters
        'pedestrians commence crossing at specified angular subtenses
        'NB - pedestrians commence crossing at specified foldist
            'inner row of pedestrians
                tanpedang(1) = TAN(pedang(1) * (PI / 180))
                pedkerbdist(1) = (foldist * tanpedang(1)) - (rdwidth / 2)
            'middle row of pedestrians
                tanpedang(2) = TAN(pedang(2) * (PI / 180))
                pedkerbdist(2) = (foldist * tanpedang(2)) - (rdwidth / 2)
            'outer row of pedestrians
                tanpedang(3) = TAN(pedang(3) * (PI / 180))
                pedkerbdist(3) = (foldist * tanpedang(3)) - (rdwidth / 2)
    IF interval = 0 THEN interval = 100
        'set initial value of dynamic interval (procedure 3)
            dinterval = interval

    IF eventnum = 0 THEN eventnum = 8
    IF staticopt = 1 THEN scenopt3 = 1
    IF staticopt = 1 THEN scenopt4 = 1
    IF repeats = 0 THEN repeats = 3

    'default monitor widths based on laptop screen
        'monitor width (m)
            IF mwidth = 0 THEN mwidth = .21
        'monitor height (m)
            IF mheight = 0 AND resopt = 0 THEN mheight = .131
            IF mheight = 0 AND resopt = 1 THEN mheight = .158
    'calculate pixel sizes
        'individual pixel width (m)
            pixwidth = mwidth / hpix
        'individual pixel height (m)
            pixheight = mheight / vpix

'carry out photometry option here
        IF photopt = 1 THEN GOSUB photometer

'processor calibration sequence
'NB - NO SCREEN COMMANDS AFTER THIS LINE OTHERWISE THIS INCLUDED IN TIME
    'calibration to be carried out during event x=1
```

Appendix 2a

```
    'calculate theoretical duration of event x=1 (ms)
            eventime = (dlimit / vms) * 1000
    'determine actual duration of event x=1
            TIMER ON
            actestart = TIMER

'generate continuous road scene until all tasks have been completed
DO
    'main loop counter (will never exceed eventnum*repeats)
        mainloopcount = mainloopcount + 1

    'EVENT CONTROLLER
    'ensure that there are two initial sweeps of event x=1
    'the first sweep of x=1 involves processor calibration
    'the second sweep of event x=1 ensures sequence starts with no event
        IF mainloopcount < 3 THEN x = 1
        IF mainloopcount < 3 THEN GOTO randjump

    'use randomiser to initiate various events
    'this yields 2 to eventnum randomly
tryagain:
                RANDOMIZE TIMER
                x = INT(RND * (eventnum - 1)) + 2
            'explanation
                'x=1 then no event occurs
                'x=2 then leading car suddenly stops
                    x2$ = "leading car stops"
                'x=3 then nearside pedestrian crosses
                    x3$ = "inner nearside pedestrian crosses"
                'x=4 then offside pedestrian crosses
                    x4$ = "inner offside pedestrian crosses"
                'x=5 then nearside pedestrian crosses
                    x5$ = "middle nearside pedestrian crosses"
                'x=6 then offside pedestrian crosses
                    x6$ = "middle offside pedestrian crosses"
                'x=7 then nearside pedestrian crosses
                    x7$ = "outer nearside pedestrian crosses"
                'x=8 then offside pedestrian crosses
                    x8$ = "outer offside pedestrian crosses"

            'ensure that all events shown equal number of times
                IF x > 1 THEN GOSUB eventcontrol
                IF zap(x) = 1 THEN GOTO tryagain

    'SUBJECT REACTIONS
        'reset keystrike to zero
            keystrike = 0
        'handle subject responses
            IF x > 1 THEN GOSUB reaction
randjump:

    'PROCEDURE ONE
    'generate moving reference point at specified time intervals
        'set initial time to zero
            time = 0
        'reset pedcount (see procedures 7-9 & subroutine latposped) to zero
            pedcount = 0
        'reset lcarelv (see procedure 6)
            lcarelv = 0
        'reset lcartotd (see procedure 6, dynamic)
            lcartotd = 0
        'reset framecount
            framecount = 0

    'keep generating scene until reference objects are 1m from observer
    DO
        'count number of frames per event
        'framecount is set to zero at beginning of event loop
```

```
            framecount = framecount + 1

    'count up to specified time interval
        starttime = TIMER
            DO WHILE timelapse < interval
            endtime = TIMER
            timelapse = (endtime - starttime) * 1000
            LOOP
            timelapse = 0
CLS

'PROCEDURE TWO
'draw static road scene - horizon, near/offside kerb edges
        IF circopt = 1 THEN GOSUB circles
        GOSUB roadscene

'PROCEDURE THREE
'generate a moving reference point for dynamic road scene
'dynamic road scene governed by speed of observer
    'distance travelled in time interval
        time = time + dinterval
        deltad = vms * (time / 1000)
    'distance from observer (dnext)
    'dnext is effectively a moving reference point
        dnext = dlimit - deltad

'PROCEDURE FOUR
'generate dynamic road scene objects
'object sets = near/offside pedestrians and lamposts
    'reference object
    'additional objects are placed with respect to this one
            d = dnext
            'do not draw pedestrians at this distance
            'because procedures 7-9 handle this
                pedskip = 1
            GOSUB objecthandler
            'reset pedskip
                pedskip = 0
    'calculate additional number of objects
        addob = (dlimit / dyndist) - 1
    'generate additional objects
        'objects in front of reference
            FOR dynloop = 1 TO addob
            d = dnext - (dynloop * dyndist)
            GOSUB objecthandler
            NEXT dynloop
        'objects behind reference
            FOR dynloop = 1 TO addob
            d = dnext + (dynloop * dyndist)
            GOSUB objecthandler
            NEXT dynloop

'PROCEDURE FIVE - approaching car removed

'PROCEDURE SIX
'generate leading car
    '**static test**
    'car suddenly appears
        'car not present unless x=2
            IF staticopt = 1 AND x <> 2 THEN GOTO lcarjump
        'show car when x = 2
            IF staticopt = 1 AND x = 2 THEN lcardnext = foldist
            IF staticopt = 1 AND x = 2 THEN GOTO showlcar
        'NB - braking in time to stop does not apply to static test

    '**dynamic test**
    'car always present at following distance but suddenly slows down
    'calculate car distance with time - see procedure 3
```

```
            'lcarelv is set to zero at beginning of event loop
            'car slows down if x=2
                IF x = 2 THEN lcarelv = lcarelv + decmss
            'ensure that speed is not less than zero
                IF lcarelv > vms THEN lcarelv = vms
            'distance travelled by lcar during dinterval
                lcardeltad = lcarelv * (dinterval / 1000)
            'total distance travelled by lcar
            'lcartotd is set to zero at beginning of event loop
                lcartotd = lcartotd + lcardeltad
            'remaining lcar braking time
                lcarbraktime = sumbraktime - (time / 1000)
            'distance from observer
                lcardnext = foldist - lcartotd
            'time separating lcar from observer
                lcardnextime = lcardnext / vms
        're-position car after F1 key has been pressed
            IF keystrike = 1 THEN lcardnext = foldist
showlcar:
    IF staticopt = 1 AND x = 2 AND keystrike = 1 THEN GOTO lcarjump
        'calculate car dimensions on screen
                d = lcardnext
                IF d < 1 THEN GOTO lcarjump
                IF d > dlimit THEN GOTO lcarjump
            wdth = rdwidth
                GOSUB genwidth
                    rdwidthpix = widthpix
            wdth = lcarw
                GOSUB genwidth
                    lcarwpix = widthpix
            height = lcarh
                GOSUB genheight
                    lcarhpix = heightpix
                GOSUB roadrop
        'draw car
            'centre car in middle of same lane
            a = (hpix / 2) - (lcarwpix / 2)
            c = a + lcarwpix
            b = (vpix / 2) + rdropix
            dd = b - lcarhpix
            LINE (a, b)-(c, dd), , BF
lcarjump:

    'PROCEDURE SEVEN
    'generate inner row target pedestrians at kerbside
        '**static test**
        'pedestrian suddenly appears
            'only one pedestrian to be shown for each event
                IF staticopt = 1 AND x = 3 THEN pednext = foldist
                IF staticopt = 1 AND x = 3 THEN GOTO showped1
                IF staticopt = 1 AND x = 4 THEN pednext = foldist
                IF staticopt = 1 AND x = 4 THEN GOTO showped1
                IF staticopt = 1 AND x = 5 THEN pednext = foldist
                IF staticopt = 1 AND x = 5 THEN GOTO showped2
                IF staticopt = 1 AND x = 6 THEN pednext = foldist
                IF staticopt = 1 AND x = 6 THEN GOTO showped2
                IF staticopt = 1 AND x = 7 THEN pednext = foldist
                IF staticopt = 1 AND x = 7 THEN GOTO showped3
                IF staticopt = 1 AND x = 8 THEN pednext = foldist
                IF staticopt = 1 AND x = 8 THEN GOTO showped3

            'NB - braking in time to stop does not apply to static test

        '**dynamic test**
        'calculate relative velocity - see procedure 3
        'pedestrians stand still at kerb edge
                pedrelv = vms
        'calculate pedestrian distance with time - see procedure 3
```

```
                pedeltad = pedrelv * (time / 1000)
        'pedestrian distance from observer
                pednext = dlimit - pedeltad
        'one of the pedestrians now crosses the road
        'pedestrian is immediately repositioned once F1 is pressed
                IF x = 3 AND keystrike = 0 THEN GOSUB latposped
                IF x = 4 AND keystrile = 0 THEN GOSUB latposped

'static option pedestrian dissappears once F1 is pressed
showped1:
    IF staticopt = 1 AND x = 3 AND keystrike = 1 THEN GOTO pedjump1
    IF staticopt = 1 AND x = 4 AND keystrike = 1 THEN GOTO pedjump1

        'calculate pedestrian size on screen
                d = pednext
                IF d < 1 THEN GOTO pedjump1
            wdth = rdwidth
                GOSUB genwidth
                    rdwidthpix = widthpix
            wdth = pedkerbdist(1)
                GOSUB genwidth
                    pedkerbpix = widthpix
            wdth = pedlatdeltad
                GOSUB genwidth
                    pedlatdeltapix = widthpix
            wdth = pedw
                GOSUB genwidth
                    pedwpix = widthpix
            height = pedh
                GOSUB genheight
                    pedhpix = heightpix
                GOSUB roadrop

        'draw nearside pedestrian
            a = (hpix / 2) - (rdwidthpix * .5) - pedkerbpix
                IF staticopt = 0 AND x = 3 AND keystrike = 0 THEN GOSUB nspedcross
            c = a - pedwpix
            b = (vpix / 2) + rdropix
            dd = b - pedhpix
            'this stops object pesistance at LH edge of screen
            'and prevents object from being shown in scenery option 4
            IF a > 0 AND scenopt4 = 0 THEN LINE (a, b)-(c, dd), , BF
            'this overrides scenery option 4 if static option chosen
            IF staticopt = 1 AND x = 3 AND a > 0 AND scenopt4 = 1 THEN LINE (a, b)-(c, dd), , BF
        'draw offside pedestrian
            a = (hpix / 2) + (rdwidthpix * .5) + pedkerbpix
                IF staticopt = 0 AND x = 4 AND keystrike = 0 THEN GOSUB ospedcross
            c = a + pedwpix
            'this stops object pesistance at LH edge of screen
            'and prevents object from being shown in scenery option 4
            IF a > 0 AND scenopt4 = 0 THEN LINE (a, b)-(c, dd), , BF
            'this overrides scenery option 4 if static option chosen
            IF staticopt = 1 AND x = 4 AND a > 0 AND scenopt4 = 1 THEN LINE (a, b)-(c, dd), , BF

 pedjump1:

     'PROCEDURE EIGHT
     'generate middle row target pedestrians at kerbside
         'pedestrian is immediately repositioned once F1 is pressed
                 IF x = 5 AND keystrike = 0 THEN GOSUB latposped
                 IF x = 6 AND keystrile = 0 THEN GOSUB latposped
         'calculate pedestrian size on screen
 showped2:
     IF staticopt = 1 AND x = 5 AND keystrike = 1 THEN GOTO pedjump2
     IF staticopt = 1 AND x = 6 AND keystrike = 1 THEN GOTO pedjump2
                 d = pednext
                 IF d < 1 THEN GOTO pedjump2
             wdth = rdwidth
```

```
                GOSUB genwidth
                    rdwidthpix = widthpix
            wdth = pedkerbdist(2)
                GOSUB genwidth
                    pedkerbpix = widthpix
            wdth = pedlatdeltad
                GOSUB genwidth
                    pedlatdeltapix = widthpix
            wdth = pedw
                GOSUB genwidth
                    pedwpix = widthpix
            height = pedh
                GOSUB genheight
                    pedhpix = heightpix
                GOSUB roadrop

        'draw nearside pedestrian
            a = (hpix / 2) - (rdwidthpix * .5) - pedkerbpix
                IF staticopt = 0 AND x = 5 AND keystrike = 0 THEN GOSUB nspedcross
            c = a - pedwpix
            b = (vpix / 2) + rdropix
            dd = b - pedhpix
            'this stops object pesistance at LH edge of screen
            'and prevents object from being shown in scenery option 4
            IF a > 0 AND scenopt4 = 0 THEN LINE (a, b)-(c, dd), , BF
            'this overrides scenery option 4 if static option chosen
            IF staticopt = 1 AND x = 5 AND a > 0 AND scenopt4 = 1 THEN LINE (a, b)-(c, dd), , BF
        'draw offside pedestrian
            a = (hpix / 2) + (rdwidthpix * .5) + pedkerbpix
                IF staticopt = 0 AND x = 6 AND keystrike = 0 THEN GOSUB ospedcross
            c = a + pedwpix
            'this stops object pesistance at LH edge of screen
            'and prevents object from being shown in scenery option 4
            IF a > 0 AND scenopt4 = 0 THEN LINE (a, b)-(c, dd), , BF
            'this overrides scenery option 4 if static option chosen
            IF staticopt = 1 AND x = 6 AND a > 0 AND scenopt4 = 1 THEN LINE (a, b)-(c, dd), , BF

pedjump2:

    'PROCEDURE NINE
    'generate outer row target pedestrians at kerbside
        'dynamic option pedestrian is immediately repositioned once F1 is pressed
                IF x = 7 AND keystrike = 0 THEN GOSUB latposped
                IF x = 8 AND keystrile = 0 THEN GOSUB latposped

'static option pedestrian dissappears once F1 is pressed
showped3:
    IF staticopt = 1 AND x = 7 AND keystrike = 1 THEN GOTO pedjump3
    IF staticopt = 1 AND x = 8 AND keystrike = 1 THEN GOTO pedjump3

        'calculate pedestrian size on screen
                d = pednext
                IF d < 1 THEN GOTO pedjump3
            wdth = rdwidth
                GOSUB genwidth
                    rdwidthpix = widthpix
            wdth = pedkerbdist(3)
                GOSUB genwidth
                    pedkerbpix = widthpix
            wdth = pedlatdeltad
                GOSUB genwidth
                    pedlatdeltapix = widthpix
            wdth = pedw
                GOSUB genwidth
                    pedwpix = widthpix
            height = pedh
                GOSUB genheight
                    pedhpix = heightpix
```

```
                GOSUB roadrop

        'draw nearside pedestrian
            a = (hpix / 2) - (rdwidthpix * .5) - pedkerbpix
                IF staticopt = 0 AND x = 7 AND keystrike = 0 THEN GOSUB nspedcross
            c = a - pedwpix
            b = (vpix / 2) + rdropix
            dd = b - pedhpix
            'this stops object pesistance at LH edge of screen
            'and prevents object from being shown in scenery option 4
            IF a > 0 AND scenopt4 = 0 THEN LINE (a, b)-(c, dd), , BF
            'this overrides scenery option 4 if static option chosen
            IF staticopt = 1 AND x = 7 AND a > 0 AND scenopt4 = 1 THEN LINE (a, b)-(c, dd), , BF
        'draw offside pedestrian
            a = (hpix / 2) + (rdwidthpix * .5) + pedkerbpix
                IF staticopt = 0 AND x = 8 AND keystrike = 0 THEN GOSUB ospedcross
            c = a + pedwpix
            'this stops object pesistance at LH edge of screen
            'and prevents object from being shown in scenery option 4
            IF a > 0 AND scenopt4 = 0 THEN LINE (a, b)-(c, dd), , BF
            'this overrides scenery option 4 if static option chosen
            IF staticopt = 1 AND x = 8 AND a > 0 AND scenopt4 = 1 THEN LINE (a, b)-(c, dd), , BF

pedjump3:

    LOOP UNTIL dnext < 1

'carry out automatic processor calibration
    IF mainloopcount = 1 THEN GOSUB autoprocess

'STOP PROGRAM
    sumevents = eventcount(2) + eventcount(3) + eventcount(4) + eventcount(5) + eventcount(6) + eventcount(7) +
eventcount(8)
    LOOP UNTIL sumevents = (eventnum - 1) * repeats

    'calculate time of test (minus processor calibration) (ms)
        actestrestop = TIMER
        actestretime = (actestrestop - actestrestart) * 1000

    KEY(15) OFF
    TIMER OFF

'display detailed results on screen
    'show results for events - 1 page per event
        FOR x = 2 TO eventnum
            GOSUB reactdisplay

            'calculate total false positives
                totsporadpre = totsporadpre + sumsporadpre(x)
                totsporadpost = totsporadpost + sumsporadpost(x)
        NEXT x
            totfalsepos = totsporadpre + totsporadpost

' display summary results on screen
CLS
PRINT : PRINT : PRINT "    SUMMARY TABLE :"

   PRINT : PRINT "    total false positives = "; totfalsepos
   PRINT : PRINT "    ____________________________________________________________"
   PRINT : PRINT "    event                : 7  5  3  2  4  6  8"
       PRINT "    ____________________________________________________________"
PRINT : PRINT USING "    reaction time (ms)       : #### #### #### #### #### #### ####"; rt(7); rt(5); rt(3); rt(2); rt(4);
rt(6); rt(8)
PRINT : PRINT USING "    standard deviation (ms)  : #### #### #### #### #### #### ####"; sd(7); sd(5); sd(3); sd(2);
sd(4); sd(6); sd(8)
PRINT
PRINT : PRINT USING "    repeats                  : #### #### #### #### #### #### ####"; eventcount(7); eventcount(5);
eventcount(3); eventcount(2); eventcount(4); eventcount(6); eventcount(8)
```

Appendix 2a

```
PRINT : PRINT USING "   reactions            : #### #### #### #### #### #### ####"; reactot(7); reactot(5);
reactot(3); reactot(2); reactot(4); reactot(6); reactot(8)
IF staticopt = 0 THEN PRINT : PRINT USING "   reactions in time to stop : #### #### #### #### #### #### ####";
reactintime(7); reactintime(5); reactintime(3); reactintime(2); reactintime(4); reactintime(6); reactintime(8)
        PRINT " ____________________________________________________________________"
PRINT : PRINT : INPUT "    press RETURN to continue"; xxxx

'print adjusted dynamic time interval
    CLS
        PRINT : PRINT "   PROCESSOR CALIBRATION REPORT :"
        PRINT : PRINT USING "   adjusted dynamic interval = ###.### ms"; dinterval
        PRINT : PRINT USING "        predicted test duration = ###.### mins"; (seqtime / (60000))
        PRINT USING "         actual test duration = ###.### mins"; (actestretime / (60000))
    'calculate actual simulation speed
    'calculate average frame processing time
        meandifproctime = (actestretime - seqtime) / ((((eventnum - 1) * repeats) + 1) * framecount)
        PRINT : PRINT USING "   mean differential frame processing time = ##.## ms"; meandifproctime
    'distance travelled at specified speed and adjusted dynamic interval (m)
        distance = vms * (dinterval / 1000)
    'actual time interval (ms)
        actinterval = meandifproctime + dinterval
    'actual speed (m/s)
            actvms = distance / (actinterval / 1000)
        'conversion to mph
            actmph = actvms / .447
        PRINT : PRINT USING "   actual simulated speed = ###.## mph"; actmph
    'advice to operator
        PRINT : PRINT : PRINT "    at end of this program, press F5 key to start again"
END

mainopt1:
'subroutine for option 1
CLS
PRINT : PRINT : PRINT "                    ********* OPTION 1 *********"

    PRINT : PRINT "enter number then press RETURN or just press RETURN to skip"

    PRINT : INPUT "    delete horizon and kerb edges (press 1) or not"; scenopt1
    PRINT : INPUT "    delete kerbside lamposts (press 1) or not"; scenopt2
    PRINT : INPUT "    delete distractor pedestrians (press 1) or not"; scenopt3
    PRINT : INPUT "    delete target pedestrians (press 1) or not"; scenopt4
    PRINT : PRINT : INPUT "    add angular subtense circles (press 1) or not"; circopt
RETURN

mainopt2:
'subroutine for option 2
CLS
PRINT : PRINT "                    ********* OPTION 2 *********"

    PRINT : PRINT "enter number then press RETURN or just press RETURN to skip"

    PRINT : INPUT "    monitor viewing distance = 0.5 m "; mwd
    INPUT "   driver's eye height = 1.25 m "; eyeht

    IF scenopt1 = 0 THEN INPUT "    distance to horizon = 400 m "; dlimit
    IF scenopt1 = 0 THEN INPUT "    road width = 7 m "; rdwidth

    IF scenopt2 = 0 THEN PRINT "    separation of lamposts = 100 m "
    IF scenopt2 = 0 THEN INPUT "    ** must be integer of distance to horizon **"; dyndist
    IF scenopt2 = 0 THEN INPUT "        lampost height = 5 m "; koh
    IF scenopt2 = 0 THEN INPUT "        lampost width = 0.2 m "; kow

    INPUT "   leading car height = 1.5 m "; lcarh
    INPUT "   leading car width = 2 m "; lcarw
    PRINT "   separation from lead car"
    INPUT "       time in seconds (press 1) or distance in metres (RETURN)"; sepopt
    IF sepopt = 0 THEN INPUT "          following distance = 100 m"; foldist
    IF sepopt = 1 THEN INPUT "          time in seconds"; foltime
```

```
    IF scenopt4 = 0 THEN INPUT "    pedestrian height = 1.8 m "; pedh
    IF scenopt4 = 0 THEN INPUT "    pedestrian width = 0.75 m "; pedw
    IF scenopt4 = 0 THEN INPUT "    pedestrian crossing speed = 7.5 mph "; pedvmph
    IF scenopt4 = 0 THEN INPUT "        angular subtense of pedestrian inner row = 2.5 degrees "; pedang(1)
    IF scenopt4 = 0 THEN INPUT "        angular subtense of pedestrian middle row = 5 degrees "; pedang(2)
    IF scenopt4 = 0 THEN INPUT "        angular subtense of pedestrian outer row = 7.5 degrees "; pedang(3)

    INPUT "    initial frame time interval = 100 ms "; interval
RETURN

mainopt3:
'subroutine for option 3
CLS
PRINT : PRINT : PRINT "                    ********* OPTION 3 *********"
    PRINT : PRINT : INPUT "    photometry (press 1) or not (press RETURN)"; photopt
        IF photopt = 1 THEN PRINT "    photometry will carried out at later stage"
    PRINT : PRINT : INPUT "    calibrate monitor size (press 1) or not (press RETURN)"; calopt
        IF calopt = 1 THEN GOSUB calibrate
RETURN

mainopt4:
'subroutine for option 4
CLS
PRINT : PRINT : PRINT "                    ********* OPTION 4 *********"
PRINT : PRINT "    list of events :"
        PRINT : PRINT "        2. leading car stops"
        PRINT : PRINT "        3. inner nearside pedestrian crosses"
        PRINT : PRINT "        4. inner offside pedestrian crosses"
        PRINT : PRINT "        5. middle nearside pedestrian crosses"
        PRINT : PRINT "        6. middle offside pedestrian crosses"
        PRINT : PRINT "        7. outer nearside pedestrian crosses"
        PRINT : PRINT "        8. outer offside pedestrian crosses"
    PRINT : INPUT "    number of events (2 to 8), default = 8"; eventnum
    PRINT : INPUT "    number of repeats of each event, default = 3"; repeats
RETURN

mainopt5:
'subroutine for option 5
CLS
PRINT : PRINT : PRINT "                    ********* OPTION 5 *********"
PRINT : INPUT "        STATIC (press 1) or DYNAMIC test (press RETURN)"; staticopt
PRINT : INPUT "        driver's speed, default = 50 mph"; vmph
RETURN

calibrate:
'subroutine to calibrate monitor size
    'draw horizontal and vertical line lines
        CLS
        LINE (0, (vpix / 2))-(hpix, (vpix / 2))
        LINE ((hpix / 2), 0)-((hpix / 2), vpix)
    'prompt for measurements
        INPUT "vertical (mm)"; mheightmm
        mheight = mheightmm / 1000
        INPUT "horizontal (mm)"; mwidthmm
        mwidth = mwidthmm / 1000
RETURN

photometer:
'subroutine for photometric calibration
    'draw series of sampling squares
    'size of square should match photometer sampling circle diameter
    'photometer sampling circle diameter is given in degrees
    'angular subtense (diameter) of photometer sampling circle
        pang = 1
        tanpang = TAN(pang * (PI / 180))
    'size of square on monitor (m)
        mpss = tanpang * mwd
```

```
    'pixel size of square on monitor
        hpsp = INT(mpss / pixwidth)
        vpsp = INT(mpss / pixheight)
    'place squares in 5 x 3 (h x v) matrix over screen
        hsep = INT(hpix / 6)
        vsep = INT(vpix / 4)
    'draw squares
        CLS
        'three rows
        FOR vn = 1 TO 3
            'this draws four columns
            FOR hn = 1 TO 5
        LINE (((hsep * hn) - (hpsp / 2)), ((vsep * vn) - vpsp))-(((hsep * hn) + (hpsp / 2)), (vsep * vn)), , BF
        LINE (((hsep * hn) - (hpsp / 2)), ((vsep * vn)))-(((hsep * hn) + (hpsp / 2)), ((vsep * vn) + vpsp)), , B
            NEXT hn
        NEXT vn
        INPUT "see circles (press 1) or not (press RETURN)"; seecirc
        IF seecirc = 1 THEN GOSUB circles
        INPUT "press RETURN when photometry completed"; ccc
        CLS
RETURN

circles:
'subroutine to draw circles of varying angular subtense
    FOR fang = pedang(1) TO pedang(3) STEP pedang(1)
        GOSUB drawcircle
    NEXT fang
RETURN

drawcircle:
'general subroutine to draw a circle
    tanfang = TAN(fang * (PI / 180))
  'size of circle on monitor (m)
    moncircrad = tanfang * mwd
  'pixel size of circle on monitor
    hmoncircpix = INT(moncircrad / pixwidth)
    vmoncircpix = INT(moncircrad / pixheight)
    aspect = vmoncircpix / hmoncircpix
  'draw circle
    CIRCLE ((hpix / 2), (vpix / 2)), hmoncircpix, , , , aspect
RETURN

roadscene:
'subroutine to draw static road scene
'print any "on screen" messages here
    IF mainloopcount = 1 THEN PRINT "PROCESSOR CALIBRATION"
'draw horizon
    IF scenopt1 = 0 THEN LINE (0, (vpix / 2))-(hpix, (vpix / 2))
'draw kerb edges
    'calculate initial roadwidth/drop
        d = dlimit
        wdth = rdwidth
        GOSUB genwidth
        rdwidth1 = widthpix
        GOSUB roadrop
        rdrop1 = rdropix
    'calculate final road width/drop
        d = 1
        wdth = rdwidth
        GOSUB genwidth
        rdwidth2 = widthpix
        GOSUB roadrop
        rdrop2 = rdropix
    'draw a road as seen at the observer headheight
    'car positioned in middle of road
    'i.e. 50% of way across the road
    'draw nearside kerb edge
        a = (hpix / 2) - (rdwidth1 * .5)
```

```
        c = (hpix / 2) - (rdwidth2 * .5)
        b = (vpix / 2) + rdrop1
        dd = (vpix / 2) + rdrop2
        IF scenopt1 = 0 THEN LINE (a, b)-(c, dd)
    'draw offside kerb edge
        a = (hpix / 2) + (rdwidth1 * .5)
        c = (hpix / 2) + (rdwidth2 * .5)
        IF scenopt1 = 0 THEN LINE (a, b)-(c, dd)
RETURN

objecthandler:
'subroutine to handle dynamic road scene objects
    IF d < 1 THEN GOTO jump
    IF d > dlimit THEN GOTO jump

    'these items relate to lamp posts

            wdth = rdwidth
                GOSUB genwidth
                    rdwidthpix = widthpix
            wdth = kow
                GOSUB genwidth
                    kowpix = widthpix
            height = koh
                GOSUB genheight
                    kohpix = heightpix

    'these items relate to pedestrians
    IF pedskip = 1 THEN GOTO skipeds
            wdth = rdwidth
                GOSUB genwidth
                    rdwidthpix = widthpix

        'do calculations for three rows of pedestrians
        FOR row = 1 TO 3
            wdth = pedkerbdist(row)
                GOSUB genwidth
                    pedkerbpix(row) = widthpix
        NEXT row

            wdth = pedlatdeltad
                GOSUB genwidth
                    pedlatdeltapix = widthpix
            wdth = pedw
                GOSUB genwidth
                    pedwpix = widthpix
            height = pedh
                GOSUB genheight
                    pedhpix = heightpix

                GOSUB roadrop
                GOSUB graphics
                GOTO jump:
skipeds:
                GOSUB roadrop
                GOSUB graphics

jump:
bypass = 0
RETURN

genwidth:
'subroutine to calculate general widths at distance, d
    'width on monitor (m)
        monwidth = (mwd * wdth) / d
    'number of pixels representing width
        widthpix = INT(monwidth / pixwidth)
RETURN
```

Appendix 2a

```
genheight:
'subroutine to calculate general heights at distance, d
    'height on monitor (m)
        monheight = (mwd * height) / d
    'number of pixels representing height
        heightpix = INT(monheight / pixheight)
RETURN

roadrop:
'subroutine to calculate drop of road/objects below horizon at distance, d
    'new angle of line of sight to road surface
        tanang = eyeht / d
    'angular drop of road/object below horizon
        'this equals difference between anglimit and angnext
        tanangdiff = tanang - tananglimit
    'drop from monitor horizon in metres
        rdrop = mwd * tanangdiff
    'drop from monitor horizon in pixels
        rdropix = INT(rdrop / pixheight)
RETURN

graphics:
'subroutine to draw dynamic road scene object set

'draw lamposts

    'draw nearside kerb edge lampost
    a = (hpix / 2) - (rdwidthpix * .5)
    c = a - kowpix
    b = (vpix / 2) + rdropix
    dd = b - kohpix
    'this stops object pesistance at LH edge of screen
    IF a > 0 AND scenopt2 = 0 THEN LINE (a, b)-(c, dd), , BF

    'draw offside kerb edge lampost
    a = (hpix / 2) + (rdwidthpix * .5)
    c = a + kowpix
    IF scenopt2 = 0 THEN LINE (a, b)-(c, dd), , BF

'draw three rows of distractor pedestrians
IF pedskip = 1 THEN GOTO skip
FOR row = 1 TO 3
    'draw nearside pedestrian
    a = (hpix / 2) - (rdwidthpix * .5) - pedkerbpix(row)
    c = a - pedwpix
    b = (vpix / 2) + rdropix
    dd = b - pedhpix
    'this stops object pesistance at LH edge of screen
    IF a > 0 AND scenopt3 = 0 THEN LINE (a, b)-(c, dd), , BF

    'draw offside pedestrian
    a = (hpix / 2) + (rdwidthpix * .5) + pedkerbpix(row)
    c = a + pedwpix
    IF scenopt3 = 0 THEN LINE (a, b)-(c, dd), , BF
NEXT row

skip:
RETURN

autoprocess:
'subroutine to carry out automatic processor calibration
    'carry out automatic processor calibration during first sweep of event x=1
        CLS : PRINT "PLEASE WAIT ..."
    'time first event (ms)
        actestop = TIMER
        actestime = (actestop - actestart) * 1000
    'calculate average frame processing time
```

```
        meanproctime = (actestime - eventime) / framecount
    'make automatic adjustment to dynamic interval (procedure 3)
        dinterval = dinterval + meanproctime
    'calculate deceleration of leading car (dependent upon dinterval)
        GOSUB decelerate
    'print advice to driver
        CLS : PRINT : PRINT "     ADVICE TO DRIVER :"
    'calculate duration of all events/repeats (ms)
        seqtime = eventime * (1 + ((eventnum - 1) * repeats))
    'screen display
        PRINT : PRINT USING "         estimated test duration = ##.# mins "; (seqtime / (60000))
        PRINT : PRINT "     BRAKING DATA :"
        PRINT : PRINT USING "             deceleration while braking = ##.# ms-2 "; decmss
        PRINT USING "             total braking time = ##.# s "; sumbraktime
        PRINT : PRINT "     INSTRUCTIONS TO DRIVER :"
        PRINT : PRINT "     respond by pressing the SPACEBAR"
        PRINT : INPUT "     press RETURN to begin testing"; xxxx
    'start timing again to check on accuracy of dinterval estimate
        actestrestart = TIMER
RETURN

decelerate:
'subroutine to calculate deceleration needed to stop car in stopping distance
    'find correct deceleration for given speed, braking distance, dinterval
        'initial deceleration (m/s/s)
            decmss = 1
decloop:
        'set initial parameters

            sumdistance = 0
            sumbraktime = 0

    'find stopping distance for given amount of deceleration
        speed = vms
        DO
        speed = speed - (decmss * (dinterval / 1000))
        decdistance = speed * (dinterval / 1000)
        sumdistance = sumdistance + decdistance
        sumbraktime = sumbraktime + (dinterval / 1000)
        LOOP UNTIL speed < 0

    'iteratively alter deceleration
        IF sumdistance > brakdist THEN decmss = decmss + .01
        IF sumdistance > brakdist THEN GOTO decloop
    RETURN

'subroutine to control static test option
statrand:
RETURN

'**PROCEDURE SEVEN SUBROUTINES**
latposped:
    'calculate change in lateral position for near or offside pedestrian
        IF pednext < foldist THEN pedcount = pedcount + 1
        IF pedcount = 1 THEN pedstartime = time
        IF pedcount = 1 THEN actpedstartime(x) = TIMER
        IF pednext < foldist THEN pedcrosstime = time - pedstartime
        IF pednext < foldist THEN pedlatdeltad = pedvms * (pedcrosstime / 1000)
    RETURN
nspedcross:
    'nearside pedestrian crosses road
        IF pednext < foldist THEN a = (hpix / 2) - (rdwidthpix * .5) - pedkerbpix + pedlatdeltapix
    RETURN
ospedcross:
    'offside pedestrian crosses road
        IF pednext < foldist THEN a = (hpix / 2) + (rdwidthpix * .5) + pedkerbpix - pedlatdeltapix
    RETURN
```

```
'**END OF PROCEDURE SEVEN SUBROUTINES**

'**SUBJECT REACTION SUBROUTINES**

eventcontrol:
'subroutine controlling number of events
    IF eventcount(x) = repeats THEN zap(x) = 1
    RETURN

reaction:
'subroutine allowing subject to respond via SPACEBAR
    'start timing
        reactstart(x) = TIMER
    'count number of times that an event happens
        eventcount(x) = eventcount(x) + 1
    'listen out for response via SPACEBAR
        ON KEY(15) GOSUB record
        KEY(15) ON
    RETURN

record:
'subroutine to record reaction

    'ensure that driver cannot react before pedestrian crosses
    'record each time this happens
    IF x > 2 AND pednext > foldist THEN sporadpre(x) = 1
    IF x > 2 AND pednext > foldist THEN GOTO jumprecord

    'ensure that driver cannot react again after event has occured
    'record each time this happens
    IF keystrike = 1 THEN sporadpost(x) = 1 ELSE sporadpost(x) = 0
    IF keystrike = 1 THEN GOTO jumprecord

    'count total reactions
        reactot(x) = reactot(x) + 1

    'count reactions allowing time to stop
        IF x = 2 AND sumbraktime < (lcardnextime + lcarbraktime) THEN reactintime(x) = reactintime(x) + 1
        IF x > 2 AND pednext > brakdist THEN reactintime(x) = reactintime(x) + 1

    'calculate reaction time
        reactstop(x) = TIMER
        reactlapse(x) = (reactstop(x) - reactstart(x)) * 1000

    'the next 2 lines relate to dynamic option pedestrian events
    'must account for fact that pedestrian does not cross immediately
        IF staticopt = 0 AND x > 2 THEN reactlapse(x) = reactlapse(x) - ((actpedstartime(x) - reactstart(x)) * 1000)

    'intermediate steps for estimating mean and standard deviation
        'sum of values
            sumreactlapse(x) = sumreactlapse(x) + reactlapse(x)
        'sum of values squared
            reactlapse2(x) = reactlapse(x) ^ 2
            sumreactlapse2(x) = sumreactlapse2(x) + reactlapse2(x)

    'record the occurence of a key strike
        keystrike = 1
jumprecord:
    IF x > 2 AND pednext > foldist THEN sumsporadpre(x) = sumsporadpre(x) + sporadpre(x)
    IF keystrike = 1 THEN sumsporadpost(x) = sumsporadpost(x) + sporadpost(x)
    RETURN

reactdisplay:
    CLS

    IF x = 2 THEN blurb$ = x2$
    IF x = 3 THEN blurb$ = x3$
    IF x = 4 THEN blurb$ = x4$
```

```
    IF x = 5 THEN blurb$ = x5$
    IF x = 6 THEN blurb$ = x6$
    IF x = 7 THEN blurb$ = x7$
    IF x = 8 THEN blurb$ = x8$

    PRINT : PRINT "REACTION TASK : "; blurb$

    'print number of pre-event false positives
    IF x = 2 THEN PRINT : PRINT "not possible to have pre-event false positives"
    IF x > 2 THEN PRINT : PRINT "number of pre-event false positives ="; sumsporadpre(x)

    'print number of post-event false positives
    PRINT : PRINT "number of post-event false positives ="; sumsporadpost(x)

        score(x) = (reactintime(x) / eventcount(x)) * 100
    PRINT : PRINT "score (%)"; score(x)
    PRINT : PRINT "total events"; eventcount(x)
    PRINT "total reactions"; reactot(x)
    PRINT "reactions in time to stop"; reactintime(x)
        'estimate mean
            'prevent overflow error if reactot is zero
            IF reactot(x) > 0 THEN rt(x) = sumreactlapse(x) / reactot(x)
    PRINT "mean reaction time (ms)"; INT(rt(x))
        'estimate variance
            'skip calculations if less than 3 repeats
            IF repeats < 3 THEN GOTO sdskip
            IF reactot(x) < 3 THEN GOTO sdskip
            'estimate sum of squares about the mean
            ssam(x) = sumreactlapse2(x) - ((sumreactlapse(x) ^ 2) / reactot(x))
            'mean square about the mean = variance
            s2(x) = ssam(x) / (reactot(x) - 1)
        'root mean square about the mean = standard deviation
            sd(x) = SQR(s2(x))
sdskip:
    PRINT "standard deviation (ms)"; INT(sd(x))
    INPUT "press return to continue"; XXX
    RETURN

'**END OF SUBJECT REACTION SUBROUTINES**
```

Appendix 2b

2b.1 Introduction

The DRTS1 program was written using Quick Basic. Five changes were made in order to correct for the effect of optic flow field on edge speed of the pedestrian crossing events. The changes can be found on the following pages:

1/5	238
2/5	243
3/5	244
4/5	245
5/5	247

The changes are indicated by a row of stars including the words "alteration */5 for NP" at the beginning and end of each amendment.

2b.2 The program

```
'DRIVER'S REACTION TIME SIMULATOR; APPROA30.BAS; NP modification
'copyright Mark Dunne
'version 21/6/99
'renamed DRTS(NP)

'value of PI for degree-radian conversions
CONST PI = 3.141592654#

'OPENING SCREEN
    CLS
    PRINT : PRINT : PRINT "          ********* DRIVER'S REACTION TIME SIMULATOR *********"
        'prompt the operator to press keys "Fn" + "F10"
        'this necesary for responses made via SPACEBAR
        'pressing these keys twice allows normal keyboard use
        'which is necessary to allow change of options
    PRINT : PRINT "   IMPORTANT - IF YOU HAVE JUST SWITCHED THE COMPUTER ON"
    PRINT "   YOU WILL NEED TO ACTIVATE THE SPACEBAR AS FOLLOWS"
    PRINT : PRINT "       Hold down Fn key, then press F10 key"
    PRINT "       Do this twice and then press RETURN"
    PRINT : INPUT "   YOU DO NOT NEED TO DO THIS AGAIN WHEN RE-RUNNING SIMULATOR"; xxxx
        'declare that KEY 15 is SPACEBAR
            KEY 15, CHR$(0) + CHR$(57)

    PRINT : INPUT "   STANDARD (press RETURN) or ENHANCED (press 1) monitor resolution"; resopt

        'screen mode
            IF resopt = 0 THEN SCREEN 2
            IF resopt = 1 THEN SCREEN 12
        'horizontal dimension of monitor in pixels
            hpix = 640
        'vertical dimension of monitor in pixels
            IF resopt = 1 THEN vpix = 480 ELSE vpix = 200

optscreen:
'OPTIONS SCREEN
```

Appendix 2b

```
CLS
PRINT : PRINT : PRINT "                    ********* OPTIONS *********"

PRINT : PRINT "    IMPORTANT - THESE OPTIONS ARE HIERARCHICAL"

PRINT : PRINT "        1. option scenery complexity"
PRINT : PRINT "        2. option simulator characteristics"
PRINT : PRINT "        3. option monitor calibration"
PRINT : PRINT "        4. option events and repeats"
PRINT : PRINT "        5. option static/dynamic and speed"
PRINT : PRINT "        press RETURN to proceed straight away"
PRINT : PRINT : INPUT "        select option"; mainopt

        IF mainopt = 1 THEN GOSUB mainopt1
        IF mainopt = 2 THEN GOSUB mainopt2
        IF mainopt = 3 THEN GOSUB mainopt3
        IF mainopt = 4 THEN GOSUB mainopt4
        IF mainopt = 5 THEN GOSUB mainopt5

        IF mainopt > 0 THEN PRINT : INPUT "     more changes (press 1) or not (press RETURN)"; moropt
            IF moropt = 1 THEN GOTO optscreen

'** DEFAULT SETTINGS **

    IF mwd = 0 THEN mwd = .5
    IF eyeht = 0 THEN eyeht = 1.25
    IF vmph = 0 THEN vmph = 50
        'convert mph to m/s (1 mph = 0.447 m/s)
            vms = vmph * .447
        'braking distances at driving speed (m) - from DVLA figures
            brakdist = .6 - (.037 * vmph) + (.016 * (vmph ^ 2))
    IF dlimit = 0 THEN dlimit = 400
        'calculate initial angle of line of sight to road surface
            tananglimit = eyeht / dlimit
    IF rdwidth = 0 THEN rdwidth = 7
    IF dyndist = 0 THEN dyndist = 100
    IF koh = 0 THEN koh = 5
    IF kow = 0 THEN kow = .2

    IF lcarh = 0 THEN lcarh = 1.5
    IF lcarw = 0 THEN lcarw = 2
    IF foldist = 0 THEN foldist = 100
    IF sepopt = 1 THEN foldist = vms * foltime
    IF pedh = 0 THEN pedh = 1.8
    IF pedw = 0 THEN pedw = .75

'********** alteration 1/5 for NP **********
    IF pedvmph(1) = 0 THEN pedvmph(1) = 5.33
    IF pedvmph(2) = 0 THEN pedvmph(2) = 7.5
    IF pedvmph(3) = 0 THEN pedvmph(3) = 9.797
        'convert mph-m/s (1 mph = 0.447 m/s)
            pedvms(1) = pedvmph(1) * .447
            pedvms(2) = pedvmph(2) * .447
            pedvms(3) = pedvmph(3) * .447
'********** end alteration 1/5 for NP **********

    IF pedang(1) = 0 THEN pedang(1) = 2.5
    IF pedang(2) = 0 THEN pedang(2) = 5
    IF pedang(3) = 0 THEN pedang(3) = 7.5
        'calculate pedestrian crossing parameters
        'pedestrians commence crossing at specified angular subtenses
        'NB - pedestrians commence crossing at specified foldist
            'inner row of pedestrians
                tanpedang(1) = TAN(pedang(1) * (PI / 180))
                pedkerbdist(1) = (foldist * tanpedang(1)) - (rdwidth / 2)
            'middle row of pedestrians
                tanpedang(2) = TAN(pedang(2) * (PI / 180))
                pedkerbdist(2) = (foldist * tanpedang(2)) - (rdwidth / 2)
```

```
            'outer row of pedestrians
                tanpedang(3) = TAN(pedang(3) * (PI / 180))
                pedkerbdist(3) = (foldist * tanpedang(3)) - (rdwidth / 2)
    IF interval = 0 THEN interval = 100
        'set initial value of dynamic interval (procedure 3)
            dinterval = interval

    IF eventnum = 0 THEN eventnum = 8
    IF staticopt = 1 THEN scenopt3 = 1
    IF staticopt = 1 THEN scenopt4 = 1
    IF repeats = 0 THEN repeats = 3

    'default monitor widths based on laptop screen
        'monitor width (m)
            IF mwidth = 0 THEN mwidth = .21
        'monitor height (m)
            IF mheight = 0 AND resopt = 0 THEN mheight = .131
            IF mheight = 0 AND resopt = 1 THEN mheight = .158
    'calculate pixel sizes
        'individual pixel width (m)
            pixwidth = mwidth / hpix
        'individual pixel height (m)
            pixheight = mheight / vpix

'carry out photometry option here
        IF photopt = 1 THEN GOSUB photometer

'processor calibration sequence
'NB - NO SCREEN COMMANDS AFTER THIS LINE OTHERWISE THIS INCLUDED IN TIME
    'calibration to be carried out during event x=1
    'calculate theoretical duration of event x=1 (ms)
            eventime = (dlimit / vms) * 1000
    'determine actual duration of event x=1
            TIMER ON
            actestart = TIMER

'generate continuous road scene until all tasks have been completed
DO
    'main loop counter (will never exceed eventnum*repeats)
        mainloopcount = mainloopcount + 1

    'EVENT CONTROLLER
    'ensure that there are two initial sweeps of event x=1
    'the first sweep of x=1 involves processor calibration
    'the second sweep of event x=1 ensures sequence starts with no event
        IF mainloopcount < 3 THEN x = 1
        IF mainloopcount < 3 THEN GOTO randjump

    'use randomiser to initiate various events
    'this yields 2 to eventnum randomly
tryagain:
                RANDOMIZE TIMER
                x = INT(RND * (eventnum - 1)) + 2
            'explanation
                'x=1 then no event occurs
                'x=2 then leading car suddenly stops
                    x2$ = "leading car stops"
                'x=3 then nearside pedestrian crosses
                    x3$ = "inner nearside pedestrian crosses"
                'x=4 then offside pedestrian crosses
                    x4$ = "inner offside pedestrian crosses"
                'x=5 then nearside pedestrian crosses
                    x5$ = "middle nearside pedestrian crosses"
                'x=6 then offside pedestrian crosses
                    x6$ = "middle offside pedestrian crosses"
                'x=7 then nearside pedestrian crosses
                    x7$ = "outer nearside pedestrian crosses"
                'x=8 then offside pedestrian crosses
```

```
                    x8$ = "outer offside pedestrian crosses"

                'ensure that all events shown equal number of times
                    IF x > 1 THEN GOSUB eventcontrol
                    IF zap(x) = 1 THEN GOTO tryagain

    'SUBJECT REACTIONS
        'reset keystrike to zero
            keystrike = 0
        'handle subject responses
            IF x > 1 THEN GOSUB reaction
randjump:

    'PROCEDURE ONE
    'generate moving reference point at specified time intervals
        'set initial time to zero
            time = 0
        'reset pedcount (see procedures 7-9 & subroutine latposped) to zero
            pedcount = 0
        'reset lcarelv (see procedure 6)
            lcarelv = 0
        'reset lcartotd (see procedure 6, dynamic)
            lcartotd = 0
        'reset framecount
            framecount = 0

    'keep generating scene until reference objects are 1m from observer
    DO
        'count number of frames per event
        'framecount is set to zero at beginning of event loop
                framecount = framecount + 1

        'count up to specified time interval
            starttime = TIMER
                DO WHILE timelapse < interval
                endtime = TIMER
                timelapse = (endtime - starttime) * 1000
                LOOP
                timelapse = 0
    CLS

    'PROCEDURE TWO
    'draw static road scene - horizon, near/offside kerb edges
            IF circopt = 1 THEN GOSUB circles
            GOSUB roadscene

    'PROCEDURE THREE
    'generate a moving reference point for dynamic road scene
    'dynamic road scene governed by speed of observer
        'distance travelled in time interval
            time = time + dinterval
            deltad = vms * (time / 1000)
        'distance from observer (dnext)
        'dnext is effectively a moving reference point
            dnext = dlimit - deltad

    'PROCEDURE FOUR
    'generate dynamic road scene objects
    'object sets = near/offside pedestrians and lamposts
        'reference object
        'additional objects are placed with respect to this one
                d = dnext
                'do not draw pedestrians at this distance
                'because procedures 7-9 handle this
                    pedskip = 1
                GOSUB objecthandler
                'reset pedskip
                    pedskip = 0
```

```
        'calculate additional number of objects
            addob = (dlimit / dyndist) - 1
        'generate additional objects
            'objects in front of reference
                FOR dynloop = 1 TO addob
                d = dnext - (dynloop * dyndist)
                GOSUB objecthandler
                NEXT dynloop
            'objects behind reference
                FOR dynloop = 1 TO addob
                d = dnext + (dynloop * dyndist)
                GOSUB objecthandler
                NEXT dynloop

    'PROCEDURE FIVE - approaching car removed

    'PROCEDURE SIX
    'generate leading car
        '**static test**
        'car suddenly appears
            'car not present unless x=2
                IF staticopt = 1 AND x <> 2 THEN GOTO lcarjump
            'show car when x = 2
                IF staticopt = 1 AND x = 2 THEN lcardnext = foldist
                IF staticopt = 1 AND x = 2 THEN GOTO showlcar
            'NB - braking in time to stop does not apply to static test

        '**dynamic test**
        'car always present at following distance but suddenly slows down
        'calculate car distance with time - see procedure 3
            'lcarelv is set to zero at beginning of event loop
            'car slows down if x=2
                IF x = 2 THEN lcarelv = lcarelv + decmss
            'ensure that speed is not less than zero
                IF lcarelv > vms THEN lcarelv = vms
            'distance travelled by lcar during dinterval
                lcardeltad = lcarelv * (dinterval / 1000)
            'total distance travelled by lcar
            'lcartotd is set to zero at beginning of event loop
                lcartotd = lcartotd + lcardeltad
            'remaining lcar braking time
                lcarbraktime = sumbraktime - (time / 1000)
            'distance from observer
                lcardnext = foldist - lcartotd
            'time separating lcar from observer
                lcardnexttime = lcardnext / vms
        're-position car after F1 key has been pressed
            IF keystrike = 1 THEN lcardnext = foldist
showlcar:
    IF staticopt = 1 AND x = 2 AND keystrike = 1 THEN GOTO lcarjump
        'calculate car dimensions on screen
                d = lcardnext
                IF d < 1 THEN GOTO lcarjump
                IF d > dlimit THEN GOTO lcarjump
            wdth = rdwidth
                GOSUB genwidth
                    rdwidthpix = widthpix
            wdth = lcarw
                GOSUB genwidth
                    lcarwpix = widthpix
            height = lcarh
                GOSUB genheight
                    lcarhpix = heightpix
                GOSUB roadrop
        'draw car
            'centre car in middle of same lane
            a = (hpix / 2) - (lcarwpix / 2)
            c = a + lcarwpix
```

```
                b = (vpix / 2) + rdropix
                dd = b - lcarhpix
                LINE (a, b)-(c, dd), , BF
lcarjump:

    'PROCEDURE SEVEN
    'generate inner row target pedestrians at kerbside
        '**static test**
        'pedestrian suddenly appears
            'only one pedestrian to be shown for each event
                IF staticopt = 1 AND x = 3 THEN pednext = foldist
                IF staticopt = 1 AND x = 3 THEN GOTO showped1
                IF staticopt = 1 AND x = 4 THEN pednext = foldist
                IF staticopt = 1 AND x = 4 THEN GOTO showped1
                IF staticopt = 1 AND x = 5 THEN pednext = foldist
                IF staticopt = 1 AND x = 5 THEN GOTO showped2
                IF staticopt = 1 AND x = 6 THEN pednext = foldist
                IF staticopt = 1 AND x = 6 THEN GOTO showped2
                IF staticopt = 1 AND x = 7 THEN pednext = foldist
                IF staticopt = 1 AND x = 7 THEN GOTO showped3
                IF staticopt = 1 AND x = 8 THEN pednext = foldist
                IF staticopt = 1 AND x = 8 THEN GOTO showped3

            'NB - braking in time to stop does not apply to static test

        '**dynamic test**
        'calculate relative velocity - see procedure 3
        'pedestrians stand still at kerb edge
                pedrelv = vms
        'calculate pedestrian distance with time - see procedure 3
                pedeltad = pedrelv * (time / 1000)
        'pedestrian distance from observer
                pednext = dlimit - pedeltad
        'one of the pedestrians now crosses the road
        'pedestrian is immediately repositioned once F1 is pressed


' ********** alteration 2/5 for NP **********
IF x = 3 THEN pedvms = pedvms(1)
IF x = 4 THEN pedvms = pedvms(1)
' ********** end alteration 2/5 for NP **********

                IF x = 3 AND keystrike = 0 THEN GOSUB latposped
                IF x = 4 AND keystrile = 0 THEN GOSUB latposped

'static option pedestrian dissappears once F1 is pressed
showped1:
    IF staticopt = 1 AND x = 3 AND keystrike = 1 THEN GOTO pedjump1
    IF staticopt = 1 AND x = 4 AND keystrike = 1 THEN GOTO pedjump1

        'calculate pedestrian size on screen
                d = pednext
                IF d < 1 THEN GOTO pedjump1
            wdth = rdwidth
                GOSUB genwidth
                    rdwidthpix = widthpix
            wdth = pedkerbdist(1)
                GOSUB genwidth
                    pedkerbpix = widthpix
            wdth = pedlatdeltad
                GOSUB genwidth
                    pedlatdeltapix = widthpix
            wdth = pedw
                GOSUB genwidth
                    pedwpix = widthpix
            height = pedh
                GOSUB genheight
                    pedhpix = heightpix
```

```
                GOSUB roadrop

        'draw nearside pedestrian
            a = (hpix / 2) - (rdwidthpix * .5) - pedkerbpix
                IF staticopt = 0 AND x = 3 AND keystrike = 0 THEN GOSUB nspedcross
            c = a - pedwpix
            b = (vpix / 2) + rdropix
            dd = b - pedhpix
            'this stops object pesistance at LH edge of screen
            'and prevents object from being shown in scenery option 4
            IF a > 0 AND scenopt4 = 0 THEN LINE (a, b)-(c, dd), , BF
            'this overrides scenery option 4 if static option chosen
            IF staticopt = 1 AND x = 3 AND a > 0 AND scenopt4 = 1 THEN LINE (a, b)-(c, dd), , BF
        'draw offside pedestrian
            a = (hpix / 2) + (rdwidthpix * .5) + pedkerbpix
                IF staticopt = 0 AND x = 4 AND keystrike = 0 THEN GOSUB ospedcross
            c = a + pedwpix
            'this stops object pesistance at LH edge of screen
            'and prevents object from being shown in scenery option 4
            IF a > 0 AND scenopt4 = 0 THEN LINE (a, b)-(c, dd), , BF
            'this overrides scenery option 4 if static option chosen
            IF staticopt = 1 AND x = 4 AND a > 0 AND scenopt4 = 1 THEN LINE (a, b)-(c, dd), , BF

pedjump1:

    'PROCEDURE EIGHT
    'generate middle row target pedestrians at kerbside
        'pedestrian is immediately repositioned once F1 is pressed




' ********** alteration 3/5 for NP **********
IF x = 5 THEN pedvms = pedvms(2)
IF x = 6 THEN pedvms = pedvms(2)
' ********** end alteration 3/5 for NP **********

                IF x = 5 AND keystrike = 0 THEN GOSUB latposped
                IF x = 6 AND keystrile = 0 THEN GOSUB latposped
        'calculate pedestrian size on screen
showped2:
    IF staticopt = 1 AND x = 5 AND keystrike = 1 THEN GOTO pedjump2
    IF staticopt = 1 AND x = 6 AND keystrike = 1 THEN GOTO pedjump2
                d = pednext
                IF d < 1 THEN GOTO pedjump2
            wdth = rdwidth
                GOSUB genwidth
                    rdwidthpix = widthpix
            wdth = pedkerbdist(2)
                GOSUB genwidth
                    pedkerbpix = widthpix
            wdth = pedlatdeltad
                GOSUB genwidth
                    pedlatdeltapix = widthpix
            wdth = pedw
                GOSUB genwidth
                    pedwpix = widthpix
            height = pedh
                GOSUB genheight
                    pedhpix = heightpix
                GOSUB roadrop

        'draw nearside pedestrian
            a = (hpix / 2) - (rdwidthpix * .5) - pedkerbpix
                IF staticopt = 0 AND x = 5 AND keystrike = 0 THEN GOSUB nspedcross
            c = a - pedwpix
            b = (vpix / 2) + rdropix
            dd = b - pedhpix
```

```
            'this stops object pesistance at LH edge of screen
            'and prevents object from being shown in scenery option 4
            IF a > 0 AND scenopt4 = 0 THEN LINE (a, b)-(c, dd), , BF
            'this overrides scenery option 4 if static option chosen
            IF staticopt = 1 AND x = 5 AND a > 0 AND scenopt4 = 1 THEN LINE (a, b)-(c, dd), , BF
        'draw offside pedestrian
            a = (hpix / 2) + (rdwidthpix * .5) + pedkerbpix
                IF staticopt = 0 AND x = 6 AND keystrike = 0 THEN GOSUB ospedcross
            c = a + pedwpix
            'this stops object pesistance at LH edge of screen
            'and prevents object from being shown in scenery option 4
            IF a > 0 AND scenopt4 = 0 THEN LINE (a, b)-(c, dd), , BF
            'this overrides scenery option 4 if static option chosen
            IF staticopt = 1 AND x = 6 AND a > 0 AND scenopt4 = 1 THEN LINE (a, b)-(c, dd), , BF

pedjump2:

    'PROCEDURE NINE
    'generate outer row target pedestrians at kerbside
        'dynamic option pedestrian is immediately repositioned once F1 is pressed





' ********** alteration 4/5 for NP **********
IF x = 7 THEN pedvms = pedvms(3)
IF x = 8 THEN pedvms = pedvms(3)
' ********** end alteration 4/5 for NP **********

                IF x = 7 AND keystrike = 0 THEN GOSUB latposped
                IF x = 8 AND keystrile = 0 THEN GOSUB latposped

'static option pedestrian dissappears once F1 is pressed
showped3:
    IF staticopt = 1 AND x = 7 AND keystrike = 1 THEN GOTO pedjump3
    IF staticopt = 1 AND x = 8 AND keystrike = 1 THEN GOTO pedjump3

        'calculate pedestrian size on screen
                d = pednext
                IF d < 1 THEN GOTO pedjump3
            wdth = rdwidth
                GOSUB genwidth
                    rdwidthpix = widthpix
            wdth = pedkerbdist(3)
                GOSUB genwidth
                    pedkerbpix = widthpix
            wdth = pedlatdeltad
                GOSUB genwidth
                    pedlatdeltapix = widthpix
            wdth = pedw
                GOSUB genwidth
                    pedwpix = widthpix
            height = pedh
                GOSUB genheight
                    pedhpix = heightpix
                GOSUB roadrop

        'draw nearside pedestrian
            a = (hpix / 2) - (rdwidthpix * .5) - pedkerbpix
                IF staticopt = 0 AND x = 7 AND keystrike = 0 THEN GOSUB nspedcross
            c = a - pedwpix
            b = (vpix / 2) + rdropix
            dd = b - pedhpix
            'this stops object pesistance at LH edge of screen
            'and prevents object from being shown in scenery option 4
```

```
            IF a > 0 AND scenopt4 = 0 THEN LINE (a, b)-(c, dd), , BF
            'this overrides scenery option 4 if static option chosen
            IF staticopt = 1 AND x = 7 AND a > 0 AND scenopt4 = 1 THEN LINE (a, b)-(c, dd), , BF
        'draw offside pedestrian
            a = (hpix / 2) + (rdwidthpix * .5) + pedkerbpix
                IF staticopt = 0 AND x = 8 AND keystrike = 0 THEN GOSUB ospedcross
            c = a + pedwpix
            'this stops object pesistance at LH edge of screen
            'and prevents object from being shown in scenery option 4
            IF a > 0 AND scenopt4 = 0 THEN LINE (a, b)-(c, dd), , BF
            'this overrides scenery option 4 if static option chosen
            IF staticopt = 1 AND x = 8 AND a > 0 AND scenopt4 = 1 THEN LINE (a, b)-(c, dd), , BF

pedjump3:

    LOOP UNTIL dnext < 1

'carry out automatic processor calibration
    IF mainloopcount = 1 THEN GOSUB autoprocess

'STOP PROGRAM
    sumevents = eventcount(2) + eventcount(3) + eventcount(4) + eventcount(5) + eventcount(6) + eventcount(7) +
eventcount(8)
    LOOP UNTIL sumevents = (eventnum - 1) * repeats

    'calculate time of test (minus processor calibration) (ms)
        actestrestop = TIMER
        actestretime = (actestrestop - actestrestart) * 1000

    KEY(15) OFF
    TIMER OFF

'display detailed results on screen
    'show results for events - 1 page per event
        FOR x = 2 TO eventnum
            GOSUB reactdisplay

            'calculate total false positives
                totsporadpre = totsporadpre + sumsporadpre(x)
                totsporadpost = totsporadpost + sumsporadpost(x)
        NEXT x
            totfalsepos = totsporadpre + totsporadpost

' display summary results on screen
CLS
PRINT : PRINT : PRINT "    SUMMARY TABLE :"

   PRINT : PRINT "    total false positives = "; totfalsepos
   PRINT : PRINT "    __________________________________________________________"
   PRINT : PRINT "    event                  :  7   5   3   2   4   6   8"
       PRINT "    ________________________________________________________"
PRINT : PRINT USING "    reaction time (ms)        : #### #### #### #### #### #### ####"; rt(7); rt(5); rt(3); rt(2); rt(4);
rt(6); rt(8)
PRINT : PRINT USING "    standard deviation (ms)  : #### #### #### #### #### #### ####"; sd(7); sd(5); sd(3); sd(2);
sd(4); sd(6); sd(8)
PRINT
PRINT : PRINT USING "    repeats                  : #### #### #### #### #### #### ####"; eventcount(7); eventcount(5);
eventcount(3); eventcount(2); eventcount(4); eventcount(6); eventcount(8)
PRINT : PRINT USING "    reactions                : #### #### #### #### #### #### ####"; reactot(7); reactot(5); reactot(3);
reactot(2); reactot(4); reactot(6); reactot(8)
IF staticopt = 0 THEN PRINT : PRINT USING "    reactions in time to stop : #### #### #### #### #### #### ####";
reactintime(7); reactintime(5); reactintime(3); reactintime(2); reactintime(4); reactintime(6); reactintime(8)
       PRINT "    ________________________________________________________"
PRINT : PRINT : INPUT "    press RETURN to continue"; xxxx

'print adjusted dynamic time interval
    CLS
        PRINT : PRINT "    PROCESSOR CALIBRATION REPORT :"
```

```
          PRINT : PRINT USING "    adjusted dynamic interval = ###.### ms"; dinterval
          PRINT : PRINT USING "        predicted test duration = ###.### mins"; (seqtime / (60000))
          PRINT USING "        actual test duration = ###.### mins"; (actestretime / (60000))
     'calculate actual simulation speed
     'calculate average frame processing time
          meandifproctime = (actestretime - seqtime) / ((((eventnum - 1) * repeats) + 1) * framecount)
          PRINT : PRINT USING "    mean differential frame processing time = ##.## ms"; meandifproctime
     'distance travelled at specified speed and adjusted dynamic interval (m)
          distance = vms * (dinterval / 1000)
     'actual time interval (ms)
          actinterval = meandifproctime + dinterval
     'actual speed (m/s)
               actvms = distance / (actinterval / 1000)
          'conversion to mph
               actmph = actvms / .447
          PRINT : PRINT USING "    actual simulated speed = ###.## mph"; actmph
     'advice to operator
          PRINT : PRINT : PRINT "    at end of this program, press F5 key to start again"
END

mainopt1:
'subroutine for option 1
CLS
PRINT : PRINT : PRINT "                    ********* OPTION 1 *********"

     PRINT : PRINT "enter number then press RETURN or just press RETURN to skip"

     PRINT : INPUT "    delete horizon and kerb edges (press 1) or not"; scenopt1
     PRINT : INPUT "    delete kerbside lamposts (press 1) or not"; scenopt2
     PRINT : INPUT "    delete distractor pedestrians (press 1) or not"; scenopt3
     PRINT : INPUT "    delete target pedestrians (press 1) or not"; scenopt4
     PRINT : PRINT : INPUT "    add angular subtense circles (press 1) or not"; circopt
RETURN

mainopt2:
'subroutine for option 2
CLS
PRINT : PRINT "                    ********* OPTION 2 *********"

     PRINT : PRINT "enter number then press RETURN or just press RETURN to skip"

     PRINT : INPUT "    monitor viewing distance = 0.5 m "; mwd
     INPUT "    driver's eye height = 1.25 m "; eyeht

     IF scenopt1 = 0 THEN INPUT "    distance to horizon = 400 m "; dlimit
     IF scenopt1 = 0 THEN INPUT "    road width = 7 m "; rdwidth

     IF scenopt2 = 0 THEN PRINT "    separation of lamposts = 100 m "
     IF scenopt2 = 0 THEN INPUT "    ** must be integer of distance to horizon **"; dyndist
     IF scenopt2 = 0 THEN INPUT "        lampost height = 5 m "; koh
     IF scenopt2 = 0 THEN INPUT "        lampost width = 0.2 m "; kow

     INPUT "    leading car height = 1.5 m "; lcarh
     INPUT "    leading car width = 2 m "; lcarw
     PRINT "    separation from lead car"
     INPUT "        time in seconds (press 1) or distance in metres (RETURN)"; sepopt
     IF sepopt = 0 THEN INPUT "            following distance = 100 m"; foldist
     IF sepopt = 1 THEN INPUT "            time in seconds"; foltime

     IF scenopt4 = 0 THEN INPUT "    pedestrian height = 1.8 m "; pedh
     IF scenopt4 = 0 THEN INPUT "    pedestrian width = 0.75 m "; pedw

'********** alteration 5/5 for NP **********
     IF scenopt4 = 0 THEN INPUT "    inner pedestrian crossing speed = 5.33 mph "; pedvmph(1)
     IF scenopt4 = 0 THEN INPUT "    middle pedestrian crossing speed = 7.5 mph "; pedvmph(2)
     IF scenopt4 = 0 THEN INPUT "    outer pedestrian crossing speed = 9.797 mph "; pedvmph(3)
'********** end alteration 5/5 for NP **********
```

```
    IF scenopt4 = 0 THEN INPUT "        angular subtense of pedestrian inner row = 2.5 degrees "; pedang(1)
    IF scenopt4 = 0 THEN INPUT "        angular subtense of pedestrian middle row = 5 degrees "; pedang(2)
    IF scenopt4 = 0 THEN INPUT "        angular subtense of pedestrian outer row = 7.5 degrees "; pedang(3)

    INPUT "     initial frame time interval = 100 ms "; interval
RETURN

mainopt3:
'subroutine for option 3
CLS
PRINT : PRINT : PRINT "                    ********* OPTION 3 *********"
    PRINT : PRINT : INPUT "     photometry (press 1) or not (press RETURN)"; photopt
        IF photopt = 1 THEN PRINT "     photometry will carried out at later stage"
    PRINT : PRINT : INPUT "     calibrate monitor size (press 1) or not (press RETURN)"; calopt
        IF calopt = 1 THEN GOSUB calibrate
RETURN

mainopt4:
'subroutine for option 4
CLS
PRINT : PRINT : PRINT "                    ********* OPTION 4 *********"
PRINT : PRINT "     list of events :"
        PRINT : PRINT "       2. leading car stops"
        PRINT : PRINT "       3. inner nearside pedestrian crosses"
        PRINT : PRINT "       4. inner offside pedestrian crosses"
        PRINT : PRINT "       5. middle nearside pedestrian crosses"
        PRINT : PRINT "       6. middle offside pedestrian crosses"
        PRINT : PRINT "       7. outer nearside pedestrian crosses"
        PRINT : PRINT "       8. outer offside pedestrian crosses"
    PRINT : INPUT "     number of events (2 to 8), default = 8"; eventnum
    PRINT : INPUT "     number of repeats of each event, default = 3"; repeats
RETURN

mainopt5:
'subroutine for option 5
CLS
PRINT : PRINT : PRINT "                    ********* OPTION 5 *********"
PRINT : INPUT "       STATIC (press 1) or DYNAMIC test (press RETURN)"; staticopt
PRINT : INPUT "       driver's speed, default = 50 mph"; vmph
RETURN

calibrate:
'subroutine to calibrate monitor size
    'draw horizontal and vertical line lines
        CLS
        LINE (0, (vpix / 2))-(hpix, (vpix / 2))
        LINE ((hpix / 2), 0)-((hpix / 2), vpix)
    'prompt for measurements
        INPUT "vertical (mm)"; mheightmm
        mheight = mheightmm / 1000
        INPUT "horizontal (mm)"; mwidthmm
        mwidth = mwidthmm / 1000
RETURN

photometer:
'subroutine for photometric calibration
    'draw series of sampling squares
    'size of square should match photometer sampling circle diameter
    'photometer sampling circle diameter is given in degrees
    'angular suhtense (diameter) of photometer sampling circle
        pang = 1
        tanpang = TAN(pang * (PI / 180))
    'size of square on monitor (m)
        mpss = tanpang * mwd
    'pixel size of square on monitor
        hpsp = INT(mpss / pixwidth)
        vpsp = INT(mpss / pixheight)
    'place squares in 5 x 3 (h x v) matrix over screen
```

```
        hsep = INT(hpix / 6)
        vsep = INT(vpix / 4)
    'draw squares
        CLS
        'three rows
        FOR vn = 1 TO 3
            'this draws four columns
            FOR hn = 1 TO 5
        LINE (((hsep * hn) - (hpsp / 2)), ((vsep * vn) - vpsp))-(((hsep * hn) + (hpsp / 2)), (vsep * vn)), , BF
        LINE (((hsep * hn) - (hpsp / 2)), ((vsep * vn)))-(((hsep * hn) + (hpsp / 2)), ((vsep * vn) + vpsp)), , B
            NEXT hn
        NEXT vn
        INPUT "see circles (press 1) or not (press RETURN)"; seecirc
        IF seecirc = 1 THEN GOSUB circles
        INPUT "press RETURN when photometry completed"; ccc
        CLS
RETURN

circles:
'subroutine to draw circles of varying angular subtense
    FOR fang = pedang(1) TO pedang(3) STEP pedang(1)
        GOSUB drawcircle
    NEXT fang
RETURN

drawcircle:
'general subroutine to draw a circle
    tanfang = TAN(fang * (PI / 180))
  'size of circle on monitor (m)
    moncircrad = tanfang * mwd
  'pixel size of circle on monitor
    hmoncircpix = INT(moncircrad / pixwidth)
    vmoncircpix = INT(moncircrad / pixheight)
    aspect = vmoncircpix / hmoncircpix
  'draw circle
    CIRCLE ((hpix / 2), (vpix / 2)), hmoncircpix, , , , aspect
RETURN

roadscene:
'subroutine to draw static road scene
'print any "on screen" messages here
    IF mainloopcount = 1 THEN PRINT "PROCESSOR CALIBRATION"
'draw horizon
    IF scenopt1 = 0 THEN LINE (0, (vpix / 2))-(hpix, (vpix / 2))
'draw kerb edges
    'calculate initial roadwidth/drop
        d = dlimit
        wdth = rdwidth
        GOSUB genwidth
        rdwidth1 = widthpix
        GOSUB roadrop
        rdrop1 = rdropix
    'calculate final road width/drop
        d = 1
        wdth = rdwidth
        GOSUB genwidth
        rdwidth2 = widthpix
        GOSUB roadrop
        rdrop2 = rdropix
    'draw a road as seen at the observer headheight
    'car positioned in middle of road
    'i.e. 50% of way across the road
    'draw nearside kerb edge
        a = (hpix / 2) - (rdwidth1 * .5)
        c = (hpix / 2) - (rdwidth2 * .5)
        b = (vpix / 2) + rdrop1
        dd = (vpix / 2) + rdrop2
        IF scenopt1 = 0 THEN LINE (a, b)-(c, dd)
```

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```
    'draw offside kerb edge
        a = (hpix / 2) + (rdwidth1 * .5)
        c = (hpix / 2) + (rdwidth2 * .5)
        IF scenopt1 = 0 THEN LINE (a, b)-(c, dd)
RETURN

objecthandler:
'subroutine to handle dynamic road scene objects
    IF d < 1 THEN GOTO jump
    IF d > dlimit THEN GOTO jump

    'these items relate to lamp posts

            wdth = rdwidth
                GOSUB genwidth
                    rdwidthpix = widthpix
            wdth = kow
                GOSUB genwidth
                    kowpix = widthpix
            height = koh
                GOSUB genheight
                    kohpix = heightpix

    'these items relate to pedestrians
    IF pedskip = 1 THEN GOTO skipeds
            wdth = rdwidth
                GOSUB genwidth
                    rdwidthpix = widthpix

        'do calculations for three rows of pedestrians
        FOR row = 1 TO 3
            wdth = pedkerbdist(row)
                GOSUB genwidth
                    pedkerbpix(row) = widthpix
        NEXT row

            wdth = pedlatdeltad
                GOSUB genwidth
                    pedlatdeltapix = widthpix
            wdth = pedw
                GOSUB genwidth
                    pedwpix = widthpix
            height = pedh
                GOSUB genheight
                    pedhpix = heightpix

                GOSUB roadrop
                GOSUB graphics
                GOTO jump:
skipeds:
                GOSUB roadrop
                GOSUB graphics

jump:
bypass = 0
RETURN

genwidth:
'subroutine to calculate general widths at distance, d
    'width on monitor (m)
        monwidth = (mwd * wdth) / d
    'number of pixels representing width
        widthpix = INT(monwidth / pixwidth)
RETURN

genheight:
'subroutine to calculate general heights at distance, d
    'height on monitor (m)
```

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```
          monheight = (mwd * height) / d
      'number of pixels representing height
          heightpix = INT(monheight / pixheight)
RETURN

roadrop:
'subroutine to calculate drop of road/objects below horizon at distance, d
      'new angle of line of sight to road surface
          tanang = eyeht / d
      'angular drop of road/object below horizon
          'this equals difference between anglimit and angnext
          tanangdiff = tanang - tananglimit
      'drop from monitor horizon in metres
          rdrop = mwd * tanangdiff
      'drop from monitor horizon in pixels
          rdropix = INT(rdrop / pixheight)
RETURN

graphics:
'subroutine to draw dynamic road scene object set

'draw lamposts

      'draw nearside kerb edge lampost
      a = (hpix / 2) - (rdwidthpix * .5)
      c = a - kowpix
      b = (vpix / 2) + rdropix
      dd = b - kohpix
      'this stops object pesistance at LH edge of screen
      IF a > 0 AND scenopt2 = 0 THEN LINE (a, b)-(c, dd), , BF

      'draw offside kerb edge lampost
      a = (hpix / 2) + (rdwidthpix * .5)
      c = a + kowpix
      IF scenopt2 = 0 THEN LINE (a, b)-(c, dd), , BF

'draw three rows of distractor pedestrians
IF pedskip = 1 THEN GOTO skip
FOR row = 1 TO 3
      'draw nearside pedestrian
      a = (hpix / 2) - (rdwidthpix * .5) - pedkerbpix(row)
      c = a - pedwpix
      b = (vpix / 2) + rdropix
      dd = b - pedhpix
      'this stops object pesistance at LH edge of screen
      IF a > 0 AND scenopt3 = 0 THEN LINE (a, b)-(c, dd), , BF

      'draw offside pedestrian
      a = (hpix / 2) + (rdwidthpix * .5) + pedkerbpix(row)
      c = a + pedwpix
      IF scenopt3 = 0 THEN LINE (a, b)-(c, dd), , BF
NEXT row

skip:
RETURN

autoprocess:
'subroutine to carry out automatic processor calibration
      'carry out automatic processor calibration during first sweep of event x=1
          CLS : PRINT "PLEASE WAIT ..."
      'time first event (ms)
          actestop = TIMER
          actestime = (actestop - actestart) * 1000
      'calculate average frame processing time
          meanproctime = (actestime - eventime) / framecount
      'make automatic adjustment to dynamic interval (procedure 3)
          dinterval = dinterval + meanproctime
      'calculate deceleration of leading car (dependent upon dinterval)
```

```
            GOSUB decelerate
        'print advice to driver
            CLS : PRINT : PRINT "    ADVICE TO DRIVER :"
        'calculate duration of all events/repeats (ms)
            seqtime = eventime * (1 + ((eventnum - 1) * repeats))
        'screen display
            PRINT : PRINT USING "        estimated test duration = ##.# mins "; (seqtime / (60000))
            PRINT : PRINT "    BRAKING DATA :"
            PRINT : PRINT USING "            deceleration while braking = ##.# ms-2 "; decmss
            PRINT USING "            total braking time = ##.# s "; sumbraktime
            PRINT : PRINT "    INSTRUCTIONS TO DRIVER :"
            PRINT : PRINT "    respond by pressing the SPACEBAR"
            PRINT : INPUT "    press RETURN to begin testing"; xxxx
        'start timing again to check on accuracy of dinterval estimate
            actestrestart = TIMER
RETURN

decelerate:
'subroutine to calculate deceleration needed to stop car in stopping distance
        'find correct deceleration for given speed, braking distance, dinterval
            'initial deceleration (m/s/s)
                decmss = 1
decloop:
            'set initial parameters

                sumdistance = 0
                sumbraktime = 0

        'find stopping distance for given amount of deceleration
            speed = vms
            DO
            speed = speed - (decmss * (dinterval / 1000))
            decdistance = speed * (dinterval / 1000)
            sumdistance = sumdistance + decdistance
            sumbraktime = sumbraktime + (dinterval / 1000)
            LOOP UNTIL speed < 0

        'iteratively alter deceleration
            IF sumdistance > brakdist THEN decmss = decmss + .01
            IF sumdistance > brakdist THEN GOTO decloop
        RETURN

 'subroutine to control static test option
 statrand:
 RETURN

 '**PROCEDURE SEVEN SUBROUTINES**
 latposped:
        'calculate change in lateral position for near or offside pedestrian
            IF pednext < foldist THEN pedcount = pedcount + 1
            IF pedcount = 1 THEN pedstartime = time
            IF pedcount = 1 THEN actpedstartime(x) = TIMER
            IF pednext < foldist THEN pedcrosstime = time - pedstartime
            IF pednext < foldist THEN pedlatdeltad = pedvms * (pedcrosstime / 1000)
        RETURN
 nspedcross:
        'nearside pedestrian crosses road
            IF pednext < foldist THEN a = (hpix / 2) - (rdwidthpix * .5) - pedkerbpix + pedlatdeltapix
        RETURN
 ospedcross:
        'offside pedestrian crosses road
            IF pednext < foldist THEN a = (hpix / 2) + (rdwidthpix * .5) + pedkerbpix - pedlatdeltapix
        RETURN

 '**END OF PROCEDURE SEVEN SUBROUTINES**

 '**SUBJECT REACTION SUBROUTINES**
```

Appendix 2b

```
eventcontrol:
'subroutine controlling number of events
    IF eventcount(x) = repeats THEN zap(x) = 1
    RETURN

reaction:
'subroutine allowing subject to respond via SPACEBAR
    'start timing
        reactstart(x) = TIMER
    'count number of times that an event happens
        eventcount(x) = eventcount(x) + 1
    'listen out for response via SPACEBAR
        ON KEY(15) GOSUB record
        KEY(15) ON
    RETURN

record:
'subroutine to record reaction

    'ensure that driver cannot react before pedestrian crosses
    'record each time this happens
    IF x > 2 AND pednext > foldist THEN sporadpre(x) = 1
    IF x > 2 AND pednext > foldist THEN GOTO jumprecord

    'ensure that driver cannot react again after event has occured
    'record each time this happens
    IF keystrike = 1 THEN sporadpost(x) = 1 ELSE sporadpost(x) = 0
    IF keystrike = 1 THEN GOTO jumprecord

    'count total reactions
        reactot(x) = reactot(x) + 1

    'count reactions allowing time to stop
        IF x = 2 AND sumbraktime < (lcardnextime + lcarbraktime) THEN reactintime(x) = reactintime(x) + 1
        IF x > 2 AND pednext > brakdist THEN reactintime(x) = reactintime(x) + 1

    'calculate reaction time
        reactstop(x) = TIMER
        reactlapse(x) = (reactstop(x) - reactstart(x)) * 1000

    'the next 2 lines relate to dynamic option pedestrian events
    'must account for fact that pedestrian does not cross immediately
        IF staticopt = 0 AND x > 2 THEN reactlapse(x) = reactlapse(x) - ((actpedstartime(x) - reactstart(x)) * 1000)

    'intermediate steps for estimating mean and standard deviation
        'sum of values
            sumreactlapse(x) = sumreactlapse(x) + reactlapse(x)
        'sum of values squared
            reactlapse2(x) = reactlapse(x) ^ 2
            sumreactlapse2(x) = sumreactlapse2(x) + reactlapse2(x)

    'record the occurence of a key strike
        keystrike = 1
  jumprecord:
    IF x > 2 AND pednext > foldist THEN sumsporadpre(x) = sumsporadpre(x) + sporadpre(x)
    IF keystrike = 1 THEN sumsporadpost(x) = sumsporadpost(x) + sporadpost(x)
    RETURN

  reactdisplay:
    CLS

    IF x = 2 THEN blurb$ = x2$
    IF x = 3 THEN blurb$ = x3$
    IF x = 4 THEN blurb$ = x4$
    IF x = 5 THEN blurb$ = x5$
    IF x = 6 THEN blurb$ = x6$
    IF x = 7 THEN blurb$ = x7$
    IF x = 8 THEN blurb$ = x8$
```

```
    PRINT : PRINT "REACTION TASK : "; blurb$

    'print number of pre-event false positives
    IF x = 2 THEN PRINT : PRINT "not possible to have pre-event false positives"
    IF x > 2 THEN PRINT : PRINT "number of pre-event false positives ="; sumsporadpre(x)

    'print number of post-event false positives
    PRINT : PRINT "number of post-event false positives ="; sumsporadpost(x)

        score(x) = (reactintime(x) / eventcount(x)) * 100
    PRINT : PRINT "score (%)"; score(x)
    PRINT : PRINT "total events"; eventcount(x)
    PRINT "total reactions"; reactot(x)
    PRINT "reactions in time to stop"; reactintime(x)
        'estimate mean
            'prevent overflow error if reactot is zero
            IF reactot(x) > 0 THEN rt(x) = sumreactlapse(x) / reactot(x)
    PRINT "mean reaction time (ms)"; INT(rt(x))
        'estimate variance
            'skip calculations if less than 3 repeats
            IF repeats < 3 THEN GOTO sdskip
            IF reactot(x) < 3 THEN GOTO sdskip
            'estimate sum of squares about the mean
            ssam(x) = sumreactlapse2(x) - ((sumreactlapse(x) ^ 2) / reactot(x))
            'mean square about the mean = variance
            s2(x) = ssam(x) / (reactot(x) - 1)
        'root mean square about the mean = standard deviation
            sd(x) = SQR(s2(x))
sdskip:
     PRINT "standard deviation (ms)"; INT(sd(x))
     INPUT "press return to continue"; XXX
     RETURN

'**END OF SUBJECT REACTION SUBROUTINES**
```

APPENDIX THREE

PILOT STUDIES

Appendix 3a

3a.1 Introduction

A pilot study was carried out to determine if the sex of subjects had an effect on static (UFOV) and kinetic (DRTS1 and 2) visual attention tests.

3a.2 Methods

Data were collected from 36 healthy subjects divided equally into three age groups (see section 2.4.2.1). Each group was further sub-divided into 6 males and 6 females. Each subject performed all three visual attention tests during one session (repeat 1; see appendix 6a). The order of tests was counterbalanced to avoid learning effects.

3a.3 Data analysis

All test scores were transformed for the purposes of statistical analysis. For the UFOV test, only the total UFOV score was considered, and for both the DRTS1 and 2, pooled reaction times were included in this analysis. A one-factor ANOVA was used to test for statistical significance at the 95% level.

3a.4 Results

The sex of subjects had no statistical significant effect on the UFOV ($F_{1,34} = 0.214$, $P = 0.6468$), DRTS1 ($F_{1,34} = 0.059$, $P = 0.8102$) or the DRTS2 ($F_{1,34} = 0.567$, $P = 0.4566$) test scores.

3a.5 Conclusion

Sex had no effect on performance on either static or kinetic visual attention tests and for all future analyses the data will be pooled for sex.

Appendix 3b

3b.1 Introduction

A pilot study was carried out to determine if the type of target (positive or negative contrast) had an effect on performance on the DRTS1 visual attention tests.

3b.2 Methods

Data were collected from 36 healthy subjects divided equally into three age groups (see section 2.4.2.1). Each subject performed the DRTS1 test in both positive contrast (i.e. non-reversed targets) and negative contrast (i.e. reversed targets) on two occasions (see appendix 6a). The DRTS1 test was designed to use supra-threshold white targets (non-reversed condition) on a dark background. However, because of the type of screen used (LCD type) an uncomfortable level of target flickered occurred. To overcome this, the screen contrast was reversed so that the targets appeared as dark grey stimuli on a light grey background (reversed condition). The order of tests was counterbalanced to avoid learning effects.

3b.2.1 Photometry readings

Photometry readings of the target and background were taken using a Minolta Luminance Meter model number LS-110. Readings were taken in cd/m^2 using Option 3 of the DRTS1 menu, designed for calibration of the monitor. A screen appeared containing 15 rectangles, the upper half representing the target and the lower half representing the background. Seventy-five photometry readings were taken at a working distance of 50 cm, five readings for each target and five for each background. The mean photometry readings (± standard deviation) for each condition are shown in table 3b.1.

Appendix 3b

Condition	Photometry Reading (cd/m^2)
Positive target; non-reversed	69.8 ± 4.5
Positive target background	20.8 ± 1.3
Negative target; reversed	4.8 ± 0.9
Negative target background	6.4 ± 1.1

Table 3b.1: Mean photometry readings (± standard deviation), for the target and background under both conditions.

The contrast (C) represented in each condition was calculated as a percentage using the following formula (Guenther, 1990): -

$$C = \frac{\text{Max. luminance} - \text{Min. luminance}}{\text{Max. luminance} + \text{Min. luminance}} \times 100\%$$

Table 3b.2 shows the contrast between the target and background for each condition. The contrast ratio revealed that the contrast level, when the targets were non-reversed, was 3.8x more than when the targets were reversed.

Target Type	Contrast (%)
Non-reversed	54
Reversed	14

Table 3b.2: Percentage contrast levels for each condition.

3b.3 Data analysis

All test scores were transformed for the purposes of statistical analysis. The mean pooled reaction times from each session were used in this analysis and a one-factor ANOVA was used to test for statistical significance at the 95% level.

3b.4 Results

The target's contrast had no statistical significant effect on the DRTS1 ($F_{1,70} = 0.106$, $p = 0.7457$) test scores.

3b.5 Conclusion

A comparison of reversed and non-reversed display of targets indicated that there was no significant difference in reaction times measured in each condition. The reverse contrast condition dramatically reduced the amount of flicker and was, therefore, adopted for comfort.

Appendix 3c

3c.1 Introduction

A pilot study was carried out to determine if two factors of the DRTS2 test had an influence on reaction times.

3c.2 Methods

Data were collected from 36 healthy subjects divided equally into three age groups (see section 2.4.2.1). Each subject performed the DRTS2 visual attention tests during one session (repeat 1; see appendix 6a). The application is divided into two scenes depicting daytime and night-time road conditions. The day or night conditions are simulated, but only in the context of the differences between light conditions at 4pm summertime and 4pm wintertime. Pedestrians were also equally divided into those with and without reflective Day-Glow armbands, 18 of each per scene. The intensity in brightness contrast between animated pedestrians wearing armbands and those without was scientifically based. Photometry experiments were carried out on the red-green-blue colour used to represent Day Glow on the screen. In total 36 pedestrian crossing events occurs in each scene, giving a total of 72 events. The order of tests was fixed with respect to the day-night conditions (daytime condition first). However, the targets were presented randomly for the with-without armband condition.

3c.3 Data analysis

All test scores were transformed for the purposes of statistical analysis. Reaction times were pooled for eccentricity in this analysis. A one-factor ANOVA was used to test for statistical significance at the 95% level.

3c.4 Results

Neither the day-night ($F_{1,70} = 0.013$, $P = 0.9108$) condition nor the with-without armbands ($F_{1,70} = 0.346$, $P = 0.5582$) had a statistical significant effect on the DRTS2 test scores.

3c.5 Conclusion

Since neither condition exerted an influence on performance, reaction times will be pooled for all future DRTS2 analyses.

APPENDIX FOUR

DRTS2 PARAMETERS AND ERROR ANALYSIS

Appendix 4a

4a.1 Introduction

The DRTS2 program was written by NetComms Limited, using JavaScript. Macromedia Flash 3.0 was used to produce graphical 3D modelling. Details of the parameters of the test were not supplied and it was necessary to calibrate these parameters.

4a.2 Methods

Test parameters were checked by taking measurements from a video recording of one main run that had been carried out on a Pentium 233 personal computer. In order to calculate the parameters it was necessary to assign a realistic estimate to two of the parameters. Firstly, it was assumed that the leading car was 1.8 m wide and 1.5 m high and secondly that the road was 3.6 m wide.

Ten repeat measurements were taken of each parameter and an error was calculated using error analysis (Taylor, 1939) from the mean and standard deviation of these parameters. Six correction factors were taken into consideration for working distance, running time, simulator speed, road, car and pedestrian parameters.

Error analysis involves the use of five formulae:

1) Fractional uncertainty = standard deviation / mean measurement
2) Correction factor (ratio) = working parameter / enlarged parameter
3) Mean uncertainty = √ (sum of the "fractional uncertainty ^ 2")
4) Estimated error = correction factor * mean
5) Tangent of angle (triangle) = length of opposite / length of adjacent

4a.3 Results

Measurements were taken of the working (PC) and enlarged (video) screen width and height to determine the ratio of sizing between them. This would provide a correction factor to apply to the enlarged parameters in order to estimate the actual parameters of the DRTS2 test. The following tables give the mean and standard deviation for all parameters measured.

4a.3.1 Distance correction factor

Parameter	Mean measurement	Standard deviation	Fractional uncertainty
Enlarged screen width (mm)	238.5	0.4	0.00168
Enlarged screen height (mm)	157.3	0.4	0.00254
Working screen width (mm)	149.6	0.5	0.00334
Working screen height (mm)	84.5	0.4	0.00473

Table 4a.1: The mean, standard deviation and fractional uncertainty of measurements taken from the enlarged and working screen height and width (mm).

Parameter	Correction factor	Mean uncertainty	Estimated error
Width	0.627	0.00374	0.00235
Height	0.537	0.00537	0.00289

Table 4a.2: The correction factor, mean uncertainty and estimated error for the working screen height and width.

4a.3.2 Time correction factor

Parameter	Mean time	Standard deviation	Fractional uncertainty
Enlarged screen test time (min)	13.6	-	-
Working screen test time (min)	7.4	0.3	0.0405

Table 4a.3: The enlarged screen mean test time (min) and the mean, standard deviation and fractional uncertainty of measurements taken from the working screen test time (min).

Parameter	Correction factor	Mean uncertainty	Estimated error
Time	0.544	0.0405	0.0221

Table 4a.4: The correction factor, mean uncertainty and estimated error for the working screen height and width. There is no mean uncertainty as there is only one fractional uncertainty.

4a.3.3 Simulator speed correction factor

Parameter	Mean measurement	Standard deviation	Fractional uncertainty
Based on single non-crossing pedestrian			
Estimated pedestrian height (m)	1.2	0.01	0.00833
Uncorrected start height (mm)	4.6	0.2	0.0435
Uncorrected finish height (mm)	66.2	0.5	0.00755
Uncorrected lapse time (s)	8.6	0.5	0.0581
Based on five non-crossing pedestrian			
Estimated pedestrian height (m)	1.2	0.01	0.00833
Uncorrected start height (mm)	5.95	2.05	0.345
Uncorrected finish height (mm)	67.4	1.2	0.0178
Uncorrected lapse time (s)	10.5	1.5	0.143

Table 4a.5: The mean measurement, standard deviation and fractional uncertainty of measurements taken from the enlarged screen for the non-crossing pedestrian height (m, mm) from the time (s) it appeared on the horizon till it disappeared at the base, based on one and five pedestrians.

Parameter	Correction factor	Mean uncertainty	Estimated error
Based on single non-crossing pedestrian			
Width correction factor	0.627	0.00374	-
Time correction factor	0.54	0.0405	-
Corrected start height (mm)	2.8842	0.0436	-
Tangent of angle	0.0058	0.0436	-
Actual start distance (m)	208.03	0.0444	9.242
Corrected finish height (mm)	41.507	0.00843	-
Tangent of angle	0.083	0.00843	-
Actual finish distance (m)	14.455	0.0119	0.171
Actual distance travelled (m)	193.57	0.0478	9.244
Actual time lapse (s)	4.644	0.0709	-
Simulator speed (m/s)	41.683	0.0855	3.562
Simulator speed (mph)	93.25	0.0855	7.969
Based on five non-crossing pedestrian			
Width correction factor	0.627	0.00374	-
Time correction factor	0.54	0.0405	-
Corrected start height (mm)	3.7307	0.0345	-
Tangent of angle	0.0075	0.0345	-
Actual start distance (m)	160.83	0.0345	55.43
Corrected finish height (mm)	42.26	0.00182	-
Tangent of angle	0.0845	0.00182	-
Actual finish distance (m)	14.198	0.02	0.284
Actual distance travelled (m)	146.63	0.0378	55.43
Actual time lapse (s)	5.67	0.148	-
Simulator speed (m/s)	25.861	0.406	10.5
Simulator speed (mph)	57.855	0.406	23.5

Table 4a.6: The mean correction factor, mean uncertainty and estimated error of measurements taken from the enlarged screen for the non-crossing pedestrian height (m, mm) from the time (s) it appeared on the horizon till it disappeared at the base, based on one and five pedestrians.

4a.3.4 Road parameters

Parameter	Mean measurement	Standard deviation	Fractional uncertainty
Assumed width (m)	3.6*	-	-
Uncorrected road width at horizon (mm)	11.1	0.3	0.0270
Uncorrected road width at base (mm)	232	0.4	0.00172

Table 4a.7: The mean measurement, standard deviation and fractional uncertainty of measurements taken from the enlarged screen for road width. An asterix indicates an assumed measure.

Parameter	Corrected measure	Mean uncertainty	Estimated error
Corrected road width at horizon (mm)	6.9625	0.273	0.189
Corrected road width at base (mm)	145.52	0.00412	0.599
Half road width at horizon (mm)	3.4813	0.0273	-
Assumed working distance (mm)	500*	-	-
Tangent of angle	0.007	0.0273	-
Distance to horizon (mm)	258.53	0.0273	7.054
Half road width at base (mm)	72.761	0.00412	-
Tangent of angle	0.1455	0.00412	-
Distance to base (mm)	12.369	0.00412	0.0509
Length of road (mm)	246.16	-	7.054

Table 4a.8: The corrected measure, mean uncertainty and estimated error for various parameters relating to the road of the working screen.

4a.3.5 Central car parameters

Parameter	Mean measurement	Standard deviation	Fractional uncertainty
Assumed car width (m)	1.8*	-	-
Assumed car height (m)	1.5*	-	-
Uncorrected far car width (mm)	11.1	0.2	0.0180
Uncorrected far car height (mm)	9.6	0.3	0.0312
Uncorrected near car width (mm)	28.6	0.4	0.0139
Uncorrected near car height (mm)	23.3	0.4	0.0172

Table 4a.9: The mean measurement, standard deviation and fractional uncertainty of measurements taken from the enlarged screen for the central car. An asterix indicates an assumed measure.

Parameter	Ratio	Mean uncertainty	Estimated error
Assumed width/height fraction	1.2*	-	-
Far width/height fraction	1.156	0.0361	0.0417
Near width/height fraction	1.228	0.0221	0.0272

Table 4a.10: The width : height ratio, mean uncertainty and estimated error for the enlarged screen central car event.

Parameter	Corrected measure	Mean uncertainty	Estimated error
Corrected far car width (mm)	6.9625	0.0184	0.128
Corrected near car width (mm)	17.939	0.0145	0.259
Half far car width (mm)	3.4813	0.0184	-
Tangent of angle	0.007	0.0184	-
Distance to far car (m)	129.26	0.0184	2.379
Half near car width	8.9697	0.0145	-
Tangent of angle	0.0179	0.0145	-
Distance to near car (m)	50.169	0.0145	0.726
Length of road travelled by car (m)	79.095	-	2.487

Table 4a.11: The corrected measure, mean uncertainty and estimated error for various parameters relating to the central car event of the working screen.

4a.3.6 Crossing pedestrian parameters

The DRTS2 test has six pedestrian crossing events (see table 4a.12) and this section will be further sub-divided into distant, intermediate and near pedestrians for this analysis.

Pedestrian Number	3	2	1	6	5	4
Position	Left of center			Right of center		
Eccentricity	Near	Intermediate	Distant	Distant	Intermediate	Near
Angle (°)	- 5.5	- 3.9	- 2.5	2.5	3.9	5.5

Table 4a.12: Pedestrian identity number, position, eccentricity and angle (degrees) of each event, relative to the center of the screen.

4a.3.6.1 Distant pedestrian parameters

Parameter	Mean measurement	Standard deviation	Fractional uncertainty
Pedestrian 1			
Uncorrected pedestrian height (mm)	21.1	0.5	0.0237
Uncorrected pedestrian width (mm)	3	0.4	0.133
Assumed road width (m)	3.6*	-	-
Uncorrected start adjacent road width (mm)	67	0.4	0.00597
Uncorrected start from middle of road (mm)	33.3	0.5	0.015
Uncorrected stop from middle of road (mm)	-3.5	0.7	-0.2
Uncorrected stop adjacent road width (mm)	141.3	0.4	0.00283
Uncorrected crossing time (s)	2.111	-	-
Time correction factor	0.54	0.02	0.037
Width correction factor	0.627	-	0.00374
Pedestrian 6			
Uncorrected pedestrian height (mm)	21.1	0.5	0.0237
Uncorrected pedestrian width (mm)	3	0.4	0.133
Assumed road width (m)	3.6*	-	-
Uncorrected start adjacent road width (mm)	74.9	0.4	0.00534
Uncorrected start from middle of road (mm)	37.7	0.9	0.0239
Uncorrected stop from middle of road (mm)	14	0.5	0.0357
Uncorrected stop adjacent road width (mm)	75.4	0.6	0.00796
Uncorrected crossing time (s)	0.664	-	-
Time correction factor	0.54	0.02	0.037
Width correction factor	0.627	-	0.00374

Table 4a.13: The mean measurement, standard deviation and fractional uncertainty of measurements taken from the enlarged screen for the distant pedestrian crossing events. An asterix indicates an assumed measure.

Parameter	Ratio	Mean uncertainty
Pedestrian 1		
Pedestrian height/road width fraction	0.3149	0.0244
Pedestrian height/width fraction	7.033	0.135
Start/road width fraction	0.497	0.0162
Stop/road width fraction	-0.025	0.200
Pedestrian 6		
Pedestrian height/road width fraction	0.2817	0.0243
Pedestrian height/width fraction	7.033	0.135
Start/road width fraction	0.5033	0.0245
Stop/road width fraction	0.1857	0.0366

Table 4a.14: The ratio and mean uncertainty for various parameters relating to the distant pedestrian crossing event of the working screen.

Parameter	Corrected measure	Mean uncertainty	Estimated error
Pedestrian 1			
Actual pedestrian height (m)	1.134	0.0244	0.0277
Actual pedestrian width (m)	0.1612	0.138	0.0222
Actual start distance from middle of road (m)	1.7893	0.0162	-
Actual stop distance from middle of road (m)	-0.089	0.2	-
Actual pedestrian travelling distance (m)	1.8784	0.107	0.201
Corrected crossing time (s)	1.1399	0.037	-
Actual crossing speed (m/s)	1.6478	0.113	-
Actual crossing speed (mph)	3.6864	0.113	0.417
Corrected start from middle of road (mm)	20.879	0.0155	-
Pedestrian eccentricity (degrees)	2.3912	0.0155	0.037
Pedestrian 6			
Actual pedestrian height (m)	1.0142	0.0243	0.0246
Actual pedestrian width (m)	0.1442	0.138	0.0198
Actual start distance from middle of road (m)	1.812	0.0245	-
Actual stop distance from middle of road (m)	0.6684	0.0366	-
Actual pedestrian travelling distance (m)	1.1436	0.0385	0.044
Corrected crossing time (s)	0.3586	0.037	-
Actual crossing speed (m/s)	3.1894	0.0534	-
Actual crossing speed (mph)	7.1351	0.0534	0.381
Corrected start from middle of road (mm)	23.638	0.0242	-
Pedestrian eccentricity (degrees)	2.7067	0.0242	0.0654

Table 4a.15: The corrected measure, mean uncertainty and estimated error for various parameters relating to the distant pedestrian crossing event of the working screen.

4a.3.6.2 Intermediate pedestrian parameters

Parameter	Mean measurement	Standard deviation	Fractional uncertainty
Pedestrian 2			
Uncorrected pedestrian height (mm)	30.9	0.5	0.0162
Uncorrected pedestrian width (mm)	4.2	0.5	0.119
Assumed road width (m)	3.6*	-	-
Uncorrected start adjacent road width (mm)	101.8	0.5	0.00491
Uncorrected start from middle of road (mm)	49.2	0.5	0.0102
Uncorrected stop from middle of road (mm)	-18	0.7	-0.0389
Uncorrected stop adjacent road width (mm)	200.5	0.5	0.0249
Uncorrected crossing time (s)	1.418	-	-
Time correction factor	0.54	0.02	0.037
Width correction factor	0.627	-	0.0374
Pedestrian 5			
Uncorrected pedestrian height (mm)	30.9	0.5	0.0162
Uncorrected pedestrian width (mm)	4.2	0.5	0.119
Assumed road width (m)	3.6*	-	-
Uncorrected start adjacent road width (mm)	110.3	0.6	0.00491
Uncorrected start from middle of road (mm)	60.8	0.7	0.0102
Uncorrected stop from middle of road (mm)	31.4	0.6	-0.0389
Uncorrected stop adjacent road width (mm)	232	0	0.0249
Uncorrected crossing time (s)	2.212	-	-
Time correction factor	0.54	0.02	0.037
Width correction factor	0.627	-	0.00374

Table 4a.16: The mean measurement, standard deviation and fractional uncertainty of measurements taken from the enlarged screen for the intermediate pedestrian crossing events. An asterix indicates an assumed measure.

Parameter	Ratio	Mean uncertainty
Pedestrian 2		
Pedestrian height/road width fraction	0.3035	0.0169
Pedestrian height/width fraction	7.3571	0.012
Start/road width fraction	0.4833	0.0113
Stop/road width fraction	-0.09	0.0389
Pedestrian 5		
Pedestrian height/road width fraction	0.2801	0.0171
Pedestrian height/width fraction	7.3571	0.12
Start/road width fraction	0.5512	0.0127
Stop/road width fraction	0.1353	0.0191

Table 4a.17: The ratio and mean uncertainty for various parameters relating to the intermediate pedestrian crossing event of the working screen.

Parameter	Corrected parameter	Mean uncertainty	Estimated error
Pedestrian 2			
Actual pedestrian height (m)	1.0927	0.0169	0.0185
Actual pedestrian width (m)	0.1485	0.121	0.018
Actual start distance from middle of road (m)	1.7399	0.0113	-
Actual stop distance from middle of road (m)	-0.323	0.0389	-
Actual pedestrian travelling distance (m)	2.0631	0.0197	0.0406
Corrected crossing time (s)	0.7657	0.037	-
Actual crossing speed (m/s)	2.6943	0.0419	-
Actual crossing speed (mph)	6.0275	0.0419	0.253
Corrected start from middle of road (mm)	30.848	0.0108	-
Pedestrian eccentricity (degrees)	3.5305	0.0108	0.0382
Pedestrian 5			
Actual pedestrian height (m)	1.0085	0.0171	0.0172
Actual pedestrian width (m)	0.1371	0.121	0.0166
Actual start distance from middle of road (m)	1.9844	0.0127	-
Actual stop distance from middle of road (m)	0.4872	0.0191	-
Actual pedestrian travelling distance (m)	1.4972	0.0153	0.0229
Corrected crossing time (s)	1.1945	0.037	-
Actual crossing speed (m/s)	1.2534	0.04	-
Actual crossing speed (mph)	2.804	0.04	0.112
Corrected start from middle of road (mm)	38.122	0.0121	-
Pedestrian eccentricity (degrees)	4.36	0.0121	0.0528

Table 4a.18: The corrected measure, mean uncertainty and estimated error for various parameters relating to the intermediate pedestrian crossing event of the working screen.

4a.3.6.3 Near pedestrian parameters

Parameter	Mean measurement	Standard deviation	Fractional uncertainty
Pedestrian 3			
Uncorrected pedestrian height (mm)	56	0.7	0.0125
Uncorrected pedestrian width (mm)	7.75	0.4	0.0516
Assumed road width (m)	3.6*	-	-
Uncorrected start adjacent road width (mm)	133.5	0.5	0.00375
Uncorrected start from middle of road (mm)	76.3	0.6	0.00786
Uncorrected stop from middle of road (mm)	-23.4	0.6	-0.0256
Uncorrected stop adjacent road width (mm)	171	0.4	0.0034
Uncorrected crossing time (s)	3.103	-	-
Time correction factor	0.54	0.02	0.037
Width correction factor	0.627	-	0.00374
Pedestrian 4			
Uncorrected pedestrian height (mm)	56	0.7	0.0125
Uncorrected pedestrian width (mm)	7.75	0.4	0.0516
Assumed road width (m)	3.6*	-	-
Uncorrected start adjacent road width (mm)	141.7	0.5	0.00352
Uncorrected start from middle of road (mm)	77	0	0
Uncorrected stop from middle of road (mm)	57.2	0.2	0.00349
Uncorrected stop adjacent road width (mm)	152.8	0.6	0.00393
Uncorrected crossing time (s)	1.409	-	-
Time correction factor	0.54	0.02	0.037
Width correction factor	0.627	-	0.00374

Table 4a.19: The mean measurement, standard deviation and fractional uncertainty of measurements taken from the enlarged screen for the near pedestrian crossing events. An asterix indicates an assumed measure.

Parameter	Ratio	Mean uncertainty
Pedestrian 3		
Pedestrian height/road width fraction	0.4195	0.013
Pedestrian height/width fraction	7.2258	0.0531
Start/road width fraction	0.5715	0.00871
Stop/road width fraction	-0.137	0.0257
Pedestrian 4		
Pedestrian height/road width fraction	0.3952	0.0129
Pedestrian height/width fraction	7.2258	0.0531
Start/road width fraction	0.5434	0.00353
Stop/road width fraction	0.3743	0.00526

Table 4a.20: The ratio and mean uncertainty for various parameters relating to the near pedestrian crossing event of the working screen.

Parameter	Corrected parameter	Mean uncertainty	Estimated error
Pedestrian 3			
Actual pedestrian height (m)	1.5101	0.013	0.0197
Actual pedestrian width (m)	0.209	0.0547	0.0114
Actual start distance from middle of road (m)	2.0575	0.00871	-
Actual stop distance from middle of road (m)	-0.493	0.0257	-
Actual pedestrian travelling distance (m)	2.5502	0.0107	0.0272
Corrected crossing time (s)	1.6756	0.037	-
Actual crossing speed (m/s)	1.5219	0.0385	-
Actual crossing speed (mph)	3.4047	0.0385	0.131
Corrected start from middle of road (mm)	47.84	0.00871	-
Pedestrian eccentricity (degrees)	5.4654	0.00871	0.0476
Pedestrian 4			
Actual pedestrian height (m)	1.4227	0.0129	0.0185
Actual pedestrian width (m)	0.1969	0.0547	0.0108
Actual start distance from middle of road (m)	1.9562	0.00353	-
Actual stop distance from middle of road (m)	1.3476	0.00526	-
Actual pedestrian travelling distance (m)	0.6086	0.0104	0.00633
Corrected crossing time (s)	0.7609	0.037	-
Actual crossing speed (m/s)	0.7999	0.0385	-
Actual crossing speed (mph)	1.7895	0.0385	0.0688
Corrected start from middle of road (mm)	48.279	0.00374	-
Pedestrian eccentricity (degrees)	5.5153	0.00374	0.0206

Table 4a.21: The corrected measure, mean uncertainty and estimated error for various parameters relating to the near pedestrian crossing event of the working screen.

4a.7 Weighted mean of pedestrian parameters

Pedestrian	Mean	Error	Weight	Weighted mean
Height				
1	1.13	0.03	1111.11	1255.56
6	1.01	0.02	2500	2525
2	1.09	0.02	2500	2725
5	1.01	0.02	2500	2525
3	1.51	0.02	2500	3775
4	1.42	0.02	2500	3550
Sum			13611.11	16355.56
Overall (standard deviation)				1.2016 (0.00857)
Width				
1	0.16	0.02	2500	400
6	0.14	0.02	2500	350
2	0.15	0.02	2500	375
5	0.14	0.02	2500	350
3	0.21	0.01	10000	2100
4	0.2	0.01	10000	2000
Sum			30000	5575
Overall (standard deviation)				0.1858 (0.00577)
Crossing speed				
1	3.7	0.4	6.25	23.125
6	7.1	0.4	6.25	44.375
2	6	0.3	11.11	66.667
5	2.8	0.1	100	280
3	3.4	0.1	100	340
4	1.8	0.1	100	180
Sum			323.61	934.167
Overall (standard deviation)				2.8867 (0.0556)

Table 4a.22: The mean, error, weight and weighted mean for the six pedestrian crossing events for their height, width and crossing speed. The overall weighted mean (standard deviation) for height, width and crossing speed are also shown.

Pedestrian	Mean	Error	Weight	Weighted mean
Distant				
1 6	2.39 2.7	0.04 0.07	625 204.082	1493.75 551.02
Sum			829.082	2044.77
Overall (standard deviation)				2.4663 (0.0347)
Intermediate				
2 5	3.53 4.36	0.04 0.05	625 400	2206.25 1744
Sum			1025	3950.25
Overall (standard deviation)				3.8539 (0.0312)
Near				
3 4	5.47 5.52	0.05 0.02	400 2500	2188 13800
Sum			2900	15988
Overall (standard deviation)				5.5131 (0.0186)

Table 4a.23: The mean, error, weight and weighted mean for the distant, intermediate and near pedestrian crossing events for their height, width and crossing speed. The overall weighted mean (standard deviation) for height, width and crossing speed are also shown.

4a.8 Summary

The following table (4a.24) provides a summary of the estimated DRTS2 parameters.

	DRTS2	
Test parameter	Mean	Standard error
Assumed working distance (m)	0.5	-
Assumed road width (m)	3.6	-
Road length (m)	246	2.2
Travelling speed (mph)	58	7.3
Assumed width of central car (m)	1.8	-
Distance to central car before braking event (m)	129	0.6
Distance to central car after full braking event (m)	50	0.3
Height of child pedestrian (m)	1.2	0.003
Width of child pedestrian (m)	0.19	0.003
Eccentricity #1 of crossing pedestrians (°)	2.5	0.009
Eccentricity #2 of crossing pedestrians (°)	3.9	0.009
Eccentricity #3 of crossing pedestrians (°)	5.5	0.006
Pedestrian crossing speed (mph)	2.9	0.03

Table 4a.24: Parameters of the DRTS2 kinetic visual attention tests.

The high standard deviation recorded for travelling speed revealed that the moving scene would frequently speed up or slow down as scenery density varied.

APPENDIX FIVE

TRANSFORMATIONS

Appendix 5a

5a.1: Introduction

Initial examination revealed that data for all tests were not normally distributed. Transformation of the data was thus necessary so that powerful and versatile parametric statistical tests could be applied to the results of each study.

5a.2: Method

The standard transformation that is used for a percentage is the inverse sine of the square root of the value (Ball et al., 1990). This transformation was adjusted for the data collected in this study (see equation 2.1) as the majority of test scores for the young and middle-aged group were zero and the inverse of zero is infinity.

Equation 5a.1:

$$\text{Transformation} = \frac{1}{\text{Sine}\sqrt{(90 - X)}}$$

Where: X = UFOV loss

The degree of normality of the transformed data were examined using a method described by Sachs (1992) which states that:

1) The mean divided by the median should fall between 0.9 and 1.1
2) The mean should be more than three times the standard deviation

If these conditions are satisfied then the data is approximately normally distributed.

5a.3: Results

Power	mean	median	Mean/ Median	SD	Mean /SD
UFOV Percentage loss	6.793	6.335	1.07	1.413	4.81

Table 5a.1: The mean, median and standard deviation of the transformed UFOV scores. The values indicate fulfilment of the rules defined by Sachs (1992).

5a.4: Summary

The results show that the transformation used fulfils the rules defined by Sachs (1992). Consequently all subsequent analyses involving UFOV scores will use data transformed using this formula.

Appendix 5b

5b.1: Introduction

Initial examination revealed that data for all tests were not normally distributed. Transformation of the data was thus necessary so that powerful and versatile parametric statistical tests could be applied to the results of each study.

5b.2: Method

For the DRTS tests it was necessary to experiment with various transformations in order to determine the ideal one. To this end reaction times and processing speeds for all trials were pooled and transformed by raising them to a power (n), where n varied from 2 to –3 in 0.5 steps (see equation 2.3, table 2.7).

Equation 5b.1: Transformation = RT^{n}

The degree of normality of the transformed data were examined using the method described in appendix section 5a.2 (Sachs, 1992). If these conditions are satisfied then the data is approximately normally distributed.

5b.3: Results

Power	Mean	Median	Mean/ Median	SD	Mean /SD
RT^{2}	0.973	0.410	2.373	2.563	0.380
$RT^{1.5}$	0.843	0.512	1.646	1.125	0.749
RT^{1}	0.820	0.640	1.281	0.548	1.496
$RT^{0.5}$	0.875	0.800	1.094	0.235	3.723
$RT^{-0.5}$	**1.204**	**1.250**	**0.9632**	**0.248**	**4.855**
RT^{-1}	1.512	1.563	0.967	0.688	2.198
$RT^{-1.5}$	1.975	1.953	1.011	2.148	0.919
RT^{-2}	2.733	2.441	1.120	9.1	0.300
$RT^{-2.5}$	4.262	3.052	1.396	41.666	0.102
RT^{-3}	8.514	3.815	2.232	193.544	0.044

Table 5b.1: Various transformations (see equation 2.3), of DRTS1 reaction times (sec) carried out to achieve a normal distribution. The best transformation is highlighted in bold.

Table 5b.1 shows that powers (n) of 0.5 and -0.5 satisfied these conditions.

DRTS1 reaction times were thus raised to the power of -0.5 in this study. The application of this transformation to DRTS2 reaction times was also found to satisfy the conditions for normality described by Sachs (1992).

Test	Mean	Median	Mean/ Median	SD	Mean /SD
DRTS2	1.177	1.230	0.957	0.248	4.746
UFOV Processing speed	6.942	7.906	0.878	1.519	5.205

Table 5b.2: Statistical values using the transformation $RT^{-0.5}$, for all DRTS2 reaction times (sec) and UFOV processing speeds (sec).

5b.4: Summary

The results show that the transformation used fulfils the rules defined by Sachs (1992). Consequently all subsequent analyses of reaction times will use data transformed using this formula.

APPENDIX SIX

PROTOCOL

Appendix 6a

SUBJECT GROUP 1: DRTS1 and REPEATABILITY PROTOCOL

Each of 36 subjects attended 6 experimental sessions. Sessions 1 – 4 were carried out to evaluate DRTS1 test parameters and the factors (treatments) that were explored can be found in the table 6a.1 below.

	Treatment A	Treatment B	Treatment C
Session 1: static versus kinetic presentation			
Mode	**Static**	**Kinetic**	
Speed	50 mph	50 mph	
Row spacing	100 m	100 m	
Target:distractor ratio	1:6	1:6	
Field width	15°	15°	
Targets included	all targets	all targets	
Session 2: influence of travelling speed			
Mode	Kinetic	Kinetic	Kinetic
Speed	**30 mph**	**50 mph**	**70 mph**
Row spacing	100 m	100 m	100 m
Target:distractor ratio	1:6	1:6	1:6
Field width	15°	15°	15°
Targets included	all targets	all targets	all targets
Session 3: effect of target field width			
Mode	Kinetic	Kinetic	Kinetic
Speed	50 mph	50 mph	50 mph
Row spacing	100 m	100 m	100 m
Target:distractor ratio	1:6	1:6	1:6
Field width	**5°**	**10°**	**15°**
Targets included	**center, inner**	**center, inner, middle**	**all targets**
Session 4: influence of clutter			
Mode	Kinetic	Kinetic	Kinetic
Speed	50 mph	50 mph	50 mph
Row spacing	**400 m**	**133 m**	**80 m**
Target:distractor ratio	**1:6**	**1:18**	**1:30**
Field width	15°	15°	15°
Targets included	all targets	all targets	all targets

Table 6a.1: The factors investigated during sessions 1-4 using the DRTS1 test. The factors shown in bold are the optional changes made to the default settings (kinetic, 50 mph, 100 m, 1:6, 15° and all targets).

Results were recorded as the mean reaction time of three pedestrian crossing events that occurred at each of seven eccentricities. The seven eccentricities or event locations, numbered 2 to 8, are explained in table 2.

Pedestrian Number	7	5	3	2	4	6	8
Position	Left of center			Center	Right of center		
Eccentricity	Outer	Middle	Inner		Inner	Middle	Outer
Angle (°)	- 7.5	- 5	- 2.5	0	2.5	5	7.5

Table 6a.2: Pedestrian identity number, position, eccentricity and angle (degrees) of each event, relative to the center of the screen of the DRTS1 test.

The full protocol for the six sessions is laid out in tables 6a.4 (young group), 6a.5 (middle group) and 6a.6 (older group). The data collected during these four sessions can be found in appendix 7a and the data for the two repeat sessions can be found in appendix 7b. Each subject performed a familiarisation (F) run at the start of each session, followed by the two or three treatments (A, B, C). The order of treatments was balanced to avoid learning effects. Further, on two occasions (indicated by *) an extra familiarisation run (F+) was performed to consider the effect of non-reversed and reversed target contrast. A key for these tables can be found below.

Abbreviation	Definition
F	Familiarisation run (reversed targets)
F+	Familiarisation run (non-reversed targets)
A	Treatment A
B	Treatment B
C	Treatment C
*	Reversed/non-reversed run performed
♀	Female
♂	Male
ID	Subject identification code
U	UFOV test
D	DRTS1 test
V	DRTS2 test

Table 6a.3: Key for abbreviations used in the following protocol tables.

YOUNG AGE < 20	STATIC – KINETIC	SPEED * F+ and F	FIELD	CLUTTER * F+ and F	REPEAT 1	REPEAT 2
ID AGE SEX: ♂/♀	A: static B: kinetic	A: 30 mph B: 50 mph C: 70 mph	A: 2.5 B: 5 C: 7.5	A: 1:6 B: 1:18 C: 1:30	U: UFOV D: DRTS1 V: DRTS2	U: UFOV D: DRTS1 V: DRTS2
JS 20 ♂ * F+	F-A-B	F-B-C-A	F-C-A-B	F-A-B-C	D-U-V	D-U-V
MR2 20 ♂ * F	F-B-A	F-C-A-B	F-A-B-C	F-B-C-A	U-V-D	U-V-D
MR 20 ♂ * F+	F-A-B	F-A-B-C	F-B-C-A	F-C-A-B	V-D-U	V-D-U
CL 20 ♂ * F	F-B-A	F-B-C-A	F-C-A-B	F-A-B-C	D-U-V	D-U-V
NB 20 ♂ * F+	F-A-B	F-C-A-B	F-A-B-C	F-B-C-A	U-V-D	U-V-D
EE 20 ♂ * F	F-B-A	F-A-B-C	F-B-C-A	F-C-A-B	V-D-U	V-D-U
SD 20 ♀ * F+	F-A-B	F-B-C-A	F-C-A-B	F-A-B-C	D-U-V	D-U-V
RD 20 ♀ * F	F-B-A	F-C-A-B	F-A-B-C	F-B-C-A	U-V-D	U-V-D
KJ 20 ♀ * F+	F-A-B	F-A-B-C	F-B-C-A	F-C-A-B	V-D-U	V-D-U
SM 20 ♀ * F	F-B-A	F-B-C-A	F-C-A-B	F-A-B-C	D-U-V	D-U-V
LC 20 ♀ * F+	F-A-B	F-C-A-B	F-A-B-C	F-B-C-A	U-V-D	U-V-D
FB 20 ♀ * F	F-B-A	F-A-B-C	F-B-C-A	F-C-A-B	V-D-U	V-D-U

Table 6a.4: The order of tests for the six sessions performed by the 12 subjects in the young age group. The table includes the ID, age and sex (♂ = male, ♀ = female) of each subject. The asterix denotes the order of the familiarisation (F) run when both non-reversed (F+) and reversed (F) contrast targets were used.

MIDDLE AGE 30 – 55	STATIC – KINETIC	SPEED * F+ and F	FIELD	CLUTTER * F+ and F	REPEAT 1	REPEAT 2
ID AGE SEX: ♂/♀	A: static B: kinetic	A: 30 mph B: 50 mph C: 70 mph	A: 2.5 B: 5 C: 7.5	A: 1:6 B: 1:18 C: 1:30	U: UFOV D: DRTS1 V: DRTS2	U: UFOV D: DRTS1 V: DRTS2
JH 31 ♂ * F+	F-A-B	F-B-C-A	F-C-A-B	F-A-B-C	D-U-V	D-U-V
MT 30 ♂ * F	F-B-A	F-C-A-B	F-A-B-C	F-B-C-A	U-V-D	U-V-D
PS 32 ♂ * F+	F-A-B	F-A-B-C	F-B-C-A	F-C-A-B	V-D-U	V-D-U
JSi 38 ♂ * F	F-B-A	F-B-C-A	F-C-A-B	F-A-B-C	D-U-V	D-U-V
JMc 38 ♂ * F+	F-A-B	F-C-A-B	F-A-B-C	F-B-C-A	U-V-D	U-V-D
MM 30 ♂ * F	F-B-A	F-A-B-C	F-B-C-A	F-C-A-B	V-D-U	V-D-U
WO 43 ♀ * F+	F-A-B	F-B-C-A	F-C-A-B	F-A-B-C	D-U-V	D-U-V
NP 34 ♀ * F	F-B-A	F-C-A-B	F-A-B-C	F-B-C-A	U-V-D	U-V-D
AG 32 ♀ * F+	F-A-B	F-A-B-C	F-B-C-A	F-C-A-B	V-D-U	V-D-U
SW 38 ♀ * F	F-B-A	F-B-C-A	F-C-A-B	F-A-B-C	D-U-V	D-U-V
GR 42 ♀ * F+	F-A-B	F-C-A-B	F-A-B-C	F-B-C-A	U-V-D	U-V-D
SG 34 ♀ * F	F-B-A	F-A-B-C	F-B-C-A	F-C-A-B	V-D-U	V-D-U

Table 6a.5: The order of tests for the six sessions performed by the 12 subjects in the middle age group. The table includes the ID, age and sex (♂ = male, ♀ = female) of each subject. The asterix denotes the order of the familiarisation (F) run when both non-reversed (F+) and reversed (F) contrast targets were used.

OLDER AGE 60+	STATIC – KINETIC	SPEED * F+ and F	FIELD	CLUTTER * F+ and F	REPEAT 1	REPEAT 2
ID AGE SEX: ♂/♀	A: static B: kinetic	A: 30 mph B: 50 mph C: 70 mph	A: 2.5 B: 5 C: 7.5	A: 1:6 B: 1:18 C: 1:30	U: UFOV D: DRTS1 V: DRTS2	U: UFOV D: DRTS1 V: DRTS2
DA 77 ♂ * F+	F-A-B	F-B-C-A	F-C-A-B	F-A-B-C	D-U-V	D-U-V
BO 78 ♂ * F	F-B-A	F-C-A-B	F-A-B-C	F-B-C-A	U-V-D	U-V-D
EL 76 ♂ * F+	F-A-B	F-A-B-C	F-B-C-A	F-C-A-B	V-D-U	V-D-U
KP 66 ♂ * F	F-B-A	F-B-C-A	F-C-A-B	F-A-B-C	D-U-V	D-U-V
BY 73 ♂ * F+	F-A-B	F-C-A-B	F-A-B-C	F-B-C-A	U-V-D	U-V-D
JE 71 ♂ * F	F-B-A	F-A-B-C	F-B-C-A	F-C-A-B	V-D-U	V-D-U
PO 79 ♀ * F+	F-A-B	F-B-C-A	F-C-A-B	F-A-B-C	D-U-V	D-U-V
EB 68 ♀ * F	F-B-A	F-C-A-B	F-A-B-C	F-B-C-A	U-V-D	U-V-D
RP 72 ♀ * F+	F-A-B	F-A-B-C	F-B-C-A	F-C-A-B	V-D-U	V-D-U
MU 70 ♀ * F	F-B-A	F-B-C-A	F-C-A-B	F-A-B-C	D-U-V	D-U-V
DF 67 ♀ * F+	F-A-B	F-C-A-B	F-A-B-C	F-B-C-A	U-V-D	U-V-D
PF 66 ♀ * F	F-B-A	F-A-B-C	F-B-C-A	F-C-A-B	V-D-U	V-D-U

Table 6a.6: The order of tests for the six sessions performed by the 12 subjects in the older age group. The table includes the ID, age and sex (♂ = male, ♀ = female) of each subject. The asterix denotes the order of the familiarisation (F) run when both non-reversed (F+) and reversed (F) contrast targets were used.

SUBJECT GROUP 2: LEEDS DRIVING SIMULATOR PROTOCOL

Each of 19 subjects attended 1 experimental session. The sample comprised 9 female and 10 male older drivers whose ages ranged from 61 to 79 years (mean ± standard deviation: 70 ± 5 years). Each subject had previously taken part in a research project carried out by Dr Lily Read in the Psychology Department at Leeds University. The self-reported at-fault crash history of each driver had been established. Each driver had also been assessed on the Institute of Transport Safety's driving simulator (Read, 2001). Arrangements were made to recall each driver to take the UFOV and DRTS2 tests; the order of tests was balanced to avoid learning effects. No data were collected on the DRTS1 test because of time restrictions.

ID	Age (years)	Sex	Order of tests
BU	61	♂	U V
CO	69	♂	V U
EL	74	♂	U V
GO	65	♂	V U
KE	79	♂	U V
NE	62	♂	V U
PI	74	♂	U V
PU	71	♂	V U
SP	75	♂	U V
ST	72	♂	V U
EL1	70	♀	U V
LA	74	♀	V U
PE	68	♀	U V
PR	71	♀	V U
PU1	66	♀	U V
SM	66	♀	V U
TA	77	♀	U V
WE	69	♀	V U
WI	67	♀	U V

Table 6b.1: The order of tests for the 19 older drivers (U: UFOV test; V: DRTS2 test). The table includes the ID, age (years) and sex (♂ = male, ♀ = female) of each subject.

SUBJECT GROUP 3: POLICE DRIVING STUDY PROTOCOL

Each of 25 police drivers attended 1 experimental session. The sample included 25 male drivers whose ages ranged from 29 to 62 years (mean ± standard deviation: 42 ± 9 years). Crash histories were obtained from police records making them more reliable than self-reported data. Driving performance was also based upon a percentage examiner-rated open-road driving score, which again, may be more relevant than driving simulator performance. Randomly selected police drivers took the UFOV and DRTS2 tests; the order of tests was balanced to avoid learning effects. Again, no data were collected on the DRTS1 test because of time restrictions.

ID	Age (years)	Experience	Order of tests
1	42	Advanced	U V
2	62	Advanced	V U
3	41	Advanced	U V
4	62	Advanced	V U
5	54	Advanced	U V
6	46	Advanced	V U
7	29	Standard	U V
8	36	Standard	V U
9	47	Advanced	U V
10	29	Standard	U V
11	45	Standard	V U
12	35	Standard	U V
13	41	Standard	V U
14	41	Advanced	V U
15	44	Advanced	U V
16	41	Advanced	V U
17	47	Advanced	U V
18	34	Standard	U V
19	30	Standard	V U
20	40	Standard	U V
21	37	Standard	V U
22	39	Advanced	V U
23	35	Standard	U V
24	41	Standard	V U
25	43	Standard	U V

Table 6c.1: The order of tests for the 25 police drivers (U: UFOV test; V: DRTS2 test). The table includes the ID, age (years) and the police driver grade (advanced or standard) of each subject.

SUBJECT GROUP 4: OPTIC FLOW EDGE CORRECTION STUDY PROTOCOL

Each of 4 subjects attended 1 experimental session. The sample included 4 young drivers whose ages ranged from 17 to 29 years (mean ± standard deviation: 23 ± 5 years). Each subject performed the DRTS1 test 3 times. The first test run acted as a familiarisation run, followed by the two treatment runs, the order of which was balanced to avoid learning effects.

ID	Age (years)	Sex	Order of tests
1	24	♂	F D O
2	22	♂	F O D
3	17	♀	F D O
4	29	♀	F O D

Table 6d.1: The order of tests for the 4 subjects (F: familiarisation; D: default and O: optic flow edge corrected). The table includes the ID, age (years) and sex (♂: male; ♀: female) of each subject.

APPENDIX SEVEN

DATA

Repeat measurements were taken from 36 subjects divided equally into young, middle and older age groups (see section 2.4.2.1). Each subject performed all three visual attention tests on two separate sessions. The order of tests carried out in each session was counterbalanced (see appendix 6a). The data collected during these sessions are presented here.

The UFOV data is divided into two tables, one for each session (repeat 1 and repeat 2) and the following data are shown: processing speed duration, processing speed loss, divided attention loss, selective attention loss, total UFOV loss and total time to complete the test (see tables 7a.3 and 7a.4).

The DRTS1 data is also divided into two tables, one for each session. Reaction times for each position are recorded (targets 2 – 8) in tables 7a.5 and 7a.6. The location of each of the targets can be found in table 7a.1 below.

Pedestrian Number	7	5	3	2	4	6	8
Position	Left of center			Center	Right of center		
Eccentricity	Outer	Middle	Inner		Inner	Middle	Outer
Angle (°)	- 7.5	- 5	- 2.5	0	2.5	5	7.5

Table 7a.1: Pedestrian identity number, position, eccentricity and angle (degrees) of each event, relative to the center of the screen.

The DRTS2 data is presented in eight tables, four for each session. The first table, for each session, presents the reaction times that are displayed at the end of each DRTS2 test run (day: with and without armbands, night: with and without armbands). The following three tables (divided by age group) present the reaction times for each pedestrian crossing event during daytime and nighttime conditions. Reaction times for each position are presented (targets 1 – 6). The location of each of the targets can be found in table 7a.2 below.

Pedestrian Number	3	2	1	6	5	4
Position	Left of center					Right of center
Eccentricity	Near	Intermediate	Distant	Distant	Intermediate	Near
Angle (°)	- 5.5	- 3.9	- 2.5	2.5	3.9	5.5

Table 7a.2: Pedestrian identity number, position, eccentricity and angle (degrees) of each event, relative to the center of the screen.

ID	Event	Event number						
		7	5	3	2	4	6	8
		Mean reaction time						
CL	F	1807	692	510	1569	712	876	2565
	B	440	421	436	441	671	346	477
	A	768	583	494	1080	513	679	912
EE	F	563	514	675	1132	514	785	674
	B	477	472	524	532	492	492	473
	A	653	606	492	1078	511	675	673
FB	F	513	507	513	1613	455	583	507
	B	526	533	471	524	585	545	570
	A	542	494	549	1076	476	550	601
JS2	F	822	550	619	2016	565	708	787
	A	863	619	513	1365	494	545	843
	B	589	454	549	677	493	513	489
KJ	F	932	585	635	1282	473	585	2634
	A	692	675	606	1132	476	602	783
	B	510	492	493	509	513	550	550
LC	F	697	567	510	750	492	638	901
	A	583	531	473	898	489	536	565
	B	476	492	476	460	492	455	492
MR	F	675	604	602	841	598	770	932
	A	937	694	622	1881	658	640	1169
	B	513	528	509	493	529	513	494
MR1	F	769	546	608	1264	550	549	769
	B	582	511	677	582	566	472	680
	A	731	587	548	1113	528	622	933
NB	F	1740	696	547	1574	621	579	881
	A	790	513	453	2192	497	658	967
	B	566	416	455	513	423	437	510
RD	F	696	604	506	1972	440	549	770
	B	470	527	532	346	858	546	475
	A	694	475	328	1097	440	680	476
SD	F	623	494	661	972	587	550	583
	A	675	677	549	1188	619	605	641
	B	639	591	526	604	772	748	713
SM	F	566	934	513	1279	583	582	623
	B	550	582	583	532	528	457	531
	A	677	545	514	1226	509	563	789

Table 7a.3: The mean DRTS1 reaction times taken from the younger age group during the static versus kinetic target presentation session (1).

ID	Event	Event number						
		7	5	3	2	4	6	8
		Mean reaction time						
AG	F	1002	587	545	1246	709	696	807
	A	825	712	526	1296	514	604	966
	B	712	456	533	419	476	479	493
GR	F	787	587	440	1205	489	601	604
	A	492	589	378	1699	494	546	966
	B	399	438	403	403	437	476	493
JH	F	787	510	477	950	454	455	733
	A	656	457	476	988	416	493	692
	B	419	421	440	437	457	455	453
JMc	F	1205	803	591	692	567	677	1341
	A	967	636	587	912	571	674	766
	B	566	766	438	438	513	606	513
JS1	F	656	604	489	713	514	652	919
	B	458	457	472	549	493	526	455
	A	531	432	479	716	454	455	598
MM	F	1042	584	528	990	531	589	908
	B	420	424	420	421	438	419	434
	A	640	492	440	954	454	473	657
MT	F	1044	638	618	1354	619	750	822
	B	472	476	513	493	440	438	436
	A	1100	477	438	1260	529	545	621
NP	F	787	550	509	1242	625	570	713
	B	472	514	531	549	510	565	454
	A	675	674	544	1156	533	549	696
PS	F	782	587	494	1078	475	690	640
	A	660	531	493	1027	510	492	807
	B	440	459	457	403	514	488	1606
SG	F	694	550	550	1280	599	606	803
	B	602	546	828	619	545	570	545
	A	623	582	550	1427	658	807	657
SW	F	638	606	549	839	473	562	694
	B	455	440	528	475	493	457	454
	A	641	494	490	1044	455	511	842
WO	F	677	657	549	1065	734	696	1536
	A	678	584	493	1119	549	476	694
	B	571	472	566	533	548	584	559

Table 7a.4: The mean DRTS1 reaction times taken from the middle age group during the static versus kinetic target presentation session (1).

ID	Event	Event number						
		7	5	3	2	4	6	8
		Mean reaction time						
BO	F	2433	1263	1023	2450	1113	1442	3954
	B	350	893	1205	553	619	604	691
	A	1829	861	786	2397	804	971	1902
BY	F	1226	914	804	2029	769	786	953
	A	826	863	635	1742	808	730	1058
	B	660	606	600	582	640	625	643
DA	F	3134	2124	1279	2656	1346	1961	2913
	A	2654	1867	1113	3516	1037	2363	3092
	B	746	712	619	657	915	678	839
DF	F	1156	658	566	1480	602	729	1279
	A	765	602	570	3350	546	730	1080
	B	585	588	531	475	1022	437	533
EB	F	3645	2152	1042	2669	917	1920	3954
	B	1738	622	621	716	729	604	691
	A	3421	2031	1003	2175	951	971	1902
EL	F	3093	1296	713	*	932	899	3075
	A	1282	970	708	2799	640	1192	3294
	B	361	569	772	183	606	542	604
JE	F	1003	1080	782	1759	729	983	1101
	B	583	587	584	528	583	790	566
	A	899	820	622	1834	748	970	1595
JP	F	919	640	565	1244	674	861	1059
	B	513	565	546	479	546	549	458
	A	658	643	513	1555	567	601	770
MU	F	2597	910	825	3842	1373	1208	2819
	B	893	635	643	602	709	750	714
	A	2796	970	822	4725	847	805	1667
PF	F	748	953	622	2196	733	1132	1662
	B	546	526	601	566	570	533	598
	A	602	657	587	2550	583	692	3113
PO	F	3492	2269	1040	3332	1192	1462	3640
	A	598	1263	986	3420	985	1597	3113
	B	*	567	656	710	606	545	598
RP	F	1497	916	619	2338	731	695	1460
	A	1096	862	693	1445	586	766	1380
	B	932	658	747	609	604	697	929

Table 7a.5: The mean DRTS1 reaction times taken from the older age group during the static versus kinetic target presentation session (1).

ID	Event	Event number						
		7	5	3	2	4	6	8
		Mean reaction time						
CL	F	619	569	460	1132	420	507	546
	F +	787	509	476	1065	477	528	751
	B	1136	476	416	1373	420	510	710
	C	900	493	457	1205	438	473	783
	A	549	488	493	1717	494	475	531
EE	F	601	526	492	1113	546	533	750
	F +	548	493	436	1165	472	528	656
	A	545	677	510	1450	514	583	600
	B	533	529	457	1080	529	472	694
	C	897	584	548	1063	548	528	897
FB	F	897	566	566	1553	509	604	786
	F+	639	584	640	1205	404	550	639
	A	1083	1083	583	1234	583	733	1005
	B	729	618	472	1483	510	622	753
	C	984	674	510	1703	476	606	1042
JS2	F +	766	623	716	1113	619	584	7331
	F	802	672	1040	1352	679	675	1356
	B	656	639	532	1190	674	533	636
	C	764	709	598	1134	696	549	1606
	A	583	677	601	1591	623	656	855
KJ	F+	803	710	549	1500	602	639	915
	F	989	804	549	1332	567	766	713
	A	1079	764	934	2270	550	1149	875
	B	1134	585	346	1540	1026	748	877
	C	*	750	730	1613	748	622	1460
LC	F+	638	585	513	770	546	604	789
	F	623	548	436	930	493	533	677
	C	1210	566	493	909	509	605	1259
	A	603	533	526	913	490	513	529
	B	660	473	514	803	496	545	731
MR	F+	876	660	545	1117	569	692	929
	F	860	636	716	1500	602	785	1191
	A	621	623	730	1572	674	770	679
	B	822	713	636	1553	734	696	951
	C	805	601	600	1391	621	643	1373
MR1	F	714	619	1023	1537	643	563	733
	F +	533	497	752	1169	471	529	893
	C	933	692	472	989	621	528	859
	A	606	638	476	1148	626	569	566
	B	658	553	640	1006	562	526	660
NB	F+	602	514	440	970	570	514	468
	F	1389	604	640	1196	656	707	953
	C	1173	623	506	1365	514	618	1181
	A	606	566	513	1704	528	548	621
	B	529	460	470	1518	457	566	580

Table 7a.6: The mean DRTS1 reaction times taken from younger age group during the speed session (2). This session includes a familiarisation run (F+) where the target contrast is non-reversed.

RD	F	533	585	510	1243	529	569	691
	F +	643	598	419	1393	509	509	660
	C	712	457	384	1132	457	603	880
	A	785	542	513	1537	532	476	621
	B	513	459	511	1317	493	509	546
SD	F +	696	531	549	983	569	509	807
	F	787	580	509	1045	510	657	803
	B	710	579	640	1042	528	584	750
	C	949	604	510	1096	536	654	839
	A	622	598	524	1260	510	570	700
SM	F	895	584	678	1100	550	656	893
	F +	692	662	601	876	621	713	734
	B	640	654	550	1084	598	608	752
	C	1009	583	550	1118	497	545	849
	A	692	554	562	1300	658	566	606

Table 7a.6 (continued): The mean DRTS1 reaction times taken from the younger age group during the speed session (2). This session includes a familiarisation run (F+) where the target contrast is non-reversed.

ID	Event	Event number						
		7	5	3	2	4	6	8
		Mean reaction time						
AG	F +	713	549	639	897	531	549	677
	F	510	604	421	1755	494	531	661
	A	440	479	421	1572	421	424	424
	B	440	458	421	1026	406	421	1286
	C	533	460	401	1003	395	455	1390
GR	F +	766	529	460	1210	583	656	911
	F	496	399	417	898	420	528	477
	C	786	477	440	1153	423	545	1390
	A	477	476	440	1555	440	457	424
	B	566	388	420	729	420	437	1286
JH	F +	733	661	510	933	496	770	753
	F	565	550	441	894	457	477	549
	B	826	472	423	914	476	460	569
	C	880	492	477	1169	472	565	619
	A	477	401	420	1169	417	416	493
JMc	F+	1317	640	641	803	548	639	1300
	F	734	662	511	949	533	627	786
	C	*	697	510	932	513	638	*
	A	619	585	513	733	550	546	661
	B	730	641	529	790	492	565	708
JS1	F	566	511	386	803	492	490	510
	F +	617	565	531	805	532	606	765
	B	532	438	440	842	403	455	604
	C	656	513	415	788	388	493	566
	A	677	420	421	893	529	514	549

Table 7a.7: The mean DRTS1 reaction times taken from the middle age group during the speed session (2). This session includes a familiarisation run (F+) where the target contrast is non-reversed.

MM	F	640	493	453	822	420	460	677
	F +	716	475	453	789	457	492	664
	A	472	460	437	803	440	438	545
	B	587	457	419	673	381	438	528
	C	1480	567	531	1002	529	529	1433
MT	F	696	587	549	1699	622	604	914
	F +	805	712	803	1446	550	751	860
	C	550	712	695	1572	529	569	893
	A	1045	623	675	2070	549	677	694
	B	639	635	489	1460	549	528	606
NP	F	808	528	454	1080	401	570	657
	F +	680	531	496	805	513	476	653
	C	822	567	493	936	475	566	729
	A	656	477	492	949	509	490	455
	B	602	529	420	820	493	492	548
PS	F +	627	617	588	1453	585	658	671
	F	583	438	420	928	457	476	549
	A	473	459	476	1576	438	455	490
	B	514	440	403	843	419	489	511
	C	785	490	583	1279	510	549	1084
SG	F	453	309	330	1445	421	421	460
	F +	846	569	619	1080	494	584	769
	A	696	606	458	1589	585	565	587
	B	638	694	622	1136	587	697	738
	C	1117	618	529	1447	636	656	1320
SW	F	493	476	458	895	493	459	638
	F +	677	897	493	894	513	587	803
	B	566	423	493	1244	476	454	636
	C	694	510	490	988	402	496	550
	A	582	549	475	990	566	457	635
WO	F+	587	565	441	1007	548	529	587
	F	1005	552	606	978	598	493	695
	B		476	510	1792	510	549	
	C	583	571	510	1589	509	656	727
	A			472	1321	493		

Table 7a.7 (continued): The mean DRTS1 reaction times taken from the middle age group during the speed session (2). This session includes a familiarisation run (F+) where the target contrast is non-reversed.

ID	Event	Event number						
		7	5	3	2	4	6	8
		Mean reaction time						
BO	F	1296	783	716	1390	804	729	1023
	F +	875	656	6704	1059	783	839	750
	C	*	747	636	1210	636	838	*
	A	1173	623	550	2285	799	643	785
	B	1264	623	623	1244	679	677	1130
BY	F +	834	681	621	3097	637	724	1059
	F	860	733	643	2966	619	730	1117
	C	820	843	764	2279	753	820	1121
	A	876	738	826	3203	766	839	877
	B	1237	800	714	2636	802	809	1042
DA	F +	3733	1592	1134	2252	970	1136	2742
	F	2947	2200	1389	3678	1282	2376	3402
	B	3350	1919	1279	3660	1481	2108	3513
	C	*	1980	1406	2102	1373	2049	*
	A	1483	1223	839	4390	1026	1390	1830
DF	F +	2820	1169	766	1865	914	1134	3240
	F	916	713	545	2727	545	674	897
	C	1236	694	661	1570	657	638	1367
	A	766	656	528	2764	533	656	766
	B	766	713	619	1191	691	658	791
EB	F	3294	1906	783	1975	766	1881	1023
	F+	3587	2164	972	1880	820	2197	750
	C	*	1885	694	1622	916	838	*
	A	3126	1756	839	1976	782	643	7885
	B	3221	1805	712	2067	766	677	1130
EL	F +	1023	895	765	1861	716	809	1111
	F	934	783	772	2289	820	1373	2140
	A	878	766	819	1335	695	842	916
	B	1000	713	640	1720	660	802	1996
	C	2472	807	787	2101	897	1026	1808
JE	F	859	707	619	1578	675	752	860
	F +	746	709	550	932	604	638	766
	A	604	660	766	1096	623	635	712
	B	915	692	696	1298	638	696	842
	C	877	766	583	990	604	747	941
JP	F	783	591	549	809	567	617	950
	F+	1187	640	497	1497	528	713	1885
	B	916	585	570	1117	526	601	937
	C	1382	750	611	1096	619	729	*
	A	700	585	531	1632	635	598	783
MU	F	1865	890	989	5654	1027	1630	2602
	F +	1572	927	733	3864	766	970	1261
	B	1408	1171	664	1532	1019	1040	2138
	C		932	1388	1499	1350	1113	
	A	1643	750	625	2070	640	825	2190

Table 7a.8: The mean DRTS1 reaction times taken from the older age group during the speed session (2). This session includes a familiarisation run (F+) where the target contrast is non-reversed.

PF	F	786	654	552	3367	604	695	873
	F+	1113	751	730	2539	653	733	774
	A	657	696	673	2180	769	726	753
	B	770	570	621	1600	699	639	619
	C	660	660	585	1980	604	657	1093
PO	F	2895	1442	750	1299	731	1023	3076
	F+	3950		1152	1498			3921
	B	2618	988	601	1682	781	1079	1647
	C		933	860	1150	820	929	
	A	915	876	786	2928	1165	805	1078
RP	F+	820	710	606	1898	531	791	1117
	F	898	783	643	2325	609	1028	1114
	A	1393	783	773	4268	661	1023	1429
	B	932	1283	747	2638	953	1195	1005
	C	1621	872	841	2361	861	1263	1210

Table 7a.8 (continued): The mean DRTS1 reaction times taken from the older age group during the speed session (2). This session includes a familiarisation run (F+) where the target contrast is non-reversed.

ID	Event	Event number						
		7	5	3	2	4	6	8
		Mean reaction time						
CL	F	772	533	533	934	459	506	621
	C	602	454	477	766	440	348	545
	A			419	970	419		
	B		460	398	1167	476	455	
EE	F	529	550	488	880	476	533	623
	B		528	457	727	490	493	
	C	671	494	472	1132	509	493	641
	A			476	950	459		
FB	F	731	597	492	692	440	606	692
	B		582	622	1203	619	677	
	C	1484	640	533	1115	455	605	931
	A			513	1172	619		
JS2	F	582	437	438	1194	420	434	546
	C	623	432	472	1005	457	494	582
	A			440	1006	440		
	B		492	438	1040	421	476	
KJ	F	692	584	1082	1296		606	912
	B		1167	526	1357	950	1645	
	C	950	636	876	1937	714	804	1463
	A			736	1059	858		
LC	F	626	496	453	1225	496	546	692
	A			472	784	549		
	B		529	514	803	523	567	
	C	639	549	480	863	489	529	636
MR	F	822	627	471	1300	546	567	714
	B		513	622	1043	587	584	
	C	714	654	569	587	531	584	694
	A			587	531	583		
MR1	F	657	528	602	1373	619	566	661
	A			548	1666	489		
	B		584	636	1059	584	622	
	C	566	531	550	1316	566	733	694
NB	F	473	490	437	1191	399	458	570
	A		477	438	1097	472	492	
	B			438	1117	455		
	C	549	513	399	751	528	509	604
RD	F	544	459	476	1613	531	476	602
	A			497	1278	505		
	B		526	417	1259	545	549	
	C	548	546	623	1191	476	527	550
SD	F	799	550	623	1036	548	528	712
	C	712	621	583	1132	546	587	725
	A			476	1076	516		
	B		533	528	1002	472	493	
SM	F	606	606	529	950	472	558	750
	C	677	510	510	821	567	622	695
	A			472	990	437		
	B		585	493	1169	514	493	

Table 7a.9: The mean DRTS1 reaction times taken from the younger age group during the field session (3).

ID	Event	Event number						
		7	5	3	2	4	6	8
		Mean reaction time						
AG	F	513	442	440	1822	455	507	604
	B		403	440	1257	494	455	
	C	528	494	497	825	421	473	1122
	A			460	986	437		
GR	F	531	471	787	1299	472	513	602
	A			421	1117	457		
	B		440	402	986	459	476	
	C	531	492	421	895	476	492	531
JH	F	472	423	420	967	404	365	476
	C	451	492	363	696	380	380	528
	A			402	638	382		
	B		399	395	730	514	403	
JMc	F	838	619	527	891	493	621	842
	A			475	860	509		
	B		585	477	864	507	584	
	C	709	602	510	789	493	604	864
JS1	F	330	458	401	805	403	457	401
	C	457	438	455	808	382	453	492
	A			419	622	384		
	B		441	463	677	433	477	
MM	F	529	545	440	791	420	582	507
	B		471	4554	708	440	444	
	C	549	440	420	710	403	531	587
	A			401	718	440		
MT	F	639	618	496	1191	602	587	713
	A			861	861	510		
	B		660	493	1023	509	584	
	C	802	695	677	1302	606	860	697
NP	F	563	515	453	989	441	472	602
	A			455	966	471		
	B		604	442	843	480	549	
	C	583	546	403	839	434	493	802
PS	F	533	531	492	1484	473	567	531
	B		494	528	1393	513	533	
	C	606	533	513	1080	567	635	635
	A			513	1223	567		
SG	F	532	524	437	1118	466	486	619
	B		513	480	1024	434	566	
	C	514	531	472	1098	567	546	623
	A			471	1279	548		
SW	F	623	511	492	746	571	562	696
	C	675	473	480	1009	476	493	730
	A			529	929	473		
	B		546	493	950	455	571	
WO	F	531	510	494	1055	454	565	585
	C	717	533	436	1078	473	567	587
	A			459	947	472		
	B		583	424	998	494	473	

Table 7a.10: The mean DRTS1 reaction times taken from the middle age group during the field session (3).

ID	Event	Event number						
		7	5	3	2	4	6	8
		Mean reaction time						
BO	F	912	731	623	1643	678	808	859
	A			493	1792	731		
	B		842	602	1376	716	677	
	C	1003	733	643	968	584	696	1114
BY	F	807	496		1776	660	680	876
	A			990	1955	817		
	B		954	807	1554	750	1046	
	C	932	1044	786	1976	839	859	1367
DA	F	3167	1976	1169	5817	1540	2175	3091
	C	2269	1227	917	2338	988	764	2639
	A			1045	2529	750		
	B		986	1154	2125	662	1335	
DF	F	824	621	510	1666	454	567	968
	A			569	1861	605		
	B		602	528	1664	493	567	
	C	1113	600	509	1901	511	805	782
EB	F	2985	1808	842	1898	839	1714	859
	A			842	1829	639		
	B		1829	791	1700	729	677	
	C	3057	1777	750	1354	807	696	1114
EL	F	933	747	713	1501	660	914	1062
	B		773	677	1403	764	897	
	C	1391	713	640	2255	677	786	1138
	A			678	1605	602		
JE	F	713	658	601	1423	602	714	656
	B		619	550	972	471	643	
	C	658	550	549	1407	562	639	929
	A			527	1169	526		
JP	F	878	622	636	1630	601	692	878
	C	789	641	619	1333	692	656	
	A			532	1427	677		
	B			477	386	658		
MU	F	1805	957	723	2395	872	1002	876
	C	937	821	693	2283	711	894	982
	A			673	1572	814		
	B		802	711	1288	894	854	
PF	F	803	550	546	1131	529	750	1264
	B		640	546	1352	548	657	
	C	696	604	618	1498	526	622	674
	A			575	1406	537		
PO	F	1647	782	730	1610	822	897	2217
	C	1920	880	785	1404	750	843	1993
	A			746	1809	763		
	B		929	661	1332	989	950	
RP	F	1062	617	562	2781	638	811	1079
	B		696	710	2600	619	858	
	C	1115	716	583	2529	727	805	858
	A			747	2290	697		

Table 7a.11: The mean DRTS1 reaction times taken from the older age group during the field session (3).

ID	Event	Event number						
		7	5	3	2	4	6	8
		Mean reaction time						
CL	F	619	419	436	783	458	480	532
	F +	641	509	419	1096	397	509	526
	A	713	477	384	932	399	476	509
	B	566	455	424	824	454	441	567
	C	730	513	480	454	527	549	601
EE	F	510	511	489	1064	553	493	826
	F +	1063	644	547	1111	548	638	1041
	C	639	513	930	930	526	529	713
	A	453	492	839	839	476	476	526
	B	585	477	858	858	453	546	639
FB	F	789	604	513	1157	626	677	914
	F+	720	667	585	750	532	639	772
	C	1247	441	511	1090	545	766	897
	A	783	638	531	1393	529	656	1027
	B	1003	644	460	1259	548	549	1006
JS2	F +	824	619	585	1259	549	641	783
	F	746	605	660	1791	675	660	656
	A	608	532	548	1059	514	548	748
	B	746	597	580	1174	619	674	678
	C	764	550	583	1467	566	566	619
KJ	F+	932	585	635	1282	473	585	2634
	F	1024	658	513	1243	477	606	787
	C	893	550	579	1096	639	619	769
	A	835	494	545	1957	527	566	660
	B	679	678	549	1536	471	621	824
LC	F+	783	477	490	786	477	493	696
	F	583	520	440	841	489	552	695
	B	625	515	497	773	513	531	656
	C	604	455	473	773	513	510	671
	A	562	463	440	898	437	471	588
MR	F +	733	605	565	1606	605	657	713
	F	546	604	580	1024	582	896	680
	C	710	639	580	1080	583	657	842
	A	623	548	819	1007	493	582	710
	B	654	585	598	1263	639	658	734
MR1	F	583	583	544	1041	541	494	528
	F +	658	523	494	950	585	638	677
	B	690	635	528	1919	604	546	638
	C	643	601	664	934	763	656	638
	A	695	544	528	1078	598	638	734
NB	F+	657	545	470	953	458	476	697
	F	635	438	438	1136	420	477	528
	B	529	472	404	1113	440	471	567
	C	657	604	549	1041	531	509	790
	A	560	493	457	916	475	587	493

Table 7a.12: The mean DRTS1 reaction times taken from the younger age group during the clutter session (4). This session includes a familiarisation run (F+) where the target contrast is non-reversed.

RD	F	545	507	438	1117	493	459	514
	F +	677	636	550	1210	679	623	747
	B	587	493	489	1316	453	436	566
	C	509	457	457	1156	441	496	619
	A	545	546	458	1738	473	494	513
SD	F +	824	619	585	1259	549	641	783
	F	746	605	660	1791	675	660	656
	A	608	532	548	1059	514	548	748
	B	746	597	580	1174	619	674	678
	C	764	550	583	1463	566	566	619
SM	F	636	524	675	1055	566	545	1042
	F +	640	529	532	1097	509	587	673
	A	606	546	475	1427	533	497	694
	B	696	643	582	934	561	1170	915
	C	705	509	643	1136	507	493	804

Table 7a.12 (continued): The mean DRTS1 reaction times taken from the younger age group during the clutter session (4). This session includes a familiarisation run (F+) where the target contrast is non-reversed.

ID	Event	Event number						
		7	5	3	2	4	6	8
		Mean reaction time						
AG	F+	497	421	420	912	381	475	472
	F	578	479	408	1195	497	507	468
	C	549	492	497	1242	500	570	528
	A	440	476	473	1075	427	546	585
	B	583	476	460	973	419	492	638
GR	F +	549	476	492	1210	493	492	468
	F	420	458	416	898	436	423	548
	B	529	434	440	729	420	455	510
	C	513	471	421	1153	423	455	550
	A	497	384	434	1555	440	458	455
JH	F+	496	381	365	876	382	399	477
	F	550	382	382	730	382	385	513
	A	570	404	401	787	398	382	511
	B	513	380	365	746	386	397	514
	C	417	416	384	893	384	385	436
JMc	F+	786	675	513	787	549	658	859
	F	716	584	565	802	497	563	1669
	A	697	549	436	1040	459	506	570
	B	751	546	510	1115	511	516	839
	C	951	585	600	856	493	643	632
JS1	F	514	367	382	716	363	455	1203
	F +	533	529	399	769	434	549	513
	A	493	378	290	993	399	380	528
	B	549	457	420	807	399	479	639
	C	480	454	453	766	441	510	475

Table 7a.13: The mean DRTS1 reaction times taken from the middle age group during the clutter session (4). This session includes a familiarisation run (F+) where the target contrast is non-reversed.

MM	F	566	395	407	713	423	440	545
	F+	640	513	436	729	438	492	618
	C	533	476	458	675	419	458	595
	A	529	455	441	713	421	440	459
	B	550	451	423	769	440	438	567
MT	F	671	575	503	959	536	576	693
	F +	766	658	697	1483	643	584	619
	B	709	532	509	942	541	560	721
	C	750	610	631	930	551	579	792
	A	636	571	502	969	541	609	657
NP	F	544	507	459	967	473	545	550
	F +	680	531	496	805	513	476	653
	B	652	472	440	781	416	492	712
	C	513	473	458	1073	441	513	575
	A	587	440	457	971	403	436	509
PS	F +	552	492	679	1333	622	513	710
	F -	513	510	455	1184	492	531	656
	C	549	549	528	1044	531	476	682
	A	443	421	416	1076	494	529	632
	B	533	494	515	1046	489	510	601
SG	F	505	602	565	1135	476	533	589
	F +	640	509	477	914	785	528	623
	C	716	584	583	912	514	690	678
	A	546	545	458	2140	570	602	640
	B	567	600	475	1030	510	510	582
SW	F	608	479	513	954	476	472	1695
	F +	842	671	604	822	604	658	911
	A	550	548	529	880	436	473	514
	B	640	489	476	1320	441	514	652
	C	566	527	494	822	552	566	694
WO	F+	567	550	455	1170	527	514	713
	F	709	497	436	951	460	579	492
	A	639	623	548	1100	549	567	713
	B	696	566	531	916	477	528	533
	C	656	563	513	1010	587	623	587

Table 7a.13 (continued): The mean DRTS1 reaction times taken from the middle age group during the clutter session (4). This session includes a familiarisation run (F+) where the target contrast is non-reversed.

ID	Event	Event number						
		7	5	3	2	4	6	8
		Mean reaction time						
BO	F	786	748	566	1536	604	768	1611
	F +	986	805	639	1938	710	839	920
	B	950	696	567	1373	605	615	1062
	C	932	657	656	1156	643	675	1082
	A	863	712	582	1154	604	692	790
BY	F +	804	733	712	1791	841	746	1045
	F	822	785	604	1519	785	803	863
	B	930	734	692	1149	733	791	877
	C	805	696	673	1941	677	822	839
	A	863	750	696	1463	694	730	894
DA	F +	2764	1207	1059	2653	951	1095	3532
	F	3679	1098	970	2634	875	1007	2472
	A	2489	856	1130	1830	604	876	1572
	B	2395	932	859	2695	950	915	1937
	C	3311	933	1204	2509	1149	1113	3332
DF	F+	1059	696	656	1203	730	656	1664
	F	750	639	639	2541	1845	661	1169
	B	783	566	492	1298	606	598	915
	C	824	744	643	1973	529	619	1023
	A	677	545	529	1280	563	571	783
EB	F	2852	1718	675	1484	604	1791	3553
	F+	3294	1993	1006	1406	880	1954	*
	B	2066	916	529	1334	675	677	658
	C	2690	1444	640	1337	708	*	*
	A	1936	967	696	1205	696	2106	3496
EL	F +	1003	878	694	2011	635	807	1496
	F	1096	692	623	1371	680	837	1096
	C	824	766	657	1315	730	822	1066
	A	766	639	550	1320	587	729	822
	B	746	750	636	1350	639	750	1044
JE	F	604	636	472	1042	488	550	729
	F +	899	820	622	1834	748	970	1595
	C	566	511	509	1022	497	529	597
	A	641	638	529	1296	532	618	733
	B	639	506	473	1408	510	570	550
JP	F	912	640	514	2033	619	585	826
	F+	1191	820	567	1278	1244	881	1153
	A	820	1774	363	1756	460	514	1804
	B	860	710	619	1212	694	768	1010
	C	748	1006	695	1464	1207	841	1296
MU	F	1316	927	701	1846	985	1772	1816
	F +	1684	911	749	1645	669	968	1809
	A	858	715	574	1403	669	828	822
	B	879	767	665	1348	731	859	1002
	C	877	671	683	1741	893	874	1004

Table 7a.14: The mean DRTS1 reaction times taken from the older age group during the clutter session (4). This session includes a familiarisation run (F+) where the target contrast is non-reversed.

PF	F	893	626	617	2707	696	688	863
	F+	877	713	692	2053	697	751	716
	C	790	622	618	2542	658	544	865
	A	583	582	566	1003	473	587	657
	B	674	529	584	1152	528	553	730
PO	F+	1753	1059	609	1736	751	990	1118
	F	1645	1393	730	1404	751	895	1138
	A	1393	822	751	1332	1009	894	1151
	B	1026	843	694	1406	914	893	1246
	C	1647	914	1002	1367	786	989	1701
RP	F+	770	640	636	2291	622	622	930
	F	881	712	654	2507	656	643	985
	C	1075	786	680	2489	619	912	1226
	A	839	729	623	2397	713	877	989
	B	893	713	750	2563	643	766	1207

Table 7a.14 (continued): The mean DRTS1 reaction times taken from the older age group during the clutter session (4). This session includes a familiarisation run (F+) where the target contrast is non-reversed.

Appendix 7b

	UFOV parameters					
ID	Processing speed duration (ms)	Processing speed loss (%)	Divided attention loss (%)	Selective attention loss (%)	Total UFOV (%)	Test completion time (min)
AG	16ms	0	0	7.5	7.5	14.77
BO	16ms	0	5	17.5	22.5	20.91
BY	44ms	5	5	25	35	18.93
CL	16ms	0	0	7.5	7.5	14.7
DA	325ms	90				5.79
DF	37ms	5	5	30	40	17.19
EB	23ms	0	0	12.5	12.5	16.92
EE	16ms	0	0	0	0	15.39
EL	23ms	0	0	25	25	26.9
FB	20ms	0	5	12.5	17.5	17.01
GR	20ms	0	0	7.5	7.5	16.05
JE	16ms	0	0	7.5	7.5	16.04
JH	16ms	0	0	7.5	7.5	14.76
JMc	16ms	0	0	0	0	16.16
JP	27ms	0	5	30	35	19.45
JS1	16ms	0	0	7.5	7.5	15.07
JS2	16ms	0	0	0	0	16.12
KJ	27ms	0	0	0	0	13.91
LC	16ms	0	0	0	0	15.68
MM	16ms	0	0	7.5	7.5	19.10
MR	16ms	0	0	7.5	7.5	21.86
MR1	16ms	0	0	0	0	15.57
MT	16ms	0	0	0	0	15.74
MU	16ms	0	15	30	45	20.39
NB	16ms	0	0	0	0	13.37
NP	16ms	0	0	0	0	13.61
PF	23ms	0	5	7.5	12.5	18.26
PO	37ms	5	10	30	45	20.85
PS	20ms	0	0	0	0	16.95
RD	16ms	0	0	0	0	17.33
RP	16ms	0	5	30	35	17.66
SD	16ms	0	0	0	0	21.44
SG	23ms	0	0	7.5	7.5	15.49
SM	16ms	0	0	0	0	15.65
SW	16ms	0	0	7.5	7.5	16.83
WO	16ms	0	0	0	0	15.15

Table 7b.1: The UFOV scores taken from 36 subjects during the first repeat session.

	UFOV parameters					
ID	Processing speed duration (ms)	Processing speed Loss (%)	Divided attention loss (%)	Selective attention loss (%)	Total UFOV (%)	Test completion time (min)
AG	16	0	0	0	0	13.63
BO	16	0	0%	22.5	22.5	14.09
BY	20	0	10	22.5	32.5	15.67
CL	16	0	0	0	0	18.17
DA	78	25	10	22.5	57.5	39.6
DF	20	0	5	25	30	24.89
EB	20	0	5	17.5	22.5	22.52
EE	16	0	0	0	0	14.3
EL	37	5	10	30	45	23.6
FB	27	0	5	7.5	12.5	18.81
GR	16	0	0	7.5	7.5	17.82
JE	16	0	0	17.5	17.5	17.97
JH	16	0	0	7.5	7.5	17.99
JMc	16	7.5	0	0	7.5	17.75
JP	188	15	10	30	55	27.51
JS1	16	0	0	0	0	15.09
JS2	16	0	0	0	0	16.26
KJ	16	0	0	0	0	13.53
LC	16	0	0	7.5	7.5	13.59
MM	20	0	0	0	0	16.37
MR	23	0	0	7.5	7.5	14.38
MR1	16	0	0	0	0	14.85
MT	16	0	0	0	0	12.95
MU	16	0	10	17.5	27.5	27.5
NB	16	0	0	0	0	15.23
NP	16	0	0	0	0	13.75
PF	136	5	0	7.5	12.5	27.5
PO	37	5	10	30	45	15.72
PS	16	0	0	0	0	16.81
RD	16	0	0	0	0	14.19
RP	63	20	10	22.5	52.5	26.69
SD	16	0	0	0	0	15.31
SG	37	5	0	5	10	18.17
SM	16	0	0	0	0	15.58
SW	16	0	0	0	0	13.32
WO	16	0	0	0	0	16.92

Table 7b.2: The UFOV scores taken from 36 subjects during the second repeat session.

	DRTS1 target locations						
ID	7	5	3	2	4	6	8
AG	609	549	533	1244	546	677	671
BO	919	639	587	1113	753	751	766
BY	897	765	769	1776	733	932	1210
CL	529	417	423	984	477	436	544
DA	2562	1076	1006	2196	1041	2380	3055
DF	1036	585	550	2103	534	701	1088
EB	2945	1703	733	1410	675	1808	3055
EE	675	602	531	1442	546	567	1243
EL	1686	915	733	2363	714	916	2105
FB	714	557	524	1286	468	591	*
GR	598	643	488	2579	497	764	733
JE	1377	747	570	1187	802	699	839
JH	820	643	496	1117	458	565	803
JMc	697	566	513	826	496	532	8764
JP	1388	876	529	1359	764	1503	3290
JS1	766	549	476	932	493	623	729
JS2	839	587	604	1462	639	660	696
KJ	765	602	526	1041	475	658	860
LC	659	565	582	939	526	605	692
MM	542	453	440	986	395	480	549
MR	677	643	546	1484	618	604	695
MR1	601	623	510	1115	638	622	729
MT	658	604	641	973	528	639	694
MU	1171	602	527	1210	511	656	1772
NB	839	675	473	1063	528	640	734
NP	589	440	401	917	417	438	513
PF	794	602	549	2249	561	722	801
PO	2213	1285	782	2164	821	1138	2213
PS	671	585	625	2250	661	588	750
RD	567	459	472	1300	500	438	647
RP	1682	859	695	2101	725	789	1084
SD	679	604	546	934	529	566	692
SG	1079	510	565	659	696	892	709
SM	621	570	549	1083	565	656	763
SW	1063	605	623	1044	550	638	803
WO	570	477	494	1919	455	476	511

Table 7b.3: The DRTS1 reaction times taken from 36 subjects during the first repeat session for each target location.

	DRTS1 target locations						
ID	7	5	3	2	4	6	8
AG	606	570	494	974	643	606	598
BO	824	713	692	1555	692	750	1045
BY	992	807	730	2345	712	841	1023
CL	489	509	459	1020	477	473	529
DA	3257	1649	1138	3634	1102	1722	2943
DF	965	675	541	2088	533	657	981
EB	3166	1027	602	1427	748	1446	2649
EE	566	497	471	1190	533	529	751
EL	785	696	714	1061	638	677	1299
FB	719	735	551	1162	528	646	*
GR	493	490	458	1097	458	475	533
JE	730	730	770	1244	647	730	803
JH	477	406	398	734	382	420	438
JMc	1661	701	529	860	533	656	970
JP	1023	804	677	1850	897	677	1505
JS1	839	587	604	1462	639	660	696
JS2	769	529	752	1027	549	526	893
KJ	954	746	550	1169	839	621	765
LC	591	532	498	907	490	525	547
MM	549	460	434	786	420	493	567
MR	876	643	782	1848	678	733	808
MR1	661	549	549	1276	531	515	580
MT	649	602	586	1033	556	621	757
MU	981	545	460	2305	513	606	1352
NB	511	490	514	1096	424	639	531
NP	509	480	492	912	440	436	458
PF	903	645	604	1414	579	611	740
PO	1132	897	733	1118	653	1042	1132
PS	807	580	601	1359	528	552	695
RD	766	496	621	1100	546	493	753
RP	984	751	644	2269	691	841	867
SD	696	514	473	1080	493	604	708
SG	860	670	570	1389	623	604	643
SM	533	531	472	983	454	494	674
SW	633	523	486	908	513	505	627
WO	587	516	510	954	476	566	783

Table 7b.4: The DRTS1 reaction times taken from 36 subjects during the second repeat session for each target location.

	DRTS2 reaction time parameters			
ID	DAY WITH ARMBANDS	DAY WITHOUT ARMBANDS	NIGHT WITH ARMBANDS	NIGHT WITHOUT ARMBANDS
AG	771.8	710.7	820.2	908.0
BO	NO RESULTS			
BY	923	1013.1	959.6	934.3
CL	649.3	640.8	597.9	618.9
DA	1048.4	1173.9	622.6	736.6
DF	1319.9	1032.3	1020.0	857.7
EB	992	1010.5	1009.8	1006.1
EE	602.1	623.9	584.2	642.6
EL	1011.6	1322.5	920.1	933.1
FB	900.4	938.5	877.8	999.6
GR	582.8	551.2	591.2	557.4
JE	682.9	754.9	695.8	677.8
JH	636.7	599.8	612.6	649.2
JMc	681.7	734.7	737.7	721.2
JP	720.4	905.2	799.2	751.3
JS1	622.3	588.1	656.3	647.3
JS2	681.6	681.1	706.8	652.2
KJ	668.6	658.5	611.9	616.3
LC	606.3	631.4	634.2	658.3
MM	604.5	617.7	637.2	586.5
MR	621.4	577.8	647.9	619.7
MR1	671.3	663.8	664	697.6
MT	690.6	710.1	795.2	863
MU	926.2	950.9	821.7	933.9
NB	585.9	623.9	649.8	697.9
NP	495.7	484.9	514.2	502.7
PF	899.4	687.6	864.3	895.7
PO	1257.5	1315.7	1176.2	1196.9
PS	665.3	641.2	772.6	723
RD	504.7	495.3	552.3	571.6
RP	730.47	826	804.94	810.62
SD	580.7	593.8	599.9	609.5
SG	692.8	611.7	708.4	763.3
SM	634.1	704.3	616	648.4
SW	602.2	664.9	647.4	668.1
WO	645	591.4	675.5	748.6

Table 7b.5: The DRTS2 reaction times taken from 36 subjects during the first repeat session for day and night conditions with and without armbands.

		DRTS2 target location					
ID	Condition	3	2	1	6	5	4
CL	DAY	733.500	551.500	686.500	720.500	575.000	603.333
	NIGHT	600.000	704.167	553.667	601.000	626.833	565.000
EE	DAY	536.333	563.833	631.167	709.167	607.333	630.333
	NIGHT	521.667	598.667	639.000	671.667	641.167	608.167
FB	DAY	885.000	712.667	912.000	874.833	976.833	1269.83
	NIGHT	1022.16	764.500	924.333	940.833	838.667	776.333
JS2	DAY	607.667	688.167	674.833	704.167	634.500	770.167
	NIGHT	592.333	547.500	676.000	710.167	617.833	675.167
KJ	DAY	710.500	635.167	632.500	665.000	602.500	735.500
	NIGHT	573.667	579.167	616.667	659.833	606.833	648.500
LC	DAY	562.500	563.833	605.667	587.000	576.000	818.167
	NIGHT	613.833	603.500	682.167	673.500	644.167	660.500
MR	DAY	452.333	566.833	619.833	753.333	621.333	584.000
	NIGHT	550.000	596.667	608.667	729.333	713.167	605.000
MR1	DAY	654.167	566.000	661.167	764.833	671.167	688.167
	NIGHT	660.500	647.333	660.333	722.667	662.167	731.833
NB	DAY	601.167	604.500	691.333	588.500	624.000	520.167
	NIGHT	590.000	723.167	709.833	722.167	698.000	600.000
RD	DAY	522.167	468.167	526.167	630.000	444.667	408.833
	NIGHT	479.167	477.167	547.667	636.500	507.167	557.167
SD	DAY	1226.66	616.333	549.333	586.400	728.333	576.167
	NIGHT	603.167	573.833	561.000	656.833	682.167	551.333
SM	DAY	650.000	581.000	650.833	643.333	897.667	592.167
	NIGHT	676.833	684.000	602.000	631.000	566.000	668.500

Table 7b.6: The DRTS2 reaction times taken from the young age group during the first repeat session for each target location and for day and night conditions.

		DRTS2 target location					
ID	Condition	3	2	1	6	5	4
AG	DAY	687.833	840.167	800.667	583.333	738.500	796.833
	NIGHT	727.167	709.833	765.000	912.000	1055.33	1015.33
GR	DAY	465.167	592.500	585.000	584.667	655.500	519.000
	NIGHT	500.167	596.800	565.333	635.833	552.167	602.000
JH	DAY	518.833	596.833	733.667	682.333	586.833	591.000
	NIGHT	567.833	641.167	672.000	645.833	571.167	687.333
JMc	DAY	680.333	748.167	628.167	730.667	857.400	843.800
	NIGHT	675.167	607.333	830.167	789.333	729.333	745.333
JS1	DAY	701.500	494.167	569.333	671.833	527.333	639.000
	NIGHT	605.333	679.833	624.333	599.333	753.167	648.833
MM	DAY	560.833	559.833	715.167	627.667	620.833	582.167
	NIGHT	564.833	510.833	700.333	653.833	627.167	614.167
MT	DAY	642.833	632.000	632.667	697.333	779.167	818.000
	NIGHT	831.667	792.833	923.500	832.667	867.833	726.167
NP	DAY	464.500	493.500	504.833	477.000	487.667	514.333
	NIGHT	418.500	516.333	522.167	497.833	517.333	578.500
PS	DAY	552.167	664.000	829.167	676.167	610.500	587.667
	NIGHT	741.000	776.200	929.333	777.667	603.000	668.500
SG	DAY	780.833	605.167	675.833	669.833	514.333	667.500
	NIGHT	700.500	660.667	702.667	753.167	852.667	745.667
SW	DAY	607.667	688.167	674.833	704.167	634.500	924.200
	NIGHT	592.333	547.500	676.000	710.167	617.833	675.167
WO	DAY	493.500	608.667	643.000	606.667	714.167	643.167
	NIGHT	624.333	626.833	807.000	788.333	836.167	589.667

Table 7b.7: The DRTS2 reaction times taken from the middle age group during the first repeat session for each target location and for day and night conditions.

		DRTS2 target location					
ID	Condition	3	2	1	6	5	4
BO	DAY	788.750	696.167	736.000	853.000	646.500	750.000
	NIGHT	730.800	705.500	1066.66	810.600	950.200	582.667
BY	DAY	1125.60	771.333	908.000	1389.33	855.750	702.000
	NIGHT	878.333	855.167	902.333	1050.16	954.000	1029.83
DA	DAY	1201.50	1069.66	1299.60	1166.50	1027.00	943.500
	NIGHT	1054.75	957.000	942.000	1225.50	1155.50	825.000
DF	DAY	1207.16	1174.83	1021.50	1402.16	1101.66	1131.33
	NIGHT	666.500	1086.66	941.667	1069.50	1015.50	853.167
EB	DAY	1298.50	1163.75	908.667	933.333	884.000	939.667
	NIGHT	1136.25	964.500	852.333	996.500	1002.83	1164.60
EL	DAY	1024.83	903.000	1229.33	823.250	989.167	1445.60
	NIGHT	706.167	820.200	795.667	1002.00	1063.16	1037.50
JE	DAY	678.000	599.800	664.833	905.833	704.000	734.333
	NIGHT	617.833	709.000	671.333	696.833	675.333	750.333
JP	DAY	446.000	732.500	723.667	1079.33	873.833	727.333
	NIGHT	645.000	784.000	662.333	963.833	802.000	794.500
MU	DAY	997.333	867.000	2325.00	813.167	1345.25	933.800
	NIGHT	1160.75	941.200	1114.00	595.667	928.800	1007.33
PF	DAY	896.667	715.833	714.167	787.167	651.333	845.667
	NIGHT	782.167	824.333	677.167	893.500	993.500	1109.33
PO	DAY	1255.00	1082.40	1059.50	1412.00	1401.50	1749.50
	NIGHT	1296.16	909.400	962.667	1225.66	1469.00	1212.00
RP	DAY	686.000	770.800	805.833	886.667	736.833	766.667
	NIGHT	732.000	983.200	945.333	925.200	728.000	771.000

Table 7b.8: The DRTS2 reaction times taken from the older age group during the first repeat session for each target location and for day and night conditions.

	DRTS2 reaction time parameters			
ID	DAY WITH ARMBANDS	DAY WITHOUT ARMBANDS	NIGHT WITH ARMBANDS	NIGHT WITHOUT ARMBANDS
AG	807.4	748.7	749.6	769.4
BO	820.5	915	749.4	790.8
BY	921.9	914.5	909.7	926.5
CL	583.5	612.6	630.7	557.2
DA	976.3	922.7	1016.3	971.8
DF	870.4	956.7	849.3	883.8
EB	907.1	959.6	914.6	985.7
EE	622.8	665.9	666.3	598.1
EL	951.4	1044.5	1060.0	1061.1
FB	877.7	923.2	983.6	1015.7
GR	658.6	684.4	649.7	710.1
JE	659.5	668.1	634.3	697.1
JH	581.1	669.7	646.3	583.1
JMc	905.4	972.8	985.7	929.6
JP	887.8	901.3	744.4	810.8
JS1	681.6	681.1	706.8	652.2
JS2	595.8	724.1	634.7	682.5
KJ	612.8	688.9	710.9	670.7
LC	744.9	735.5	674.8	732.4
MM	586.2	607.0	645.4	649.6
MR	560.1	620.6	610.6	714.5
MR1	693.4	705.9	759.7	693.3
MT	567.4	568.4	593.4	572.1
MU	845.7	598.4	865.1	702.4
NB	852.3	904.7	819.8	853.8
NP	574.8	589.3	668.3	628.2
PF	783.8	769.2	821.9	827.6
PO	1172.6	1119.1	1295.2	1343.0
PS	640.8	636.2	649	641.5
RD	499.6	557.3	552.3	556.6
RP	950	819.9	842.2	719.4
SD	615.8	656.3	673.1	615.6
SG	693.6	697.3	673	806.9
SM	566.6	589.6	658	679.2
SW	617.6	695.5	596.0	598.7
WO	755.9	804.7	783.6	828.9

Table 7b.9: The DRTS2 reaction times taken from 36 subjects during the second repeat session for day and night conditions with and without armbands.

		DRTS2 target location					
ID	Condition	3	2	1	6	5	4
CL	DAY	607.167	625.667	504.500	575.333	653.333	622.333
	NIGHT	524.333	631.167	569.000	643.167	608.500	651.333
EE	DAY	633.500	638.667	606.000	655.000	613.500	863.200
	NIGHT	639.833	547.333	664.333	690.500	705.500	545.667
FB	DAY	737.000	832.500	806.000	1141.00	847.500	1038.66
	NIGHT	855.500	852.000	1029.33	1300.83	955.500	1004.50
JS2	DAY	561.667	565.333	553.833	573.333	526.333	506.400
	NIGHT	593.833	530.667	600.333	616.333	585.833	618.333
KJ	DAY	638.000	656.167	666.167	558.667	660.500	675.833
	NIGHT	619.333	589.167	658.167	905.167	678.000	695.000
LC	DAY	770.333	694.667	704.833	686.667	676.167	908.500
	NIGHT	737.833	699.000	617.833	690.000	761.833	715.333
MR	DAY	588.333	542.833	587.167	560.333	660.000	603.500
	NIGHT	614.400	521.333	699.500	678.167	698.833	746.333
MR1	DAY	648.833	615.833	639.667	743.333	658.833	700.000
	NIGHT	737.667	895.833	715.333	735.333	797.667	668.667
NB	DAY	561.667	565.333	553.833	573.333	526.333	506.400
	NIGHT	593.833	530.667	600.333	616.333	585.833	618.333
RD	DAY	547.667	503.667	579.167	585.333	426.667	528.000
	NIGHT	480.000	496.667	668.667	605.833	530.333	545.167
SD	DAY	617.500	631.167	627.167	618.333	658.667	663.667
	NIGHT	595.000	652.167	695.167	643.667	624.333	656.167
SM	DAY	620.500	572.000	556.667	553.167	621.667	544.667
	NIGHT	621.500	581.333	682.000	694.167	751.833	680.667

Table 7b.10: The DRTS2 reaction times taken from the young age group during the second repeat session for each target location and for day and night conditions.

		DRTS2 target location					
ID	Condition	3	2	1	6	5	4
AG	DAY	701.500	717.000	888.667	907.000	647.167	968.200
	NIGHT	626.833	836.500	738.667	790.333	743.667	820.833
GR	DAY	791.500	586.833	713.000	740.167	570.833	752.000
	NIGHT	672.833	646.333	650.833	818.000	653.167	638.167
JH	DAY	522.833	576.167	625.167	737.333	684.167	606.667
	NIGHT	594.000	544.667	579.667	611.667	661.500	696.667
JMc	DAY	950.000	912.000	825.833	995.833	951.167	999.800
	NIGHT	898.167	907.000	798.167	895.000	846.000	984.500
JS1	DAY	679.667	673.833	539.167	709.000	824.500	1778.40
	NIGHT	579.667	603.833	748.333	725.500	670.000	749.667
MM	DAY	505.333	616.667	622.500	603.000	681.000	551.167
	NIGHT	564.333	611.333	584.833	743.167	710.833	670.500
MT	DAY	610.333	616.167	628.167	674.5	638.5	743.833
	NIGHT	571	619.833	704.5	666.5	688.167	509.667
NP	DAY	485.833	608.000	598.667	617.500	627.667	554.667
	NIGHT	583.500	632.000	643.667	704.000	665.833	660.667
PS	DAY	671.833	502.000	675.833	730.500	650.000	720.800
	NIGHT	549.667	725.667	750.333	764.500	567.000	514.333
SG	DAY	691.500	628.167	606.833	764.667	696.500	785.167
	NIGHT	645.833	601.833	696.000	774.833	952.833	768.333
SW	DAY	655.500	561.500	584.500	666.667	740.333	730.833
	NIGHT	567.667	603.500	567.167	644.333	549.833	651.667
WO	DAY	609.000	737.833	993.333	754.500	817.667	923.600
	NIGHT	755.167	828.500	742.333	851.167	838.833	821.500

Table 7b.11: The DRTS2 reaction times taken from the middle age group during the second repeat session for each target location and for day and night conditions.

		DRTS2 target location					
ID	Condition	3	2	1	6	5	4
BO	DAY	779.750	934.200	1019.25	840.500	871.000	803.000
	NIGHT	665.167	752.167	810.167	775.600	670.333	784.667
BY	DAY	876.500	932.500	997.167	929.500	893.833	879.833
	NIGHT	847.000	885.167	959.333	952.667	916.833	947.667
DA	DAY	970.833	1029.83	863.000	919.000	930.500	983.833
	NIGHT	905.167	920.500	962.500	1126.33	933.000	889.667
DF	DAY	862.000	794.500	939.333	999.000	964.167	922.333
	NIGHT	922.167	760.167	851.500	994.167	883.000	788.167
EB	DAY	961.667	938.500	844.667	733.667	1185.66	935.833
	NIGHT	925.833	873.667	928.000	1087.00	1020.83	865.333
EL	DAY	1042.50	888.500	842.167	1335.33	835.833	886.000
	NIGHT	820.500	793.167	1002.66	1152.66	1565.83	861.667
JE	DAY	668.667	642.167	594.333	684.833	761.250	754.200
	NIGHT	632.000	648.500	698.500	708.333	610.000	696.667
JP	DAY	866.667	670.833	762.667	1279.16	1063.00	724.833
	NIGHT	656.000	604.167	640.833	1029.33	746.333	989.167
MU	DAY	696.333	539.333	712.167	677.500	821.333	790.833
	NIGHT	821.000	689.333	759.667	879.333	718.833	855.167
PF	DAY	782.000	748.833	742.833	909.500	760.667	858.400
	NIGHT	742.833	847.833	760.667	843.500	783.333	970.333
PO	DAY	1166.83	1135.50	947.000	1225.60	1350.50	1208.00
	NIGHT	1318.66	1194.16	1348.33	1328.50	1258.16	1311.66
RP	DAY	849.500	929.000	1128.83	744.833	946.333	853.400
	NIGHT	827.833	725.167	847.833	864.400	705.500	738.333

Table 7b.12: The DRTS2 reaction times taken from the older age group during the second repeat session for each target location and for day and night conditions.

	UFOV parameters			
ID	Processing speed loss (%)	Divided attention loss (%)	Selective attention loss (%)	Total UFOV (%)
BU	0.0	0.0	12.5	12.5
CO	0.0	5.0	30.0	35.0
EL	0.0	5.0	17.5	22.5
GO	0.0	0.0	25.0	25.0
KE	5.0	0.0	30.0	35.0
NE	0.0	0.0	17.5	17.5
PI	0.0	0.0	17.5	17.5
PU	0.0	10.0	25.0	35.0
SP	0.0	5.0	17.5	22.5
ST	0.0	15.0	30.0	45.0
EL1	0.0	0.0	17.5	17.5
LA	0.0	10.0	25.0	35.0
PE	0.0	0.0	22.5	22.5
PR	0.0	5.0	30.0	35.0
PU1	0.0	0.0	17.5	17.5
SM	0.0	0.0	12.5	12.5
TA	0.0	15.0	30.0	45.0
WE	5.0	5.0	17.5	27.5
WI	0.0	15.0	17.5	32.5

Table 7c.1: The UFOV scores taken from 19 older drivers for the sub-tests and total UFOV score.

	DRTS2 target location					
ID	3	2	1	6	5	4
BU	564.25	556.833	621.167	742	622.417	714.917
CO	600.818	666.091	744.25	785.917	620.909	643.444
EL	699.833	574.417	717.417	760.727	724.25	693.833
GO	651.917	690.1	610.25	697.167	663.182	587.167
KE	951.818	918.375	1102.364	980.444	934.333	890.545
NE	658.333	802.833	717.5	753.917	854.583	751.083
PI	649.167	746.417	698	766.417	752.25	699.667
PU	700.2	710	920.667	781.75	756.091	789.2
SP	499.5	710.583	703.333	681.25	552.333	619.417
ST	816.667	643.5	763.083	730.917	655.5	620.917
EL1	751.364	615.545	686	745.636	641.25	550.25
LA	773.167	721.5	742.25	897.417	704.417	789.667
PE	631.75	764.583	736.583	892	824.333	741.25
PR	980.083	887.333	1102.917	1232.333	929.167	1054.417
PU1	767.917	710	703.25	736.417	775.583	645.25
SM	714.727	634.583	946.333	893.333	627.25	713.167
TA	728.583	755.333	863.167	825.167	875.333	796.4
WE	620.75	623.833	757.333	590.583	590.583	605.667
WI	853.083	891.5	973.417	1153.5	875.833	914.833

Table 7c.2: The DRTS2 reaction times taken 19 older drivers for each pedestrian crossing event.

ID	Standard deviation of lane position	Standard deviation of time headway	Crash history
BU	0.136	0.285	No
CO	0.180	0.397	Yes
EL	0.050	0.218	Yes
GO	0.113	0.360	No
KE	0.097	1.923	Yes
NE	0.055	0.381	Yes
PI	0.119	0.507	No
PU	0.120	0.915	Yes
SP	0.179	0.710	No
ST	0.095	0.902	Yes
EL1	0.079	0.167	Yes
LA	0.055	0.289	Yes
PE	0.068	1.328	No
PR	0.145	0.669	No
PU1	0.232	0.328	Yes
SM	0.112	3.929	No
TA	0.048	0.690	No
WE	0.106	0.209	Yes
WI	0.115	0.686	No

Table 7c.3: The driving simulator data taken 19 older drivers for each pedestrian crossing event.

Appendix 7d

	UFOV parameters			
ID	Processing speed loss (%)	Divided attention loss (%)	Selective attention loss (%)	Total UFOV (%)
1	0.0	0.0	7.5	7.5
2	0.0	0.0	7.5	7.5
3	0.0	0.0	7.5	7.5
4	0.0	0.0	30.0	30.0
5	0.0	10.0	17.5	27.5
6	0.0	0.0	7.5	7.5
7	0.0	0.0	0.0	0.0
8	0.0	0.0	12.5	12.5
9	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0
11	0.0	0.0	7.5	7.5
12	0.0	0.0	7.5	7.5
13	0.0	0.0	7.5	7.5
14	0.0	0.0	12.5	12.5
15	0.0	0.0	7.5	7.5
16	0.0	0.0	7.5	7.5
17	0.0	0.0	0.0	0.0
18	0.0	0.0	7.5	7.5
19	0.0	0.0	0.0	0.0
20	0.0	0.0	7.5	7.5
21	0.0	0.0	7.5	7.5
22	0.0	0.0	0.0	0.0
23	0.0	0.0	7.5	7.5
24	0.0	0.0	0.0	0.0
25	0.0	0.0	7.5	7.5

Table 7d.1: The UFOV scores taken from 25 police drivers for the sub-tests and total UFOV score.

	DRTS2 target location					
ID	3	2	1	6	5	4
1	543.5	531.833	589.182	569.083	546.833	580.273
2	605.25	547.167	553	537.833	628.917	524.917
3	670.583	605.455	788.167	709.833	665	597.667
4	558.091	585.917	595.9	584.273	582.909	584.818
5	573.083	628.917	696.25	659.833	637.583	626.5
6	589.333	636.417	633.833	663.75	618.667	572.417
7	585.917	572.917	600	621.833	618.417	609.083
8	559.917	614.167	682.167	625.833	622.667	639.25
9	561.75	509.917	639.833	694.909	608.667	534.25
10	454.833	542.25	561.333	584.5	503.5	489.636
11	491	540.833	533.875	542.5	528	549.417
12	530.25	521.5	548.167	613.083	553.75	522.3
13	507.364	527.333	524.25	539.833	566.833	508.25
14	583.182	594.083	558.167	577.917	540.667	533.182
15	519.5	519.167	529.636	620.583	568.083	602.667
16	575.583	499.667	540.75	583.417	520.9	543.75
17	564.364	570.167	622.167	668.167	548.833	598.667
18	576.083	630.833	721.417	655.083	617.167	588
19	650.833	582.667	769.333	687.667	691.417	592.083
20	645.083	570.417	582.667	656.917	577.333	661.833
21	571.417	529.917	589.667	555.636	593	562.25
22	612.727	549.636	571.917	597.333	578.182	682.167
23	603.25	543.167	656.083	670.667	621.333	614.5
24	565.583	583.417	594.833	571.5	606.333	571
25	694.222	636.75	692.417	816.25	715.167	812.636

Table 7d.2: The DRTS2 reaction times taken 25 police drivers for each pedestrian crossing event.

ID	Crash history	Driving score	Driving score median
1	No	91	Best
2	Yes	89	Best
3	No	85	Best
4	Yes	90	Best
5	Yes	90	Best
6	No	90	Best
7	No	67	Worst
8	No	70	Worst
9	No	86	Best
10	Yes	71	Worst
11	No	74	Best
12	No	72	Worst
13	No	70	Worst
14	No	89	Best
15	No	89	Best
16	No	90	Best
17	No	87	Best
18	No	70	Worst
19	Yes	66	Worst
20	No	71	Worst
21	No	67	Worst
22	Yes	88	Best
23	No	65	Worst
24	No	71	Worst
25	No	73	Worst

Table 7d.3: The driving score data for 25 police drivers for each pedestrian crossing event.

	DRTS1 target locations						
ID	7	5	3	2	4	6	8
Familiarisation							
1	1463	782	605	1302	511	733	2178
2	825	820	549	2421	747	604	627
3	1101	1083	625	1320	546	950	1794
4	916	911	565	1812	591	601	731
Default							
1	658	567	602	1266	531	566	1006
2	567	533	572	2013	476	583	786
3	606	565	585	1539	531	658	859
4	734	591	658	1424	601	692	898
Optic flow edge speed corrected							
1	621	600	477	855	472	664	514
2	552	531	625	1791	528	473	635
3	622	552	549	1153	528	604	661
4	585	658	619	1500	562	656	604

Table 7e.1: The DRTS1 reaction times (ms) taken from 4 subjects during one session for each target location. Results are subdivided into the familiarisation run, the default run and the optic flow edge speed corrected run.

APPENDIX EIGHT

PAPERS

Appendix 8a

Phelps N.K., Dunne M.C.M. & Hyland B. (1999) Age, Driving Frequency and Pedestrian Visibility Influence Performance on an Internet Dynamic Visual Attention Test. Poster presented at the Association of Research in Vision and Ophthalmology Conference, Fort Lauderdale, 1999. INVESTIGATIVE OPHTHALMOLOGY & VISUAL SCIENCE 40 (4): 274B234 MAR 15 1999.

1 Introduction

We present the findings of a dynamic visual attention test carried out on the Internet during autumn 1998. The test was developed by Aston University and Vauxhall Motors. Our aim was to determine whether reflective armbands increase the conspicuity of children to motorists.

It is recommended that pedestrians wear reflective clothing for increased conspicuity (Owens and Sivak, 1993). Visual attention tests, such as the UFOV (Owsley et al., 1998), are more relevant to motorists than are traditional visual tests such as visual acuity and perimetry. The UFOV achieves this by accounting for the fact that driving demands include (1) movement in cluttered environments, (2) simultaneous use of central and peripheral vision, (3) execution of primary and secondary tasks and (4) uncertainty of when or where important visual events will occur.

In 1997, the UFOV was demonstrated to the Visual Standards Subcommittee of the Royal College of Ophthalmologists in Britain. The Committee felt that the use of briefly presented stationary images by the UFOV could be improved upon by incorporating moving images. The dynamic visual attention test was developed along these lines.

2 Method

The dynamic visual attention test program was written in JavaScript. Macromedia Flash 3.0 was used to produce graphical 3D modelling. Microsoft ASP was used to store participants' responses in a database. Although the test was performed on the Internet, it has now been incorporated on CD-ROM.

Participants downloaded a questionnaire with the test and were required to adjust the display to the correct dimensions using a ruler. The questionnaire prompted for age and gender and required participants to tick a box if they had no eye defects other than the need for spectacles or contact lenses. Participants were then able to view an explanatory demonstration, take part in a practice run and carry out the main run. Results of the main run were downloaded to a database. Only one completed main run could be downloaded.

Features of the dynamic visual attention test are listed below:

(1) movement in cluttered environments - the observer was shown a moving scene depicting the view through the windscreen of a car travelling along a straight road. Visual clutter included hills, fences, lamp posts, houses, bridges, pedestrians and even airplanes. The test was divided into two parts, depicting day and night light levels.

(2) simultaneous use of central and peripheral vision - the observer was required to respond to a centrally positioned car that would randomly brake and peripherally positioned pedestrians that would randomly cross the road. Pedestrians were equally divided into those with and without reflective armbands. Responses to the braking car were made via the mouse. Failure to perform this task led to termination of the test. Responses to crossing pedestrians were made via the keyboard space bar and were stored as reaction times.

(3) execution of primary and secondary tasks observer responses to the central car and crossing pedestrians served as the primary and secondary.

(4) uncertainty of when or where important visual events will occur the observer was not able to predict which of a number of pedestrians in the scene would randomly cross the road. Pedestrians also crossed from one of six locations, three on the right hand side of the road and three on the left.

Test parameters were checked by taking measurements from a video recording of one main run that had been carried out on a Pentium 233 personal computer. The measurements are shown in Table 1. The high standard deviation recorded for travelling speed revealed that the moving scene would frequently speed up or slow down as scenery density varied.

Test parameter	Mean	Standard deviation
Assumed working distance (m)	0.5	5
Assumed road width (m)	3.6	3.6
Road length (m)	246	246
Travelling speed (mph)	58	58
Assumed width of central car (m)	1.8	1.8
Distance to central car before braking event (m)	129	129
Distance to central car after full braking event (m)	50	50
Height of child pedestrian (m)	1.2	1.2
Width of child pedestrian (m)	0.19	0.19
Eccentricity #1 of crossing pedestrians (°)	2.5	2.5
Eccentricity #2 of crossing pedestrians (°)	3.9	3.9
Eccentricity #3 of crossing pedestrians (°)	5.5	5.5
Pedestrian crossing speed (mph)	2.9	2.9

Table 1: Dynamic visual attention test parameters.

3 Results

Data were analysed from 1520 self-selected British participants who reported having no eye defects. Figure 2 illustrates the age distribution of males and females (age ranged from 11 to 86 years; 1363 males and 157 females).

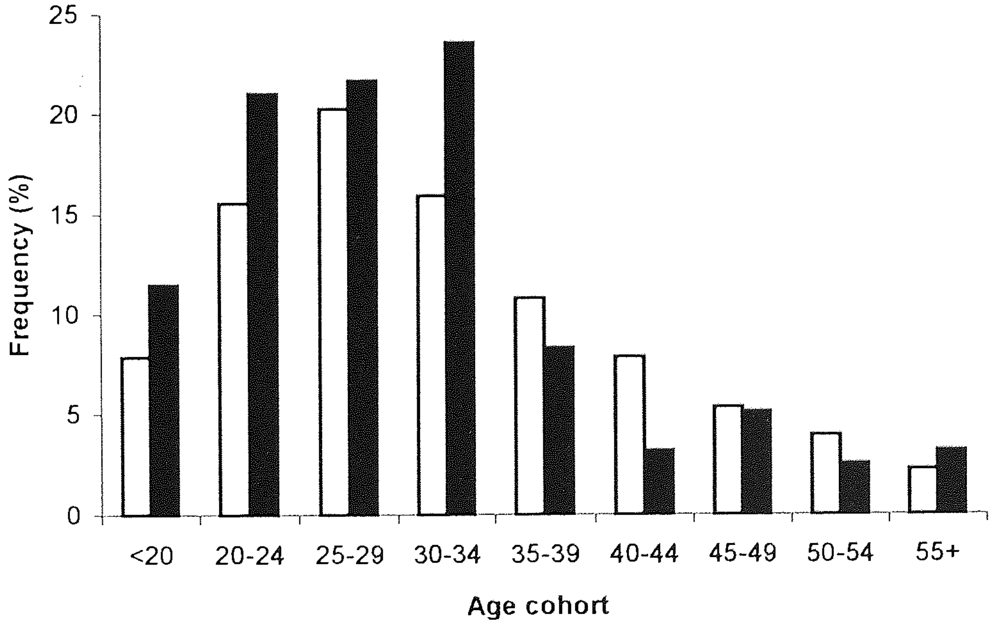

Figure 2. Frequency (%, y-axis) of males (white bars) and females (black bars) included in various age cohorts (years, x- axis).

Figure 3 shows the frequency distribution of reaction times for all participants. The average reaction time was 562 ms (95% confidence limits: 557 to 567 ms). Linear regression revealed that reaction times increase between 4.6 and 10.2 ms (95% confidence limits) for every five-year age cohort from 20-24 years up to 50-54 years (figure 4). The relationship between age and reaction time was statistically significant (Pearson's correlation coefficient r = 0.92, df =5, P <0.01).

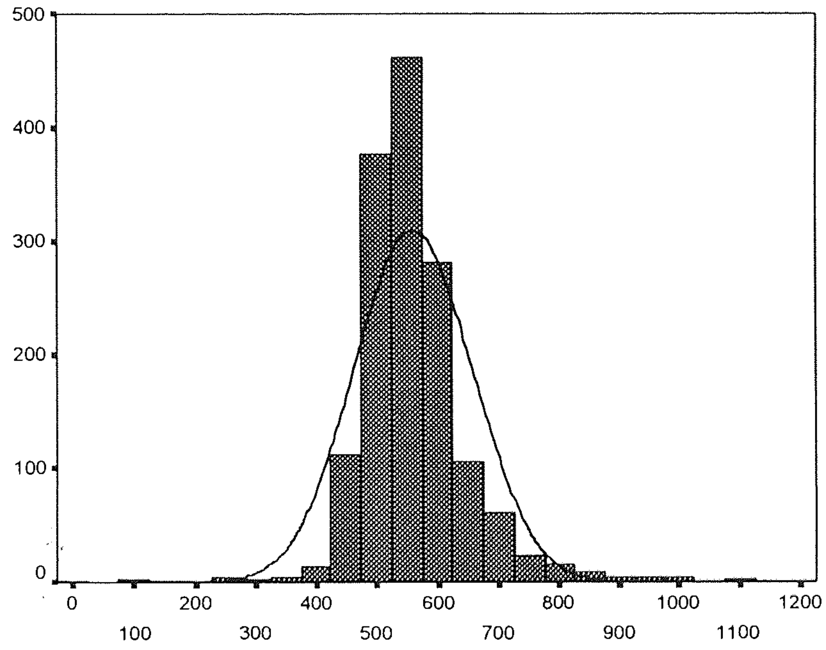

Figure 3. Frequency distribution (y-axis) of reaction times (ms, x-axis) measured using the dynamic visual attention test. A normal distribution curve is also shown.

Slightly shorter reaction times were recorded in response to pedestrians with reflective armbands (95% confidence limits: 561 to 565 ms) compared to those without (95% confidence limits: 566 to 570 ms). This difference was not found to be statistically significant. Gender had no influence on reaction times.

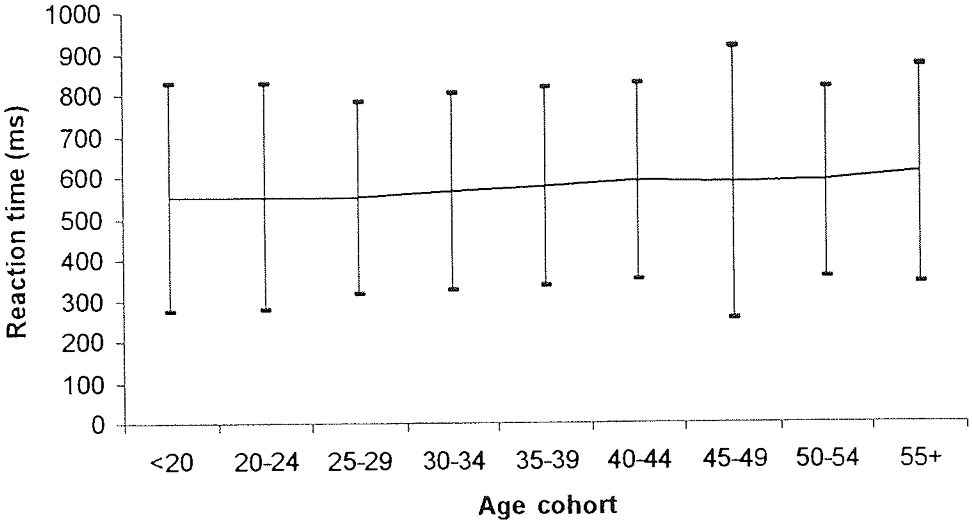

Figure 4. Reaction time (ms, y-axis) plotted as a function of age (years, x- axis). Mean values (black line) are shown with upper and lower 95% confidence interval.

4 Discussion

The British Driver and Vehicle Licensing Agency publishes stopping distances (The Highway Code, HMSO, London, 1996) that include a "thinking distance" and a "braking distance". The "thinking distance" is based on a "thinking time" of 671 ms that can be compared to the upper limit of reaction times measured using the dynamic visual attention test. Based on the normal distribution shown in Figure 3, the upper 99% limit (790 ms) contains the "thinking time" quoted above.

It was a surprise to us that reaction times were not significantly reduced for pedestrians with reflective armbands. However, the brightness of the reflective armbands depicted in our test was approximately 6 times less than real reflective armbands. Therefore, the true impact of reflective clothing on stopping distances is likely to be greater than that indicated in our study.

Some reservations about using the Internet to collect data are presented here:

1. Experimental conditions were not controlled e.g. working distance.
2. Processor speed was not controlled. A Pentium 75 ran at nearly half the speed and delivered reaction times of nearly double the value compared to a Pentium 233 computer. .
3 Practice strategy was not controlled. We have found, that reaction times may systematically improve for consecutively repeated main runs.
4 The population was biased to those who regularly used the Internet and who were willing to take part in these study-mainly men.

Points 1-3 will have effected internal validity for estimation of typical reaction times and their variation with age. Point 4 will have had an impact mainly on the external validity of the study.

5 Conclusion

To within the limitations described above, the Internet based dynamic visual attention test yields reaction times that are comparable to figures used by British driving authorities. Reaction times were also found to decline with age. Unfortunately, the positive impact of reflective clothing on child safety has not been supported by this study. The results of Internet based tests must be regarded with caution, as their internal and external validity are not beyond question.

Acknowledgments

This research was supported by Vauxhall Motors as part of their Glow Power campaign to promote safety on the road.

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Phelps N.K., Dunne M.C.M. & Hyland B. (1999) The Effect of Age and Defective Vision upon Performance on an Internet Visual Attention Test. Poster presented at the Association of Research in Vision and Ophthalmology Conference, Fort Lauderdale, 1999. INVESTIGATIVE OPHTHALMOLOGY & VISUAL SCIENCE 40 (4): B234 MAR 15 1999.

The Effect of Age and Defective Vision upon Performance on an Internet Dynamic Visual Attention Test

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We investigated the effects of age and defective vision on reaction times measured using an Internet based dynamic visual attention test. All participants downloaded a questionnaire and the test onto their own computers via the Internet. The questionnaire was used to establish the age of each participant and to identify those with eye defects, other than the need for spectacles or contact lenses, which barred them from driving. The test consisted of a moving driving scene. The primary task involved maintenance of following distance from a leading car. The secondary task involved responding to a crossing pedestrian. Pedestrians randomly crossed from one of six possible roadside positions. Visual clutter included traffic signs, bridges, trees, houses, aeroplanes and non-crossing pedestrians. Responses were made via the keyboard or mouse and reaction times to crossing pedestrians were uploaded into a central database.

Regression analysis of data from 1499 British drivers, aged between 17 and 76 years, revealed a 1.5 ± 0.2 ms per year (standard error) age related increase in reaction time. Post hoc analysis of drivers grouped in 5 year age cohorts revealed that reaction times remained stable up to 30 years of age, after which a progressive increase occurred (Fisher's PLSD tests carried out at the 95% confidence level). Longer averaged reaction times were found for 24 individuals barred from driving because of visual defects (552 ± 18 ms standard error) compared to 24 randomly selected, age and gender matched, drivers without visual defects (537 ± 13 ms standard error). However, the observed difference in reaction time was not statistically significant at the 95% level.

1. INTRODUCTION

Visual attention tests, such as the UFOV (Useful Field of View), are more likely to predict one's ability to drive safely than are more traditional tests such as visual acuity and visual fields (1). The UFOV achieves this by including the following visual demands required for driving: -

1) movement in cluttered environments
2) simultaneous use of central and peripheral vision
3) execution of primary and secondary visual tasks
4) uncertainty about where, or when, important visual tasks will take place.

In 1997, the UFOV was demonstrated to the Visual Standards Sub-Committee of the Royal College of Ophthalmologists in Britain. The Committee felt that the use of briefly presented stationary images by the UFOV could be improved upon by incorporating moving images. The dynamic visual attention test was developed along these lines.

We present the findings of a dynamic visual attention test carried out on the Internet during autumn 1998. The test is the result of collaboration between the Department of Vision Sciences at Aston University and Vauxhall Motors. The aim of this study was to determine the effect of age and defective vision upon test performance.

2. METHOD

The dynamic visual attention test program was written in JavaScript. Macromedia Flash 3.0 was used to produce graphical 3D modelling. Microsoft ASP was used to store participants' responses in a database. Although the test was performed on the Internet, it has now been incorporated on CD-ROM.

Appendix 8b

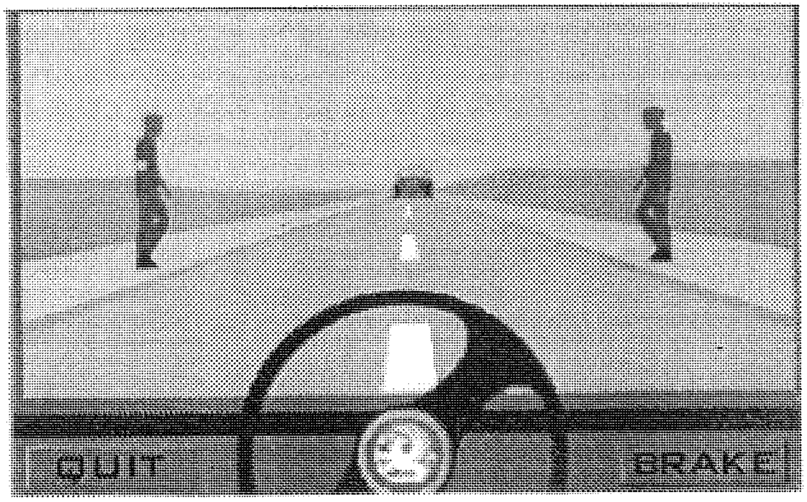

Figure 1. Road scene depicted by the dynamic visual attention test.

Participants downloaded a questionnaire with the test and were required to adjust the display to the correct dimensions using a ruler. The questionnaire prompted for age and gender. Participants were also required to indicate (i) if they had no eye defects other than the need for spectacles or contact lenses, (ii) if they had an eye defect that barred them from driving. Participants were then able to view an explanatory demonstration, take part in a practice run and then carry out the main run. Results of the main run were downloaded to a database. Only one completed main run could be downloaded.

Features of the dynamic visual attention test are listed below: -

1) *movement in cluttered environments* - the observer was shown a scene depicting the view through the windscreen of a car travelling along a straight road (figure 1). Visual clutter included hills, fences, lampposts, houses, bridges, pedestrians and even aeroplanes. The test was divided into two parts, depicting day and night light levels.
2) *simultaneous use of central and peripheral vision* - the observer was required to respond to a centrally positioned car that would randomly brake and peripherally positioned pedestrians that would randomly cross the road. Pedestrians were equally divided into those with and without reflective armbands. Responses to the braking car were made via the mouse. Failure to perform this task led to termination of the test. Responses to crossing pedestrians were made via the keyboard space bar and were stored as reaction times.

3) *execution of primary and secondary tasks* – observer responses to the central car and crossing pedestrians served as the primary and secondary tasks, respectively.
4) *uncertainty of when or where important visual events will occur* – the observer was not able to predict which of a number of pedestrians in the scene would randomly cross the road. Pedestrians also crossed from one of six locations, three on the right hand side of the road and three on the left.

Test parameters were checked by taking measurements from a video recording of one main run, which had been carried out on a Pentium 233 personal computer. The measurements are shown in Table 1. The high standard deviation recorded for travelling speed revealed that the moving scene would frequently speed up or slow down as scenery density varied.

Test parameter	**Mean**	**Standard deviation**
Assumed working distance (m)	0.5	-
Assumed road width (m)	3.6	-
Road length (m)	246	7
Travelling speed (mph)	58	23
Assumed width of central car (m)	1.8	-
Distance to central car before braking event (m)	129	2
Distance to central car after full braking event (m)	50	1
Height of child pedestrian (m)	1.2	0.01
Width of child pedestrian (m)	0.19	0.01
Eccentricity #1 of crossing pedestrians (°)	2.5	0.03
Eccentricity #2 of crossing pedestrians (°)	3.9	0.03
Eccentricity #3 of crossing pedestrians (°)	5.5	0.02
Pedestrian crossing speed (mph)	2.9	0.1

Table 1. Parameters of the dynamic visual attention test.

3. RESULTS

The first stage of data analysis was carried out on 1499 self-selected British participants who reported having no eye defects. Figure 2 illustrates the age distribution of males and females in this group. Age ranged from 17 to 76 years. More males (90.3 %) than females (9.7 %) took part in the study.

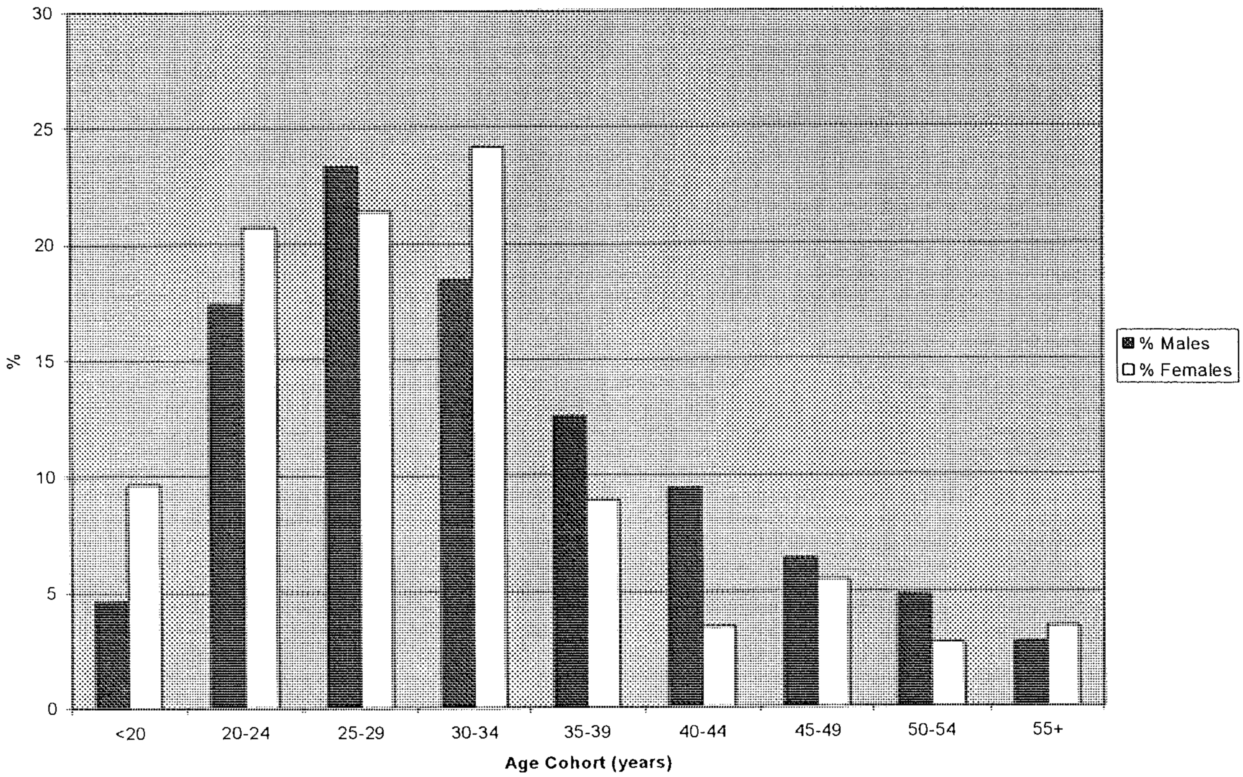

Figure 2. Frequency (%, y-axis) of males (black bars) and females (white bars) included in various age cohorts (years, x-axis).

Figure 3 shows the frequency distribution of overall reaction times for all participants. The average reaction time for all participants was 564 ms (95% confidence limits: 559 to 569 ms).

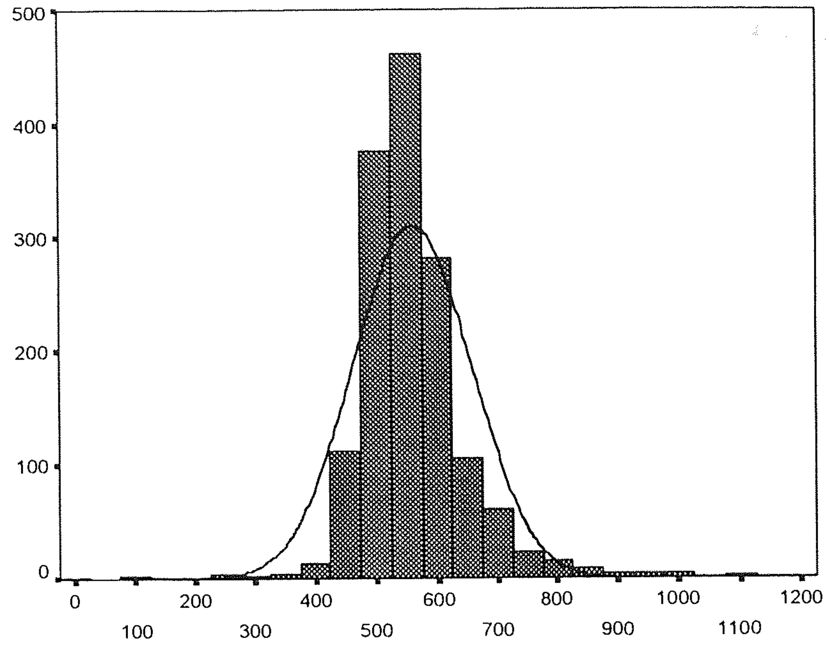

Figure 3. Frequency distribution (y-axis) of reaction times (ms, x-axis) measured using the dynamic visual attention test.

Linear regression revealed that reaction times increased between 1.1 and 1.9 ms (95% confidence limits) per year. The relationship between age and overall reaction time (Figure 4) was found to be statistically significant (ANOVA, $F_{1,1497} = 42.562$, $P = <0.0001$).

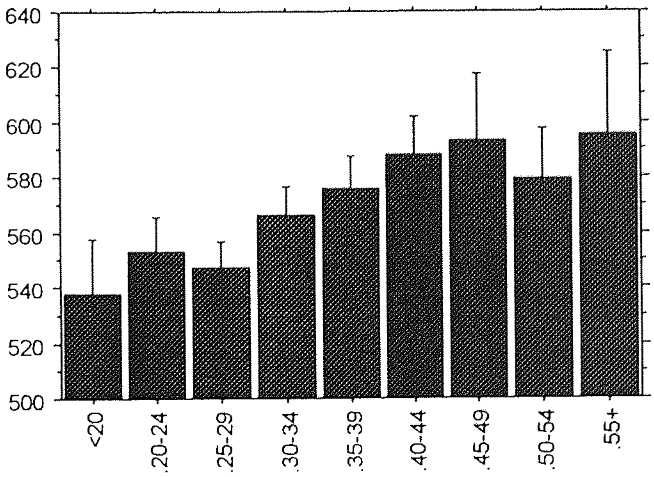

Figure 4. Reaction times (ms, y-axis) plotted as a function of age (years, x-axis), error bars represent 95 % confidence limits.

Post hoc analysis (Table 2) of drivers revealed that reaction times remain stable for all age cohorts up to 25 - 29 years of age and beyond 35 - 39 years of age. With the 30 – 34 year age cohort being the point of change.

	<20	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55+
<20	-								
20-24	-	-							
25-29	-	-	-						
30-34	*	-	*	-					
35-39	*	*	*	-	-				
40-44	*	*	*	*	-	-			
45-49	*	*	*	*	-	-	-		
50-54	*	*	*	-	-	-	-	-	
55+	*	*	*	-	-	-	-	-	-

Table 2. Post hoc comparison (Fisher's PLSD Test) of mean reaction times recorded for each age cohort expressed in years. An * indicates that the difference between reaction times achieves statistical significance at the 95 % level.

Table 3 summarises the second stage of the analysis that was carried out on 24 individuals barred from driving because of visual defects versus 24 matched individuals without visual defects. The observed difference in reaction time was not statistically significant at the 95 % level (One-way ANOVA, $F_{1,46}$= 0.464, P = 0.4993)

Visual Defect	**No**	**Yes**
Age (years): mean ± standard deviation.	29.5 ± 7.9	29.5 ± 7.9
Male : female	24 : 0	24 : 0
Reaction time(ms): 95 % confidence limits	511 - 563	515 – 589

Table 3. Summary of the comparison between drivers with and without visual defects.

4. DISCUSSION

The British Driver and Vehicle Licensing Agency publishes stopping distances over a range of speeds (The Highway Code, HMSO, London, 1996). In this publication, the stopping distance comprises of a "thinking distance" and "braking distance". The "thinking distance" is based on a "thinking time" of 671 ms. Reaction times measured using the dynamic visual attention test equate to this "thinking time". Based on the distribution shown in Figure 3, the upper 95% limit for reaction times measured in our study, was 746ms. This upper limit of the distribution contains the "thinking time" quoted above. It is likely that the quoted "thinking time" also represents the upper limit of a distribution, though we have not been able to confirm this. It, therefore, appears that the dynamic visual attention test yields reasonably realistic reaction times despite the fact that responses were made via a keyboard rather than a brake pedal.

Our results show that reaction times decline starting from about 35 years of age onwards. This contrasts with the decline of static visual acuity after 60 years of age (2). However, it is known that dynamic visual acuity declines earlier and faster than static visual acuity (2). Our research is continuing to compare the decline of static visual attention (i.e. the UFOV) to that of dynamic visual attention, as measured here.

Our results also revealed some decline in performance for people who reported having visual defects that barred them from driving. Unfortunately, the nature of these visual defects was not disclosed.

We have several reservations about using the Internet to collect the data presented here:

1) Experimental conditions were not controlled – e.g. test luminance, working distance and observer vigilance.
2) Processor speed was not controlled – the dynamic visual attention test could be run on a wide range of PCs. When comparing overall reaction times measured for the same 10 observers on a Pentium 75 and Pentium 233 computer, we have found that the slower computer ran at nearly half the speed and delivered reaction times of nearly double the value compared to the faster computer. This could have been overcome by prompting each observer for details of their computer.
3) Practice strategy was not controlled – each observer was free to decide how much practice proceeded the main run. We have found, on 10 observers, that overall reaction time may systematically increase for up to six consecutively repeated main runs.
4) The population was clearly biased to those who regularly used the Internet at home or work and who were willing to take part in this study – mainly men.
5) There is no way to confirm the personal data entered by the user.

5. CONCLUSION

To within the limitations described above, the Internet based dynamic visual attention test yields reaction times that are comparable to figures used by British driving authorities. The decline of reaction times with age was more demonstrable than for a small sample of drivers reporting unspecified visual defects. Given our reservations about Internet based tests, research is currently under way to replicate these findings under more controlled experimental conditions and using a defined set of individual with visual defects.

6. ACKNOWLEDGEMENTS

Many thanks, to Vauxhall Motors who sponsored this research. We would also like to thank all participants who took part in this study.

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Appendix 8c

Phelps N.R. & Dunne M.C.M. (2000) Visual Attention Tests to Enhance the Mobility of Elderly and Disabled Drivers. Poster presented at Set for Britain, London, 2000.

VISUAL ATTENTION TESTS TO ENHANCE MOBILITY OF ELDERLY AND DISABLED DRIVERS.

Abstract: There are approximately 30 million private drivers in the UK. By 2000 over 25% of the driving population will be at least 60 years old. Our eyes deteriorate with age, and other problems such as dementia and stroke increase. Traditional eye tests unfairly discriminate against the elderly driver suffering with various visual and cognitive impairments. This is not the case for visual attention tests. These tests examine the eye and brain together and are more able to identify drivers at risk of accident involvement. They have also demonstrated that safe driving can be achieved by many elderly drivers, including those with visual or cognitive impairments that would currently loose their driving license. This presentation describes and makes a case for the latest research in this field. We suggest that commercially available visual attention tests provide a practical and affordable means of examining elderly and disabled drivers who have had their licenses revoked. These tests should precede the practical part of a standard driving test – success in both should lead to re-issue of driving licenses. These tests could be administered in driving test centres, mobility centres, hospitals or private practice (medical or optometric) using the infrastructure that already exists. They would thus enhance the mobility of elderly and disabled drivers.

Do age-related visual and neurological disabilities necessarily cause driving accidents?

In 1997 there were over 30 million drivers in the UK (DETR report 'Road Accidents Great Britain 1997'). By the year 2000 over 25% of the driving population will be 60 years of age or older (O'Neill, 1992). The accident rate per mile is known to increase in older drivers (Hills & Burg, 1977). These drivers are likely to present with various visual (Taylor, 1991) and neurological disabilities (Rizzo & Dingus, 1996). It is, however, still not known how these age-related disabilities affect accident rates.

Traditional visual tests are weak predictors of accidents.

It is well known that traditional visual tests, of eye health, central vision and peripheral vision, such as those employed by the current driving visual standards (Munton, 1995), are only weakly correlated with driving accidents.

Visual attention tests may provide fairer assessment of older and disabled drivers.

On the other hand, more recently developed visual attention tests, such as the Useful Field of View (UFOV) test, appear to be better predictors of accident involvement (see figure 1. after Owsley, 1994). Further, these tests show that not all of elderly drivers have a higher accident risk (Owsley et al., 1998).

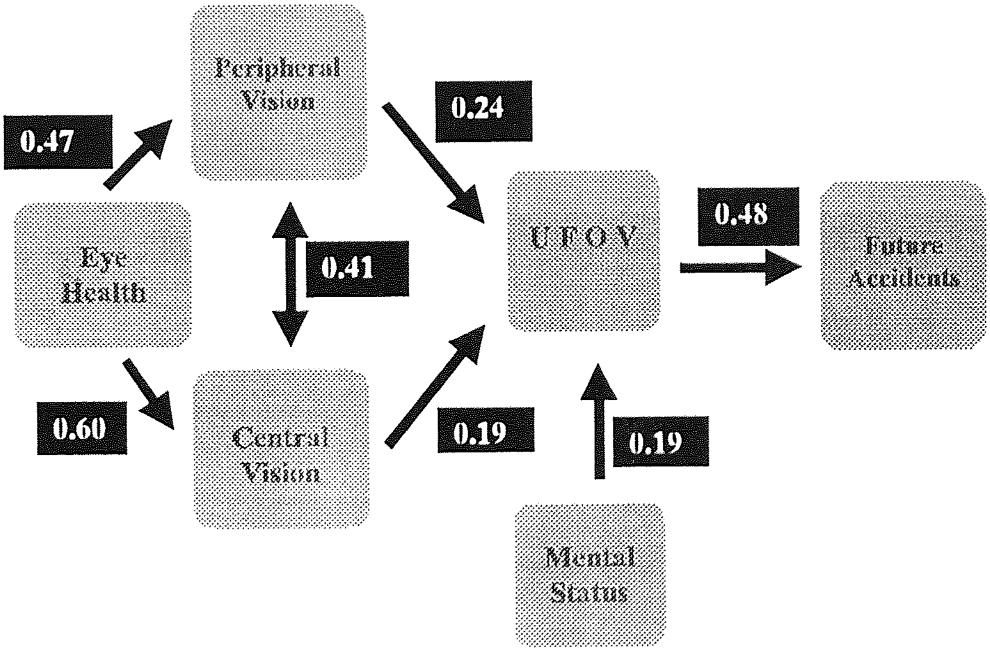


Figure 1. Statistical model for the relationship between visual functions and future driving accidents. Figures represent correlation coefficients (r), the critical value for r is 0.13 and all are statistically significant to the 95% level.

UFOV, a static visual attention test.

The UFOV (Ball *et al.*, 1993) tests the drivers' ability to locate peripheral hazards in cluttered environments while also attending to a primary central task like driving (see figure 2.).

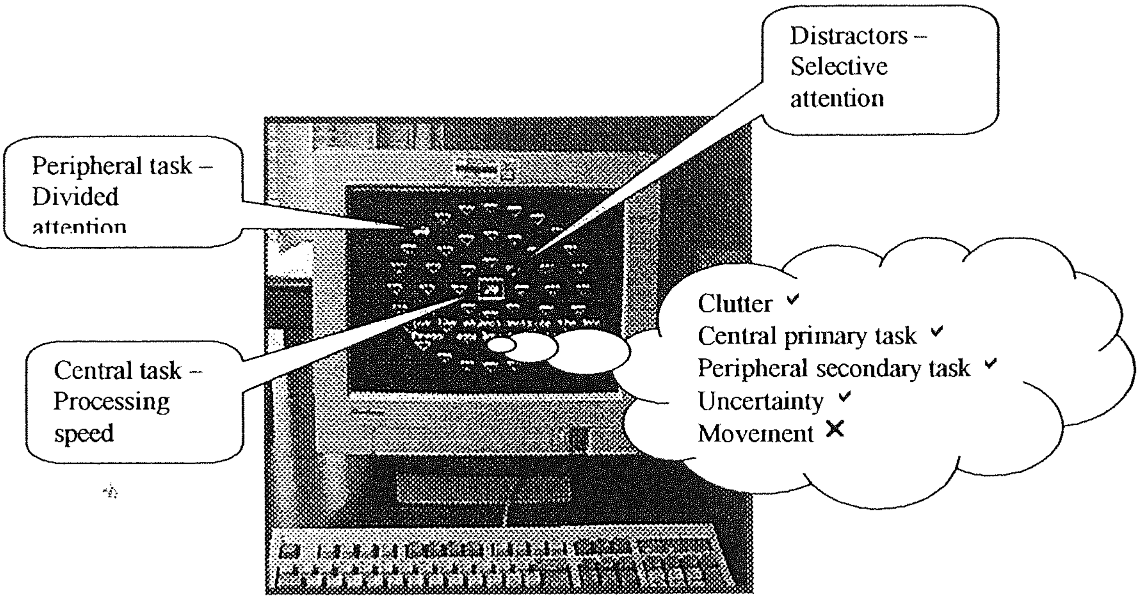


Figure 2. Key elements of the UFOV (Useful Field of View), a commercially available test, designed to evaluate driving visual demands.

In 1997, the UFOV was demonstrated to the Honorary Medical Advisory Panel on Driving and Visual Disorders. The Committee felt:

1) the test should be dynamic, as driving involves movement through visual clutter.
2) they were concerned that the test only covered the central 60°, while the current minimum visual field requirement for driving is 120° horizontally.

DRTS, a dynamic visual attention test.

The Driver Reaction Time Simulator (DRTS) was developed to determine whether the inclusion of moving targets made visual attention tests more effective. This test incorporated the key elements of the UFOV test (see figure 3).

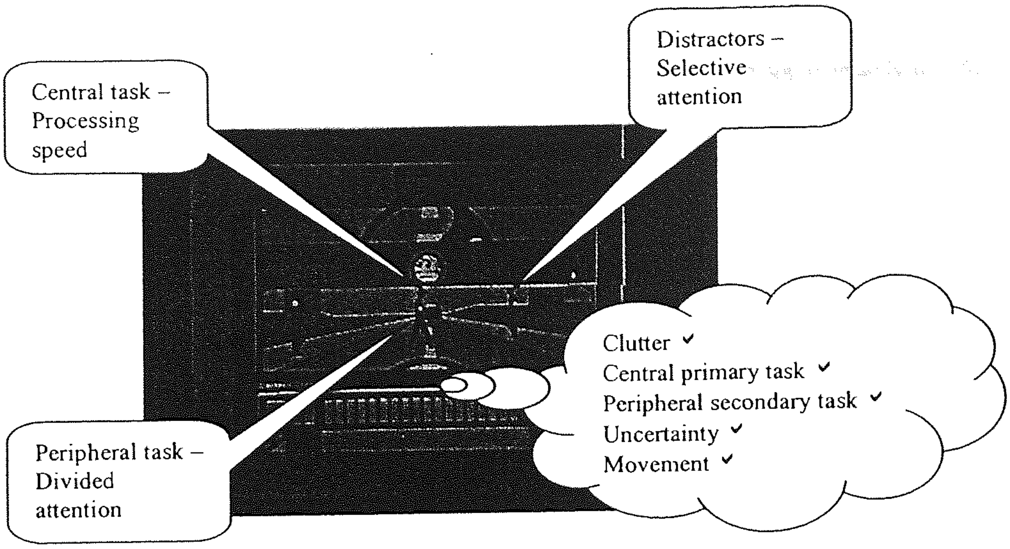


Figure 3. Key elements of the DRTS (Driver Reaction Time Simulator), a CD-ROM based test sponsored by Vauxhall Motors, and used to determine whether moving targets improve the measurement of visual attention.

Moving targets do not improve visual attention tests.

The ability of the UFOV and DRTS to detect age-related changes was compared on 36 subjects, with no ocular pathology and with visual acuities of at least 6/12, the minimum standard of vision to drive in the UK (Munton, 1995). Subjects were divided into three groups (see table 1.) with six males and six females in each. All subjects performed both tests, the order of which was balanced to avoid unwanted bias. Both tests were then repeated in the same manner at least 1 month later (see table 1.) to determine the reproducibility of results.

Age Group	Age Range	Mean Age	Mean Interval
Young	18 – 20	20 ± 0	85 ± 27.8
Middle	30 – 55	35.2 ± 4.5	89.7 ± 41.4
Older	65+	71.8 ± 4.9	45.9 ± 20.7

Table 1. Age range (years), mean age (± standard deviation) and mean interval (days ± standard deviation) between repeat runs for each group.

The data were not normally distributed so that statistical analysis was carried out with non-parametric tests. All results were tested for statistical significance at the 95% level.

Both tests were equally repeatable with 95% confidence limits spanning approximately one fifth of the range of measured values (see figure 4 and 5). This equality was important to avoid any unwanted bias that would otherwise confuse the comparison between the relationships exhibited by both tests and age. Correlations between repeated readings (Kendall rank correlation, Tau) revealed that the UFOV test (Tau = 0.763) was slightly more repeatable than the DRTS test (Tau = 0.627).

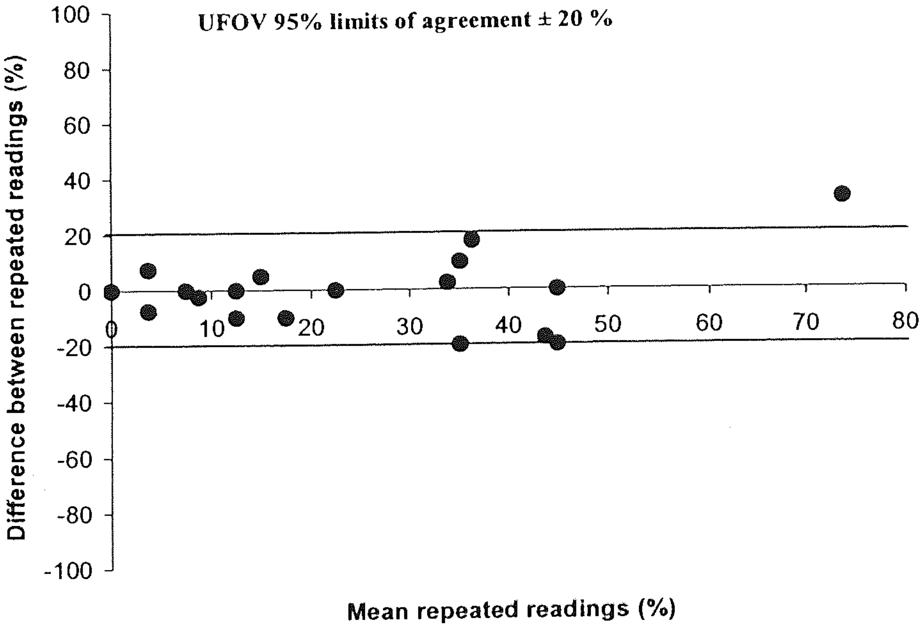


Figure 4. Repeatability (95% limits of agreement) of the UFOV test.

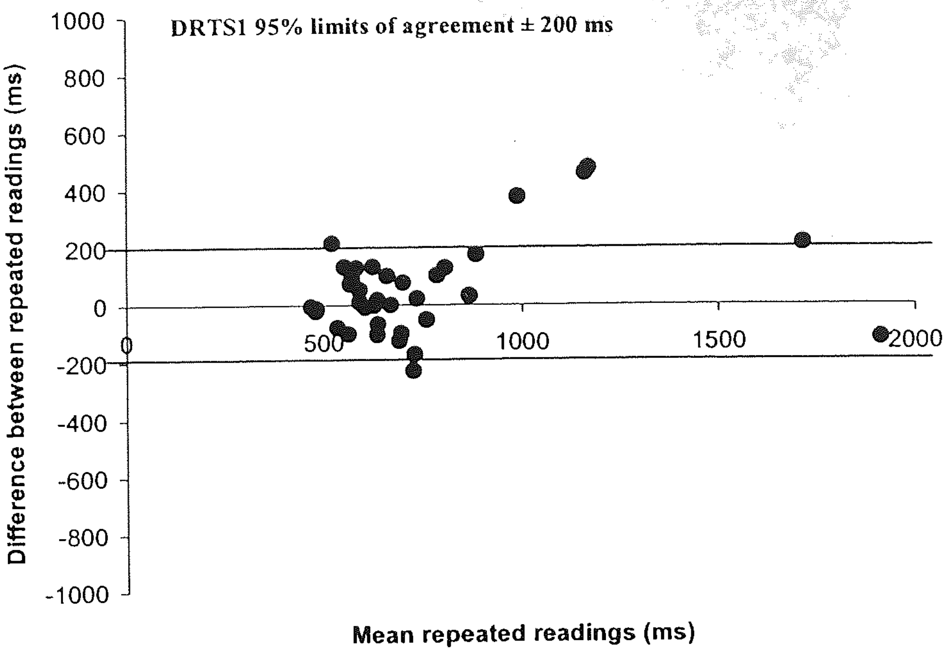
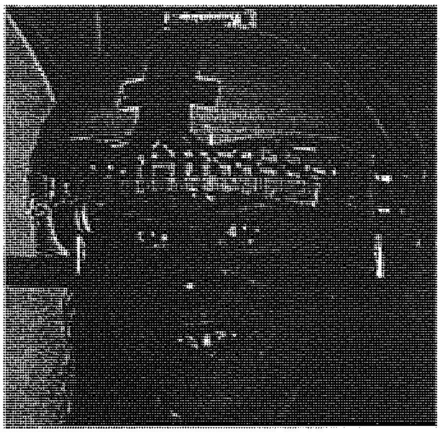


Figure 5. Repeatability (95% limits of agreement) of the DRTS test.

Both the UFOV and DRTS tests showed statistically significant (Kruskall-Wallis test) deterioration with age. However, the Kruskall-Wallis statistic (H) indicated that the UFOV test (H = 24.404) exhibited a slightly stronger relationship with age than did the DRTS test (H = 19.465). Post hoc tests (Mann Whitney U) revealed that neither test could discriminate between young and middle-aged drivers. However, both tests were able to discriminate the older drivers from the other two age groups.

Extent of the driving visual attention field

The driving task is known to place such a cognitive demand on the visual system that the useable visual field is reduced in extent (Sekuler and Ball, 1986). Hence, although the human binocular field extends over 200° horizontally (Harrington, 1976) the UFOV assesses a field of only 60°. Figure 6 shows apparatus used to confirm that visual field sensitivity reduced while driving. This would manifest itself as a reduced visual attention field.



LED'S mounted at 10° intervals over 180° of visual field in a horizontal line

Figure 6. Apparatus designed to confirm that visual field sensitivity reduced while driving.

Driving reduces visual field sensitivity

Figure 7 shows that visual field sensitivity, measured in 3 drivers, was found to be less when measured during driving than while sitting in a parked car. This indicated that driving was likely to reduce the extent of the visual attention field.

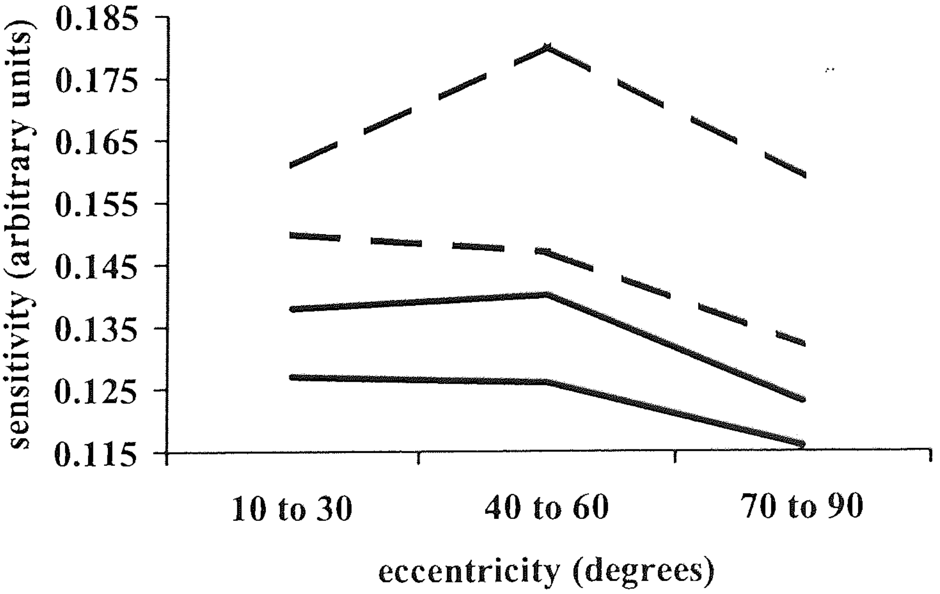


Figure 7. Visual field sensitivity plotted as a function of eccentricity for 3 drivers while parked (dashed lines) and driving (solid lines). Upper and lower lines represent inter-quartile range limits.

Visual attention tests and driving standards

The UFOV test, with its static stimuli, was slightly more repeatable and more able to detect age related changes to the visual system than was the DRTS test, with its dynamic stimuli. This indicates that the UFOV test may not be enhanced by the addition of moving stimuli. Of course, this does not rule out the possibility that another type of dynamic visual attention test might lead to different conclusions. Although the research described above is still in progress, early indications are that the UFOV test may potentially be adequate for the assessment of British drivers whilst also providing a fairer means of testing those that are elderly and disabled. These tests should precede the practical part of a standard driving test - success in both, should lead to re-issue of driving licenses.

Research plans are underway to compare the UFOV and DRTS tests in terms of their ability to predict driving performance on various simulators and on open roads.

Acknowledgments

This research was supported by Vauxhall Motors as part of their Glow Power campaign to promote safety on the road. Thanks to Brendan Hyland of Netcomms Europe Ltd. for construction of the DRTS.

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Purpose. To examine the ability of the UFOV test (a static visual attention test) and the DRTS (a kinetic visual attention test) to detect age related changes in the visual system. **Methods**. Data were analysed from 12 healthy subjects (6 males and 6 females) belonging to either a young (aged 18 – 20 years), middle (aged 30 – 55 years) or older (aged 65+ years) age group. Each subject performed both tests, the order of which was balanced to avoid learning effects. Initial examination revealed the data were not normally distributed and non-parametric statistical tests were used. The Kruskal-Wallis test (H values) was used to assess the ability of each test to detect age-related changes in the visual system. Post hoc analyses using the Mann Whitney U-test (p values) was carried out to determine the differences in test scores recorded for each age group. **Results**. All parameters for both UFOV and DRTS deteriorated with age, and were significant to the 95% level ($H_{UFOV} = 24.4$, $H_{DRTS} = 19.99$). The UFOV and the DRTS tests were about equally able to identify age-related changes to the visual system. No difference was found between the young and middle-aged groups for either UFOV or DRTS ($P_{UFOV} = 0.19$, $P_{DRTS} = 0.15$). Yet both young and middle-aged groups were significantly different to the old group to the 95% level. The DRTS though less sensitive to age, could better differentiate age groups. **Conclusion**. This suggests that visual attention tests need not include moving stimuli, a result we did not anticipate. Perhaps static tests are requisite to identifying drivers at risk of accidents caused by age related visual deficits. Though kinetic tests are more sensitive to age changes.

Appendix 8d

1 Purpose

To examine the ability of the UFOV (a static visual attention test) and the DRTS (a kinetic visual attention test) to detect age related changes in the visual system.

2 Introduction

Basic visual functions relate to attributes of the eye as a sensory organ. These functions include visual acuity, contrast sensitivity and visual field sensitivity. Many of them decline with age. Visual acuity declines after 60 years of age but dynamic visual acuity declines earlier and faster (Figure 1. after Shinar and Scheiber, 1991).

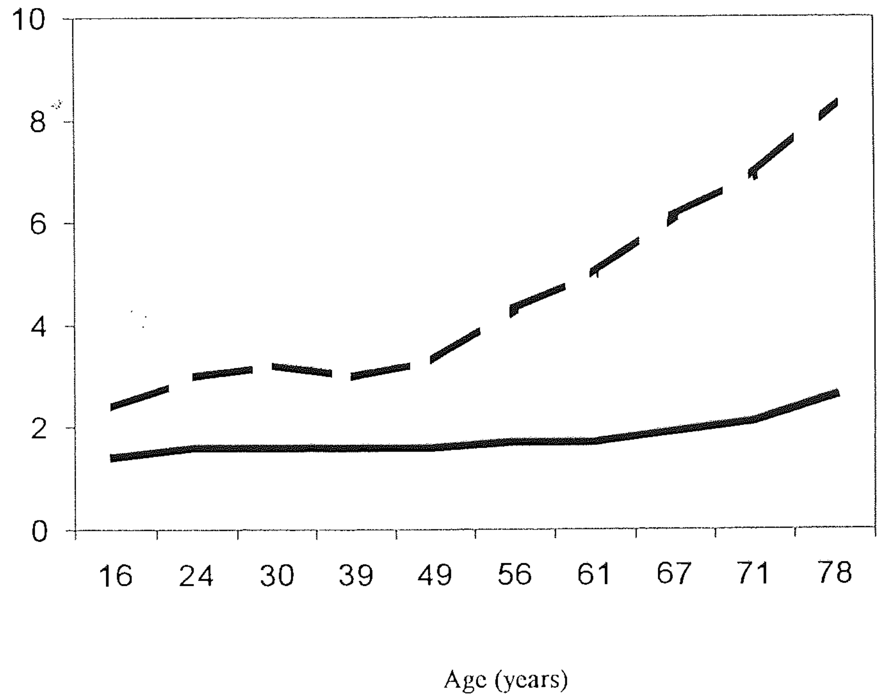


Figure 1. The decline of static (solid line) and dynamic (dashed line) visual acuity with age (after Shinar and Scheiber, 1991).

Higher order visual functions relate to attributes of the whole visual system including the eye and brain. These functions, such as visual attention, show more deterioration with age than do basic visual functions (Owsley, 1994).

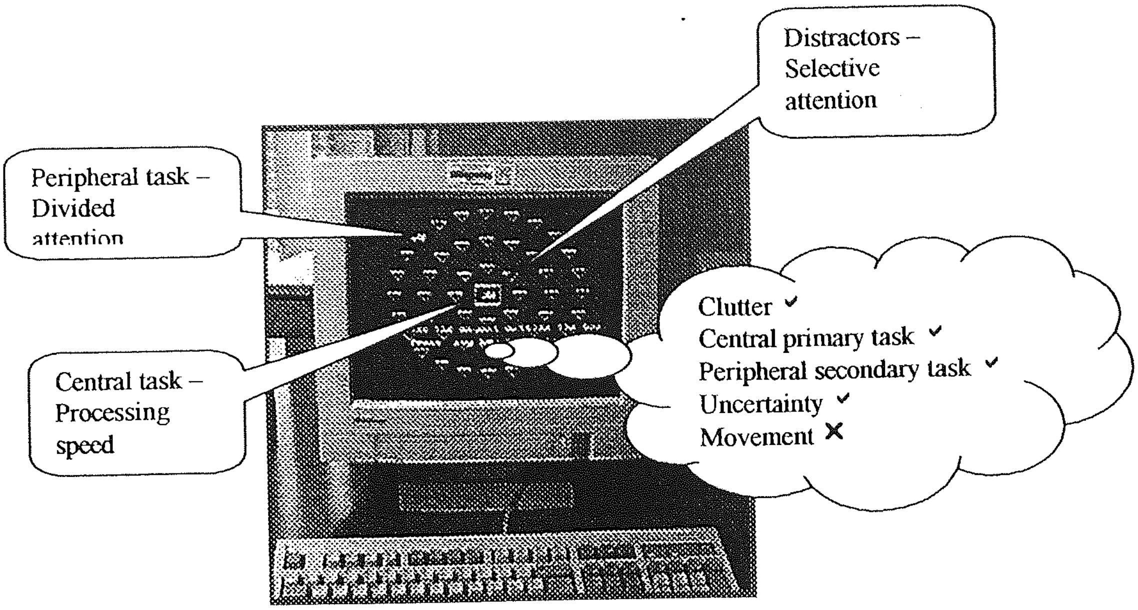
All drivers are susceptible to accidents, but older drivers are likely to have more accidents, per mile driven, because of factors that tend to accompany ageing (Shinar and Scheiber, 1991). Indeed, Wolffsohn et al. (1998) have pointed out that healthy elderly drivers' road skills are well preserved and they make fewer errors than young adult drivers (Carr et al., 1992). The elderly are simply more likely to have cognitive motor or sensory perceptual deficits, be on medication or have chronic illness, than the young. It is these age-extrinsic factors, more than calendar age, that affect driving performance (Jones et al., 1991; Morgan and King, 1995).

There is compelling evidence that indicates that visual attention tests, such as the UFOV (Useful Field of View), are more able to identify older drivers at greater risk of accident than are more traditional used tests of basic function (Owsley et al., 1998). The UFOV makes use of briefly presented static target arrays.

Given that basic visual tests that include moving stimuli change more with age than do tests with static stimuli (Figure 1.), the question arises as to whether the moving, or kinetic, stimuli might further enhance the ability of visual attention tests to detect age related visual deterioration.

3 Method

The key features of the UFOV test are illustrated in Figure 2. The UFOV assesses processing speed, divided attention and selective attention. These components contribute to the overall UFOV score (Ball et al., 1993).



Distractors – Selective attention

Peripheral task – Divided attention

Central task – Processing speed

Clutter ✓
Central primary task ✓
Peripheral secondary task ✓
Uncertainty ✓
Movement ✗

Figure 2. Key features of the UFOV test, a visual attention test that uses static stimuli.

The DRTS test (Figure 3. and Table 1.), built for the purpose of a collaborative research project carried out by Aston University and Vauxhall Motors, was designed to incorporate the key features of the UFOV test whilst also including moving stimuli (Phelps et al., 1999). This test measures reaction times to pedestrians crossing the road at three distances from the observer along the horizontal and on either side of the central task. These reaction times contribute to the overall DRTS score (Phelps et al., 1999).

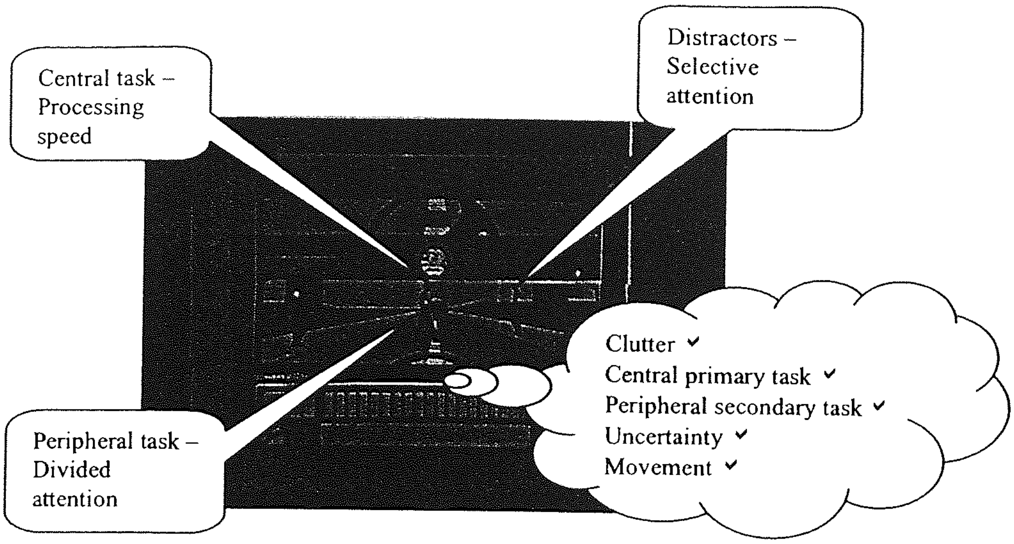


Figure 3. Key features of the DRTS test, a visual attention test that uses kinetic stimuli.

Parameter	Value
Assumed working distance (m)	0.5
Assumed road width (m)	3.6
Road length (m)	246
Travelling speed (mph)	58
Assumed width of central car (m)	1.8
Assumed height of car (m)	1.5
Distance to central car before braking event (m)	129
Distance to central car after braking event (m)	50
Height of child pedestrian (m)	1.2
Width of child pedestrian (m)	0.19
Eccentricity #1 of crossing pedestrians (°)	2.5
Eccentricity #2 of crossing pedestrians (°)	3.9
Eccentricity #3 of crossing pedestrians (°)	5.5
Pedestrian crossing speed (mph)	2.9

Table 1. Parameters of the DRTS test (after Phelps et al., 1999).

Data were analysed from 36 subjects with no ocular pathology and with binocular visual acuities of at least 6/20, the minimum standard of vision required to drive in the UK (Munton, 1995). Subjects were divided into three groups (Table 2.) with six males and six females in each. All subjects performed both tests, the order of which was balanced to avoid unwanted bias. Both tests were then repeated in the same manner at least 1 month later (Table 2.) to determine the reproducibility of results.

Age group	Mean age	Mean interval
Young	20 ± 0	85 ± 27.8
Middle	35.2 ± 4.5	89.7 ± 41.4
Older	71.8 ± 4.9	45.9 ± 20.7

Table 2. Mean (± standard deviation) for age (years) and time interval between repeated measurements (days) for each age group.

4 Results

The data were not normally distributed so that statistical analysis was carried out with non-parametric tests. All results were tested for statistical significance at the 95% level.

Both tests were equally repeatable with 95% confidence limits spanning approximately one fifth of the range of measured values (Figure 4.). This equality was important to avoid any unwanted bias that would otherwise confuse the comparison between the relationships exhibited by both tests and age. Correlations between repeated readings (Kendall rank correlation, Tau) revealed that the UFOV test (Tau = 0.763) was slightly more repeatable than the DRTS test (Tau = 0.627).

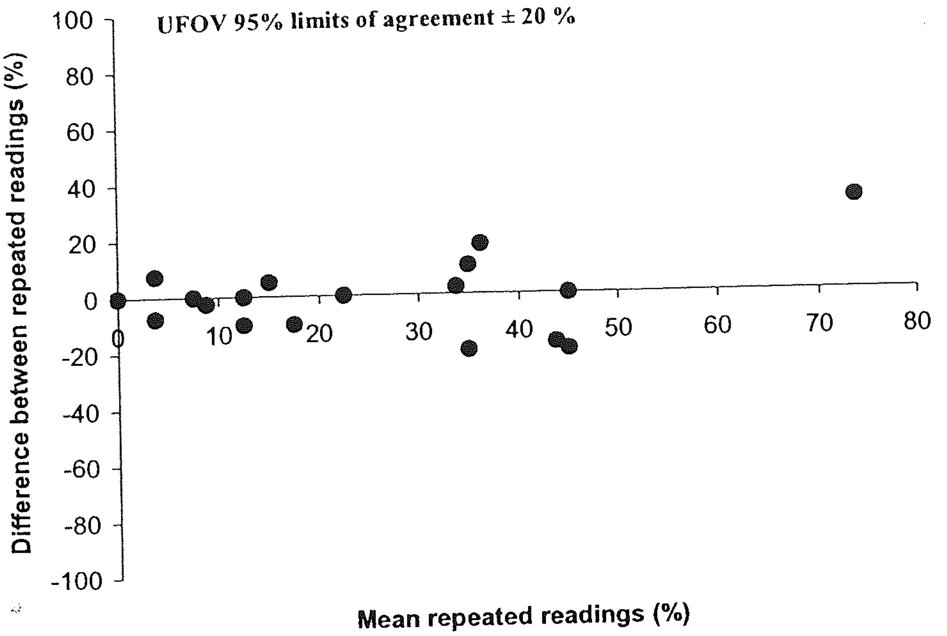


Figure 4. Repeatability of the UFOV test.

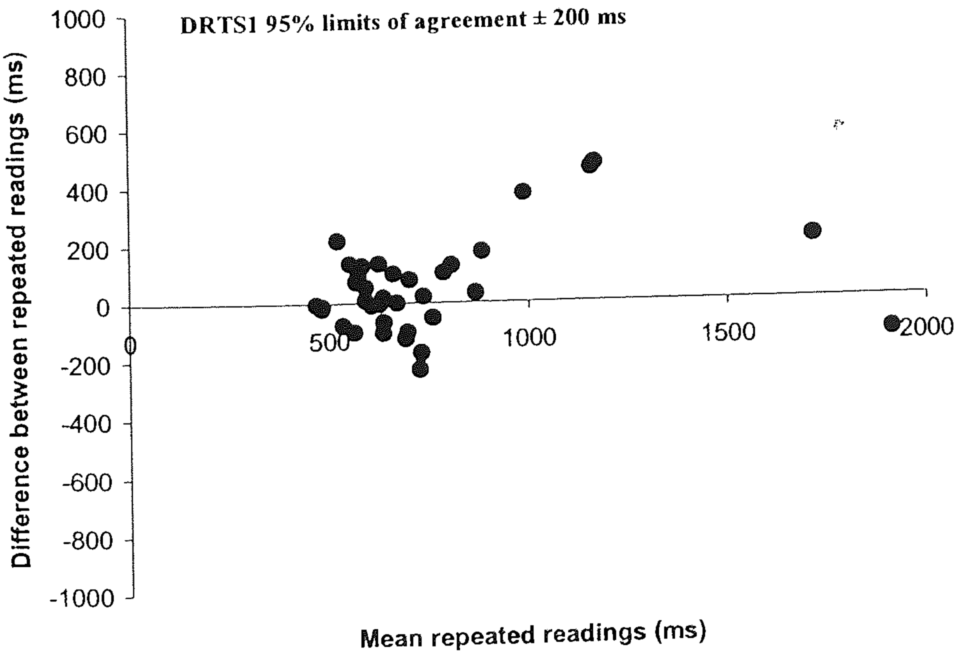


Figure 5. Repeatability of the DRTS test.

Both the UFOV and DRTS tests showed statistically significant (Kruskall-Wallis test) deteriorations with age. The rate of decline of both tests with age was approximately equal. However, the Kruskall-Wallis statistic (H) indicated that the UFOV test (H = 24.404) exhibited a slightly stronger relationship with age than did the DRTS test (H = 19.465). Post hoc tests (Mann Whitney U) revealed that neither test could discriminate between young and middle-aged drivers. Both tests could, however, discriminate old drivers from the other two age groups.

5 Conclusion

The UFOV test, with its static stimuli, was slightly more repeatable and more able to detect age related changes to the visual system than was the DRTS test, with its kinetic stimuli. This indicates that the UFOV test may not be enhanced by the addition of moving stimuli. Of course, this does not rule out the possibility that another type of kinetic visual attention test might lead to different conclusions. Research plans are underway to compare the UFOV and DRTS tests in terms of their ability to predict driving performance on various simulators and on open roads.

Acknowledgments

This research was supported by Vauxhall Motors as part of their Glow Power campaign to promote safety on the road. Thanks to Brendan Hyland of Netcomms Europe Ltd. for construction of the DRTS.

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Phelps N.R. & Dunne M.C.M. (2001) Factors that influence driver reaction times on a PC-based test. Vision in Vehicles (VIV9) Conference, Brisbane, 2001.

The purpose of this study was to examine the factors that influence driver reaction times measured using a PC-based test. The simulator depicted a driver's view while travelling along a straight road through a cluttered environment. Dark rectangular objects (4.8 ± 0.9cdm^{-2}), representing pedestrians and a leading car, were shown against a light background (6.4 ± 1.1cdm^{-2}). Drivers responded, via the keyboard, every time the leading car stopped or pedestrians crossed the road. Pedestrians were programmed to cross at emergent eccentricities of 2.5°, 5° and 7.5° on both sides of the road. Data were analysed from 36 healthy drivers divided equally into young (aged 18 – 20 years), middle (aged 30 – 55 years) and older (aged 65+ years) age groups. Drivers reacted more slowly to targets that moved out of a flow-field (kinetic targets) compared to those that suddenly appeared (static targets). This target presentation effect was statistically significant ($P<0.0001$). Slower reaction times were also recorded as simulated travelling speed increased from 30 mph to 70 mph ($P<0.0001$), as the target : distractor ratio increased from 1:6 to 1:30 ($P<0.0001$), for targets that moved with longitudinal (leading car) compared to angular (crossing pedestrians) motion ($P<0.0001$) and as emergent eccentricity increased ($P<0.0001$). Older drivers were slower than the other age groups ($P<0.0001$), whereas the young and middle age groups did not differ. The results described for target presentation, speed and distraction exhibited statistically significant interactions with age (P at least 0.0019) and target location ($P<0.0001$).

1. INTRODUCTION

This paper describes experiments carried out on the Driver Reaction Time Simulator (DRTS) developed at Aston University. The DRTS represents the "first stab" at developing a kinetic visual attention test for drivers.

Research has revealed that visual attention tests are more able to predict age related decline of the visual system (Owsley et al., 1991) and crash risk (Owsley, 1994) than are tests of basic visual function (such as visual acuity or perimetry). The UFOV (Useful Field of View) is currently the only commercially available visual attention test designed for drivers (Ball et al., 1993). This test can be described as a static visual attention test as it measures the detection of briefly presented stimuli. However, the road environment involves the detection of hazards that move in a flow field. The DRTS was thus developed to add a kinetic element to this type of test.

Although the DRTS is quite different from the UFOV, both tests are similar in that they cover the visual attention requirements of a driver as previously outlined by Ball et al. (1993);

- exposure to visually cluttered environments
- simultaneous use of central and peripheral vision
- execution of primary and secondary tasks
- uncertainty of when or where important visual events occur

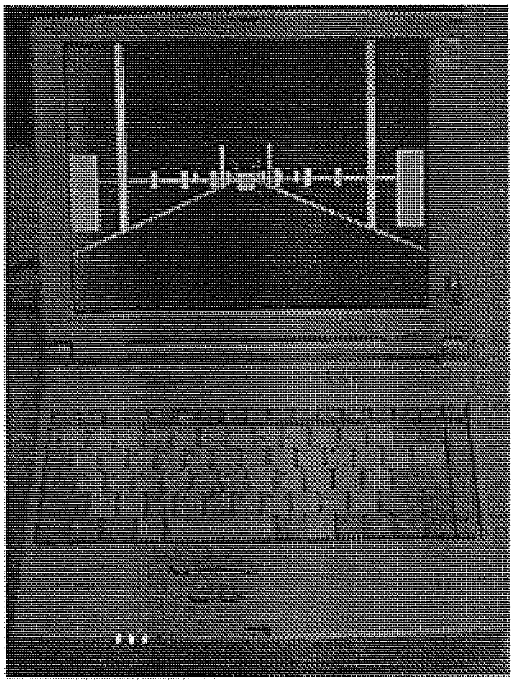

Figure 1. The Driver reaction time simulator (DRTS).

The DRTS test was designed for use on a laptop computer. The computer monitor depicted the view of a driver moving down the middle of a straight road (see Figure 1). A leading car (**comprising the central primary task**) was positioned 100 metres in front of the driver. This car could suddenly stop and its movement represented longitudinal motion (Hills, 1975). When this happened, the driver was required to press the spacebar of the laptop computer as quickly as possible and a reaction time was recorded. Pedestrians (**comprising the peripheral secondary task**) were positioned on the right and left hand sides of the road in several rows. Any one of these pedestrians could suddenly cross the road and this movement represented angular motion (Hills, 1975). Pedestrians crossed at emergent eccentricities of 2.5°, 5° and 7.5° degrees. When this happened, the driver was, again, required to press the spacebar and a reaction time was recorded. Pedestrians that did not cross but remained in the flow field served as distractors (**contributing to clutter**). The computer only allowed these events to occur one at a time. The order in which each event took place was randomised (**adding uncertainty as to when or where important visual events would occur**) and consequently the driver's attention had to be directed at the whole screen at the same time (**simultaneous use of central and peripheral vision**).

Car stopping distances, found on the Department of the Environment Transport and Regions' (DETR) website (www.roads.detr.gov.uk) are divided into two parts; a thinking and braking distance. The thinking distance is based upon a thinking time of 671 ms that is constant for all travelling speeds. DRTS reaction times represented thinking times.

The purpose of this study was to determine how reaction (or thinking) times varied with target presentation (static or kinetic), travelling speed, clutter, target motion (angular or longitudinal), target emergent eccentricity and age.

2. METHODS

Data were collected from 36 drivers with no ocular pathology and with binocular visual acuities of at least the number plate standard. Drivers were divided equally into young (18-20 years), middle (30-55 years) and older (65+ years) age groups; the actual ages (mean ± standard deviation) of the drivers in each age group were 20 ± 0, 35 ± 5 and 72 ± 5 years, respectively. Each group included an equal number of males and females.

Appendix 8e

The DRTS test was carried out on a Pentium II laptop computer (Toshiba 4000CDS, Japan) in a darkened room, to prevent unwanted reflections. Under these conditions, the luminance of the dark rectangular pedestrians and leading car was 4.8 ± $0.9cdm^{-2}$ (mean ± standard deviation) and these objects appeared in positive contrast against a light background of 6.4 ± $1.1cdm^{-2}$. Drivers were positioned 0.5 metres from the screen. At this distance, all pedestrians (height x width: 1.8 x 0.75 meters) and the leading car (height and width: 1.5 x 2 metres) were programmed to appear to be their natural sizes; which would, of course, vary depending upon where they were in the flow field. This also applied to the kerb edges of the 7 metre wide road that disappeared over the horizon 400 metres away. At its default setting, the DRTS test was run at a travelling speed of 50 mph. Four rows of pedestrians were seen at any one time. The flow field thus included 25 potential targets; comprising 6 pedestrians in each of the 4 rows and 1 leading car. This gave rise to a target : distractor ratio of 1:24, as only one of these items was designated to be a target at any point in time. When a pedestrian crossed the road, it moved at a running speed of 7.5 mph. When the leading car stopped, it did so abruptly so that it would appear to move towards the driver at the designated travelling speed (i.e. at 50 mph in this instance).

Data were collected in four sessions. Three or four trials were carried out during each session. The first trial always served as a familiarisation run using the DRTS at the default settings described above. The remaining trials were counterbalanced to remove learning effects. Session 1 was designed to compare reaction times to sudden onset stimuli (i.e. simple reaction time to **STATIC** stimuli) and to stimuli that move out of the flow field (i.e. complex reaction time to **KINETIC** stimuli). Session 2 determined reaction times at travelling speeds of 30, 50 and 70 mph. In session 3, the influence upon reaction times of target : distractor ratios of 1:6, 1:18 and 1:30 were explored. Session 4 was used to examine target motion (i.e. longitudinal and angular) and eccentricity. The interactive effects of age and target location upon the results of each session were also analysed.

Reaction times required inverse square root transformation in order to achieve normal distribution and allow use of parametric statistical tests. Effects were examined for statistical significance using 1, 2 and 3-factor analyses of variance followed by Bonferroni/Dunn post-hoc test (Abacus Concepts, 1996).

3. RESULTS

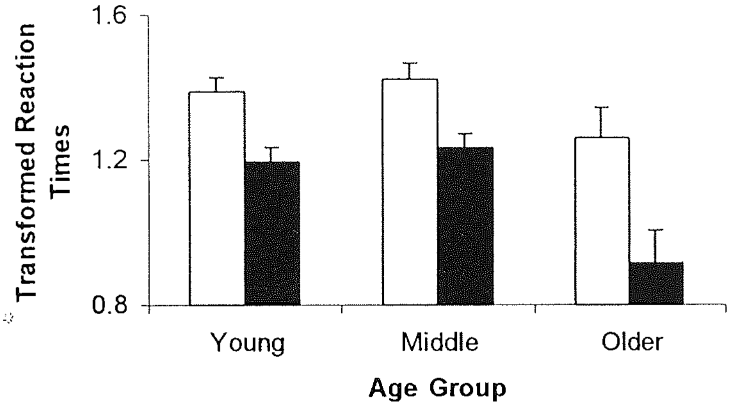

Figure 2. Transformed reaction times (mean and upper 95% confidence limit) for static (white bars) and kinetic (black bars) stimuli in young, middle and older age groups. Higher values represent faster reaction times.

Figure 2 shows that drivers reacted more slowly to targets that moved out of a flow-field (kinetic, mean reaction time = 850ms) compared to targets that suddenly appeared (static, mean reaction time = 547ms). A 3-factor ANOVA revealed that the effect of kinetic and static target presentation was statistically significant ($F_{1, 262} = 260$, $P<0.0001$) and was influenced by age ($F_{2, 262} = 13.3$, $P<0.0001$) and target location ($F_{3, 262} = 61.5$, $P<0.0001$). Age tended to increase the difference in reaction times recorded for static and dynamic target presentation. Differences also increased with greater pedestrian target eccentricity and for longitudinal compared to angular motion.

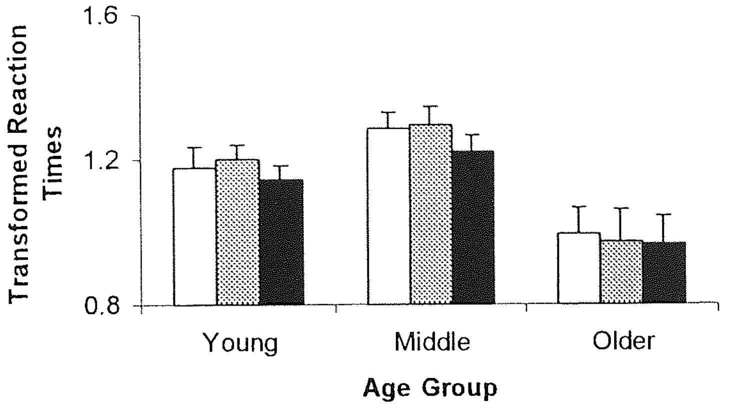

Figure 3. Transformed reaction times (mean and upper 95% confidence limit) for travelling speeds of 30mph (white bars), 50mph (grey bars) and 70mph (black bars) in young, middle and older age groups. Higher values represent faster reaction times.

Figure 3 shows that there was a general tendency for slower reaction times as travelling speeds increased from 30mph (mean reaction time = 781ms) through 50mph (mean reaction time = 783ms) to 70mph (mean reaction time = 836ms). A 3-factor ANOVA revealed that the effect of speed was statistically significant ($F_{2,386} = 30.5$, $P<0.0001$) and was influenced by age ($F_{4,386} = 4.35$, $P = 0.0019$) and target location ($F_{6,386} = 37.2$, $P<0.0001$). The influence of speed upon reaction times was least noticeable in older drivers and for central (leading car) and innermost pedestrian targets (those that crossed at eccentricities of 2.5 degrees).

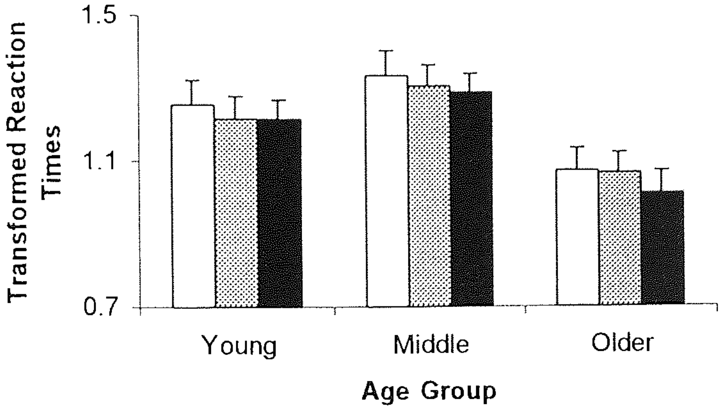

Figure 4. Transformed reaction times (mean and upper 95% confidence limit) for target : distractor ratios of 1:6 (white bars), 1:18 (grey bars) and 1:30 (black bars) in young, middle and older age groups. Higher values represent faster reaction times.

Figure 4 shows that there was a general tendency for slower reaction times as the target : distractor ratio (i.e. clutter) increased from 1:6 (mean reaction time = 675ms) through 1:18 (mean reaction time = 698ms) to 1:30 (mean reaction time = 727ms). A 3-factor ANOVA revealed that the effect of clutter was statistically significant ($F_{2,396} = 35.9$, $P<0.0001$) and was influenced by age ($F_{4,396} = 4.64$, $P = 0.0011$) and target location ($F_{6,396} = 67.5$, $P<0.0001$). As with the effect of travelling speed, the influence of clutter upon reaction times was least noticeable in older drivers and for the central (leading car) target.

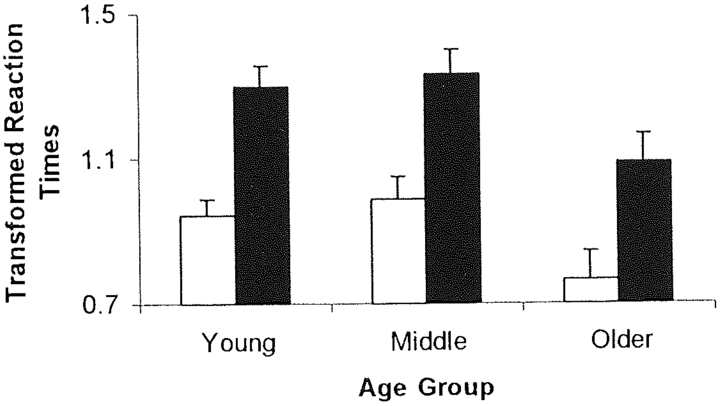

Figure 5. Transformed reaction times (mean and upper 95% confidence limit) for angular target motion (pedestrian crossing events, white bars) and longitudinal target motion (leading car event, black bars) in young, middle and older age groups. Higher values represent faster reaction times.

Figure 5 shows that drivers reacted more slowly to longitudinal motion (leading car stopping, mean reaction time = 1278ms) compared to angular motion (pedestrian crossing road, mean reaction time = 665ms). A 2-factor ANOVA revealed that the effect of target motion was statistically significant ($F_{1,66} = 160$, $P<0.0001$) and was not influenced by age ($F_{2,66} = 0.143$, $P = 0.867$). This agrees with previous research by Hills (1980).

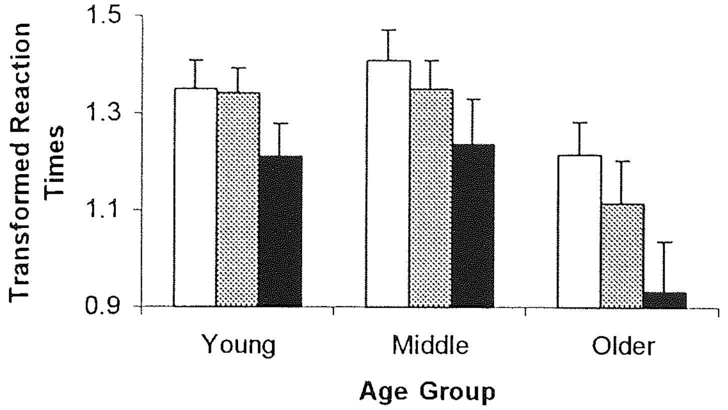

Figure 6. Transformed reaction times (mean and upper 95% confidence limit) for angular motion (pedestrian crossing events) at eccentricities of 2.5° (white bars), 5° (grey bars) and 7.5° (black bars) in young, middle and older age groups. Higher values represent faster reaction times.

Figure 6 shows that drivers tended to react more slowly as the emergent eccentricity of pedestrian targets (angular motion) increased from 2.5° (mean reaction time = 576ms) through 5° (mean reaction time = 635ms) to 7.5° (mean reaction time = 825ms). A 2-factor ANOVA revealed that the effect of target eccentricity was statistically significant ($F_{2, 99}$ = 21.4, P<0.0001) and was not influenced by age ($F_{4, 99}$ = 1.07, P = 0.377).

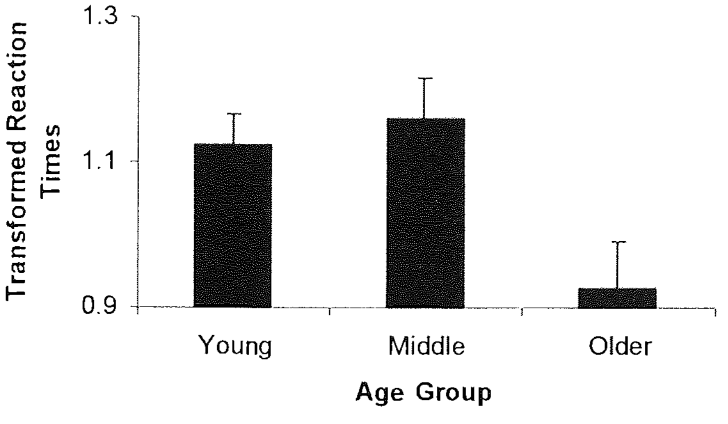

Figure 7. Transformed reaction times (mean and upper 95% confidence limit) for the young, middle and older age groups. Higher values represent faster reaction times.

Figure 7 shows that older drivers were slower (mean reaction time = 1159ms) than the young (mean reaction time = 792ms) and middle (mean reaction time = 742ms) age groups. A 1-factor ANOVA revealed that the effect of age was statistically significant ($F_{2, 33}$ = 19.7, P<0.0001). Post-hoc tests showed that the reaction times of young and middle age groups did not differ ($P = 0.351$) while both groups were quicker than older drivers ($P<0.0001$).

4. DISCUSSION

Reaction times recorded for the DRTS test operating with default settings ranged from 538 to 2419ms, which spans the 671ms thinking times used by the DETR (www.roads.detr.gov.uk). It must, however, be pointed out that thinking times will have been based upon drivers responding via a footbrake while DRTS reaction times were based upon responses made via the keyboard (i.e. hand control). An unpublished study by the authors of this article showed, on 12 young healthy drivers, that faster reaction times (paired t-test: $T_{11} = 6.70$, $P<0.0001$) were recorded using hand controls on the DRTS test (mean reaction time = 809ms) compared to footbrake controls on the driving simulator (mean reaction time = 1191ms) used by the Transport Research Laboratory (Crowthorne, UK). This corresponds to a keyboard : footbrake reaction time ratio of 1:1.47. This is in general agreement with previous research (Ritcher & Hyman, 1974).

DETR's published thinking times and stopping distances					
		Speed (mph)	Thinking time	Total stopping distance	
		30	671ms	23m	
		50	671ms	53m	
		70	671ms	96m	
DRTS estimated reaction times and additional stopping distances					
Factor		Speed (mph)	Reaction time	Additional stopping distance	
				Keyboard	Footbrake
Target presentation	Kinetic	50	850 ms	4m (8%)	6m (11%)
	Static	50	547 ms	-3m (-6%)	3m (6%)
Speed (mph)	30	30	781 ms	1m (4%)	6m (26%)
	50	50	783 ms	3m (6%)	11m (21%)
	70	70	836 ms	5m (5%)	12m (13%)
Clutter (target : distractor ratio)	1:6	50	675 ms	0m (<0%)	7m (13%)
	1:18	50	698 ms	1m (1%)	8m (15%)
	1:30	50	727 ms	1m (2%)	9m (17%)
Motion	Longitudinal	50	1278 ms	13m (25%)	27m (51%)
	Angular	50	665 ms	<1m (<1%)	7m (13%)
Emergent eccentricity	2.5°	50	567 ms	-2m (-4%)	4m (8%)
	5°	50	635 ms	-1m (-2%)	6m (11%)
	7.5°	50	825 ms	3m (6%)	12m (23%)
Age	Young	50	792 ms	3m (6%)	11m (21%)
	Middle	50	742 ms	2m (4%)	9m (17%)
	Older	50	1159 ms	11m (21%)	23m (43%)

Table 1. Comparison of stopping distances as published by the DETR and as estimated using the DRTS test for each factor examined in this study.

Table 1 compares the DETR's published stopping distances to those calculated from mean reaction times measured using the DRTS test for each factor examined in this study. Differences in stopping distances, expressed in metres and percentages, are shown for responses made via a keyboard and, after multiplication by 1.47, a footbrake. Stopping distances increased by up to 51%. This figure arose for longitudinal motion suggesting that drivers may have particular difficulty detecting deceleration (without braking) of cars travelling in front of them. Another point worth mentioning is that older drivers typically exhibited a 43% increase in stopping distances. These findings suggest that the DETR's published stopping distances may need revision. Research on steering responses to roadside obstacles appearing at night (Summala, 1981) appears to support this notion.

In this context we have provided evidence that reaction times also increase with target presentation, travelling speed, clutter, angular compared to longitudinal target motion, target eccentricity and age. The finding that reaction times are nearly doubled for longitudinal motion (i.e. when a car that is being followed suddenly brakes) compared to angular motion (i.e. when a pedestrian crosses a road). This finding has been reported before by Hills (1980).

The influences of travelling speed and clutter upon reaction times were least noticeable in older drivers and for central targets. This may have occurred because the reaction times of older drivers were much slower than the other age groups (see figure 7). This would mean that pedestrian targets will have crossed further towards the centre of the road, away from distractor pedestrians, by the time the older drivers responded. Younger drivers, in contrast, responded more quickly so that crossing pedestrians were still in the midst of distractor pedestrians.

The DRTS (a kinetic visual attention test) was designed to determine whether kinetic stimuli could improve upon crash predictability of the UFOV (a static visual attention test). It is thus interesting to note that our previous research (Phelps & Dunne, 2000) shows that a later version of the DRTS was no more capable of detecting age-related changes to the visual system that could be responsible for crash involvement, than was the UFOV. Whether this is true for actual crash involvement remains to be seen.

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