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Role of inhibition of return in the safe driving of elderly persons

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The Role of Inhibition of Return in the Safe Driving of Elderly Persons

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Abstract

Elderly individuals represent a growing portion of our population and a growing number of elderly individuals are driving. A concern arises over the fact that elderly drivers are involved in more crashes than any other age group except for teenagers when the number of miles driven is accounted for. Research has found that deficits in visual attention are related to crashes in elderly drivers. Therefore, the current study attempted to look at a visual attention process, inhibition of return (IOR), and to try to determine its role in safe driving in the elderly. This is the first known study looking at the relationship between these two phenomena. Forty-one individuals aged 55 years and older completed an IOR task and these results were compared with psychological tests and driving evaluations that were completed earlier. Thirteen younger individuals completed the IOR task and served as the control group. An IOR effect was found and it was discovered that older and younger individuals differ in terms of the amount and type of IOR they show. Few correlations between IOR scores and psychological test scores and driving scores were significant. Two of the five regression models including age and IOR were significant. Location-based IOR added predictive ability to models that predicted driving evaluation scores and scanning errors. Because this is a new study in this area of research, subsequent research can expand on this study and make a number of modifications in order to discover more about the role of IOR in the safe driving of the elderly.

The Role of Inhibition of Return in the Safe Driving of Elderly Persons

Elderly individuals constitute a growing portion of the population. Persons aged 55 years and older now represent almost 23% of the population (Statistics Canada, 2003a). Furthermore, it has been estimated that the percentage of this group will reach almost 35% of the population by 2026 (Statistics Canada, 2003b). The growing number of elderly individuals has altered the dynamics of a variety of activities. One area of particular interest in the last number of years is driving. Elderly individuals are remaining active in driving as it allows them greater independence and freedom.

Presently, approximately 70% of persons aged 55 and older possess a driver's licence (Safety Canada, 2000). Additionally, the number of drivers at least 55 years of age is nearly twice that of drivers 16-24 years of age (Nicoletta, 2002). Research has demonstrated that the habits of elderly drivers differ from those of younger drivers. Elderly drivers tend to drive most frequently during 9 a.m. and 3 p.m., drive most frequently on Wednesday, Thursday, and Friday (Nicoletta, 2002), and drive rather short distances a few times a week (Safety Canada, 2000). Alternatively, younger drivers tend to drive most frequently during 3 p.m. and 6 p.m., drive most frequently on Friday, Saturday and Sunday (Nicoletta, 2003) and drive longer distances (Safety Canada, 2000).

However, the most researched and concerning difference between younger and older drivers is in to crash rates. Elderly drivers are involved in more crashes than all other age groups of drivers other than teenagers when the number of miles driven is accounted for (Evans, 1988; Hu, Trumble, Foley, Eberard, & Wallace, 1998; Lefrancois

& D'Amours, 1997; Margolis et al., 2002). More distressing is the fact that the consequences of a crash are larger for the elderly population. It has been noted that the recovery time after a crash is usually longer for individuals over the age of 65 years (Evans, 1988). In addition, the elderly have a higher risk of a car crash resulting in death than younger individuals. For instance, a driver who is 80 years old has a four-fold increase in the risk of being killed in a car crash of the same strength than a driver who is 20 years old (Eberhard, 1996). Death as a consequence of a car crash has been documented to be the primary cause of accidental death for 65-74 year olds and the secondary cause of accidental death for 75 year olds and older (Persson, 1993). Therefore, the consequences of car crashes in the elderly population are quite disturbing and have caused many to investigate the issue of elderly driving more in depth.

Researchers have attempted to describe the characteristics of the crashes that elderly individuals are predominantly involved in. Primarily, they are involved in crashes that include more than one car (Daigneault, Joly, & Frigon, 2002a; McGwin & Brown, 1999). One study (Daigneault et al., 2002a) found that elderly drivers' crashes involved more than one car over 90% of the time. This is of great importance because it signifies that not only are the elderly drivers more at risk of being in a car crash, but so are the other individuals who are on the road when elderly individuals are driving. Additionally, it has been noted that many of the crashes occur in good weather conditions, including sunshine, dry road surface, and good visibility (Daigneault et al., 2002a; Stamatiadis & Deacon, 1995). Also, it has been repeatedly shown that crashes involving elderly drivers are more likely to occur at intersections (Daigneault et al., 2002a; McGwin & Brown, 1999; Owsley et al., 1991; Stamatiadis & Deacon, 1995). Furthermore, these drivers have a large percentage of their crashes while turning left at the intersections (Daigneault et al., 2002a). McGwin and Deacon (1995) found that elderly drivers who were at fault in the crash were more likely than elderly drivers who were not at fault to be involved in turning related crashes.

It has repeatedly been shown that a number of factors may lead to an increased crash risk in certain elderly drivers. Primarily, demographic and historical factors have been found to be associated with an increased risk for crashes. Some propose that as drivers age, their risk of being in a crash steadily increases (Daigneault et al., 2002a; Margolis et al., 2002; McGwin & Brown, 1999). Margolis and colleagues (2002) found that every 5 years of age increased the risk of a crash by 14% in a group of women. More specifically, it has been found that with an increase in age after 65 years, the probability of right-angle and left-turn crashes increase (Daigneault et al., 2002a). As a result of studying drivers from the ages of 15 – 75 and older, McGwin and Brown (1999) discovered that the youngest and oldest drivers most often are the ones responsible for crashes when they are involved in such instances.

There also appears to be a consistent relationship between crash risk rate and marital status. A higher proportion of drivers who are involved in crashes live alone compared to drivers who live with a spouse (Daigneault et al., 2002b; Lefrancois & D'Amours, 1997). It has also been found that elderly drivers with less education are at a greater risk (Daigneault et al., 2002b; McCloskey et al., 1994). However, one study (Lefrancois & D'Amours, 1997) demonstrated that white-collar drivers, who presumably have more education, seem to be at a greater risk when compared to blue-collar drivers. Furthermore, an interesting study (Lyman et al., 2001) compared individuals who had less than 12 years of schooling with those who had more than 12 years of schooling. They concluded that elderly drivers with 12 or more years of education reported more difficulty driving but were less likely to report a low number of mileage. Therefore, it seems that the number of years of education is also associated with the number of miles driven, which is likely to increase the elderly driver's risk of a crash.

The more an individual drives, presumably the more opportunities he or she has of being involved in a crash. Numerous researchers have attempted to determine if this is the case with elderly drivers and have found that as the number of kilometers driven by elderly drivers increase, so does the risk of a crash (Hu et al., 1998; Lefrancois & D'Amours, 1997; Margolis et al., 2002). Margolis and colleagues (2002) reported that every extra 50 miles driven by elderly women per week increases their risk of a car crash by 16%. Additionally, Hu and colleagues (1998) found that the number of miles driven per year was the only common risk factor for a crash for both elderly men and women.

Although the risk of elderly drivers being involved in a crash is elevated, it is not aging, per se, that leads to a heightened risk of being involved in a crash. There are a number of factors relating to the individual that play a role in increasing the risk. These include medical conditions and medications, visual functioning deficits, cognitive functioning, psychomotor functioning, and attentional processes.

Medical conditions and particular types of medications have been suggested to play a role in the higher crash risk found in elderly drivers. As people age they are more likely to have a variety of medical problems that affect their functioning, including their ability to drive a car. First, the impact of having a stroke appears to negatively effect driving in the elderly population (Klavora & Heslegrave, 2002; Lyman, McGwin, &

Sims, 2001; Sims et al., 2000). One study (Lyman et al., 2001) concluded that elderly drivers who had a stroke reported more difficulty driving in particular situations such as at night, in fog, in the rain, while alone, during rush hour, on the highway/freeway, with children, in high density traffic, when passing cars, when changing lanes, when making left had turns at intersections, and parallel parking. Furthermore, Sims and colleagues (2000) found that a history of stroke was one of only 2 medical conditions out of 18 that were significantly associated with higher risk of crashing.

Parkinson's disease is another condition that is associated with an increased crash risk (Heikkila et al., 1998; as cited in Morgan & King, 1995). This disease effects bodily control, which plays a major role in driving ability. It has also been found that elderly drivers with diabetes have a higher number of crashes than those without the condition (Daigneault et al., 2002b; as cited in Morgan & King, 1995). It has been speculated that this may be because diabetes can effect one's cognitive functioning, which is an important aspect for driving (Daigneault et al., 2002b; Morgan & King, 1995). Other medical conditions associated with an increased crash risk rate are epilepsy (as cited in Liley, Arie, & Chilvers, 1995; as cited in Morgan & King, 1995), heart disease (as cited in Lilley et al., 1995; as cited in Morgan et al., 1995), and kidney disease (Lyman et al., 2001).

Medical conditions may play a part in predicting those who will be at an increased risk for a crash. However, medical conditions are complicated and their effects will most definitely vary depending on the individual. The effects of a number of these conditions combined may be important to analyze. Marolloli and colleagues (1994) examined a variety of health factors and concluded that only the number of chronic conditions was significantly associated with adverse driving events.

Because of their heightened susceptibility to more medical conditions, elderly individuals are also more likely to be taking medications. A side effect of some of these medications may be a deterioration of the drivers' competence behind the wheel. In addition, elderly individuals are more prone to the side effects of medications because of age-related changes in pharmacokinetics and pharmacodynamics (Morgan & King, 1995). The most common type of medication associated with adverse driving events in the elderly is antidepressants (Hu et al., 1998; Ray, Fought, & Decker, 1992). Tricyclic antidepressants have been associated with double the risk of being involved in a road traffic crash that results in injury (Ray et al., 1992). Hu and colleagues (1998), incorporating over 60 variables, found that the use of antidepression drug is the single most essential risk factor other than amount of driving when predicting crash rates in elderly men. They also found that the crash risk rate is doubled when elderly men use this medication (Hu et al., 1998).

There have been a few other medications found to be associated with adverse driving events in the elderly. First, one study (Sims et al., 2000) concluded that participants who were taking hypnotic medications had almost three times a greater risk of experiencing a vehicle crash than those who were not taking the medication. Second, it has been demonstrated that elderly drivers using benzodiazephines have a 50% higher rate of crashes resulting in injury (Ray et al., 1992).

Although some researchers have reported a link between the use of certain medications and the increased crash risk rate in elderly drivers, numerous other researchers have failed to replicate these results (Daigneault et al., 2002b; Sims et al., 2000). Therefore, the effect of medication appears to vary across individuals. Even though the use of particular medications may play a role in the crash risk rate of some elderly individuals, there are several other factors that most likely play a larger role in the risk of a crash.

It has been found that sensory factors may contribute to the changes in driving experience that a number of elderly drivers deal with. Vision is a necessary component to driving ability. As much as 90% of the information essential for driving is obtained visually (as cited in Lilley et al., 1995). This is especially important when considering elderly drivers because visual processes are known to deteriorate with age. However, it is important to note that the amount, rate, and the age at which deterioration begins differ for the various visual functions and for different individuals (Shinar & Schieber, 1991).

A major function of vision that shows declines with age is visual acuity (Fox, 1989; Klavora & Heslegrave, 2002; Morgan & King, 1995). This decline in the ability to see clearly is due, in part, to the lens (Fox, 1989). As we age, the lenses grow and do not shed so that new layers are entrenched on the outside surfaces. The amount of light that reaches the retinas is decreased by this resulting thickness. Additionally, the lenses' loss of elasticity with age and the consequential lack of ability to bulge outward, creates a problem with seeing clearly objects that are near.

Changes also occur in the irises and pupils that lead to a decline in general acuity. Usually in bright light the irises swells in width and, subsequently, the pupils become smaller (Fox, 1989). Thus, less light is able to reach the rods and cones, which protect them from harm. Conversely, in dim lighting conditions, the irises become narrower and the pupil dilates. This lets more light reach the rods and cones. However, as individuals age, the irises are not as able to change their widths. Consequently, elderly individuals are apt to have smaller pupils in both dim and bright light. This confines the elderly individuals' night vision to basically nothing (Fox, 1989; Klavora & Heslegrave, 2002). However, their vision in well-lit areas may be only somewhat worse.

There are a number of factors that play a part in the clarity in which one can see in detail. The first factor is glare. Elderly persons are more sensitive to glare because the lenses become denser as they age (Fox, 1989). Light rays disperse when they hit the lenses (Morgan & King, 1995). In very bright conditions, the glare is superimposed over the image, creating a blind spot that interferes with the image (Fox, 1989). Also, the effect of glare becomes more intense and the time needed to recover from glare becomes longer as the eyes age (Fox, 1989; Klavora & Heslegrave, 2002; Morgan & King, 1995). It has been suggested that a 55 year old takes eight times longer to recover from glare as a 16 year old (Malfetti & Winter, as cited in Fox, 1989).

Visual contrast also plays a role in the clarity in which one sees. Older people tend to have a hard time seeing patterns that have low contrast, particularly if there is a bright background (Fox, 1989). This affects elderly drivers' ability to see objects. One study (Evans & Ginsburg, as cited in Fox, 1989) demonstrated that the smaller a sign on the highway, the more contrast was needed to identify it. Therefore, it is much harder for the elderly to recognize significant objects around them that blend in with their background. For instance, it would be particularly hard for an older driver to see a black dog on the side of the road in the night, as compared to a younger driver.

A final factor that contributes to the clarity of vision is illumination. Because of the changes that occur, the amount of light that reaches the retina is limited. This means that older individuals require a greater amount of illumination (Fox, 1989). It has been noted that a 45 year old driver requires four times as much light as a 19 year old driver to see as clearly (Malfetti & Winter, as cited in Fox, 1989). Consequently, the driving ability of an older driver is limited in the nighttime and in situations in which there is insufficient light available.

In summary, older drivers' visual acuity is limited because of a variety of factors. They have a more difficult time picking out particular objects than younger drivers. This is particularly the case when the driving situation is less than ideal, such as when it is dark. It has been suggested that this decline in acuity is not major until an individual reaches 60 years old (Shinar & Schieber, 1991). However, the decline in other complex tasks becomes apparent at an earlier age and declines at a faster rate as people age.

One of the tasks in which older people experience a decline earlier in life is acuity for a moving object (Shinar & Schieber, 1991; Wist, Schrauf & Ehrenstein, 2000). This is of particular significance because, when driving, many critical objects that need to be identified are moving relative to the driver. Motion sensitivity in the central and peripheral fields has been shown to be significantly compromised as people age (Wojciechowski, Trick, & Steinman, 1995).

Peripheral vision deteriorates with age as well. The horizontal visual field drops to 140 degrees by 50 years old from 170 degrees in young adulthood (Panek, Barrett, & Sterns, 1977). A large portion of information obtained when driving comes from the periphery. Therefore, it is almost certain that elderly individuals will have a more difficult and a longer time seeing an object that suddenly appears in their visual field, such as a dog running from a front lawn into the road. It has been shown that individuals with worse peripheral vision have twice as many road traffic crashes than individuals with normal peripheral vision (Morgan & King, 1995).

Vision also deteriorates because of eye diseases. Ocular conditions, primarily cataracts, glaucoma, macular degeneration, corneal disease and diabetic retinopathy are more prevalent in older adults and contribute to the decline in visual functioning (Brouwer & Ponds, 1994; Morgan & King, 1995; Klavora & Heslegrave, 2002). The eye lenses become unclear with cataracts, which affects glare sensitivity, color perception, and night vision (Brouwer & Ponds, 1994). Glaucoma can lead to damage to the optic nerve, which, in turn, gradually restricts peripheral vision (Brouwer & Ponds, 1994) and, as previously indicated, peripheral vision plays an important role in driving ability. With macular degeneration, the central part of the retina is damaged, which decreases the ability to see details (Brouwer & Ponds, 1994). Individuals with diabetes are at an increased risk of developing eye problems, such as retinopathy and cataracts (Brouwer & Ponds, 1994). All of these eye diseases effect visual functioning, which is an essential component to safe driving.

In summary, there are numerous eye diseases that are associated with decreases in visual acuity. However, the evidence is unclear as to whether or not the presence of these eye problems is associated with problems in driving in elderly individuals. Hu and colleagues (1998) determined that the presence of glaucoma is important in assessing the risk of a crash in the elderly, however, this finding was only found with men.

Driving is a highly visual task. Therefore, it seems logical that elderly drivers with visual impairments may experience more difficulty driving and thus, an elevated crash risk rate. However, when considering only these abilities, it is unlikely that they will predict those elderly individuals who have an increased crash risk rate. A number of studies have failed to find a significant association of visual functioning and adverse events in elderly drivers (Marottoli et al., 1994). Ball and her colleagues (1993) posit that studies of vehicle crashes and visual deficits have found only weak correlations and that these visual deficits account for less than 5% of crash variance.

There have been several reasons postulated as to why researchers have not found a strong association between visual deficits and crash rates. First, crashes are fairly rare happenings and, thus, it is difficult to statistically predict such an event (Ball et al., 1993). Second, many drivers with visual deficits alter their driving behaviors (Ball et al., 1993). In particular, it has also been found that the occurrence of visual deficits is higher among the elderly who drive less than 3000 miles per year (Stutts, 1998). Additionally, individuals with visual deficits often report avoiding driving in challenging situations, such as during rush hour (Lyman et al., 2001; Owsley et al., 1991; Stutts, 1998). Therefore, the association between visual deficits and crash rates may be weaker because individuals frequently know that they have these impairments and regulate their driving habits. Third, the most probable reason for why a strong association between simply visual functions and crash rates has not been established is because driving [illegible] complex task that requires much more than simply visual functioning. Driving also requires attentional/perceptual and cognitive components (Ball et al., 1993; Owsley et al., 1991). Driving a vehicle requires individuals to be able to attend to other objects and vehicles around them, but also to ascertain which objects and vehicles to focus on, decide quickly what to do when an object suddenly appears in front of the vehicle, and many other processes. Therefore, driving involves a great deal of information-processing (Owsley et al., 1991). This is not to say that visual functioning is not necessary when researching elderly drivers' crash rates. Visual functioning is important to obtain information required to drive and is vitally linked to higher-order attentional and cognitive processes necessary for safe driving. For example, although central vision and peripheral vision were not found to be directly linked to crash frequency, Ball and colleagues determined that central and peripheral vision are significantly associated with the useful field of view (UFOV), which has been found to be significantly associated with crash frequency.

Driving is a complex task that requires the individual to process an abundance of information, integrate this information, make a variety of decisions, and execute responses pertaining to the decisions. Consequently, much of the research on driving focuses on cognitive processes and their role in safe driving. The majority of research supports the notion that individuals experience impairments in a number of cognitive functions as they age (Daigneault et al., 2002b; Morgan & King, 1995; Lilley et al., 1995). It has been demonstrated that older individuals are involved in more crashes because of errors or informational causes, whereas younger individuals are involved in more crashes because of traffic violations (Blockley & Havely, 1995). Specifically, older drivers' crashes are primarily due to cognitive deficits as they do not succeed in planning actions to result in a preferred event while younger drivers' crashes are primarily due to a motivational aspect.

One way to examine the association between cognitive functioning and driving performance is to compare individuals with different scores on a variety of cognitive tests with driving performance results. Developing a model to attempt to account for predictors of crashes, Owsley and colleagues (1991) stated that mental status is the second best predictor of vehicle crashes. Mental status is a collaboration of a variety of abilities. Researchers have attempted to assess cognitive abilities and describe their relationship with safe driving in the elderly population.

Memory is a component of cognitive functioning that is vital for driving. Elderly drivers who were involved in crashes tend to score lower on visuospatial memory tests than those who have not been involved in crashes (Lundberg, Hakamies-Blomvqist, Almkvist, & Johansson, 1998). However, elderly drivers with suspended licenses but had not been involved in a crash were not found to differ from control drivers (Lundberg et al., 1998). Working memory is an important function necessary for driving as individuals must keep a variety of information in their minds and use it simultaneously to decide what actions to take. Guerrier, Manivannan, and Nair (1999) found that the greater the working memory elderly drivers possessed, the longer the driver waited to make a decision. They also found that working memory had a significant indirect effect on the gap chosen between them and another car. The researchers hypothesize that because individuals with greater working memory ability can handle more information, they may take an extended amount of time to collect pertinent information, whereas those with limited working memory abilities cannot hold as much pertinent information and may make a faster decision and choose a smaller gap (Guerrier et al., 1999). Other research has also found that elderly drivers' ability to judge gap size is deficient (as cited in

Klavora & Heslegrave, 2002; McKnight & McKnight, 1999). McKnight and McKnight (1999) found that drivers who were previously involved in a crash tended to underestimate gap size, by expressing that they could safely enter gaps that were less than 6 seconds. However, these drivers in practice tended to err on the safe side of entering gaps.

General measures of cognitive functioning have been widely utilized to examine the effect of cognition on driving performance. A wealth of research has demonstrated that individuals who perform worse on these tests experience more negative driving experiences (Daigneault et al., 2002b; Lyman et al., 2001; Marottoli et al., 1994; Owsley et al., 1991; Stutts, Stewart, & Martell, 1998). Stutts, Stewart, and Martell (1998) found that drivers who performed in the lowest 10% of performance on cognitive tests, including the Trail Making Test, Reaction Time test, Short Blessed test, and a Traffic Sign test, had nearly twice the crash risk as those scoring in the highest 10%. Additionally, they concluded that the crash risk rate from the lowest to the highest scores on the cognitive tests was extremely gradual.

Psychomotor processes have also been proposed to be associated with an increased crash risk rate in elderly drivers. Psychomotor slowing is often a consequence of aging and maybe due to both central and peripheral processes (Welford, 1984). Firstly, motor functions are important for driving as individuals behind the wheel are required to press the brake pedal, for example. Deficits in physical and motor processes have been investigated to see how they may be related to driving capability. Elderly individuals who report driving three or less days each week tend to have a functional impairment, including difficulty using stairs, difficulty walking at least a quarter of a mile, difficulty carrying a heavy object, and difficulty feeding oneself (Lyman et al., 2001).

Other research has attempted to determine the exact relationship between physical and motor deficiencies and crash risk rate (Hu et al., 1998; Margolis et al., 2002; Marottoli et al., 1994; Sims et al., 2000). These studies found that having an impaired left-knee flexion, taking longer than 7 seconds to walk 10 feet (Marottoli et al, 1994), having difficulty opening a jar, having difficulty doing light housework or yard work (Sims et al., 2000) and having three or more foot abnormalities (Marottoli et al., 1994) is associated with an increased crash risk rate. Also, Margolis and colleagues (2002) report that women who have an abnormal foot reaction time are at about a 10% higher risk of being involved in a crash. One study (Hu et al., 1998) showed that women, but not men, who have a hard time raising their arms above their shoulders have double the risk of being in a crash compared to individuals who can do the same movement without any trouble.

Hence, the psychomotor abilities of elderly drivers are a combination of both psychological and motor functions. Psychomotor functioning is commonly assessed using a simple reaction time (Morgan & King, 1995). This speed of response to a stimulus in the environment increases with age (Lerner, 1994; Welford, 1984). Reaction times typically are even slower when the task is more complex and there are a multitude of stimuli to process (Stelmach & Nahom, 1992). As the uncertainty of the responses becomes greater, elderly drivers are slower to react (Stelmach & Nahom, 1992). Thus, it appears logical that elderly drivers may experience difficulties driving because the task is a complex one in which a variety of information must be incorporated in order to make a decision. In some driving situations, it has been demonstrated that drivers over the age of 70 years have longer perception-reaction times and a third of the time these are frequently over 2 seconds (as cited in Lerner, 1994). When elderly drivers are driving on the highway at greater speeds, these differences can amount to a need of hundreds of feet of distance in order to notice a hard to see stimulus, realize its potential danger, think of the suitable response, and then follow through with the response (Lerner, 1994). Research looking at this issue has found that elderly drivers who perform worse than others on tests of psychomotor speed have an increased risk of being involved in a crash (Daigneault et al., 2002b; Lundberg et al., 1998). By comparing a group of elderly individuals who were involved in crashes with those who were not, a group of researchers (Daigneault et al., 2002b) came to the conclusion that elderly men who were involved in crashes did more poorly on all test measures that involved planning and execution. In particular, they found that these men made more errors.

It has been suggested by some that a portion of elderly drivers may be aware of this limitation in their abilities and alter their driving as such (Perryman & Fitten, 1994). They posit that elderly drivers slow down their speed to compensate for their increased psychomotor reaction time. It does seem to be the case that some elderly drivers do drive at slower speeds than younger drivers or than they previously drove (Daigneault et al., 2002b; Morgan & King, 1995), and some elderly drivers who experienced crashes communicate the intent to drive more carefully (Daigneault et al. et al., 2002b; Dobbs, Heller, & Schopflocher, 1998).

Because it is widely agreed that cognitive processes are a fundamental aspect of driving ability, research is increasingly being done on elderly drivers with key cognitive impairments, specifically those with dementia. This issue is important because of the number of elderly individuals that have the condition. Two percent of individuals aged 65-74, 11% of individuals aged 75-84, and 34% of individuals over the age of 85 are reported to have dementia (Canadian Study of Health and Aging, 1994). Of greater interest is the fact that a considerable number of these individuals continue to operate a vehicle (Odenheimer, 1993). However, it has also been noted that some of these individuals alter their driving habits. Freund and Szinovacz (2002) found that men with mild and severe cognitive impairments are apt to confine their driving to shorter distances, whereas women are apt to terminate driving altogether.

Because a number of individuals with dementia continue to drive, it is important to examine how their driving abilities may be compromised. Much of the research assessing this issue utilizes individuals with Alzheimer disease in which it has been shown that the more severe the disease, the lower the score on a traffic sign test (Carr, LaBarge, Dunnigan, & Storandt, 1998). This could have severe repercussions, especially when an individual is faced with unfamiliar signs in a different environment. Additionally, individuals with Alzheimer seem to make more hazardous or potentially catastrophic errors when driving than individuals without such cognitive impairment (Dobbs, 1997; Dobbs et al., 1998). In particular, 50% of these errors occur when the driver is changing lanes, merging, and coming up to intersections, 21% occur during left turns, and 15% occur because of a failure to stop (Dobbs et al., 1998). Hence, there appears to be sufficient evidence to suggest that the type of errors may distinguish individuals with cognitive deficits from those without cognitive deficits.

Driving performance tests are also conducted to determine how Alzheimer patients do in comparison to drivers without the disease. Some research has shown that Alzheimer patients receive lower scores on these tests (Harvey et al., 1995; Odenheimer et al., 1994). Harvey and colleagues (1995) found that when they gave useful information to individuals without Alzheimer, their performance improved, whereas the performance of individuals with Alzheimer did not improve. Analyses of crash rates in these drivers also help indicate the effects of their condition on their driving performance. Some researchers have found that drivers with Alzheimer disease are two to six times more prone to be in a vehicle crash (Cooper, Tallman, Tuokko, & Beattie, 1993; Drachman & Swearer, 1993; Kaszniak, Keyl, & Albert, 1991).

Other researchers have reported conflicting results about the effects of Alzheimer disease on driving performance and crash risk rate. Trobe and colleagues (1996) discovered that the crash and violation rates of elderly drivers with Alzheimer were the same as those without the disorder. However, it is important when studying this issue to consider the number of years the individual has been inflicted with the disease. The participants included in Trobe and colleagues' (1996) only had the disease for a mean of 2.57 years.

Attentional processes in elderly drivers are believed to affect their driving ability. Because the driving environment is so complex and contains a multitude of stimuli, the allocation of attention to the most relevant information is crucial. It is important for drivers to be able to switch attention from one area of the environment to another, search for vital information in the environment, and focus on a variety of stimuli when necessary. Generally, older individuals have more difficulty attending to a large area of space when compared with younger individuals (Kosslyn, Brown, Dror, 1999). Older individuals also find it easier to adjust attention to smaller areas than to larger areas, whereas younger individuals find it more difficult to make the adjustments than to keep focused on the original size (Kosslyn et al., 1999). This is important when considering driving as the area to remain focused on is often a large one and attention must be focused on several aspects of it. There are numerous subtypes of attention that significant in many activities, including driving.

Initially, it is imperative that drivers be able to switch attention from one area to another or one method of problem solving to another. Flexibility is an extremely important aspect of driving because there are many instances in which the driver is obligated to react suddenly to a situation that changes (DeRaedt & Ponjaert-Kristoffersen, 2000). This flexibility is known to decrease as individuals age (Brouwer & Ponds, 1994). DeRaedt and Ponjaert-Kristoffersen (2000), by using a variety of neuropsychological tests, reported that flexibility is the third best road test predictor and accounts for 13% of the crash variance. Furthermore, it has been noted that elderly drivers who were involved in crashes made more errors on several cognitive tests than elderly drivers who were not involved in crashes (Daigneault et al., 2002b). Parasuraman and Nestor (1991) suggested that the most essential determinant of being involved in a crash is the ability to switch attention.

Both divided attention and selective attention are processes required for safe driving. Divided attention involves individuals focusing on a variety of information or tasks concurrently. Divided attention is crucial when operating a vehicle because drivers often need to perform several tasks and integrate numerous pieces of information all at once. For example, the driver must steer the vehicle to remain on the road, watch for oncoming traffic, watch for objects coming from the sides of the car, and be aware of signs that are posted. Impairment in divided attention performance tasks is often associated with an increase in age, although the extent of the impairment is dependent on the kinds of tasks required (as cited in Brouwer & Ponds, 1994). Using a driving stimulator task, Brouwer, Waterink, Van Wolffelaar, and Rothengatter (1991) found that older individuals experienced greater performance losses when they had to perform two manual operations and when they had to perform a manual operation and answer a question. However, the performance decline for older drivers was a great deal larger when they had to perform two manual operations. It may be the case that when performing a task, older individuals use much of their cognitive resources and, therefore, have a smaller amount of capacity when they must perform an additional task (Brouwer & Ponds, 1994).

Selective attention requires individuals to choose to focus on the most relevant stimuli. This is important for safe driving as the driving environment contains many relevant and irrelevant sources of information. Safe drivers are able to focus on relevant information, such as road signs and potential hazards, while ignoring irrelevant information, such as birds flying in the sky. While the task is even sometimes difficult for younger individuals, it has been suggested that this distractibility increases with age (as cited in Brouwer & Ponds, 1994) and interferes more with the performance in older individuals (Tipper, 1991). Selective attention is often important when performing visual searches.

A visual attention task that has been considered to be important in the driving performance of elderly drivers is visual search. Visual search is important as drivers have a huge area in front, behind, and around them to determine what stimuli are most important to focus on. It has been demonstrated that as individuals age, their visual search performance decline (Cobb & Coughlin, 1998; Guerrier, Manivannan, & Nair, 1999). It has been demonstrated that the performance of elderly people compared with younger people is relatively preserved when the task is a simple parallel extraction phase, whereby participants had to detect a filled in circle that was on a black background with empty circles (Foster, Behrmann, & Stuss, 1995). However, when the task was a serial one in which participants had to detect the filled in circle on the background with empty circles and filled in squares, the elderly participants' performance was markedly lower than the younger participants. Therefore, it appears that healthy elderly individual perform quite similarly to younger individuals on simpler, more automatic search tasks, their performance is impaired when the search task requires more effort, processing, and attention.

Visual searches are constantly being executed while driving. It has been demonstrated that while driving, healthy older individuals make less horizontal eye movement excursions than younger drivers, indicating decreased scanning and searching (Perryman & Fitten, 1996). Using driving traffic scenes, Maltz and Shinar (1999) discovered that elderly individuals take significantly longer time searching and their searches involve more fixations and shorter saccades to obtain the same of amount of information as younger individuals. Furthermore, they found that while younger individuals scanned images evenly, older individuals spent a larger portion of their search time focusing on a limited number of areas in the image. Older individuals additionally went back to the same areas they already looked at whereas younger individuals did not (Maltz & Shinar, 1999).

One visual attention process that has received considerable attention with respect to elderly drivers is the useful field of view (UFOV). The UFOV is a measure of the spatial area in which an individual is aware of the visual stimuli (Sanders, 1970). Therefore, the UFOV is a measure of visual processing speed, attention, and sensory function (Sims et al., 2000). Even though the UFOV is not a sensory task, it uses information that is received from the visual sensory channel and relies on this information (Owsley et al., 1991). This measure assesses the preattentive or parallel processing level of visual attention, which is especially pertinent to driving because this beginning stage is used to capture attention quickly and aim attention to very salient visual events (Owsley et al., 1991). For instance, this helps an individual see a car approaching in their peripheral vision. The UFOV is quite different from visual field size and is normally smaller than the visual sensitivity area (Ball, Owsley, & Beard, 1990).

As with most other human processes, UFOV differs across people and circumstances. The UFOV is smaller when there is a secondary task, when the target is surrounded by distractors, when the target and distractors are more similar, and when the duration of the stimulus presentation is decreased (as cited in Owsley, 1991). Ball, Roenker, and Bruni (1990) demonstrated that the influence of these variables is typically larger for older persons. It has been suggested that a decreased speed of visual attention processing, an incapability to discount distractors, and the incapability to divide attention explain why some elderly people have a limited UFOV (Ball, Roenker, & Bruni, 1990).

Consequently, because the UFOV appears to be negatively affected in older adults, it is presumed that this visual-spatial ability would affect the driving performance of these individuals as well. It has been consistently documented that a reduction in the UFOV in elderly drivers is associated with an increased crash rate (Ball et al., 1993; De Raedt & Ponjaert-Kristoffersen, 2000; Owsley et al., 1991; Sims et al., 2000). Sims and colleagues (2000) randomly selected elderly individuals from a number of age categories by crash frequency stratified cells and assessed their relative risk of crashes while adjusting for age, race, gender, and days of the week driven. They found that a decrease in UFOV by at least 40% was associated with nearly two times an increased crash risk. Furthermore, by comparing elderly drivers who passed the UFOV test with those who failed it, researchers found that those who failed it experienced 4.2 times more crashes than those who passed (Owsley et al., 1991). One study (Ball et al., 1993) even demonstrated that elderly individuals with great reductions in UFOV were 6 times more at risk to have been involved in at least one crash in the last 5 years. In addition, UFOV has been found to be the strongest correlate to crash frequency relative to a number of other variables including measures of eye health status and measures of visual sensory function (Ball et al., 1993). In particular, the UFOV test appears to possess high sensitivity (89%) and specificity (81%) in predicting the older drivers who have experienced crashes. Combining UFOV and mental status has been posited to account for approximately 20% of crash variance (Owsley et al., 1991).

Because UFOV is important when considering peripheral information, UFOV has been looked at with respect to intersection crashes. By analyzing all of the participants who failed the UFOV view test, Owsley and colleagues (1991) concluded that all except for one were responsible for crashes at intersections. This is particularly noteworthy as it has been consistently shown that a large portion of elderly drivers' crashes occur in intersections. Moreover, the individuals who failed the UFOV test had 15.6 times more crashes at intersections than those who passed the test. What is of great interest is that, of the other few people who did pass the UFOV test and were involved in crashes, their crashes were quite different. The majority of their crashes were not their fault as they were either hit from behind or lost control on the wet pavement (Owsley et al., 1991).

Another significant visual attention component is inhibition of return (IOR). This refers to the phenomenon that responses to targets are slower to locations where attention has been earlier summoned than at locations to which it has not (Posner & Cohen, 1984). When the target appears in less than 150 ms after the cue, individuals' reaction times are normally faster when the target is in the cued location than when it is in the uncued location (Posner & Cohen, 1984). This facilitory effect is hypothesized to occur because the information of the stimulus is gathered more quickly and correctly at the cued location (Bennett & Pratt, 2001). However, IOR typically starts about 300 ms after the appearance of the cue and it has been suggested that it lasts no longer than 2,000 ms (Posner & Cohen, 1984). Posner and Cohen (1984) explained that this may function to make visual searches more efficient because it impedes attention and gaze from returning to the same location.

Inhibition of return has been demonstrated in a number of different tasks, including detection tasks with key pressing responses, choice key pressing responses, eye movement responses, and discrimination task whereby responses are the result of the identity of the target or the identity and location of the target (as cited in Pratt &

McAuliffe, 1999). Interestingly, it has been noted that IOR extends outside the cued location and IOR is exhibited in areas around the cued location (Bennett & Pratt, 2001). In particular, slower reaction times are shown throughout the whole quadrant in which the cue appears and the size of this effect diminishes with increased distance from the cued location such that the opposite location produces facilitation (Bennett & Pratt, 2001).

Two frames of reference for IOR have been distinguished. Location-based IOR was first discovered using static displays. Location-based IOR refers to the inhibition of attention to a particular location in space. However, using dynamic displays, it was found that when an object that was previously cued moves, individuals show inhibition to that object even in its new location (Tipper, Driver, & Weaver, 1991). Thus, object-based IOR refers to the inhibition of a particular object, even when it moves to a different location.

Little work has been done on the impact of aging on IOR. Langley, Fuentes, Hochhalter, Brandt, and Overmier (2001) did find that while younger individuals do show declines in IOR detection and categorization tasks over time (when the considering the time from the presentation of the cue to that of the target) older individuals do not show this decline in IOR on the detection task. Therefore, it seems that IOR might exhibit different age-related differences when considering the situation and the presentation timing of the cue and the stimulus (Langley et al., 2001).

It was found that older individuals do not disengage their attention as quickly as younger individuals and they show larger facilitory effects at shorter SOAs than younger individuals do (Castel, Chasteen, Scialfa, & Pratt, 2003). Castel and colleagues (2003) also found that the onset of the IOR effect is later than it is for younger adults. However, when given enough time, IOR is intact for older adults.

Furthermore, research has been done to look at the effect of aging on the different frames of reference of IOR. Some researchers (Faust & Balota, 1997; Hartley & Kieley, 1995) discovered that there are no age-related related differences in IOR. That is, they discovered that location-based IOR and object-based IOR remains the same throughout the aging process. However, these studies both used static displays. When dynamic displays were studied, it was found that older and younger adults show the same amount of location IOR (McCrae & Abrams, 2001). On the other hand, when dynamic displays were used to measure object-based IOR, it was found that older adults do not show object-based IOR. McCrae and Abrams (2001) found that when using objects that moved after they had been cued, younger participants were slower to detect targets that appeared in the cued object. However, the older adults were faster to detect the targets in cued objects. This led these researchers to suggest that the difference between younger and older adults with respect to IOR lies in tracking movement. However, more recent research has shown that this may not be the case (McAuliffe, Chasteen, & Pratt, 2004). McAuliffe and colleagues (2004) used static displays to look at age differences in IOR. As with previous research, they discovered that there are no age-related differences with respect to location-based IOR. However, they also found that older adults did not show object IOR. This led them to conclude that there is a change in object based IOR as individuals age but this difference is not due to tracking moving objects, as previously suggested (McAuliffe et al., 2004). Hence, although the literature on aging and IOR is quickly evolving, it is pretty well accepted that the mechanism underlying location-based

IOR remains the same throughout aging but the mechanism underlying object based IOR appears to change with age (McAuliffe et al., 2004; McCrae & Abrams, 2001).

Inhibition of return is potentially an important mechanism when operating a vehicle. The driving situation is a very complex one that contains a variety of stimuli. IOR presumably allows individuals to be more efficient when assessing the conditions they are driving in because they can focus their attention on different parts of the environment rather than continually redirecting attention back to a particular area or object.

Although IOR presumably affects driving ability, research has yet to look at the role of IOR in the safe driving of elderly individuals. Elderly drivers with other visual attention deficits exhibit some problems in driving ability and it may prove useful to know if IOR has similar consequences. Therefore, the purpose of this research was to explore the IOR effects in elderly individuals and then analyze whether or not there exists an association between their level of IOR and their scores on a variety of cognitive and driving evaluations.

A number of hypotheses were made before the study was initiated. Primarily, it was hypothesized that an IOR effect would be shown with all participants. That is, it was predicted that all of the participants, no matter what their ages, would respond slower to a location or an object that was previously cued than one that had not been previously cued. The second hypothesis was that elderly participants would show a deterioration in object + location-based IOR but not in location-based IOR. Because it has been shown by a number of researchers that object + location- based IOR is greater than location- based IOR in a young sample and this difference virtually disappears with elderly participants, it was hypothesized that the elderly participants would show a deterioration in object + location-based IOR. Another hypothesis for the study was that there would be an association between IOR scores and driving evaluation scores and psychological test scores. More specifically, it was predicted that those elderly drivers who show lower IOR would have lower psychological test scores and driving evaluation scores.

Method

Participants

Older Group

Participants for the initial part of the study were recruited from September 2001 to the winter of 2002 to participate in a driver re-training study. Participants were recruited through a radio interview with one of the researchers, through television interviews and advertisements, through articles and ads in a newspaper for seniors, through articles in two community newspapers, and through posters that were distributed to hospitals and seniors centers. To be eligible to participate in the study, individuals had to be 55 years of age or older, have a valid driver's license, currently drive, and be fluent in English. Over 100 individuals showed interest in participating in the study. The study was explained to all interested and individuals were screened to ensure they met the inclusion criteria. Sixty-five were recruited and then the extra individuals were put on a waiting list.

Over the course of this part of the study, seven participants withdrew. Two participants withdrew before any aspect of the study was started. Three withdrew after completing the psychological tests and two withdrew after they completed the first driving evaluation. Participants chose to withdraw because of a death of a spouse, discomfort with the driving instructor's car, discomfort with the in-class setting, and lack of time to complete the study. Also, three participants from the control group did not take part in the re-training sessions. They indicated that the course was unnecessary after receiving positive feedback from the driving evaluator. Another individual from the control group was unable to finish the re-training course because of medical issues.

From May 2003- September 2003 all of the 65 participants from the initial part of the study were contacted again and asked if they were willing to participate in the IOR component of this study. Out of the 65 older individuals contacted, 47 actually participated.

Younger Group

A group of 13 undergraduates served as the control group. These individuals were recruited through an introductory undergraduate psychology class. They were informed that the research was looking at the relationship between visual attention and driving.

Apparatus and Procedure

Older participants first completed a variety of psychological tests in their own homes. The 3MS (Modified Mini-Mental State Examination), the SMMSE (Standardized Mini-Mental State Examination), and the clock drawing are tests that were completed to aid in identifying possible general cognitive impairment. The Trail Making Tests, the Stroop test, the Motor-Free Visual Perception Test-Vertical Format (MVPT-V), the Block Design, and the Digit Span Subtests were completed to assess more specific cognitive skills such as attention, visual perceptual skills, mental and motor processing speed, and cognitive flexibility. After completing all of the psychological tests and attaining a score of 24 or higher on the MMSE (Mini-Mental State Examination), participants then completed the first of two driving evaluations.

The driving test was made up of a standardized 45 minute driving section in the city of Thunder Bay. Six standardized sections were arranged and participants were tested on the section that was closest to their homes. Participants completed the same course for both of their driving evaluations. The same certified driving instructor tested all participants. Participants' scores on the driving test could range from 0-100. There were also subscales in which participants received scores. The subscales included vehicle handling errors, compliance/dangerous errors, and total corrected collision-free errors (CCFE). The CCFE is a sum of the four collision-free scores that were corrected for external conditions. The four collision-free error factors included look well ahead, move your eyes, keep space, and spot the problem. Factor 1, look well ahead, is defined by errors involving planning the route, following the flow of traffic, and safety precautions before moving the vehicle. Factor 2, move your eyes or scanning, is defined by errors regarding checking mirrors, scanning the surroundings while driving and scanning intersections. Factor 3, keep safe distance, is defined by errors made regarding the space between the participants' vehicles and other vehicles, blind spots, and avoiding rear crashes. Factor 4, spot the problem, is defined by errors regarding seeing and solving problems when turning, point of no return when approaching a set of lights, and reactions to potential road hazards or problems.

The second part of the study began in May 2003. The participants were asked individually to meet at Lakehead University. They sat in front of a computer in a dimly lit room. The computer was placed at the same distance away from the individual for all participants and the computer keyboard was placed on the table in front of the participants for easy access. The participants were then asked to read an information letter about what the study would entail. They signed a consent form which informed them that all of their information would be kept confidential and that they may terminate their participation at any point. They were additionally asked for their consent in linking the data from this study with the data obtained from the previous study. A copy of the information and consent form can be seen in Appendix A.

The computer task was then described by the researcher to each participant individually and participants began once the researcher left the room and they were ready to start. Participants' heads were 40 centimeters from the computer screen. The computer task was one which measured their object + location-based and location-based IOR. The computer program used was one developed by McAuliffe and colleagues (2001). An example of a trial can be seen in Appendix B. Each trial started with a blank screen for 1,000 ms. Next, a dot appeared in the center of the screen with two other boxes, either on the left and right of the dot or above and below of the dot. Participants were told to focus on the dot in the center of the screen at all times. The placeholder boxes were centered 5.5° from the middle of the fixation dot and were 1° square. After the first display had been shown for 1,000 ms, a white unfilled square (.50 square) appeared for 200 ms. This unfilled square was centered 5.5° above, below, to the left, or to the right of the fixation box. This cue may have appeared inside of a box or it may not have. Once the cue was removed, there was a delay of 200 ms before the central dot was enlarged marginally for 200 ms. Next, a filled in square (.5° square), the target, appeared again and was centered 5.5° to the right, left, top, or bottom of the fixation dot. The target stayed on the screen until either the participant responded by pushing the spacebar or until 1,000 ms (ms) elapsed. A new trial began after 1,500 ms.

The target and the cue appeared equally often in each of the locations. Placeholder-present trials occurred when both the cue and the target appeared in a placeholder box. The placeholder box represents an object that is in a particular location. Therefore, when placeholders were present when both the cue and target appeared, an individual's object + location-based IOR was assessed. In contrast, when neither the cue nor target appeared in a placeholder box, there was nothing to represent an object. Therefore, in these conditions, an individual's location-based IOR was assessed. Additionally, there were trials in which the cue was in a placeholder box and the target was not, in which the cue was not in a placeholder box but the target was, and in which neither were in placeholder boxes were presented. However, these were simply filler trials and not used in establishing IOR.

Participants were encouraged to focus on the dot in the center of the screen at all times. Additionally, they were instructed to press the spacebar on the keyboard as quickly and as accurately as they could when they saw the target appear on the screen. They were also informed there would be some trials (20%) in which the filled-in square would not appear and that they should not respond on these trials. They heard a tone if they made an error. This occurred if they responded faster than 100 ms, slower than 1,000 ms, or not at all (for target present trials). Participants completed 300 of these trials and they were randomized for each individual. The computer program allowed the participants to take three breaks at specified times and they pressed any key on the keyboard when they were ready to begin again. The entire procedure took approximately 30 minutes per participant.

Instruments

The following psychological instruments were used:

Modified Mini- Mental State Examination (3MS) and SMMSE (Standardized Mini-Mental State Examination)

The 3MS (Teng & Chui. 1987) is an expanded version of the familiar MMSE (Folstein, Folstein, & McHugh. 1975). The 3Ms is used to easily calculate an individual's MMSE score. Using the 3MS, a 3MS score out of 100 and a MMSE score out of 30 can be obtained.

Trail Making Tests

During this test, participants join letters and numbers together with a pencil on a piece of paper. The score for these tests depends on the amount of time the participants take to finish the task. These tests measure divided attention and visuomotor tracking.

Digit Span and Block Design Subtests

These tests are subtests from the Wechsler Adult Intelligence Scale, Third Edition. The digit span test measures an individual's working memory, attention, and concentration. The block design subtest measure's an individual's concentration, ability to see patterns, speed, and visuomotor coordination.

Stroop Test

In this test, names of colors are written on a piece of paper in a different color ink. Participants are required to name the color it is written in, not name the name of the word. This test measures cognitive flexibility and selective attention.

Clock Drawing Test

In this test, participants are given a piece of paper and a pencil and are asked to draw a clock with the time 11:20 on it. The score of the test is determined by dividing the clock up into quadrants and adding up the number of errors in each quadrant. This test measures cognitive impairment in older individuals.

Motor-Free Visual Perception Test-Vertical Format (MFVPT-V)

The MFVPT-V was developed by Mercier, Hebert, Colarusso, & Hammil (1997). The test measures visual-perceptual abilities, such as discrimination of figure-ground.

Statistical Analyses

Descriptive statistics were first conducted on the reaction times for placeholder-present versus placeholder-absent and cued versus uncued for younger and older participants. Further analyses were conducted to determine the relationship between age and placeholder-present versus placeholder-absent conditions. Following this analysis, the variable trial type was removed and the data was reanalyzed, made it easier to interpret the relationship between age and placeholder-present and placeholder-absent conditions. Because of the difference in reaction times between younger and older participants, a proportional analysis was then conducted on the data and this modified data was then used in the same analysis as with the original data. Correlations were also done to look at the association between placeholder-present versus placeholder-absent conditions, psychological test scores, driving test scores, education and age. Finally, linear regression was used to determine how well age and placeholder-absent (location-based IOR) and placeholder present (object + location based IOR) conditions predicted driving evaluations scores and error scores.

Results

Out of the 47 elderly individuals who participated in both the driving evaluations and the IOR task, 5 made more than 20% errors on the IOR task and their data could not be analyzed. All of the other participants, including the younger participants, who did not make more than 20% errors only made 1.6 % errors or 4.91 errors out of 300 trials. No other analyses were conducted on the error data. Also, one of the individual's data was lost because of a computer malfunction. Therefore, 41 elderly individuals constituted the sample for this study. The mean age for these individuals was 70 years and 4 months (minimum=55 years, maximum=84 years). The standard deviation was 70.84. There were 21 females and 20 males. The mean age of the younger sample was 19 years, 7 months (minimum=18, maximum=23). The standard deviation was 1.61. There were 5 females and 8 males.

A number of analyses were conducted in order to test the hypotheses. The first analyses were completed to determine the mean reaction times of younger and older participants in placeholder-present versus placeholder-absent conditions and cued versus uncued conditions. The mean reaction times and standard deviations for both the younger and older participants are show in Table 1. The within-subjects factors were type of stimuli (placeholder present and placeholder absent) and trial type (cued and uncued). The between subject factor was age (old and young). The main effect of trial type revealed that responses on cued trials (481.76 ms) were significantly slower than responses on uncued trials (416.27 ms), $F(1,52) = 90.43$, $MSE = 148126.32$, $p <.01$. This is the typical IOR effect. The main effect of stimuli was also significant, $F(1, 52) = 8.59$, $MSE = 5792.95$, $p=.01$. Responses when placeholders were present (457.34 ms) were significantly slower than responses when placeholders were absent (440.70).

Table 1

The Mean of Mean Reaction Times and Standard Deviations for Placeholder-Present, Placeholder-Absent and Cued and Uncued Trials (ms) for Elderly and Younger Participants

		Younger	Older
Placeholder Present	Cued	410.62 (SD = 81.70)	521.80 (SD = 81.94)
	Uncued	333.31(SD = 80.76)	447.00 (SD = 91.54)
	Object + location based IOR	77.31 (SD = 22.62)	74.80 (SD = 57.24)
Placeholder Absent	Cued	383.00 (SD = 84.69)	495.59 (SD = 84.64)
	Uncued	354.15 (SD = 86.12)	431.54 (SD = 76.10)
	Location based IOR	28.85 (SD = 21.22)	64.05 (SD = 45.36)

Additionally, the main effect for age was significant, $F\,(1{,}52) = 16.88$, $MSE = 25151.76$, $p < 0.1$. Overall, older participants had slower reaction times (473.98 ms) than did younger participants (370.27 ms). There was a significant interaction between type of stimuli and trial type, $F(1{,}52) = 16.50$, $MSE = 8653.18$, $p = .01$. There was greater IOR in the placeholder-present trials (75.41 ms) than in the placeholder-absent trials (55.57 ms). There was a significant interaction between age and stimuli, $F(1{,}52) = 4.46$, $MSE = 674.31$, $p = .04$. However, the interaction between age and trial type was not significant, $F(1{,}52) = 1.61$, $MSE = 1638.01$, $p = .21$. The interaction between type of stimuli, trial type, and age was also significant, $F(1{,}52) = 6.69$, $p = .01$. The difference between placeholder-present and placeholder-absent conditions was much greater in the younger group than in the older group.

Another approach to determine the nature of the relationship between age and stimuli (and yielding the same results) was done using difference scores for each participant. For each participant, the placeholder uncued score was subtracted from the placeholder cued score and the no placeholder uncued score was subtracted from the no placeholder cued score. This left two difference scores for each participant: a placeholder present score (object + location-based IOR) and a placeholder absent score (location-based IOR). A mixed ANOVA was then conducted using the difference scores. It determined that the main effect for IOR was significant, $F\,(1, 52) = 16.50$, $MSE = 1048.99$, $p = <.01$). That is, individuals show more IOR in placeholder-present trials ($M = 75.41$, $SD = 50.89$) than in placeholder-absent trials ($M = 55.57$, $SD = 43.42$). Additionally, the interaction between type of stimuli and age was significant, $F\,(1,52) = 6.69$, $MSE = 1048.99$, $p = .01$. The mean reaction times and standard deviations are shown for placeholder-present and placeholder absent trials for younger and older participants in Table 2.

Table 2

Mean Reaction Times (ms) and Standard Deviations for Placeholder-Present and Placeholder-Absent Trails for Younger and Older Participants

	Younger	Older
Placeholder Present	77.31 (SD = 22.62)	74.80 (SD = 57.24)
Placeholder Absent	28.85 (SD = 21.22)	64.05 (SD = 45.36)

These results show that the difference between placeholder-present and placeholder-absent trials is much greater between younger participants (48.46 ms) as compared to older participants (10.75). That is, younger participants showed much greater object + location-based IOR than location-based IOR whereas this difference was not great for older participants. Furthermore, t-tests were conducted to determine if this difference was significant. It was found that younger individuals show significantly more object + location-based IOR than location-based IOR, $t(13) = 5.78, p < .01$. Conversely, older adults do not show any difference between the amount of object + location-based IOR and location-based IOR that they possess, $t(40) = 1.39, p = .17$.

To further study the relationship between age and placeholder-present versus placeholder-absent IOR, scattergrams were produced. Figure 1 shows the scattergram for the older participants.

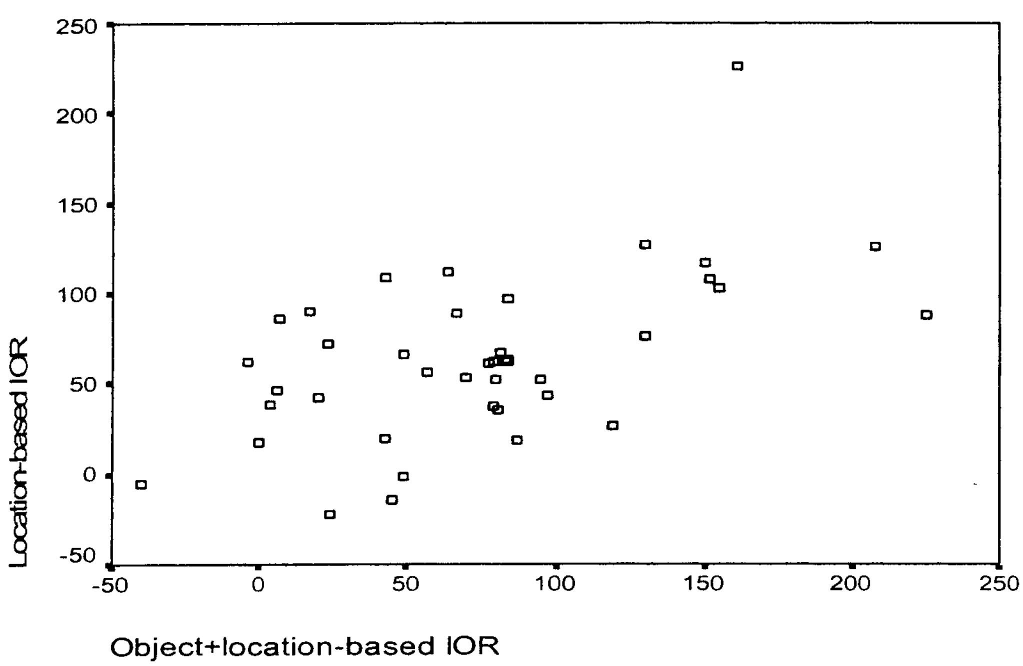

Figure 1. Object + location IOR and location IOR for older participants.

Figure 2 shows the scattergram for the younger participants.

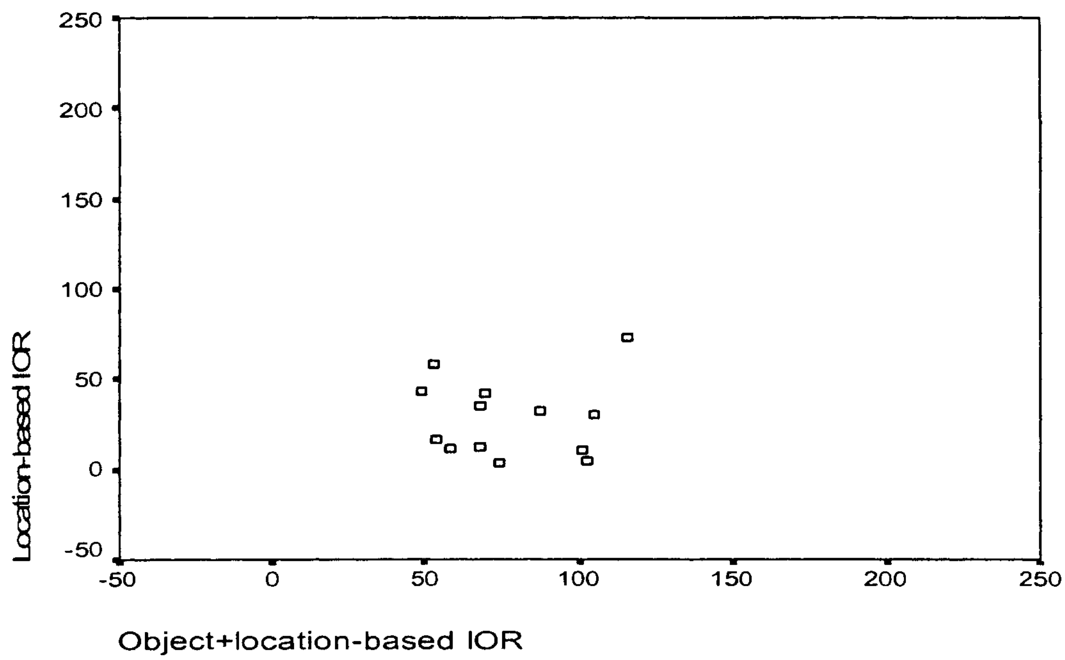

Figure 2. Object + location IOR and location IOR for younger participants.

Examining the two graphs showed that the older participants show much more variability than the younger participants in IOR, especially with respect to object + location-based IOR older participants show a huge range whereas all of the younger participants' object + location IOR was concentrated in one area of the graph. For the older individuals, location-based and object + location-based IOR were strongly correlated, r(39) = .56, *p* <.01. Object-based and location-based IOR were not correlated for the younger participants, r(11) = .05, *p* > .05.

Because the older participants had greater reaction times on the IOR task, a proportional analysis was conducted to determine if the results would differ with this aspect considered. To come up with the proportional IOR reaction times, cued reaction times were divided by uncued reaction times. These modified reaction times were then used in the same mixed ANOVA analysis as in the previous analysis. This analysis determined that placeholder-present and placeholder-absent trials differed significantly, F (1,51) = 15.54, MSE = .01, p <.01. It was found that participants took longer to respond when placeholders were present (M = 1.20, SD = .16) then when placeholders were absent (M = 1.13, SD = .11). Additionally, there was a significant interaction between type of stimuli and age, F (1, 51) = 5.68, MSE = 0.01, p = .02. The ratios and standard deviations are shown in Table 3.

Table 3

Proportional Reaction Times (ms) and Standard Deviations for Object + Location-based IOR and Location-based IOR for Younger and Older Participants

	Younger	Older
Placeholder-Present	1.25 (SD = 0.10)	1.19 (SD = 0.17)
Placeholder-Absent	1.09 (SD = 0.07)	1.15 (SD = 0.12)

These results show that once the difference in reaction times between the younger and older participants are controlled for, the younger participants took longer to respond when the placeholders were present than when placeholders were absent. In other words, the younger participants still showed a greater object + location-based than location-based IOR score. However, the difference between the object + location-based and location-based IOR score was reduced for the older participants.

It is also possible to determine indirectly the amount of object-based IOR with the data provided. Object-based IOR can be found by subtracting location-based IOR from object + location-based IOR. When this is done, the younger adults show object-based IOR. However, the older adults do not show the same inhibition to objects.

Analyses were also conducted to look at the relationship between IOR and driving. Descriptive statistics for driving and IOR can be seen in Table 4. The higher

Table 4

Descriptive Statistics for Driving Scores and IOR Scores

	Minimum	Maximum	Average	Standard Deviation
Driving Score	52.55	79.30	66.75	6.34
Look Ahead	0.90	9.00	3.99	1.60
Scan	4.50	11.64	10.67	3.01
Safe Distance	0.80	5.06	4.73	1.59
Spot Problems	1.80	5.37	5.11	1.29
Placeholder-present (ms)	-40.00	225.00	74.80	57.24
Placeholder-absent (ms)	-22.00	226.00	64.05	45.36

driving scores indicates better driving ability. The lower the error data scores, which includes look ahead, scan, safe distance, and spot problems, the better. Higher scores for the placeholder-present and placeholder-absent conditions (IOR measures) indicate more IOR.

Correlations between object + location-based IOR, location-based IOR, and object-based IOR and various psychological tests, driving evaluations and demographics for elderly participants only were also conducted. Object-based IOR was obtained for the participants by subtracting location-based IOR scores from object + location-based IOR scores. They are shown in Table 5.

Table 5

Correlations Between Object and Location-Based IOR and Psychological Tests, Driving Evaluations, and Demographics for Elderly Participants

	Object + location-based IOR	Location-based IOR	Object-based IOR (Object + location IOR – location IOR)
Object + location-based IOR	1	.49**	.66**
Location-based IOR	.49**	1	-.30*
Mini-Mental Total (100)	-.20	-.22	-.10
Modified Mini-Mental Total (30)	-.14	-.28	.02
Motor-free Visual Perception Test-Vertical Format	.16	.03	.13
Dots Only (seconds)	-.01	.21	-.19
Errors for Dots Only	--	--	--
Various Words (seconds)	-.13	.08	-.20
Errors for Various Words Only	.01	-.10	.08
Colour Words (seconds)	-.32	.08	-.42**
Errors for Colour Words Only	.10	.25	-.13
Block Design	-.17	-.19	-.05
Digit Forwards	-.08	-.32*	.20
Digit Backwards	-.14	-.36*	.15
Digit Total	-.13	-.40*	.20
Trail A	.11	.38*	-.20
Errors for Trail A	--	--	--

Time for Trail B (seconds)	.23	.30	.03
Errors for Trail B	.23	.15	.10
Clock Test (5)	-.10	-.12	.01
Difference Between Stroop 3 (colour words) and Stroop 1 (dots)	-.32*	-.02	-.34*
Driving Evaluation #1	.21	.15	.07
Driving Evaluation #2	.26	.07	.20
Average Driving Evaluation	.27	.13	.15
Age	.08	.36*	-.32*
Gender	-.16	-.17	-.05
Education Level	-.12	-.07	-.05
Look Ahead	-.14	-.10	-.05
Scan	-.26	-.11	-.16
Safe Distance	-.30	-.24	-.09
Spot Problems	.00	-.11	.11

** Correlation is significant at the 0.01 level (two-tailed).
* Correlation is significant at the 0.05 level (two-tailed).

To determine the unique contribution of age and IOR in predicting driving scores, a hierarchical linear regression was used. The associations between age and IOR and driving scores are presented in Table 6. Age was entered into the equation first to control for its effects. Next, the location- based and object + location-based IOR scores were entered to determine their effects. Age significantly predicted the driving evaluation scores, F (1, 39) = 8.61, *p*=.01. The adjusted-R^2 was .16. Lower driving evaluation scores were associated with older age (b = -0.34, *p*= .01). Location-based IOR was

Table 6

Associations Between Age and IOR and Driving Scores

Variable	R	Adjusted R^2	P (model)	F change	P (F change)
Driving Evaluation Score					
›Age	.43	.16	.01	8.61	.01
›Loc IOR	.52	.23	.01	4.70	.04
›Ob + Loc IOR	.55	.24	.01	1.39	.25
Look Ahead					
›Age	.22	.03	.16	2.02	.16
›Loc IOR	.30	.04	.18	1.57	.22
› Ob + Loc IOR	.30	.09	.31	0.16	.69
Scan					
›Age	.47	.20	.01	11.24	.01
›Loc IOR	.56	.28	.01	5.19	.03
› Ob + Loc IOR	.58	.29	.01	1.27	.27
Safe Distance					
›Age	.03	-.02	.84	0.04	.84
›Loc IOR	.28	.03	.23	3.05	.09
› Ob + Loc IOR	.30	.02	.31	0.66	.42
Spot Problem					
›Age	.26	.05	.10	2.93	.10
›Loc IOR					
› Ob + Loc	.34	.07	.25	2.03	.16
IOR	.36	.06	.15	0.61	.44

then entered to predict driving scores. Adding location-based IOR improved the model significantly (F change= 4.70, p= .04). Higher location IOR scores were associated with higher driving evaluation scores (b = 0.05, p = .04). Finally, object + location-based IOR scores were added to the model to determine their unique contribution in predicting driving evaluation scores. The addition of object + location- based IOR did not improve the prediction of driving scores (F change = 1.39, p =.25). The same procedure was used to determine to predict the error variable scores. The first error variable was looking ahead. Age was not significant in predicting looking ahead, $F(1,39) = 2.02$, MSE=1.50, p = .16. Location-based and object +location- based IOR did not significantly change the model in predicting the looking ahead score (F change = 1.57, p = .22 and F change = 0.16, p = .69 respectively). The second error variable was scanning. Analysis revealed that age significantly predicted scanning errors, $F(1,39) = 11.24$, MSE = 4.65, $p < .01$. The adjusted R^2 was .20. More scanning errors was associated with older age (b = 0.15, $p < .01$). Adding location-based IOR improved the model significantly (F change = 5.19, p = .03). More scanning errors was associated with less location-based IOR (b = -.02, p = .03). Adding object + location-based IOR did not improve the model, (F change = 1.56, p = .22). Analysis also showed that age did not significantly predict the third variable, safe distance, $F(1, 39) = 0.04$, MSE = 1.58, p = .84. Additionally, adding location-based IOR or adding object +location- based IOR did not improve the model significantly (F change = 2.74, p = .11 and F change = 0.95, p = .34, respectively). The final error variable was spotting problems. Age did not significantly predict spotting problems errors, $F(1, 39) = 2.93$, MSE = 0.80, p = .10. In addition, adding location-based and adding object + location-based IOR did not significantly improve the predictive power of the model (F change = 2.03, $p = .16$ and F change = 0.61, $p = .44$, respectively).

Discussion

Primary analyses conducted were aimed at determining the IOR effect. The results of the computer task demonstrated that all participants (younger and older) responded slower when the target was previously cued that when it was not previously cued. This is the typical IOR effect that has been demonstrated by a number of researchers (e.g., Poser & Cohen, 1984). It was also found that individuals show more IOR when placeholders are present as compared to when they are absent. This result is consistent with what other researchers have found (e.g., McAuliffe et al., 2001). In other words, it was demonstrated that individuals show more object + location-based IOR than location-based IOR. The results of this study also determined that younger individuals show a great deal more IOR when placeholders are present (object + location-based IOR) than when placeholders are absent (location-based IOR), whereas the older individuals do not show much difference between their object + location IOR and their location IOR.

The older adults had slower reaction times than the younger adults. Therefore, the proportional analysis was conducted in order to account for these differences in reaction times. This allowed for the interpretation of age related differences in IOR. Consistent with previous research, it was discovered that younger and older adults do not differ in location-based IOR (Faust & Balota, 1997; Hartley & Kieley, 1995; McAuliffe et al., 2004; McCrae & Abrams, 2001). However, it was discovered that there are age-related differences in object-based IOR. This finding is opposite with what some others have found with static displays (Faust & Balota, 1997; Hartley & Kieley, 1995).

However, McAuliffe et al. (2004) also found that younger and older individuals differ in object-based IOR. More specifically, they found that older adults do not show object-based IOR. Therefore, it appears that the mechanism underlying object-based IOR changes with age, whereas the one underlying location-based IOR remains the same.

There are some theories that attempt to explain this age-related difference. Hasher and Zachs (1988) proposed that there is a deterioration in inhibitory processes with age. They conducted negative priming studies where participants had to identify targets that had common characteristics as earlier distractors. Their results showed that younger adults showed negative priming, or inhibition, whereas older adults did not show it (Hasher & Zachs, 1988).

The scattergrams showed that the pattern of object + location-based and location-based IOR for younger and older participants is quite different. The older individuals show much more variability in the amount of IOR they possess. On the other hand, younger individuals' IOR was much less variable. This suggests that younger individuals are more homogeneous than older adults, and consequently, that it is much harder to predict the IOR of older adults because the amount of IOR they possessed is much more varied.

Correlations were also conducted to determine the relationships between location-based and object + location-based IOR, object-based IOR, and other variables for only older participants, including psychological test scores, driving evaluation scores, education, age, and the four error variables. It was expected that the higher an individual's psychological test scores, the more IOR that individual will show. Out of the 19 psychological tests completed, there was a significant association between IOR and six of these psychological tests. However, three of these relationships are in the opposite direction than what would be expected. Specifically, the more location-based IOR an individual showed, the lower his or her score on the digits forwards, digits backwards, and digit total tests.

Some results, however, were consistent with what would be expected. Results showed that the higher an individual's score on the Trail A test, the more location-based IOR the individual shows. It was also shown that more time in seconds that an individual took on the color words test, the lower the individual's object-based IOR. Additionally, the greater the difference between an individual's Stroop color words score and his or her Stroop dots score, the lower his or her object + location-based IOR and his or her object-based IOR score. Finally, consistently with what was found in earlier analyses, the older an individual, the less object-based IOR they showed.

Out of the correlations conducted between object + location-based IOR scores and location-based IOR scores and driving evaluation scores, education, age, and the four error variables, only one association was significant. It was found that the older an individual is, the more location-based IOR he or she has. None of the other correlations were significant. Although the correlations between the driving evaluation scores and IOR and the error scores and IOR were not significant, the results are still encouraging. All of the correlations are in the direction that would be expected. Therefore, the results are promising and may be used to encourage future research in the area.

The independent contribution of IOR to driving ability in the elderly was the main focus of this study. It was hypothesized that elderly individuals who exhibited greater IOR would have higher driving evaluation scores. This was predicted because, presumably, this visual attention task is important in driving. Primarily, it was found that age is clearly related to driving abilities. The older individuals' are, the lower their driving abilities tend to be. There are a number of reasons as to why driving abilities may deteriorate, not simply age, per se. It was found that IOR scores improved two regression models predicting IOR scores. Specifically, it was found that location-based IOR scores significantly improved the models for predicting overall driving evaluation scores and scanning. Individuals who showed more IOR to locations scored higher on driving evaluations. Although no research to date has studied this relationship, the results are what would be expected. While driving, individuals must pay attention to a number of locations around them and it would be expected that better drivers would take longer to allocate their attention to a location in which they previously attended rather than a new location. Adding object + location based IOR did not improve the model significantly in predicting driving evaluation scores.

Although age and location-based and object + location based IOR scores only explained 24% of the variability in driving evaluation scores in elderly individuals, this study is the first to report this. The results are novel and should be used to conduct subsequent studies in the area to further investigate this relationship.

It was also discovered that age is associated with scanning. It was found that the older the individual, the more scanning errors. These results are what would be expected and are similar to results that have been found on visual search. For instance, Foster and colleagues (1995) found that elderly individuals scored lower on visual search tasks that required a lot of attention and processing, compared to younger participants. Additionally, it was found that adding location-based IOR improved the prediction of scanning errors. It was discovered that, after controlling for age, the lower the location-based IOR, the more scanning errors individuals make. This result is also what would be expected. Presumably the people with more IOR make fewer scanning errors than people who possess less location-based IOR and return to already attended locations sooner.

However, contrary to what was expected, age nor IOR scores significantly predicted looking ahead scores, safe distance scores, and spot problem scores. One reason why IOR scores did not predict looking ahead scores, safe distance scores, and spot problem scores and did predict scanning scores may have to do with the differing levels of attention for each activity. Scanning requires individuals to be aware of everything around them and to focus on the most important information and respond to that information. Safe distance scores require attention to specific locations. For instance, safe distance scores were determined by the number of errors made regarding space left between them and another vehicle and by avoiding rear crashes. In theses instances, specific information is required and drivers do not have to focus attention on a variety of locations and objects and subsequently respond. Looking ahead and spot problem scores require a bit more complex attention, processing, and responding on the part of drivers. However, these processes are not as complex as scanning, in which all stimuli in the environment must be considered. Other reasons why IOR scores may not have significantly predicted looking ahead, safe distance and spotting the problem are discussed below.

There are a number of limitations to the study that may have affected the results in ways that are difficult to predict. Primarily, there was only one evaluator for the driving tests. Because the driving evaluator had 10 years experience, it is likely that the intrarater reliability would be sufficient. However, it is unclear whether or not the driving results for the participants would have been the same if there were different driving evaluators. Therefore, it is unclear if the fact that there was only one driving evaluator affected the driving evaluation scores. Future research should include a few evaluators simply to ensure that the interrater reliability is sufficient.

Another issue that should be considered in similar subsequent research is the use of dynamic displays in addition to static ones. This study only used static displays. Moving displays would add rich information, especially with respect to driving. Because the driving environment involves many stimuli that are constantly moving, this information would possibly be able to help understand safe driving better.

One of the reasons a larger correlation was not found between IOR scores and driving evaluations and psychological test scores may have to do with the population sampled. Overall, the psychological test scores were average to high for the individuals who participated in the study. None of the participants showed any significant cognitive deficits. For example, on the Mini Mental State Examination, participants scored between 24 and 30 out of a possible 30. However, these criteria were required to be met for the individuals to be eligible to participate in the study. Therefore, because all of the participants in this study scored high in cognitive functioning, the associations between this psychological tests and IOR and the driving evaluations may have been underestimated. Future research in this area should consider this range restriction. It is important to include individuals with a wide range of cognitive abilities, from those with severe cognitive deficits to those with virtually no cognitive deficits. This may give a more accurate picture of the associations between psychological tests and IOR scores and driving scores.

Similarly, all participants scored relatively high on the driving evaluations. Again, the associations between driving evaluations, IOR scores, and psychological test scores may have been underestimated because of this range restriction. Researchers in this area should include drivers with a wide range of driving abilities, from drivers with very low driving evaluation scores to those with very high driving evaluation scores. Associations between driving evaluation scores, IOR scores, and psychological test scores may then be greater.

Another limitation to this study was that the order of testing was the same for all of the participants. All of the participants completed the psychological testing and driving evaluations at least 1 year prior to the current study. It is unknown if the results may have been different if the order in which the psychological tests, the driving evaluations, and the IOR task were counterbalanced. Also, because the psychological testing and driving evaluations were completed at least a year prior to the IOR task, it is unclear whether or not the participants scores on the driving evaluations and on the psychological would be exactly the same. It is possible that individuals' scores on the psychological tests and on the driving evaluations may be lower than the previous year. When conducting further research in this area, researchers should ensure that tasks and/or tests completed should be counterbalanced and the tasks and/or tests not have so much time in between them.

Another aspect that may have affected the results is the fact that only the elderly participants completed the psychological tests and driving evaluations. The younger participants did not complete these previous parts of the study. This information may have proved very important for comparison purposes.

Additionally, a further limitation of the study is that not all the participants who participated in the first study were involved in the second study. Forty-seven of the original 65 original participants also participated in the second study. The individuals who did not participant did not for a number of reasons including not being able to be contacted, not interested in participating, or illness. It is unclear if there are any significant differences between those individuals who participated in the second study and those who did not.

Although there were limitations of the present study, it is the first study looking at the relationship between IOR and safe driving in the elderly. It found that younger and older adults differ in the IOR they possess, specifically with object-based IOR. It also found that IOR is related to the safe driving of elderly drivers. Additional research should be conducted to further examine the issue of IOR and safe driving. Subsequent research should include individuals with a broader range of driving abilities and cognitive abilities and the tests completed should be counterbalanced. If IOR proves to provide valuable information about elderly individuals' driving abilities, it may be useful to include it in future screening examinations.

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APPENDIX A

INFORMATION LETTER

Visual Attention and Driving

Dear Participant:

We are conducting a series of experiments looking at the role of visual attention in driving. The goal of this research project is to gain more understanding about how people allocate attention to objects and locations in their visual field, and how these processes are related to driving.

As a participant, you will be required to react to a visual display presented on a computer monitor by pressing a key on the keyboard. You will be required to complete between 200 and 600 trials. It will take approximately 20 to 45 minutes to complete a testing session. These data would then be linked to your data from our previous study on driver re-training.

The data collected will be kept strictly confidential. Your performance will be coded by an assigned subject number insuring anonymity and confidentiality. The data will be stored in the Department of Psychology at Lakehead University for a period of seven years. You may obtain a summary of the findings from the researchers upon completion of the study.

Participation in this experiment is of a volunteer nature and participants may withdraw at any time during the experiment. There is no danger of physical or psychological harm (other than that normally encountered when working on a computer for 20 to 45 minutes) associated with participation in this experiment. If you require additional information please do not hesitate to contact one of the researchers.

Sincerely,

Michel Bédard, PhD
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CONSENT FORM

My signature on this form indicates that I agree to participate as a participant in the research project of Dr. Michel Bédard and Dr. Jim E. McAuliffe at Lakehead University, on **Visual Attention and Driving**. I understand that my participation in this study is conditional on the following:

1. I have read the cover letter and have had the study explained to me.
2. I fully understand what I will be required to do as a participant in the study.
3. I am a volunteer participant and may withdraw from the study at any time without any reprisal.
4. There are no physical or psychological risks associated with participation in this study. The physical risk will be the same as that of working with a personal computer for 20 minutes to 45 minutes.
5. My data will be confidential and stored in the Department of Psychology for a period of seven years.
6. I will receive a summary of the project, upon request, following the completion of the project.

I agree to participate in the study

____

Signature of Participant Date

I agree to have my data linked with data from the previous study

____

Signature of Participant Date

I wish to obtain a summary of the findings: Yes No

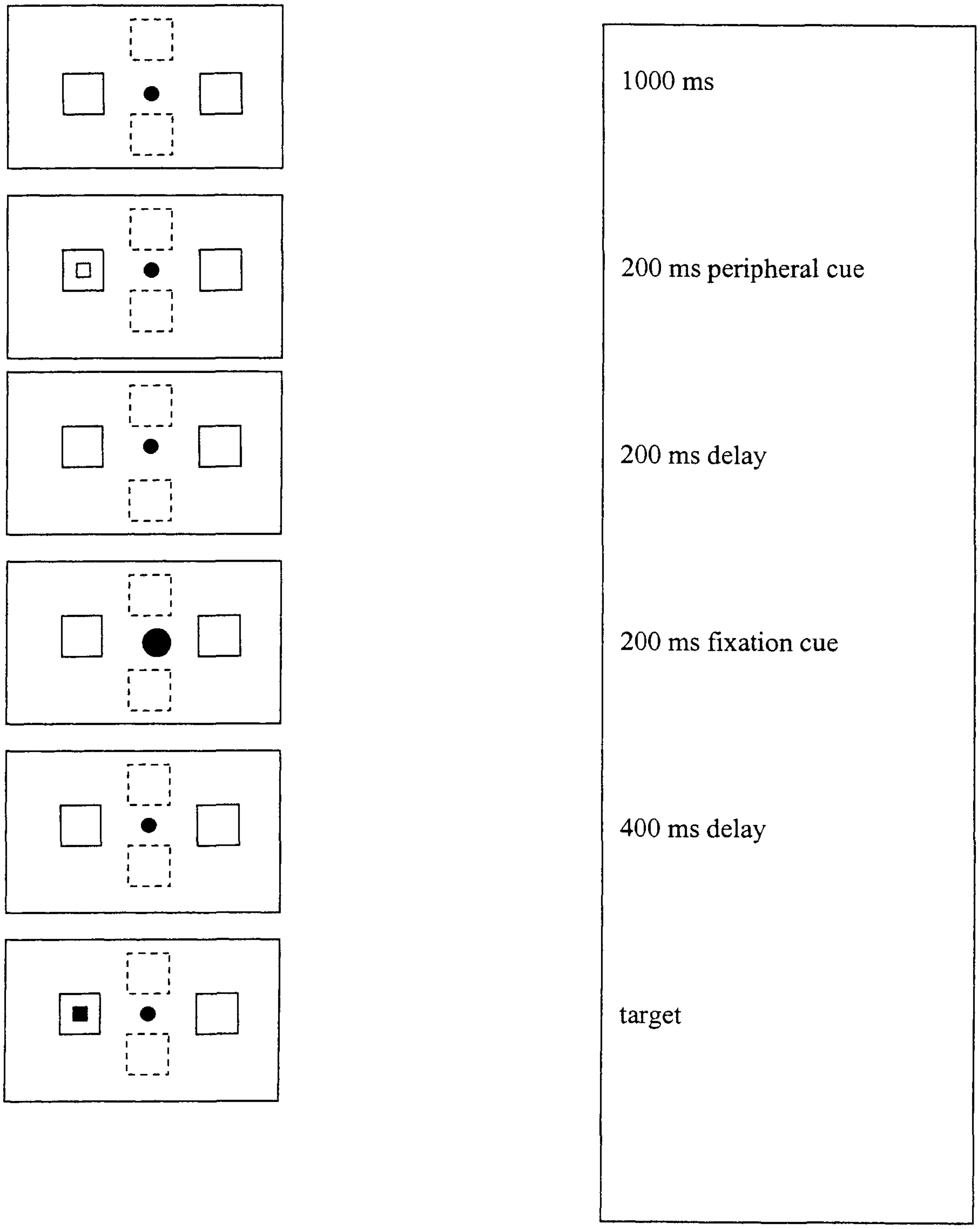
Address: ________________________

____

____

Signature of Witness Date

APPENDIX B



A basic inhibition of return trial. Individuals are instructed to respond when they see the filled in square appear. The dotted boxes represent where placeholders boxes may equally likely appear.