FACILITATING ATTENTIONAL GUIDANCE IN DRIVING SCENES: ADULT AGE DIFFERENCES IN THE EFFECTIVENESS OF DIRECTIONAL CUES

A Dissertation
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

Dustin Michael Elliott

In Partial Fulfillment of the Requirements
for the Degree of
DOCTOR OF PHILOSOPHY

Major Department:
Psychology

August 2017

Fargo, North Dakota

North Dakota State University
Graduate School

Title

Facilitating Attentional Guidance in Driving Scenes: Adult Age Differences in the Effectiveness of Directional Cues

By

Dustin Michael Elliott

The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

DOCTOR OF PHILOSOPHY

SUPERVISORY COMMITTEE:

Linda K. Langley, PhD.
Chair

Jeffrey Johnson, PhD.

Leah Irish, PhD.

Melissa O'Connor, PhD.

Approved:

November 22, 2017	Mark Nawrot, PhD.
Date	Department Chair

ABSTRACT

Aging negatively impacts multiple processes of visual attention that can influence driving performance and safety. However, spatial orienting in response to visual cues remains relatively intact into late adulthood. The two experiments in the present study were aimed to determine the extent to which two types of directional visual cues effectively guide spatial orienting of older (60-80 years) and younger (18-35 years) adults in driving scenes. In Experiment 1, I utilized a Posner cuing task to investigate reflexive orienting to a target (a car at an intersection) in response to peripheral onset and central arrow cues. Both younger and older adults showed orienting benefits to valid directional cues and costs to invalid directional cues, and older adults showed greater attentional costs and benefits than younger adults. Furthermore, only younger adults showed general alerting effects following non-directional cues. In Experiment 2, I tested whether peripheral onset cues could effectively orient younger and older adults' attention to a car's location in video clips of simulated driving. Both age groups showed attentional benefits and costs from directional cues as well as alerting effects from neutral cues. Older adults showed larger overall cuing effects, which were driven primarily by costs from invalid cues. The age differences in the magnitude of cuing effects persisted, for the most part, after reducing the influence of general slowing. The two experiments of the present study demonstrated the effectiveness of visual cues in guiding attention in driving scenes. The findings suggest that the visual attention of both younger and older adults can be facilitated by visual cues in a driving environment, and the findings serve as a stepping-stone to the applied integration of cues into automobiles.

ACKNOWLEDGEMENTS

I wish to extend my appreciation to the chair of my committee, Dr. Linda Langley, for her mentorship and guidance. A graduate student's advisor is imperative to development within an academic program, and I was fortunate to have Linda by my side throughout this process. I would also like to thank the other members of my committee, Dr. Jeff Johnson, Dr. Leah Irish, and Dr. Melissa O'Connor for their contributions to this project, and for their extremely helpful suggestions and input along the way. I am also greatly appreciative to Asenath Arauza and the undergraduate research assistants in the Cognitive Aging Lab for their help with data collection and participant scheduling. Finally, I am forever grateful to my wife Michaela who has remained supportive of all my academic endeavors.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

Age Differences in Driving Behaviors

The number of drivers aged 65 years and older in the United States is steadily increasing (Lyman, Ferguson, Braver, & Williams, 2002). As a group, older drivers demonstrate a desire for safe driving by avoiding certain behaviors such as driving during bad weather (CDC, 2014), speeding and driving while intoxicated or fatigued (Hanson & Hildebrand, 2011; McGwin & Brown, 1999), and using cell phones (Charlton, Catchlove, Scully, Koppel, & Newstead, 2013). While their safe driving behaviors and accrued driving experience should arguably be associated with fewer accidents, researchers consistently find a U-shaped distribution of crash rates when plotted as a function of age (Li, Braver, & Chen, 2003; Lyman et al., 2002). For example, McGwin and Brown (1999) looked at crashes per distance traveled and found that rates were highest for drivers 15-24 years old, decreased sharply until approximately age 35, remained relatively low until 65, and then began to steadily rise so that the crash risk of the oldest drivers rivaled that of teenagers.

When investigating accidents of older drivers, several trends emerge. Older drivers are more likely than other age groups to be at-fault, to be involved in intersection collisions, and to fail to yield the right-of-way to other vehicles (McGwin & Brown, 1999). Furthermore, the two most likely causes of collisions are inaccurately estimating the distance of approaching vehicles and failing to see other vehicles (Braitman, Kirley, Ferguson, & Chaudhary, 2007).

Age-Related Visual and Cognitive Changes that Impact Driving

What are the cognitive and sensory factors that contribute to the judgment and perceptual errors of older drivers? Potential candidates due to age-related decline are vision (e.g., Anstey, Wood, Lord, & Walker, 2005), working memory (Bopp & Verhaghen, 2005; Craik & Anderson, 1999; Hale, Rose, Myerson et al., 2011), and processing speed (Salthouse, 1996). There is only a weak (Hills & Berg, 1977; Marottoli, Cooney, Wagner, Doucette & Tinetti, 1994) or non-existent (Higgins, Wood, & Tait, 1998; Lamble, Summala, & Hyvarinen, 2002; Owsley, McGwin, & Ball, 1998) relationship between visual acuity and vehicular crash rates among licensed drivers, regardless of age. There is some evidence that working memory is associated with driving errors. For example, situational awareness is diminished when drivers simultaneously perform working memory tasks (Johannsdottir & Herdman, 2010), and older drivers with an accident history perform poorer on working memory tasks (Daigneault, Joly, & Frigon, 2002). Similarly, findings support a relationship between processing speed and driving performance. For example, Shanmugaratnman, Kass, and Arruda (2010) found that processing speed negatively correlated with driving simulator collision rates, and others have shown that processing speed training improved certain aspects of older adults' simulator driving performance (Roenker, Cissell, Ball, Wadley, & Edwards, 2003). However, Owsley et al. (1998) found that processing speed was not a significant predictor of on-road crash rates among drivers aged 55 to 87 years. To summarize, evidence indicates that working memory and processing speed are both associated with driving performance, and the extent that age-related declines in these processes contribute to crash risk requires continued examination. Next I will consider the contributions of attention.

Attention, Driving, and Aging

Age-related declines in attention are well documented. Within the visuospatial domain, older adults typically struggle with tasks that involve finding a target in a cluttered visual array such as visual search (Madden & Whiting, 2004; Potter, Grealy, Elliott & Andres, 2012; Trick & Enns, 1998) and useful field of view (UFOV; Edwards et al., 2006). Researchers have emphasized that decline is due to reduced efficiency in extracting relevant information (Cosman, Lees, Lee, Rizzo, & Vecera, 2012; Sekuler, Bennett & Mamelak, 2000) and to delayed attentional disengagement (Cosman et al., 2012) more so than to a decline in peripheral vision or processing speed (Verhaeghen & Cerella, 2002).

Older adults' scores on the UFOV task predict crash risk. A typical UFOV task evaluates the amount of visual information that can be attended to in brief periods of time using subtests that involve attending to centrally- and peripherally-located information in the presence of visual clutter (e.g., identify the location of a car from an array of triangles; Ball & Owsley, 1993; Owsley et al., 1998). Ball, Owsley, Sloane, Roenker, and Bruni (1993) found that individuals with low UFOV scores were more than twice as likely to have been involved in an at-fault automobile crash. In a meta-analysis, Clay and colleagues (2005) found that UFOV scores predicted older adults' driving performance as measured with actual crash records, on-road driving (e.g., peripheral awareness, reaction time and obeying traffic laws), and driving in a simulator (e.g., collision rates and reaction time tasks). Other research findings have substantiated the predictive nature of visual attention on driving performance (e.g., Bowers et al., 2013; Owsley et al., 1998). Taken together, these findings suggest that as one's aptitude to efficiently process spatial information via visual attention weakens, the ability to safely operate a motor vehicle is negatively affected.

Cuing, Reflexive Orienting, and Aging

One way to effectively enhance attentional guidance is via a visual cue, which is an item that draws attention to a specific location or feature. Posner (1980) suggested two distinct types of spatial cues, peripheral and central, that guide attention in different ways. Peripheral cues appear outside of foveal vision, and their abrupt onset (e.g., a bright flash of light) reflexively draws attention to them. Central cues appear central to foveal vision and the cue's symbolic meaning (e.g., an arrow pointing in a particular direction) guides attention to a spatial location. In both cases, cuing effects are reflected in faster RTs to targets presented at validly cued locations, compared to invalidly cued locations. Example task sequences for these two cue types can be seen in Figure 1.

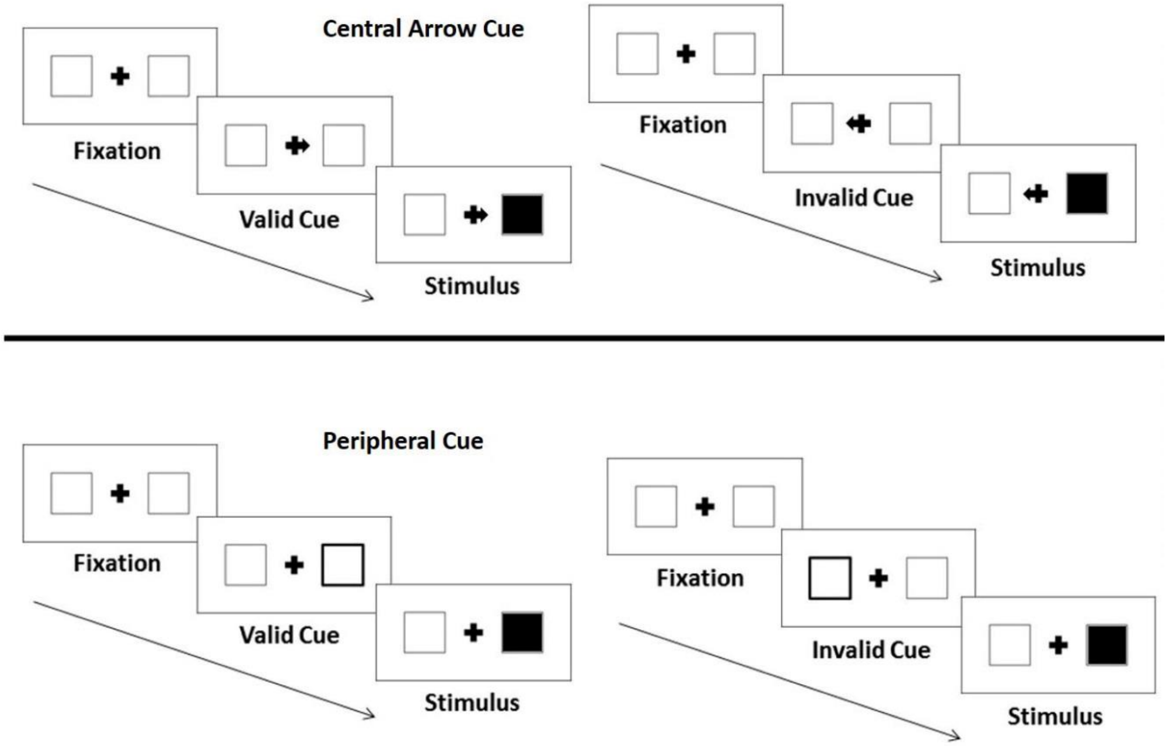

Figure 1. Example sequence of central and peripheral cuing paradigms.

Traditionally, peripheral and central cues were used to signify reflexive (i.e., exogenous) and volitional (i.e., endogenous) attentional shifting, respectively (Dennis et al., 2005; Tipples & Sharma, 2000). When a peripheral cue abruptly appeared, orienting toward its location was immediate and unavoidable (utilizing bottom-up processing). With central cues, the assumption was that the observer first needed to interpret the symbolic meaning of the cue, then voluntarily shift their attention to the indicated location (requiring top-down processing). Thus, the orienting benefit of a central cue would only be observed with sufficient time between the cue and target, as interpretation of the meaning of the cue was required. Volitional orienting also required expectation of some type of pay-off, meaning the observer believed that the cue offered valid location information (i.e., the cue was predictive of the target's location); otherwise, the cue's spatial meaning may be ignored. This characteristic was not true of peripheral cues, as the attentional shift was automatic and difficult to interrupt.

Although this traditional understanding of cues and the type of orienting they elicited certainly helped to propel the orienting literature, subsequent research showed that some central cues could rapidly shift attention in a reflexive manner, much like peripheral cues did (Tipples, 2002). In younger adults, nonpredictive centrally presented arrow cues and gaze cues elicited reflexive attentional orienting, likely due to inherent or well learned associations with those symbols (Friesen & Kingstone, 1998; Hommel, Pratt, Colzato, & Godjin, 2001; Kingstone, Smilek, Ristic, Friesen, & Eastwood, 2003; Ristic, Friesen & Kingstone, 2002). Presently, both peripheral onset and centrally presented arrow cues are thought to reflexively guide visual attention when cues are not predictive (50% valid, 50% invalid) and are presented at relatively short (< 300 ms) stimulus onset asynchronies (SOAs; Olk & Kingstone, 2015).

Researchers have investigated the influence of aging on nonpredictive peripheral cues. For example, Folk and Hoyer (1992) found that both younger and older adults were able to benefit from nonpredictive peripheral cues by showing faster RTs to validly cued locations. These findings have since been extensively replicated (e.g., Hartley & Kieley, 1995; Tales, Muir, Bayer, & Snowden, 2002). Some researchers have even reported significantly larger cuing effects for older adults when using nonpredictive peripheral cues (Lincourt, Folk, & Hoyer, 1997).

Langley, Friesen, Saville, and Ciernia (2011) studied uninformative centrally presented arrows and peripherally presented onset cues in three age groups: younger (18-30 years), young-old (60-74 years), and old-old (75 years and older) adults. When the cue remained present as the target was presented (Experiment 1), all three age groups showed significant cuing effects (faster responses to validly cued than to invalidly cued targets) at 100 ms post cue-onset for both peripheral onset and central arrow cues. This indicated that peripheral cues and centrally located arrow cues oriented attention in a reflexive manner for all ages. What is also of interest is that both older adult groups demonstrated cuing effects for longer durations of time compared to younger adults (out to a SOA of 300 ms). Further testing with limited-duration cues (Experiment 2; 100 ms) suggested that extended cuing effects on the part of older adults were due to slower attentional disengagement from persistent cues. In other words, when the cue was removed to allow easier disengagement from the cued location, age differences diminished (and even disappeared between the younger and young-old age groups).

Explanations for the age-related differences in cue-directed orienting (e.g., differences in the timing and magnitude of cuing effects) in the studies above come from the attentional control settings (ACS) theory. This theory proposes that a person must selectively tune their “attentional control settings” to specific features of stimuli necessary to complete a task (e.g., the abrupt onset of an item). When events occur with properties that match those settings, the person’s attention will automatically shift to the location of the event, increasing the likelihood of task success (Folk, Remington & Johnston, 1992). If the task is difficult, more attentional resources are needed to complete it (Klein, 2000). For example, tasks which require target processing (e.g., discriminating a target’s identity or location) are more difficult than simple detection tasks (responding when a target is detected). Therefore, target localization tasks likely illicit additional attentional resources. Because attentional control settings cannot be quickly readjusted, these additional resources not only increase the processing of the target itself, but also of the cue when it occurs in close temporal proximity to the target (Klein, 2000).

As target processing becomes more difficult with age, more attentional resources (i.e., higher attentional control settings) are required to complete a task. These higher settings cause older adults to process cues and targets with greater attention, which leads to disengagement delays away from the cued location (Klein, 2005). Langley et al. (2011) found that older adults showed stronger and longer-lasting cuing effects and delayed disengagement from cues, consistent with an ACS explanation that older adults used higher attentional control settings than younger adults, which lead to enhanced processing of the cues.

Benefits and Costs of Cued Reflexive Orienting

Visual cues are useful for more than orienting attention to spatial locations. Cues can serve as a temporal warning signal of the appearance of a relevant stimulus. The alerting potential of visual cues can be investigated using modifications to the cuing paradigm. Comparing a directionally-neutral cue condition with a no-cue condition measures the attentional benefits (i.e., alerting effects) of temporally, but not spatially, predictive cues (e.g., Green, Gamble & Woldorff, 2013; Posner, 1980; Ristic & Kingstone, 2012). For example, using younger adult participants, Green and Woldorff (2012; Experiment 2) retained the typical valid and invalid arrow cues and added a neutral arrow cue condition, in which the arrow was double sided (i.e., pointed both left and right). The neutral cue allowed the researchers to determine if the cuing effects (faster responses to validly cued targets than to invalidly cued targets) were due to attentional benefits from orienting towards the valid cues (neutral condition minus valid condition reaction times; RTs), attentional costs associated with disengaging from the invalid cues to shift attention to the target (invalid condition minus neutral condition RTs), or a combination of both (overall cuing effects).

Green and Woldorff (2012) found that when the cue-target SOA was short (100 ms) and the cue and target remained on the screen until the behavioral response, cuing effects were primarily driven by the costs of the invalid cues as opposed to benefits from the valid cues. Their explanation of this finding was that, when presented together in invalid conditions, the cue and target contained conflicting information which interfered with stimulus processing. They argued that the central arrow cues served to introduce conflict rather than to guide spatial attention, and that the arrow cues' contribution to reflexive orienting may not be as strong as that of peripheral cues. However, their cues were 80% predictive of target location, and therefore likely invoked both reflexive and volitional orienting processes (Ristic & Kingstone, 2006).

In a follow-up study, Green, Gamble, and Woldorff (2013) aimed to further determine if cuing effects from central arrow and gaze cues were due to conflicting information from the cue and target, or reflexive attentional orienting. They again utilized a double neutral cue to tease apart cuing effects, but unlike Green and Woldorff (2012), the central cues were nonpredictive of target location. They found that both types of central cues showed significant cuing effects at short SOAs (e.g., 100 ms), but further analyses again revealed that these effects were driven by costs to invalid cues. Neither central cue type elicited significant benefits from valid cues.

Importantly, at the time of this write-up, no studies could be located that investigated the age-related benefits and costs of uninformative peripheral and arrow cues, so the particular nature of the influence of aging on these specific cuing effects are not yet known. This lack of evidence was recently noted by Erel and Levy (2016) in their review of orienting and aging.

Alerting, Aging, and Cues

Researchers have used temporally predictive cues to determine the impact that age-related attentional changes have on alerting effects, and the findings typically show age-related decline. Festa-Martino, Ott, & Heindel (2004) used a cuing paradigm where the neutral cue consisted of the simultaneous bolding of two boxes flanking a central fixation point, before the appearance of the target within one of the boxes. At a SOA of 100 ms, both younger and older adults showed altering effects, but the older adult's alerting effects were significantly smaller. Other researchers who have used brief cue durations (100 ms) with the Attention Network Task (ANT; Fan, McCandliss, Sommer, Raz, & Posner, 2002) to study age-related changes in alerting have also found weaker effects for older adults (Jennings, Dagenbach, Engle and Funke, 2007; Gamboz, Zamarian, & Cavallero, 2010), or a complete absence of altering effects for older adults (Kaufman, Sozda, Dotson, and Perlstein, 2016).

Fernandez-Duque and Black (2006) used a modified version of the ANT with a cue duration of 500 ms before target presentation. They found larger alerting effects for older adults. Thus, alerting cues may elicit effects in older adults, but only under certain conditions, such as when they are longer in duration. Further studies are needed to determine age patterns in alerting.

Present Study

The goal of the introduction was to highlight a set of interconnected findings. First, older adults have a higher relative crash risk due to age-related declines in visual attention. Visual cues in the environment are able to draw visual attention in different ways. Abrupt onset peripheral cues reflexively draw attention, while symbolic cues presented centrally typically guide attention volitionally. Some cues are unique, such as centrally presented arrow cues, because they elicit reflexive guiding of attention likely due to inherent or well-learned directional information associated with the cues' common real-world uses. The reflexive nature of these cues appears to remain stable into older adulthood, though older adults often show larger cuing effects due to higher attentional control settings for processing cues and targets. Furthermore, the cuing effects of central arrow cues may be due to attentional costs of invalid cues and not actually benefits of valid cues. Lastly, studies indicate that both younger and older adults are able to use temporally predictive cues, although age patterns in alerting effects are unclear.

These studies provide evidence that certain spatial cues are successful at rapidly and reflexively drawing the attention of both younger and older adults, and can potentially help compensate age-related attentional deficits. Consequently, these cues may have potential for integration into automobiles, guiding the visual attention of drivers to relevant stimuli and aiding in the detection of hazardous obstacles.

The two experiments of this dissertation aim to provide additional clarification of the cuing and orienting patterns seen in younger and older adults. They also aim to determine if these cuing patterns translate to a design that could potentially lead to the integration of these cues into real-world driving situations. In Experiment 1, I wanted to determine if reflexive orienting to peripheral and central arrow cues occurs using driving related stimuli. I also wanted to determine if younger and older adults showed different cuing effects overall, and what the precise nature of those effects were (i.e., costs and benefits).

Several studies have shown that cuing effects to nonpredictive cues are similar for younger and older adults (Folk & Hoyer, 1992; Hartley & Kieley, 1995; Tales et al., 2002) and in some cases, even stronger for older adults (Langley et al., 2011; Lincourt et al., 1997). However, it is not known if these effects are due to the costs of invalid cues, the benefits of valid cues, or both (Erel & Levy, 2016). I predicted that both age groups would show cuing effects to both cue types, but that older adults would show larger cuing effects overall, due to larger benefits and costs. Because the processing of the target increases in difficulty with age, the older adults will utilize higher attentional control settings which will lead to increased processing of the targets and cues. This heightened processing will increase the amount of attentional resources allocated to the cues, which will cause enhanced processing of valid cues leading to faster detection, and a delayed disengagement from invalid cues (Klein, 2005).

I also predicted that older adults would not be able to utilize temporally predictive neutral cues as much as young adults because of the short SOAs between cues and targets. Evidence suggests that younger adults experience stronger alerting effects when neutral cues are presented at brief SOAs (100 ms; e.g., Jennings et al., 2007), but older adults show strong alerting effects at longer SOAs (500 ms; Fernandez-Duque & Black, 2006). To date, no study has attempted to apply the ACS theory to these findings. It could be that, because older adults' settings are already high due to their perceived difficulty with the task (Klein, 2005), neutral cues presented at brief SOAs do not allow adequate time for older adults to apply the temporally predictive information. In other words, a temporally predictive cue would act as a warning that a target presentation is imminent. Younger adults are able to use this information to quickly increase attentional resources, speeding their detection of the target. Because older adult's setting are already relatively high, it is difficult to further increase them based on the information from the neutral cue. However, with enough time between the cue and target (i.e., longer SOAs), older adults can adjust their settings to make use of the temporally predictive information because their attention may have waned from the cue by that point. In all, the alerting analyses in the present study were more exploratory in nature, and it is possible that the ACS theory does not directly apply to temporal cuing.

Experiment 2 aimed to test the effectiveness of the peripheral cues used in Experiment 1 at guiding visual attention in dynamic simulated driving scenes. Several studies have shown that visual attention decline in old age is associated with heightened crash risk (Ball et al., 1993; Bowers et al., 2013; Clay et al., 2005; Owsley et al., 1998). If visual cues can facilitate perceptual judgements in a setting where stimuli are constantly moving, then these cues may be effective at helping drivers detect other automobiles pertinent to safe roadway navigation. For Experiment 2, I predicted that similar cuing effects found in the first experiment would occur; the reflexive properties of peripheral cues would remain intact in a dynamic setting.

CHAPTER 2: EXPERIMENT 1

In Experiment 1, I investigated age differences in the spatial orienting properties of visual cues in a driving scene. Younger and older adults viewed an illustrated four-way intersection on a computer screen from the perspective of a driver approaching the intersection. The participants indicated in which half of the visual display a target car appeared, left or right. A peripheral onset cue or a central arrow cue preceded the target vehicle. The cues were not predictive (i.e., did not indicate the more likely location of the target).

I chose to look at two cue types because I wanted to know their relative effectiveness in directing spatial attention in a driving scenario. More importantly, I wanted to learn how older adults would respond to the two types of cues. If both cues guided attention in a similar fashion, the potential for flexible cue selection as implemented in automotive technology could be increased. Past research has established that both peripheral onset cues and central arrow cues elicit reflexive orienting of attention (e.g., Olk & Kingstone, 2015). Langley et al. (2011) found that the magnitude of younger adults' cuing effects was similar for peripheral and central cues, whereas older adults showed larger cuing effects for peripheral than central cues.

To optimize the orienting potential of cues, for the present experiment I selected stimulus and task parameters that were associated with robust orienting in Langley et al. (2011). They found that cue effects (valid RT < invalid RT) were maximized (a) when the cue remained present until the participant responded to the target, and (b) at cue-target SOAs of 100 and 300 ms (from SOAs of 100, 300, 600, and 1,000 ms). Thus, I presented cues and targets overlapping temporally with a cue-target SOA of 150 ms.

The peripheral cue consisted of an unfilled box that outlined the left side, right side, or both sides (neutral) of the display. The arrow cue, presented in the center of the intersection, pointed to the left arm, right arm, or both arms of the intersection. The peripheral and arrow cues were intended to provide the same relative spatial information (i.e., right or left side of the display). The peripheral cue was larger in size than what is typically used in orienting experiments (encompassing a side of the display rather than a specific potential target location) to accommodate the unknown vertical position of the target in Experiment 2. To anticipate the effectiveness of such a cue, I wanted to determine if the relatively larger peripheral cue would guide spatial attention in a static display in which the vertical position of the target was fixed. Findings by Greenwood and Parasuraman (1999) suggest that cue size may impact visual search efficiency, with larger cues (encompassing more items in a search display) leading to reduced search benefits, particularly for older adults. However, given the present task conditions of a single target item presented at a relatively stable location, I expected that a larger peripheral cue would be effective in capturing attention.

The directional properties of the peripheral onset and central arrow cues were of four types: valid, invalid, neutral, and no cue. A valid cue accurately indicated the left or right location of the upcoming target. An invalid cue indicated the wrong location of the target (e.g., the cue pointed toward or was presented on the left side of the screen, and the target was presented on the right side of the screen). The neutral cue indicated both sides of the display simultaneously and served only as a temporal predictor of the target, and the no cue condition presented the target without a preceding cue. By comparing these conditions, I was able to assess age differences in specific orienting and alerting functions: cuing effects (invalid minus valid), benefits (neutral minus valid), costs (invalid minus neutral), and alerting (no cue minus neutral).

I predicted that both younger and older adults would show cuing effects to arrow and peripheral cues, contributing to evidence that these cues are effective in reflexively guiding attention (Langley et al., 2011). Initial findings suggest that reflexive orienting is retained in older adulthood (Folk & Hoyer, 1992; Hartley & Kieley, 1995; Langley et al., 2011; Lincourt et al., 1997; Tales et al., 2002). However, these past studies have not divided cuing effects into benefits of valid cues and costs of invalid cues. In accordance with the ACS theory, I predicted that older adults would have more difficulty than younger adults with the left-right target localization task, and thus would allocate higher attentional control settings to the task. Higher settings would lead to stronger cuing benefits due to the enhanced processing of valid cues, but it would also cause the older adults to be slower to disengage attention from persistent invalid cues due to enhanced processing of those cues (e.g., Cosman et al., 2012; Gayzur et al., 2014; Langley et al., 2011), which would lead to greater attentional costs and larger overall cuing effects.

To determine whether younger and older adults benefited similarly from alerting cues, I compared reaction times in the neutral cue and no cue conditions. Because the neutral cue condition followed the same timing pattern as the valid and invalid cue conditions, it was temporally predictive of target onset although it did not have the same spatial information of the valid and invalid cue conditions. Jennings et al. (2007) found that older adults did not benefit as much as younger adults from a 100 ms temporally predictive cue, but Fernandez-Duque and Black (2006) found an age-related increase in alerting effects for older adults when using cue durations of 500 ms. The discrepancy between the findings of these studies likely illustrates that older adults require more time to benefit from temporally alerting information. Given the cue-target SOA of 150 ms in the present experiment (during which the cue remained present), I predicted that older adults would show smaller alerting effects than younger adults. This age pattern could be considered consistent with the ACS theory. If older adults already have their control settings set high in anticipation of a target, they may benefit less from alerting cues that act to temporarily heighten settings, without providing specific spatial information.

Method

Participants

Twenty-four younger adults (18 yrs - 23 yrs) and twenty-four older adults (60 yrs - 81 yrs) participated in the experiment. Younger adults were recruited from psychology courses at NDSU and were compensated with course credit for their participation. Older adults were recruited from the Fargo, ND and Moorhead, MN areas and received compensation at a rate of $10/hr. All participants had at least a high school education and were fluent in English. Participants had corrected near visual acuity of 20/40 or better according to a Snellen eye chart (Precision Vision, La Salle, IL). Participants were screened via self-report for medical conditions that could impact cognitive functioning (e.g., stroke, heart disease, head injury, dementia, and substance abuse; Christensen et al., 1992) and for depressive symptoms via the Geriatric Depression Scale (GDS; Yesavage et al., 1983). Participants with GDS scores of 10 or higher were excluded. Screening for significant cognitive impairment via the Mini-Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975) resulted in those with scores below 26 being excluded. Four younger adults were tested and removed from the data set due to high GDS scores. Five older adults were removed (three for poor visual acuity and two for low MMSE scores). Their data were replaced with data from new participants. The participant data in Table 1 reflect the data from the final sample.

Table 1

Demographic and Psychometric Data for Participants in Experiments 1 and 2

	Experiment 1				Experiment 2			
	Mean		SD		Mean		SD	
	YA	OA	YA	OA	YA	OA	YA	OA
Age (yrs)	19.3*	71.8	1.2	5.0	25.7*	72.5	4.8	7.0
Education (yrs)	13.6	15.4	0.9	3.1	16.0	15.9	2.2	2.8
WASI vocabulary (80 max)	53.7*	61.6	5.8	8.6	57.4	57.8	7.5	6.7
Snellen acuity (20/___)	16.4*	24.7	3.2	5.8	16.6*	24.7	2.3	7.0
MMSE (30 max)	29.0	29.0	1.1	0.9	29.6	29.0	0.8	1.3
GDS (30 max)	1.5	1.0	2.1	1.7	2.4	1.8	2.5	1.8

Note. SD = standard deviation; YA = younger adult group; OA = older adult group; WASI = Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999). Maximum score on the vocabulary subscale is 80 points, with a higher score indicating better performance. Snellen acuity = denominator of the Snellen fraction for corrected near vision. A smaller number indicates better vision. MMSE = Mini Mental State Examination. Maximum score is 30 points, with a higher score indicating better performance. GDS = Geriatric Depression Scale. Maximum score is 30, with a higher score indicating greater depression. An asterisk (*) indicates that mean scores differed between age groups according to an independent samples t test. Older adults were greater in age, had higher education, and had better vocabulary scores than younger adults. Younger adults had better visual acuity than older adults.

Materials

The task was programmed using Presentation software (Neurobehavioral Systems, Albany, CA). Data were collected on a PC with a Pentium 4 processor and a 17-inch color raster monitor with a refresh rate of 60 Hz. Participant viewing distance was maintained at 40 cm using a mounted chin rest. Participant responses were made on a standard computer keyboard using the left and right arrow keys.

The illustrated display was 32.3° tall × 41.4° wide in visual angle and depicted a simple traffic intersection as viewed by a driver approaching the intersection. The two roads comprising the intersection were a dark grey color. The horizontal road had a consistent width of 7.9° visual angle. The vertical road's width was 14.5° at the bottom of the display and 7.7° at the top. The intersection was surrounded by green (grass), and the center of the intersection was positioned in the center of the viewable display. At the top of the display was a light blue sky with two white clouds. The fixation cross, cues, and targets were presented superimposed onto this static background image.

The fixation cross, the central arrow cue, and the peripheral rectangle cue were orange outlined in black with a thickness of 0.6°. The fixation cross had arms 1.6° long and was presented at the midpoint of the intersection. The central arrow cue was 3.6° wide and 1.3° high with either a single or double arrow head. The peripheral rectangle cue was 27.8° in height and 18.5° in width. The side of the peripheral cue that was closest to the center of the display was 0.6° away from the end of the fixation cross' horizontal arm. The target was a car the same shade of orange as the cues because evidence suggests that RTs are faster to targets that are the same color as the visual cue (Ansorge & Becker, 2014). The car was a nondescript sedan 6.3° in width and 3.2° in height. It was presented on the horizontal road 7.2° from the end of the fixation cross and 7.2° from the edge of the background image. Examples of the conditions and trial timing for the experiment are presented in Figure 2.

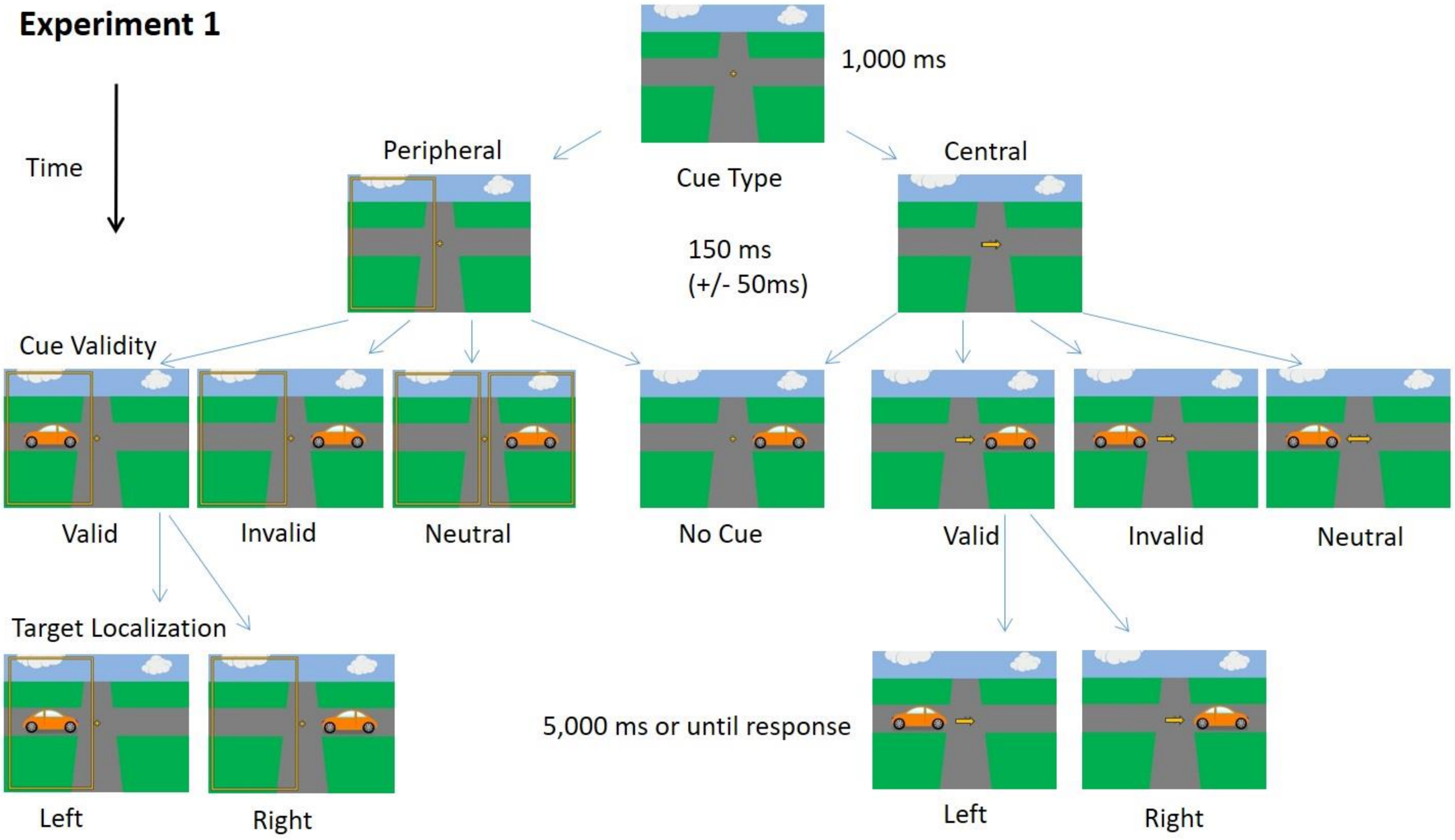

Figure 2. Task sequence and possible combinations of conditions for Experiment 1. Stimuli are not to scale.

Procedure

The study session (consent, screening, and computer task) lasted approximately one and one half hours. The computer task consisted of four blocks of 48 trials for each cue type (peripheral and arrow), for a total of 384 trials. Half the participants completed the peripheral cue trials first and then the arrow cue trials, while the other half completed the task in the reverse order. Before beginning the first testing block, participants were given the task instructions and 8 practice trials.

The experimenter told the participant that the cue was not predictive of target location, and that the cue location, the target location, and the target direction (i.e., which direction the car was facing) were random. Participants were instructed to place their index fingers on the left and right arrow keys and to press a button as quickly as possible to indicate on which side of the intersection the target appeared (left or right), but not to respond so quickly that they made errors. They were also told that whenever the fixation cross appeared (at the beginning of each trial) they should fixate on it. Eye movements were not monitored.

As depicted in Figure 2, each trial began with the fixation display presented for 1,000 ms, followed by a cue appearing (or not appearing on no-cue trials). After a stimulus onset asynchrony (SOA) of 150 ms (jittered +/- 50 ms), during which time the cue remained on the screen, the target (the car) appeared on the left or right side of the intersection. The target remained present until the participant made a location-discrimination response, for a maximum of 5,000 ms. A brief audio tone sounded to indicate errors, which included inaccurate button presses and failures to respond within the time limit. After an inter-trial interval of 1,000 ms, the next trial commenced.

The variables of interest were cue type (peripheral and arrow) and cue validity (valid, invalid, neutral, and no cue). On trials in which the cue was valid, the target appeared on the side indicated by the cue (left or right). On invalid trails, the target appeared on the opposite side. For neutral trials, the cue indicated both sides of the display (i.e., presenting both left and right peripheral cues or the double-headed arrow). For the no-cue trials, the target was not preceded by a cue. There were equal numbers of valid, invalid, neutral, and no-cue trials, and they were randomized within a block. The direction that the car was facing, and the side of the intersection that the cue and car were presented on, were randomly and equally presented throughout the four validity conditions, for a completely balanced design.

Results

Reaction Time Analyses

Mean RTs for correct trials were calculated at the individual level for each combination of cue type and cue condition. RTs which exceeded 2.5 standard deviations from a condition mean were eliminated. The remaining data were submitted to a 2 × 2 × 4 mixed analysis of variance (ANOVA). Age (younger and older) was a between-subjects variable while cue type (peripheral and central) and cue condition (valid, invalid, neutral, and no cue) were within-subjects variables. I conducted Student-Newman-Keuls (SNK) post hoc tests to assess specific cue condition effects. All of the analyses used an alpha level of .05 to indicate significance.

There was a main effect of age, $F(1, 46) = 12.92$, $p = .0008$, with older adults responding more slowly to targets than younger adults (493 ms and 412 ms, respectively). A main effect of cue condition, $F(3, 138) = 117.13$, $p = .0001$, was due to significant differences between all four cue conditions; valid (425 ms), neutral (446 ms), no cue (462 ms), and invalid (477 ms). Cuing patterns reflected overall cuing effects (invalid minus valid), benefits of valid cues (neutral minus valid), costs of invalid cues (invalid minus neutral), and alerting effects of neutral cues (no cue minus neutral), according to post hoc analysis, *p*s < .05. All interactions were significant: age × cue type, *F*(1, 46) = 5.91, *p* = .02, age × cue condition, *F*(3, 138) = 27.83, *p* = .0001, cue type × cue condition, *F*(3, 138) = 7.33, *p* = .0001, and age × cue type × cue condition, *F*(3, 138) = 3.57, *p* = .02.

To explore the interactions, particularly the age × cue type × cue condition interaction, I first conducted one-way ANOVAs on cue condition for each age group and cue type. Main effects of cue condition were significant for all combinations of age group and cue type, all *Fs* > 19.09, all *ps* < .0001. Using SNK post hoc analyses revealed that both age groups showed significant benefits to valid cues and costs to invalid cues, for both cue types. However, only younger adults showed alerting effects, which were significant for both peripheral and central cues. Mean RTs as a function of age group, cue type, and cue condition are provided in Table 2.

I then computed difference scores to reflect the magnitude of cuing effects and submitted these scores to 2 × 2 mixed ANOVAs with age group and cue type as the variables. For overall cuing effects (invalid RT minus valid RT), there was a main effect of age (older adults had larger cuing effects than younger adults), *F*(1, 46) = 9.39, *p* = .004, and of cue type (cuing effects were larger for peripheral cues than for central cues), *F*(1, 46) = 14.15, *p* = .0005, which were modified by an age x cue type interaction, *F*(1, 46) = 6.54, *p* = .01. One-way ANOVAs by age group indicated that older adults had larger cuing effects for peripheral (81 ms) compared to central cues (43 ms) *F*(1, 23) = 13.87, *p* = .0011, and there was no difference in the magnitude of cuing effects between peripheral (46 ms) and central (39 ms) cues for younger adults, *F*(1, 23) = 1.03, *p* = .3207. Comparing the two age groups, there was no age difference in cuing effects for central cues, *F* < 1, but, older adults had significantly stronger cuing effects than younger adults for peripheral cues, *F*(1, 46) = 16.43, *p* = .0002.

When looking at benefits (neutral RT minus valid RT), there was a main effect of age (older adults had larger benefits than younger adults), *F*(1, 46) = 5.42, *p* = .02, which was modified by an age × cue type interaction, *F*(1, 46) = 4.09, *p* = .049. One-way ANOVAs for each age group showed that older adults had larger cuing benefits for peripheral (33 ms) compared to central (18 ms) cues, *F*(1, 23) = 6.52, *p* = .02, whereas younger adults had similar benefits from peripheral (15 ms) and central (19 ms) cues , *F* < 1,. One-way ANOVAs by cue type showed that the age groups did not differ in the magnitude of benefits for central cues, *F* < 1, but older adults had significantly stronger benefits than younger adults for peripheral cues, *F*(1, 46) = 8.46, *p* = .006.

Exploring the attentional costs (invalid RT minus neutral RT), there was a main effect of age, *F*(1, 46) = 5.39, *p* = .03, with older adults demonstrating larger costs compared to younger adults. The main effect of cue type, *F*(1, 46) = 13.12, *p* = .0007, was driven by invalid peripheral cues causing larger costs compared to invalid central cues. The age × cue type interaction was not significant, *F*(1, 46) = 1.62, *p* = .2101.

For alerting effects, a main effect of age, *F*(1, 46) = 41.33, *p* = .0001, showed that younger adults had significantly greater alerting effects compared to older adults. There was a marginal effect of cue type, *F*(1, 46) = 3.78, *p* = .06, and the interaction between age and cue type was not significant, *F*(1, 46) = 1.90, *p* = .1746.

Transformed Reaction Time Analyses

It is possible that age-related slowing not specific to attention processes may have contributed to the observed age differences in validity effects. To minimize the contributions of general slowing, I conducted a second set of analyses on data transformed to add general slowing to the younger adult data (Madden, Pierce, & Allen, 1992; Madden, Whiting, Cabeza, & Huettel, 2004). I performed Brinley plot analyses (Cerella, 1994) using the eight condition means to establish a regression equation that best described the linear relationship between the older and younger adult means. The resulting equations can be found below and were used to transform the younger adult data.

Peripheral Cues   Older RT = 0.72(Younger RT) + 209, $r^2 = .36$

Central Cues   Older RT = 0.53(Younger RT) + 264, $r^2 = .38$

The transformed data were submitted to the same 2 × 2 × 4 mixed ANOVA described above. As anticipated, the main effect of age was no longer significant, $F < 1$. The age × cue validity interaction, $F(3, 138) = 34.68$, $p = .0001$, and the age × cue type × cue validity interaction, $F(3, 138) = 3.56$, $p = .02$, both remained significant.

Of primary importance, I again submitted the difference scores reflecting cuing effects to 2 × 2 ANOVAs. Age differences in cuing effects for both cue types using the transformed difference scores can be found in Figure 3. In the description of the analyses to follow, I emphasized the significance patterns that changed from the untransformed data to the transformed data. For overall cuing effects (invalid minus valid), one change was that younger adults' cuing effects now differed significantly in magnitude by cue type, $F(1, 23) = 7.25$, $p = .01$, with larger cuing effects for peripheral (33 ms) than central cues (21 ms). In addition, one-way ANOVAs for each cue type now revealed significant age differences in overall cuing effects for central cues, $F(1, 46) = 7.34$, $p = .01$, as well as for peripheral cues $F(1, 46) = 39.50$, $p = .0001$. For both cue types, older adults had greater cuing effects compared to younger adults.

When examining benefits (neutral minus valid), the age × cue type interaction in the 2 × 2 ANOVA was no longer significant, *F*(1, 46) = 3.17, *p* = .0817. Older adults continued to have greater benefits than younger adults (25 ms and 10 ms, for older and younger adults, respectively), but the age difference was no longer significantly greater for peripheral cues than for central cues.

Older adults (36 ms) continued to show greater costs (invalid minus neutral) than younger adults, *F*(1, 46) = 25.94, *p* = .0001, and costs continued to be greater for peripheral cues than for central cues, *F*(1, 46) = 19.07, *p* = .0001. The age × cue type interaction was still not significant, *F*(1, 46) = 1.90, *p* = .1752.

Finally, younger adults continued to have greater alerting effects (no cue minus neutral) than older adults, *F*(1, 46) = 31.07, *p* = .0001. Now, the main effect of cue type, *F*(1, 46) = 4.71, *p* = .035 became significant, as alerting effects were more prominent for peripheral cues (15 ms) than for central cues (4 ms).

Error Rates

Error rates for both age groups and both cue types were low (< 3% for younger adults, < 2% for older adults), so no further error analyses were performed. Error rates are presented in Table 2.

Table 2

Mean RTs in ms (SDs in parentheses) and Error Rates for each Cue Type and Cue Validity in Experiment 1

	Peripheral Cues		Central Cues	
	Younger *M (SD)*	Older *M (SD)*	Younger *M (SD)*	Older *M (SD)*
Valid	375 (64)	464 (91)	393 (66)	468 (94)
Neutral	390 (63)	498 (89)	411 (66)	485 (96)
No Cue	436 (82)	496 (102)	438 (82)	480 (89)
Invalid	421 (69)	545 (97)	432 (65)	510 (92)

Error Rates

	Peripheral Cues		Central Cues	
	Younger *M*	Older *M*	Younger *M*	Older *M*
Valid	.003	.003	.003	.008
Neutral	.005	.003	.005	.002
No Cue	.008	.001	.009	.004
Invalid	.02	.013	.028	.016

Note. M = mean; SD = standard deviation; RT = reaction time.

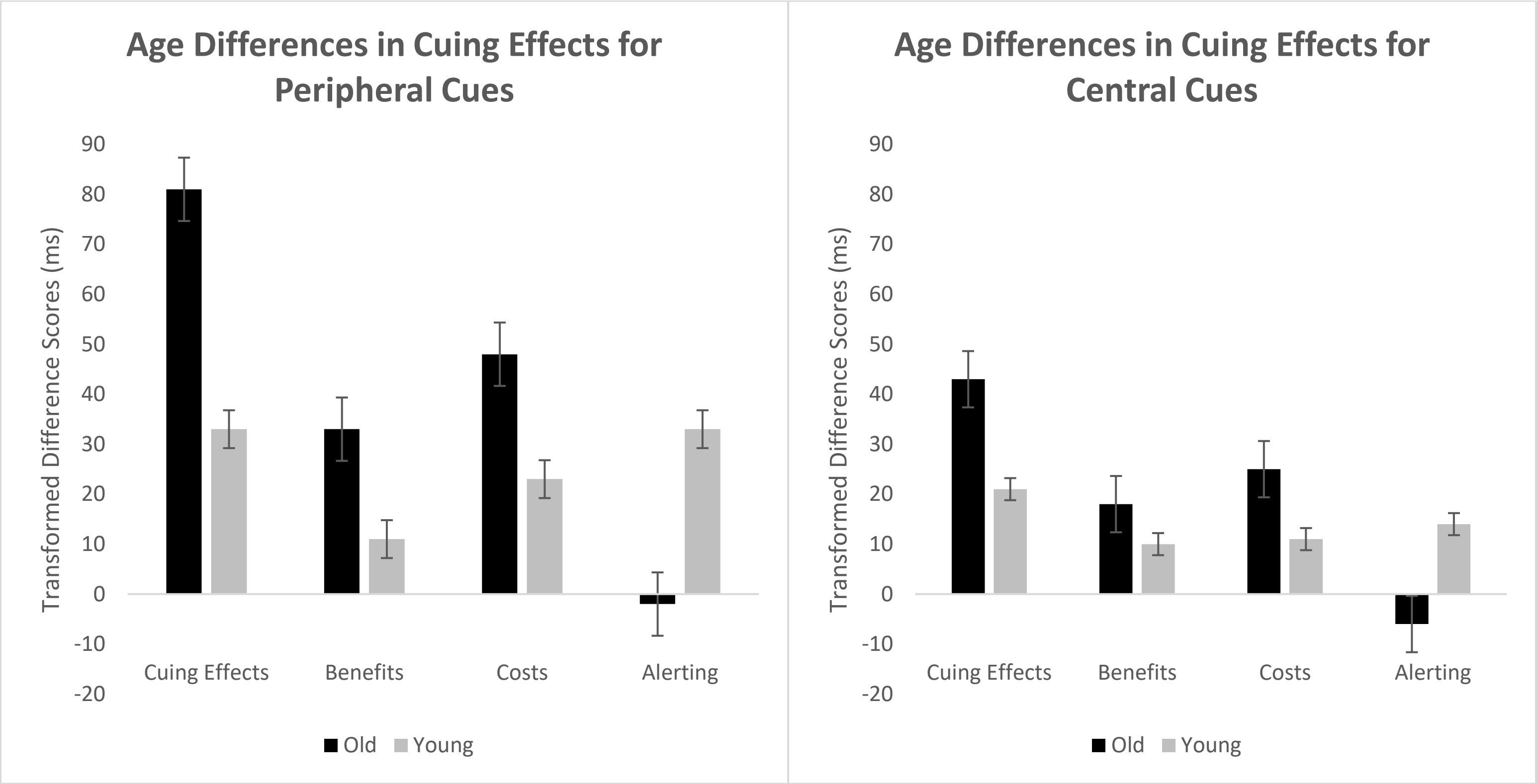

Figure 3. Age differences in cuing effects for both cue types using transformed RTs.

Discussion

Peripheral onset and central arrow cues in Experiment 1 were effective at guiding the visual attention of younger and older adults within a driving scene. Because peripheral cues typically used in Posner orienting paradigms have been small in size and closely overlapped the potential locations of the target, I was uncertain if the gross spatial information provided by the present peripheral cues (highlighting a visual field rather than a potential target location) would be similarly effective (Greenwood & Parasuraman, 1999). However, spatially expansive cues guided the visual attention of both younger and older adults, and in fact, cuing effects were generally greater for peripheral cues than for central cues, for both age groups. Although to date, no other study has directly compared the cuing effects of nonpredictive peripheral and central arrow cues, this finding does have importance regarding the implementation of visual cues into automobiles. The larger cuing effects found for peripheral cues indicates that these cues may uniquely capture attention and enhance orienting toward driving-relevant information (e.g., a car approaching from the side at an intersection). I will address more regarding the cue type differences later in this discussion.

As predicted, both cue types guided attention at short cue-target intervals and without being informative of target location, suggesting that attention was reflexively guided, which agrees with previous findings (Friesen & Kingstone, 1998; Hommel et al., 2001; Kingstone et al., 2003; Langley et al. 2011; Olk & Kingstone, 2015; Ristic et al., 2002). As found by others (Folk & Hoyer, 1992; Hartley & Kieley, 1995; Tales et al., 2002), both age groups showed significant cuing effects, and in agreement with Langley et al. (2011) and Lincourt et al. (1997), there was an age-related increase in cuing effects. I found that older adults had larger cuing effects to peripheral compared to central cues. This was also true for younger adults' cuing effects after their data were transformed to account for age-related slowing. Older adults showed stronger cuing effects compared to younger adults for peripheral cues. In the original analysis, the two age groups did not differ in cuing effects to central cues, but following the data transform, older adults showed stronger cuing effects than younger adults. Thus, the age pattern was consistent across cue type after the slowing transform.

Because I utilized neutral cuing conditions, I was able to parse cuing effects into benefits and costs. As I predicted, I found that both age groups showed cuing benefits, but older adults showed larger benefits compared to younger adults. Though I initially had evidence that older adults only showed larger benefits for peripheral cues, after the general slowing data transformation, older adults showed larger benefits for both cue types, as predicted. Both groups also showed costs (slower RTs to a target following a cue that provided invalid spatial information than to a target following a cue that provided imprecise (i.e., cued both left and right locations) spatial information). Like benefits, older adults showed greater costs than their younger counterparts, for both cue types.

The age differences in cuing patterns were consistent with the ACS theory (Folk, Remington & Johnston, 1992). With this application of the theory, attentional control settings were set higher for older adults because they found the target localization task more difficult than younger adults (Klein, 2000; Klein, 2005; Langley et. al., 2011). The control settings influenced processing of the cues as well as the targets. Thus, enhanced cue processing led to greater benefits from valid cues and greater costs for (i.e., slower disengagement from) invalid cues for older adults compared to younger adults.

It is worth noting that the current cue patterns supported reflexive orienting of attention in response to central arrow cues. Green and Woldorff (2012) argued that cuing effects for persistent central arrow cues at short SOAs were due to stimulus conflict rather than attentional orienting, as evidenced by costs without benefits. However, I found that central cues, even when persistent and presented at short cue-target SOAs, were associated with both benefits and costs. Moreover, this pattern was found for both younger and older adults. Thus, the current findings support reflexive attentional orienting by central cues as well as by peripheral cues.

As noted above, I found greater costs for peripheral cues compared to central cues, which persisted following the data transformation. This cue type effect may have been due to the orienting context (associated with driving conditions). Alternatively, this pattern may indicate that certain aspects of reflexive orienting differ between the two cue types. Ristic and Kingstone (2012) argued that nonpredictive arrow cues elicit what they termed as *automated symbolic orienting*. They asserted that these cues do not exclusively elicit reflexive nor volitional orienting, but instead elicit a separate form of orienting due to the common behaviorally relevant contexts that arrows are used for in real-life situations. Thus, the differential impact that invalid cues had for the two different cue types may in fact be due to an underlying difference in the orienting properties associated with them.

I predicted that older adults would show smaller alerting effects to neutral cues, based on evidence from Jennings et al. (2007), who found that older adults showed weaker alerting effects at short (100ms) SOAs. In accordance with the findings of Kaufman, Sozda, Dotson, and Perlstein (2016) older adults did not show any alerting effects to either of the cue types. However, younger adults benefited from the temporally predictive cue, and showed alerting effects to both cue types. A possible explanation for the lack of alerting effects for the older adult group comes from the ACS theory of attention. As previously mentioned, as tasks become more difficult to complete in older age, attentional control settings are heightened. This not only leads to enhanced processing of the spatial information provided by cues, but may heighten preparedness for targets. Older adults may not have been able to benefit from the temporal information of neutral cues because they were already highly prepared to respond to targets even in the absence of cues. However, as previously mentioned, the ACS theory may not apply as well to the alerting effects.

Although I did not have a specific hypothesis for this comparison, it is worth noting that for older adults, but not for younger adults, there was a penalty to responding to an invalid cue compared to no cue. In other words, younger adults were faster to localize a target when preceded by an invalid cue, than no cue at all, whereas older adults were faster in no cue conditions than for invalid conditions. This is important when considering the implementation of visual cues into driving environments because it means that valid, invalid, and neutral cues all speeded the RTs of young adults, so all cues could speed their reaction times in driving situations. However, because invalid cues led to slower reaction times compared to no cue conditions for older adults, invalid cuing while driving could potentially cause an accident in this population.

The novel contribution of Experiment 1 was to examine cue effectiveness for orienting and alerting attention to driving-relevant stimuli. Because I found that cues that reflexively guided visual attention were effective at enabling participants to detect (and make a determination about) targets faster, these same cues may be used in driving situations to facilitate the detection of hazards in the roadway (e.g., other vehicles). While evidence was provided for the potential utility of these stimuli, there were several limitations to this experiment that must be considered. First, the experiment examined features of attentional orienting in a static environment, but driving occurs in a dynamic environment. Therefore, it is not known if the cuing effects seen in Experiment 1 would translate to more real-world driving environments. Second, I examined orienting to nonpredictive cues in order to investigate properties of reflexive orienting, but cues as implemented in driving environments are likely to be predictive if they utilize current technology such as proximity warning systems or global positioning systems (GPS) to detect the locations of other vehicles or potential obstacles. Experiment 2 aims to address the first concern.

CHAPTER 3: EXPERIMENT 2

In Experiment 2, I examined whether visual cues guide attention within a dynamic driving scene. The question of interest was whether the orienting patterns observed in Experiment 1 would transfer to a more natural driving environment with its given distractions and continuous change. As in Experiment 1, participants indicated the half of the display in which a target car appeared. The same four types of peripheral cues (valid, invalid, neutral, and no cue) were used to direct attention. In contrast to the static intersection used in Experiment 1, cues in Experiment 2 were presented imposed on simulated driving footage. The footage was shot as from a camera mounted on a dashboard as the car drove through as many as three intersections. The target car appeared at one of the three intersections. My intent for Experiment 2 was to examine the potential of integrating visual cues into vehicle dashboards to enhance attentional guidance of younger and older drivers.

As noted in the introduction, changes in visual attention are associated with the overrepresentation of older adults in auto collisions (Braitman et al., 2007). Some have speculated that attentional decline weakens older drivers' ability to detect road hazards (Kazumi Renge et al., 2005). A typical hazard perception (or detection) task (for a review, see McKenna & Horswill, 1999) consists of a single-screen or video footage (real or simulated) of a driving scene from the driver's perspective. Participants are instructed to respond (e.g., press a button or a brake) when they detect a likely hazard on the roadway (e.g., a car or pedestrian entering their path of travel). Findings reflect age-related declines in hazard perception ability with older adults being significantly slower to detect potential hazards (Horswill, Anstey, Hatherly, & Wood, 2010; Horswill et al., 2008; Horswill et al., 2009; Scialfa et al., 2012). As a result, experimenters have looked at the effectiveness of visual cues to guide older drivers' attention in hazard perception tasks.

Schall et al. (2012) examined hazard detection in a virtual driving environment. As the driver approached a hazard, a box would appear around the hazard. As the hazard moved closer (and its visual angle grew), the cue surrounding it grew in proportion. Though the researchers found that the cues were effective at decreasing older drivers' hazard detection RTs, the technology may not be sufficiently developed to incorporate cues such as these (also see Pomarjanschi, Dorr, & Barth, 2012) into vehicle dashboard displays. The vehicle's computer must not only identify hazard-relevant stimuli (e.g., signs, vehicles, pedestrians) and track their location relative to the driver's vehicle, but also systematically change the cue's location and proportions as the hazard's relation to the driver changes.

In an effort to test the effectiveness of simpler in-vehicle cuing paradigms, Pomarjanschi, Dorr, Bex and Barth (2013) used red LED light strips horizontally mounted at the top and bottom of a simulator vehicle's bezel (the area immediately surrounding the windshield). While driving, LED lights on the left or right ends of the strips would activate (e.g., flash), and the researchers monitored participants' saccades to the sides of the display via an eye tracker. Although driving performance was not assessed, the peripheral LED lights successfully guided the driver's gaze to the cued side of the display, thus demonstrating that peripheral cues can be integrated into vehicles and can guide drivers' overt attention.

With the knowledge that visual cues aid drivers in detecting hazards, my goal for Experiment 2 was to examine age differences in peripheral cue effectiveness in dynamic driving displays. I chose to use peripheral cues only based on the findings from Experiment 1 showing that cuing effects were larger for peripheral cues for both younger and older adults. The broader goal was to consider age factors in the potential implementation of in-vehicle guidance assistance systems. For example, would cues be equally effective in guiding the attention of younger and older adults? Would the cost of an inaccurate or imprecise cue be the same across age groups? Would age patterns in the manner in which cues serve alerting and orienting functions be consistent across dynamic and static driving displays?

As in Experiment 1, I predicted that cues would influence the speed of target localization, with RTs to validly cued targets being faster than RTs to invalidly cued targets (cuing effects; Langley et al, 2011), RTs to validly cued targets being faster than RTs to neutrally cued targets (benefits; Friesen & Kingstone, 1998), and RTs to neutrally cued targets being faster than RTs to invalidly cued targets (costs; Green & Woldorff, 2012). I also anticipated that age would influence the magnitude of the validity effects, with older adults experiencing stronger benefits and costs due to higher attentional control settings (Cosman et al., 2012; Gayzur et al., 2014; Langley et al., 2011).

Predictions for how the dynamic environment would influence age-related cuing patterns relied on several previous findings. As mentioned earlier, older drivers react more slowly on hazard detection tasks compared to younger adults (Horswill, Anstey, Hatherly, & Wood, 2010; Horswill et al., 2008; Horswill et al., 2009; Scialfa et al., 2012). Like the videos in Experiment 2, typical hazard detection tasks have a level of uncertainty regarding possible target locations. Though the participants in Experiment 2 were told that the relevant event (i.e., target appearance) would occur at an intersection, each video clip had six total possible locations for target appearance, introducing an element of greater temporal and spatial unpredictability (as opposed to the two possible locations in the static scenes of Experiment 1). Furthermore, the video clips of Experiment 2 contained an environment in constant motion, with other elements (e.g., buildings and cars) moving in and out of the visual scene. Previous research has established that there is an age-related decline in inhibiting irrelevant information (Verhaeghen & Cerella, 2002), however, I predicted that the peripheral onset cues would reflexively guide attention as the orienting effects of these cues are difficult to interrupt (Posner, 1980). I predicted that the cuing effects found in Experiment 1 would be replicated in Experiment 2, as younger and older adults' reflexive orienting should still be preserved in the more dynamic environment. I also predicted that older adults would show larger cuing effects based on more benefits and costs.

Finally, because Experiment 2 used the same SOAs as Experiment 1 (≤ 200 ms), I predicted that only younger adults would be able to benefit from the temporally predictive neutral cues. These findings would replicate those of Experiment 1 and Kaufman, Sozda, Dotson, and Perlstein (2016). As compared to the stimuli in the first experiment, the spatial and temporal predictability of the onsets of cues and targets in Experiment 2 was reduced. For example, as mentioned above, cue-target presentation could occur at one of three possible intersections during the video clips. This lack of predictability, and the dynamic nature of the driving scenes, would likely increase the difficulty relative to Experiment 1. If, according to the ACS theory (Klein, 2005), older adults had to increase their attentional control settings to complete the task, then it is unlikely that they would be able to benefit from the temporally predictive cues.

Method

Participants

Twenty-eight younger adults (18 yrs - 35 yrs) and twenty-eight older adults (60 yrs - 85 yrs) who did not participate in Experiment 1 were recruited to participate in Experiment 2. I used the same recruitment strategies and exclusion criteria from Experiment 1, although I also recruited younger adults via a listserv to psychology majors and graduate students. A greater number of graduate student participants than in Experiment 1 led to the higher mean age of the younger adult group compared to Experiment 1. Three younger adults and one older adult were removed for high GDS scores; their data were replaced with new participants. Participant characteristics of the final sample are presented in Table 1.

Materials

The equipment and programs used to present stimuli and record data were unchanged from Experiment 1. The videos that participants viewed were recorded from simulated driving scenarios that were constructed using custom Vection Runtime Software (DriveSafety, Murray, UT). A total of six videos were created and all were 20 seconds in length. The video clips consisted of rural driving settings on a two-lane highway surrounded by green (grass). Visible in the environment were houses, barns, and other cars. The other cars (which always drove toward the participant), never directly interacted with the participant’s line of travel. These cars were meant to replicate regular traffic in real-world driving. Each video clip contained an average of three simulated vehicles. In two of the six clips, one of the simulated vehicles executed a turn at an intersection on the roadway ahead of the participant and in their line of sight. However, those turns were performed well in advance of a potential cue-target appearance and did not cause visual interference with cue-target presentation. Each video clip contained a total of three intersections and the time between intersections was approximately five seconds. The intersections did not contain other traffic traveling in a perpendicular direction to the participant’s vehicle except for the target vehicle.

The video clips nearly filled the entire visual display, and were 31° in height and 41° wide. Footage from the driving clips was relatively centered so that the road on which the participant was “driving” was in the middle of the screen. Because of this positioning, when the cue was presented, it was positioned relative to the road as it was in Experiment 1. The six video clips were presented multiple times; each clip was presented with all possible combinations of the intersection at which the cue and target were presented (first, second, or third), the nature of the cue (valid, invalid, neutral, and no cue), and the side of the cue and target (left or right).

The peripheral rectangle cue was identical to the one used for Experiment 1. It was 0.6° thick, with a height of 27.8° and a width of 18.5°. It was positioned around the periphery of half of the display, to mimic the placement of the peripheral cues from Experiment 1. The target was one of three computer-generated imagery (CGI) sedan cars that were red, blue, or purple in color. Although using cues and targets of different color loses the benefits highlighted earlier (Ansorge & Becker, 2014), the physical properties of the target more realistically mimicked the conditions of actual traffic (i.e., cars in the real-world would not always match the color of the cue). The target cars were approximately 6.1° in length and 3.2° in height. Though the car suddenly appeared as in the first experiment, only approximately the front half of the car was visible to the participant, and the car appeared on the edge of the display. This was meant to simulate the sudden entrance of a potential hazard at an intersection, while attempting to recognize that actual cars do not suddenly appear in the middle of an intersection.

Procedure

The complete study session lasted approximately one hour. The computer task consisted of five blocks of 24 trials, for a total of 120 trials. Each video was reused four times per block, 20 times total. Within a block, each cue validity occurred a total of six presentations. Therefore, upon task completion, each participant experienced each cue validity condition 30 times. Participants were encouraged to take short breaks between blocks.

Before starting the task, participants were shown a colored handout with snapshots of the video clips, example cues, and the target cars that they were to respond to. Instructions were given verbally, and participants were encouraged to ask questions for clarification. The experimenter told participants that they would see random buildings and cars throughout each trial but that those items would not directly influence the appearance of the cues or targets. Participants were told that the cues would appear immediately before the car targets but would not help to predict the location of the targets. As in Experiment 1, participants were instructed to use their index fingers to indicate on which side of the intersection the target appeared (left or right), by pressing the left or right arrow key. They were also told to make their responses as fast as possible without risking errors. Before beginning the experimental trials, participants completed 8 practice trials that replicated the experimental trials in order to allow the participants to acclimate to the task.

Each trial began with a black screen for 1,000 ms, which was intended to signify the beginning and end of a trial. Following the black screen, the video footage began (with the car already in motion), and the car remained in motion throughout the duration of the trial. The vehicle maintained a constant speed of 60 miles an hour and never deviated from a straight line of travel. Clips lasted a possible total of 20 seconds (as short as five seconds; intersection 1), depending on which intersection the target appeared at, and whether a response was made or not. At a randomly designated intersection during the clip, a target car appeared. The cue was presented for 150 ms (with a jitter of +/- 50 ms) before the target, and the cue and target remained present for 300 ms. Once participants made a response or the 5,000 ms limit was reached, the screen would turn black for 1,000 ms before the next video clip was presented. To indicate errors, a brief audio tone sounded whenever an inaccurate button was pressed or participants failed to respond within the 5,000 ms time limit.

The four cuing conditions (valid, invalid, neutral, no cue) were presented with an equal chance of occurrence (25% each). Within each cue condition, the cues and targets were presented equally on the left and right. Each video clip had only one cue-target appearance. An example using still shots of a valid trial from a video clip is presented in Figure 4.

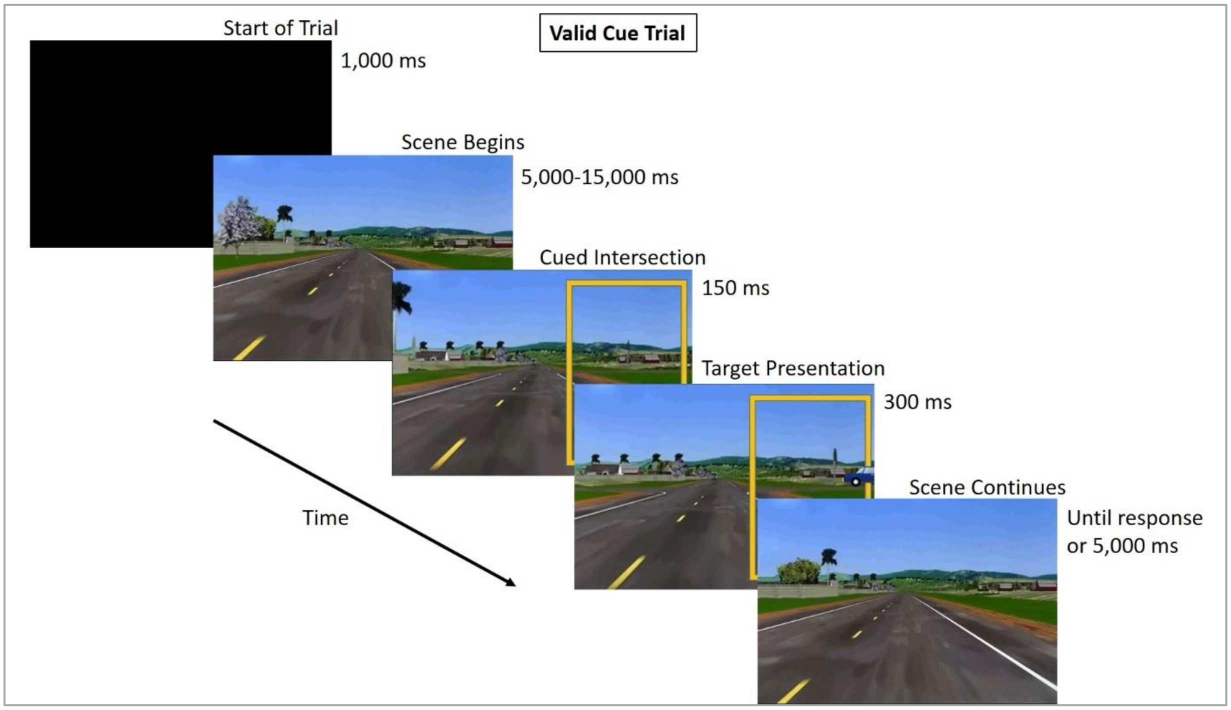

Figure 4. Sample of typical cue and target presentation for a valid cue trial in Experiment 2. Cue-target presentation could occur at the first, second, or third intersection.

Results

Reaction Time Analyses

After eliminating trials with RTs that exceeded 2.5 SDs from an individual's condition mean, mean RTs for correct trials were submitted to a 2 × 4 ANOVA. Age (younger and older) was the between-subjects variable and cue validity (valid, invalid, neutral, and no cue) was the within-subjects variable. I conducted SNK post hoc tests to examine significant validity effects.

I found a main effect of age, $F(1, 54) = 121.76$, $p = .0001$, with older adults responding more slowly to targets than younger adults (856 ms and 712 ms, respectively). A main effect of cue validity, *F*(3, 162) = 114.90, *p* = .0001, was due to significant differences between all four cue conditions; valid (737 ms), neutral (768 ms), invalid (806 ms), and no cue (824 ms). Post hoc analyses revealed that the cuing patterns reflected significant overall cuing effects (invalid minus valid), benefits (neutral minus valid), costs (invalid minus neutral), and alerting effects (no cue minus neutral). The interaction of age × cue validity, *F*(3, 162) = 7.39, *p* = .0001, was also significant.

I ran one way ANOVAs on cue validity for each age group to explore the interaction. Both younger adults, *F*(3, 81) = 71.47, *p* = .0001, and older adults, *F*(3, 81) = 55.31, *p* = .0001, showed significant validity effects. According to post hoc analyses, both age groups showed significant benefits, costs, and alerting effects, *p*s < .05. Means RTs as a function of age group and validity condition are reported in Table 3.

To determine age differences in the magnitudes of cuing effects, I conducted one-way ANOVAs, with age as the between-subjects variable, on the difference scores reflecting each cuing effect. There was an age effect for overall cuing effects (invalid minus valid), *F*(1, 54) = 15.04, *p* = .0003, with older adults having larger cuing effects (90 ms) compared to younger adults (48 ms). There was also a significant age effect for cuing costs (invalid minus neutral), *F*(1, 54) = 11.82, *p* = .0011, with larger costs for older adults (52 ms) than younger adults (23 ms). However, there was not a significant difference between age groups in cuing benefits (neutral minus valid), *F*(1, 54) = 2.54, *p* = .1170 or alerting effects (no cue minus neutral), *F*(1, 54) = 1.52, *p* = .2225.

Transformed Reaction Time Analyses

As with Experiment 1, I conducted the same analyses on a transformed data set that attempted to account for age-related general slowing (Madden et al., 1992; Madden et al., 2004).

The Brinley plot analysis (Cerella, 1994) for the four condition means was used to establish a regression equation that best described the linear relationship between the older and younger adult means. The resulting equation was used to transform the younger adult data, and can be found below.

$$\text{Older RT} = 1.03(\text{Younger RT}) + 119.3,\ r^2 = .79$$

The transformed data were submitted to the same 2 × 4 mixed ANOVA mentioned above. As anticipated, the main effect of age was no longer significant ($F < 1$). Cue validity remained significant, $F(3, 162) = 115.55$, $p = .0001$, as did the age × cue validity interaction, $F(3, 162) = 7.19$, $p = .0001$. Post hoc tests revealed that the four cuing conditions were all significantly different from one another, indicating that both older and younger adults showed significant cuing effects, benefits, costs, and alerting effects.

I again submitted the difference scores reflecting validity effects to one-way ANOVAs to assess age differences in cuing effect magnitudes. Age effects remained significant for overall cuing effects, $F(1, 54) = 13.81$, $p = .0005$, and costs, $F(1, 54) = 10.95$, $p = .0017$. There were no significant age differences in benefits, $F(1, 54) = 2.21$, $p = .1426$ or alerting effects, $F(1, 54) = 1.96$, $p = .1676$. Age differences in the transformed cuing effects for Experiment 2 are presented in Figure 5.

Table 3

Mean RTs (ms) and Error Rates for Each Cue Validity in Experiment 2

Mean RTs	Younger Adults *M(SD)*	Older Adults *M(SD)*
Valid	673 (45)	802 (58)
Neutral	697 (43)	840 (57)
No Cue	759 (45)	889 (58)
Invalid	720 (43)	892 (75)

Error Rates	Younger Adults	Older Adults
Valid	.006	.02
Neutral	.02	.04
No Cue	.02	.03
Invalid	.08	.11

Note. M = mean; SD = standard deviation; RT = reaction time.

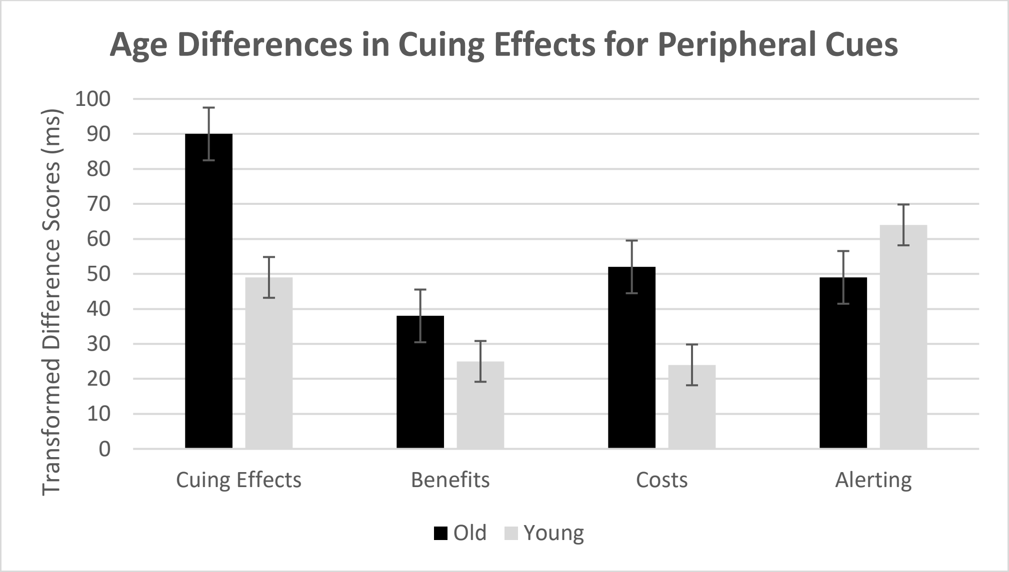

Figure 5. Age differences in transformed cuing effects for Experiment 2.

Discussion

The findings from Experiment 2 showed that peripheral onset cues were effective at guiding the visual attention of younger and older adults within dynamic driving scenes. Both groups showed evidence of overall cuing effects, benefits, costs and alerting effects. These findings support previously established models of reflexive orienting (e.g., Langley et al. 2011; Olk & Kingstone, 2015), and the cuing effects for peripheral cues were similar to those found in Experiment 1, providing further evidence that these attentional processes remain intact into later adulthood (e.g., Hartley & Kieley, 1995; Tales, Muir, Bayer, & Snowden, 2002).

I predicted that cuing effects would be greater for older adults than younger adults, driven by greater benefits and costs, consistent with Klein's (2005) application of the ACS theory (Folk, Remington & Johnston, 1992). Older adults did show larger costs compared to younger adults, but in contrast to the findings from Experiment 1 and my predictions, the groups did not differ significantly in benefits (although the trend was for greater benefits in older adults). This finding can be interpreted as older adults not experiencing enhanced processing of valid cues due to higher attentional control settings, compared to the younger adults, although it is also possible that there was not sufficient power to detect age differences. Also, although benefits were larger in Experiment 2 compared to Experiment 1, the magnitude of the age difference was smaller. Both age groups processed accurate cues to a similar extent, but inaccurate cues had a stronger detrimental impact on the older adults. The results from Experiment 2 suggest that the reflexive attentional guidance provided by onset peripheral cues occurred for both younger and older adults, even in dynamic and cluttered driving scenes.

Contrary to the findings of Experiment 1, both age groups also showed significant alerting effects in Experiment 2. It may be that the dynamic nature of the environment and increased uncertainly regarding which intersection the cue would be presented at allowed the older adults to utilize temporally predictive neutral cues. Experiment 2 used a short duration cue (150 ms), which in past studies was associated with an age-related reduction in alerting effects (Festa-Martino, Ott, & Heindel, 2004; Jennings, Dagenbach, Engle and Funke, 2007; Gamboz, Zamarian, & Cavallero, 2010), or (as in Experiment 1) a complete lack of altering effects for older adults (Kaufman, Sozda, Dotson, and Perlstein, 2016). However, the present cue appears to have been sufficient in providing temporal predictability for the impending target. Given a trial duration as long as 20 seconds, the unpredictable intersection location of the target, and high visual demands from a dynamic display, it is possible that older adults were unable to maintain their higher attentional control settings throughout the duration of the video clips. Therefore, the neutral cue was effective at temporarily heightening those settings, making older adults faster to localize the target than if they had no warning cue. Further explanation for the significant alerting effects of older adults can be found in the general discussion section below.

Another finding of interest similar to Experiment 1 is that younger adults were slowest on the no cue trials. Thus, for younger adults, even the invalid cues provided some alerting benefits for localizing the target. Although in Experiment 1 older adults' RTs were slowest on invalid cue trials, in Experiment 2 there was not a significant difference between their invalid and no cue RTs. I will discuss these findings further in the general discussion as well.

Experiment 2 was designed to introduce additional elements of driving environments (e.g., dynamic visual information and multiple areas of interest for navigation). With this design, I was able to see cuing effects using a simulated driving scenario. However, it is important to note that the participants did not simulate the motor components of driving (e.g., steering, gas and brake pedals, etc.). By viewing driving footage, participants did not have the added attentional demands of driving, and therefore the generalizability of these cuing effects to real-world driving cannot be known. Also, as in Experiment 1, the cues used in this design were not predictive. Though the use of nonpredictive cues allows for the assessment of reflexive orienting properties, visual cues integrated in real-world vehicles should likely be predictive of potential hazards, due to the significant attentional costs of the invalid cues for the older adults.

CHAPTER 4: GENERAL DISCUSSION

Previous research has shown that reflexive orienting remains intact into old age (Folk & Hoyer, 1992; Hartley & Kieley, 1995; Tales et al., 2002), and that older adults can experience even stronger cuing effects as compared to younger adults (Langley et al., 2011; Lincourt et al., 1997). The majority of past research has focused on age differences in reflexive orienting in response to peripheral cues. The present study added evidence that older adults show reflexive orienting in response to uninformative central arrow cues at short cue-target SOAs, as both younger and older adults showed cuing effects for peripheral and central cues in Experiment 1.

Green and Woldorff (2012) have argued that cuing effects following centrally-presented arrows that are observed under conditions similar to those used in Experiment 1 (short cue-target SOA with cue and target remaining present until the participant responds) do not reflect reflexive spatial orienting, but instead reflect conflict-related processing of the cue and target due to the incongruent spatial information that they convey. In support of this argument, Green and Woldorff (Experiment 2) found that under such conditions, cuing effects consisted almost completely of costs without benefits. In Experiment 1, I found both costs and benefits in response to targets following central arrow cues and peripheral onset cues, supporting instead an orienting explanation for the cuing patterns. The Experiment 1 cuing patterns for central arrows are consistent with the cuing effects that Langley et al. (2011, Experiment 2) observed at short cue-target SOAs for cues and targets that did not overlap in time (Langley et al., 2011, Experiment 2), again arguing against a conflict-related explanation. Moreover, although older adults experienced greater costs than younger adults to both peripheral and central arrow cues, they also had robust benefits at short cue-target SOAs. Therefore, Experiment 1 provided further evidence that centrally presented arrow cues elicit reflexive orienting, and that this orienting continues to be observed in older age. However, overall cuing effects and costs were still larger for peripheral cues for both age groups, and older adults showed larger benefits to peripheral than arrow cues. This likely lends further evidence that the reflexive nature of these two cues differ from one another, and perhaps central arrow cues elicit a separate form of orientating due to their well-learned symbolic meaning (Ristic and Kingstone, 2012).

The magnitude of younger adults' cuing effects were similar for central and peripheral cues (although their costs were slightly larger for peripheral than central cues). In contrast, older adults' cuing effects, benefits and costs to peripheral cues were larger than to central cues. Even after a transform to minimize the effect of general slowing, age differences in cuing effects and costs were larger for peripheral cues than for central cues. The interactions between age and cue type in cuing effects may indicate that, although both groups oriented in response to peripheral and arrow cues, different brain areas subserved orienting in response to these two cues. In fact, other studies have noted behavioral differences in cuing patterns following central and peripheral cues, and some have argued that certain aspects of orienting to these two cue types are different (Ristic & Kingstone, 2012). The unique age patterns suggest that certain brain areas associated with one form of reflexive orienting show more age-related change than the brain areas associated with the other form of reflexive orienting. Alternatively, age may differentially influence how cognitive processes (e.g., ACS settings) act on the two forms of reflexive orienting.

The results from Experiment 2 suggest that visual cues served to reflexively orient attention in dynamic scenes. These findings lend empirical support to those of Pomarjanschi et al. (2013), who found that peripheral onset cues guided overt attention (saccades) to a cued half of a display in a driving simulator. An original contribution of Experiment 2 was to demonstrate that these peripheral cues lead to cuing effects that reflected both benefits and costs, for both younger and older adults, although there was an age-related increase in costs. Additionally, in Experiment 1 older adults' RTs were slowest to invalid cues, while younger adults still had faster RTs to invalid cues than when no cue was provided. This is important when it comes to implementing cues into navigational technology. Any temporally predictive cue (even when invalid) has advantages for younger adults, as they can use that information to anticipate impending targets. However, the older adults were detrimentally impacted by the invalid cue, even more so than when no cue was provided at all. Thus, the benefits of a valid cue can quickly be outweighed by the costs of an invalid cue, and that cost to driving performance over no orienting cue at all would need to be given serious consideration.

The ACS theory of attention (Klein, 2005) can account for many findings from these two experiments. The theory stipulates that completing a task which requires target processing is more difficult for older adults. Therefore, older adults may raise their control settings to a higher level than what is necessary for younger adults. These heightened settings lead to the enhanced processing of targets and cues. This not only explains why older adults benefited more from valid cues (in Experiment 1), but also why older adults had greater costs in both experiments. The pattern of greater costs suggests they had difficulty disengaging from invalid cues to reorient their attention to the actual target location. The results of Experiments 1 and 2 provide further evidence to support application of the ACS theory to age-related changes in spatial orienting.

Previous findings have shown that neutral cues can provide temporal information for both younger and older adults, although the timing of these effects may differ (Fernandez-Duque & Black, 2006; Jennings et al., 2007). One key difference in the findings of Experiments 1 and 2 is the significant alerting effects for older adults in the second experiment. In Experiment 1, older adults did not show alerting effects to temporally-predictive, spatially-neutral, cues (central or peripheral). However, in Experiment 2, both age groups showed significant alerting effects to peripheral cues, even though the cue-target SOAs remained consistent between the two experiments. One explanation for the appearance of older adult's alerting effects in Experiment 2 comes from the ACS theory. An average trial for Experiment 1 only lasted approximately 2,000 ms, and the timing of the target's appearance within that trial was relatively constant. The trials in Experiment 2 were significantly longer, lasting at least 5,000 ms (if the target appeared at intersection 1) and upwards to 20,000 ms (if the target appeared at intersection 3). If older adults were unable to maintain their heightened settings for the duration of the trials in Experiment 2, then the neutral cues could have been effective in serving to provide this temporally predictive information about the impending target onset. Admittedly, the application of the ACS theory to the alerting data is a little tenuous and warrants further research. For example, why did older adults not show greater alerting effects than younger adults in Experiment 2 if control settings were not set at a uniformly high setting? It is difficult to apply the ACS theory to both an age difference in alerting (Experiment 1) and a lack of an age difference in alerting (Experiment 2).

Also of note, some researchers (see Wright, Richard, & McDonald, 1995) have claimed that double cues that simultaneously cue both possible target locations are likely not truly "neutral", and therefore are not a precise indicator of spatial cuing baselines. Because these cues indicate all potential target locations, some spatial information is still processed by the observer, and therefore the use of these cues may inflate costs and diminish benefits. Because both age groups showed significant benefits in both experiments of the present study, this was likely not an issue, although future research should explore the effectiveness of other types of neutral cues to provide temporally predictive information in driving scenes.

The present findings suggest that cue-assisted orienting would be effective in enhancing driving performance. Experiment 1 showed that arrow and box cues can reflexively guide the visual attention of younger and older adults toward a potential hazard at an intersection. Experiment 2 showed that these cues can be effective at guiding attention in dynamic driving scenarios when there is less predictability of stimuli. However, these findings also identify an important issue with the use of visual cues to guide the attention of drivers; invalid cues will likely cause older drivers to take more time to respond to targets (i.e., other cars) compared to no cues. In other words, cue technologies that provide inaccurate spatial information could be detrimental to driver safety by negatively impacting their attentional allocation.

There are several considerations that should be made in future research investigating this topic. For example, both experiments in the present study used nonpredictive cues. This decision was made in order to answer lingering questions about the reflexive nature of central arrow cues. In addition, reflexive orienting to cues is rapid, a desirable feature for efficient hazard detection. However, as previously iterated, cues in automobiles would likely be predictive to minimalize invalid cues. Thus, future studies should investigate if the same orienting patterns found here occur with cues that are predictive of target location, and determine if the age patterns are influenced by a change in the informativeness of the cue. There is evidence that volitional orientating is adversely impacted by age when central cues are predictive of target onset (e.g., Greenwood, Parasuraman, & Haxby, 1993). Furthermore, future studies could assess orienting in response to a greater range of cue-target SOAs. More information is needed to establish the optimal SOA for directing attention toward potential hazards before implementing cues into automobiles.

The present experiments represent an important first step toward implementing cognitive principles of orienting in natural contexts. However, a limitation of the study is generalizability to real-world driving environments. Although both experiments used driving-related stimuli, participants did not have the significant additional cognitive load of operating a motor vehicle. Furthermore, I was able to control the complexity of the driving environment (including visual and auditory stimuli and distractions from within the car). Considering that older adults particularly struggle with navigating intersections because of the relatively complex nature of traffic at those locations, the present study is unable to determine if that greater cognitive load would affect the success of cues meant to guide visual attention. Future studies should utilize technologies such as driving simulators to more closely assess these issues while ensuring safety of participants.

It is also important to note that the present study design was cross-sectional. While convenient, an inherent flaw of cross-sectional research is that it can only detail age differences between groups (i.e., generational differences), and cannot definitively describe age-related changes. However, it is important to understand generational differences. Knowing how the current generation of older drivers reacts to cues will help us develop the best technological aids for that group, but there is no guarantee that the next generation of older adults will show the same patterns. Also, the mean age of my older adult groups was 72 years old. Because older adults must utilize higher attentional control settings to complete effortful tasks, old-old adults (> 75 years old) may show different orienting patterns than the present samples. For example, if old-old adults experience even larger costs to invalid cues, then the importance of presenting valid cues to older drivers would increase.

Previous research has established that age-related declines in visual attention likely lead to older adults experiencing issues with detecting hazards in driving conditions. The results from the present study contribute to a framework for how to proceed with integrating visual cues into driver's environments to increase navigational safety. Consequently, evidence is provided that technology affords a potential way to keep older adults on the road safely, for a longer period of time, thus increasing their independence.

REFERENCES

Ansorge, U., & Becker, S. I. (2014). Contingent capture in cueing: The role of color search templates and cue-target color relations. *Psychological Research*, *78*(2), 209-221.

Anstey, K.J., Wood, J., Lord, S., & Walker, J.G. (2005). Cognitive, sensory and physical factors enabling driving safety in older adults. *Clinical Psychology Review*, *25*, 45–65.

Babcock, R.L., & Salthouse, T.A. (1990). Effects of increased processing demands on age differences in working memory. *Psychology and Aging, 5*, 421-42.

Ball, K., Owsley, C., Sloane, M. E., Roenker, D. L., & Bruni, J. R. (1993). Visual attention problems as a predictor of vehicle crashes in older drivers. *Investigative Ophthalmology and Visual Science*, *34*, 3110–3123.

Bopp, K. L., & Verhaegen, P., (2005). Aging and verbal memory span: a meta-analysis. *Journals of Gerontology*: *Series B: Psychological Sciences and Social Sciences*, *60B,* 223-233.

Bowers, A. R., Anastasio, R. J., Sheldon, S. S., O'Connor, M. G., Hollis, A. M., Howe, P. D., & Horowitz, T. S. (2013). Can we improve clinical prediction of at-risk older drivers? *Accident Analysis & Prevention*, *59,* 537-547. doi:10.1016/j.aap.2013.06.037

Braitman, K.A., Kirley, B.B., Ferguson, S., & Chaudhary, N.K. (2007). Factors leading to older drivers' intersection crashes. *Traffic Injury Prevention*, *8,* 267-274.

CDC. Centers for Disease Control and Prevention. Injury prevention & control: Motor vehicle safety. Accessed on 7/01/2014. http://www.cdc.gov/MotorVehicleSafety/ Older_Adult_Drivers/adult-drivers_factsheet.html

Cerella, J. (1994). Generalized slowing in Brinley plots. *Journal of Gerontology*, *49*(2), P65-P71.

Charlton, J.I., Catchlove, M., Scully, M., Koppel, S. & Newstead, S. (2013). Older driver distraction: A naturalistic study of behavior at intersections. *Accident Analysis and Prevention, 38,* 271-278.

Christensen, K. J., Moye, J., Armson, R. R., & Kern, T. M. (1992). Health screening and random recruitment for cognitive aging research. *Psychology and Aging*, *7*(2), 204-208.

Clay, O.J., Wadley, V.G., Edwards, J.D., Roth, D.L., Roenker, D.L., & Ball, K.K. (2005). Cumulative meta-analysis of the relationship between useful field of view and driving performance in older adults: Current and future implications. *Optometry & Vision Science, 82*, 724-731.

Cosman, J. D., Lees, M. N., Lee, J. D., Rizzo, M., & Vecera, S. P. (2012). Impaired attentional disengagement in older adults with useful field of view decline. *Journals of Gerontology Series B: Psychological Sciences & Social Sciences*, *67*(4), 405-412.

Coull, J. T., Nobre, A. C., & Frith, C. D. (2001). The noradrenergic α2 agonist clonidine modulates behavioural and neuroanatomical correlates of human attentional orienting and alerting. *Cerebral Cortex, 11*(1), 73-84.

Craik, F. I. M., & Anderson, N. D. (1999). Applying cognitive research to problems of aging. In D. Gopher & A. Koriat (Eds.), *Attention and performance XVII: Cognitive regulation of performance: Interaction of theory and application* (pp. 583–615). Cambridge, MA: The MIT Press.

Daigneault, G., Joly, P., & Frigon, J. (2002). Executive functions in the evaluation of accident risk of older drivers. *Journal of Clinical & Experimental Neuropsychology, 24,* 221-238.

Dennis, M., Edelstein, K., Copeland, K., Frederick, J., Francis, D. J., Hetherington, R., & Fletcher, J. M. (2005). Covert orienting to exogenous and endogenous cues in children with spina bifida. *Neuropsychologia*, *43*(6), 976-987. doi:10.1016/j.neuropsychologia.2004.08.012

Edwards, J. D., Ross, L. A., Wadley, V. G., Clay, O. J., Crowe, M., Roenker, D. L., & Ball, K. K. (2006). The useful field of view test: Normative data for older adults. *Archives of Clinical Neuropsychology, 21*, 275-286. doi:10.1016/j.acn.2006.03.001

Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science*, *11*(1), 19-23.

Erel, H., & Levy, D. A. (2016). Orienting of visual attention in aging. *Neuroscience & Biobehavioral Reviews*, *69*, 357-380.

Fan, J., McCandliss, B. D., Fossella, J., Flombaum, J. I., & Posner, M. I. (2005). The activation of attentional networks. *Neuroimage*, *26*(2), 471-479.

Fan, J., McCandliss, B. D., Sommer, T., Raz, A., & Posner, M. I. (2002). Testing the efficiency and independence of attentional networks. Journal of cognitive neuroscience, 14(3), 340-347.

Fernandez-Duque, D., & Black, S. E. (2006). Attentional networks in normal aging and Alzheimer's disease. *Neuropsychology*, *20*(2), 133.

Festa-Martino, E., Ott, B. R., & Heindel, W. C. (2004). Interactions between phasic alerting and spatial orienting: effects of normal aging and Alzheimer's disease. *Neuropsychology*, *18*(2), 258.

Folk, C. L., & Hoyer, W. J. (1992). Aging and shifts of visual spatial attention. *Psychology and aging*, *7*(3), 453.

Folk, C. L., Remington, R. W., & Johnston, J. C. (1992). Involuntary covert orienting is contingent on attentional control settings. *Journal of Experimental Psychology Human Perception and Performance, 18,* 1030-1030.

Folstein, M.F., Folstein, S.E., & McHugh, P.R. (1975). Mini-Mental State: A practical method for grading the cognitive state of the patient for the clinician. *Journal of Psychiatric Research, 12,* 189-198.

Friesen, C.K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin & Review*, *5,* 490-495.

Gamboz, N., Zamarian, S., & Cavallero, C. (2010). Age-related differences in the attention network test (ANT). *Experimental aging research*, *36*(3), 287-305.

Gayzur, N., Langley, L., Kelland, C., Wyman, S., Saville, A., Ciernia, A., & Padmanabhan, G. (2014). Reflexive orienting in response to short- and long-duration gaze cues in young, young-old, and old-old adults. *Attention, Perception & Psychophysics*, *76,* 407-419. doi:10.3758/s13414-013-0554-6

Green, J. J., Gamble, M. L., & Woldorff, M. G. (2013). Resolving conflicting views: Gaze and arrow cues do not trigger rapid reflexive shifts of attention. *Visual cognition*, *21*(1), 61-71.

Green, J. J., & Woldorff, M. G. (2012). Arrow-elicited cueing effects at short intervals: Rapid attentional orienting or cue-target stimulus conflict?. *Cognition*, *122*(1), 96-101.

Greenwood, P. M., & Parasuraman, R. (1999). Scale of attentional focus in visual search. *Perception & Psychophysics*, *61*(5), 837-859.

Greenwood, P. M., Parasuraman, R., & Haxby, J. V. (1993). Changes in visuospatial attention over the adult lifespan. *Neuropsychologia*, *31*(5), 471-485.

Hale, S., Rose, N. S., Myerson, J., Strube, M. J., Sommers, M., Tye-Murray, N., & Spehar, B. (2011). The structure of working memory abilities across the adult life span. *Psychology & Aging*, *26*, 92-110. doi:10.1037/a0021483

Hanson, T. R., & Hildebrand, E. D. (2011). Are rural older drivers subject to low-mileage bias? *Accident Analysis & Prevention*, *43*(5), 1872-1877. doi:10.1016/j.aap.2011.04.028

Hartley, A. A., & Kieley, J. M. (1995). Adult age differences in the inhibition of return of visual attention. *Psychology and Aging*, *10*(4), 670.

Higgins, Kent E., Wood, Joanne M., & Tait, Alan W. (1998) Vision and driving: Selective effect of optical blur on different driving tasks. *Human Factors*, *40*, 224-232.

Hills, B.L., & Burg, A. (1977). *A reanalysis of California driver vision data: General findings*. TRRL laboratory report No. 768. Transport and Road Research Laboratory, Crowthorne, UK.

Hommel, B., Pratt, J., Colzato, L., & Godijn, R. (2001). Symbolic control of visual attention. *Psychological Science*, *12*(5), 360-365.

Horswill, M. S., Anstey, K. J., Hatherly, C. G., & Wood, J. M. (2010). The crash involvement of older drivers is associated with their hazard perception latencies. *Journal of the International Neuropsychological Society*, *16*(05), 939-944.

Horswill, M. S., Marrington, S. A., McCullough, C. M., Wood, J., Pachana, N. A., McWilliam, J., & Raikos, M. K. (2008). The hazard perception ability of older drivers. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *63*(4), 212-218.

Horswill, M. S., Pachana, N. A., Wood, J., Marrington, S. A., McWilliam, J., & McCullough, C. M. (2009). A comparison of the hazard perception ability of matched groups of healthy drivers aged 35 to 55, 65 to 74, and 75 to 84 years. *Journal of the International Neuropsychological Society*, *15*(05), 799-802.

Jennings, J. M., Dagenbach, D., Engle, C. M., & Funke, L. J. (2007). Age-related changes and the attention network task: An examination of alerting, orienting, and executive function. *Aging, Neuropsychology, and Cognition*, *14*(4), 353-369.

Johannsdottir, K. R., & Herdman, C. M. (2010). The role of working memory in supporting drivers' situation awareness for surrounding traffic. *Human Factors*, *52*, 663-673. doi:10.1177/0018720810385427

Kaufman, D. A., Sozda, C. N., Dotson, V. M., & Perlstein, W. M. (2016). An Event-Related Potential Investigation of the Effects of Age on Alerting, Orienting, and Executive Function. *Frontiers in aging neuroscience*, *8*.

Kazumi Renge, T. I., Oiri, M., o Ota, H., Tsunenari, S., & Mukai, M. (2005). Elderly Driver's Hazard Perception and Driving Performance. In *Traffic and transport psychology: theory and application: proceedings of the ICTTP 2004* (p. 91). Elsevier Science Ltd.

Kingstone, A., Smilek, D., Ristic, J., Friesen, C. K., & Eastwood, J. D. (2003). Attention, researchers! It is time to take a look at the real world. *Current Directions in Psychological Science, 12*(5), 176-180.

Klein, R. M. (2000). Inhibition of return. *Trends in cognitive sciences*, *4*(4), 138-147.

Klein, R. M. (2005). On the Role of Endogenous Orienting in the Inhibitory Aftermath of Exogenous Orienting.

Kumar, N., & Priyadarshi, B. (2013). Pattern of decline of digit span tasks in adults: A comparative study of pattern of decline of digit forward span and digit backward span tasks in adults. *Indian Journal of Gerontology*, *27*, 438-449.

Lamble D, Summala H, & Hyvärinen L. (2002). Driving performance of drivers with impaired central visual field acuity. *Accident Annual Preview*, *34*, 711-716

Langley, L. K., Friesen, C. K., Saville, A. L., & Ciernia, A. T. (2011). Timing of reflexive visuospatial orienting in young, young-old, and old-old adults. *Attention, Perception & Psychophysics*, *73*, 1546-1561. doi:10.3758/s13414-011-0108-8

Lenth, R. V. (2001). Some practical guidelines for effective sample size determination. *The American Statistician*, *55*(3), 187-193.

Levitt, T., Fugelsang, J., & Crossley, M. (2006). Processing speed, attentional capacity, and age-related memory change. *Experimental Aging Research*, *32*(3), 263-295. doi:10.1080/03610730600699118

Li, G., Braver, E. R., & Chen, L. (2003). Fragility versus excessive crash involvement as determinants of high death rates per vehicle-mile of travel among older drivers. *Accident Analysis & Prevention*, *35*, 227.

Lincourt, A. E., Folk, C. L., & Hoyer, W. J. (1997). Effects of aging on voluntary and involuntary shifts of attention. *Aging, Neuropsychology, and Cognition*, *4*(4), 290-303.

Lunsman, M., Edwards, J. D., Andel, R., Small, B. J., Ball, K. K., & Roenker, D. L. (2008). What predicts changes in useful field of view test performance? *Psychology & Aging*, *23*, 917-927. doi:10.1037/a0013466

Lyman, S., Ferguson, S. A., Braver, E. R., & Williams, A. F. (2002). Older driver involvements in police reported crashes and fatal crashes: Trends and projections. *Injury Prevention, 8*, 116–120.

Madden, D. J., Pierce, T. W., & Allen, P. A. (1992). Adult age differences in attentional allocation during memory search. *Psychology and Aging*, 7(4), 594.

Madden, D. J., & Whiting, W. L. (2004). Age-related changes in visual attention. In P. T. Costa & I. C. Siegler (Eds.), *Recent advances in psychology and aging* (pp. 41–88). Amsterdam: Elsevier.

Madden, D. J., Whiting, W. L., Cabeza, R., & Huettel, S. A. (2004). Age-related preservation of top-down attentional guidance during visual search. *Psychology and Aging*, 19(2), 304-309.

Marottoli, R. A., Cooney Jr, L. M., Wagner, D. R., Doucette, J., & Tinetti, M. E. (1994). Predictors of automobile crashes and moving violations among elderly drivers. *Annuals of Internal Medicine*, *12*(11), 842.

McGwin Jr., G. & Brown, D.B. (1999). Characteristics of traffic crashes among young, middle-aged, and older drivers. *Accident Analysis and Prevention, 31*, 181-198.

McKenna, F. P., & Horswill, M. S. (1999). Hazard perception and its relevance for driver licensing. *IATSS research*, *23*(HS-042 879).

Olk, B., & Kingstone, A. (2015). Attention and ageing: Measuring effects of involuntary and voluntary orienting in isolation and in combination. *British Journal of Psychology*, *106*(2), 235-252.

Owsley, C., Ball, K., McGwin, G., Sloane, M. E., Roenker, D. L., White, M. F., & Overley, T. (1998). Visual processing impairment and risk of motor vehicle crash among older adults. *JAMA: Journal of the American Medical Association, 279*, 1083-1088.

Owsley C., McGwin, G., & Ball, K. (1998). Vision impairment, eye disease, and injurious motor vehicle crashes in the elderly. *Ophthalmic Epidemiology, 5*, 101–113.

Park, D. C., Hedden, T., Davidson, N. S., Smith, P. K., Lautenschlager, G., & Smith, A. D. (2002). Models of visuospatial and verbal memory across the adult life span. *Psychology & Aging, 17*, 299-320.

Pomarjanschi, L., Dorr, M., & Barth, E. (2012). Gaze guidance reduces the number of collisions with pedestrians in a driving simulator: *ACM Transactions on Interactive Intelligent Systems, 8*, 1-14.

Pomarjanschi, L., Dorr, M., Bex, P. J., & Barth, E. (2013). Simple gaze-contingent cues guide eye movements in a realistic driving simulator. Human Vision and Electronic Imaging XVIII (Proc. of SPIE), Bernie E. Rogowitz, Thrasyvoulos N. Pappas, and Huib de Ridder (Eds.), 8651, 865110-1.

Posner, M.I., (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology, 32*, 3-25.

Potter, L. M., Grealy, M. A., Elliott, M. A., & Andrés, P. (2012). Aging and performance on an everyday-based visual search task. *Acta Psychologica, 140*, 208-217. doi:10.1016/j.actpsy.2012.05.001

Kazumi Renge, T. I., Oiri, M., o Ota, H., Tsunenari, S., & Mukai, M. (2005, June). Elderly drivers' hazard perception and driving performance. In *Traffic and transport psychology: theory and application: proceedings of the ICTTP 2004* (p. 91). Elsevier Science Ltd.

Ristic, J., Friesen, C.K., & Kingstone, A. (2002). Are eyes special? It depends on how you look at it. *Psychonomic Bulletin & Review, 9*, 507–513.

Ristic, J., & Kingstone, A. (2006). Attention to arrows: Pointing to a new direction. *The Quarterly Journal of Experimental Psychology*, *59*(11), 1921-1930.

Ristic, J., & Kingstone, A. (2012). A new form of human spatial attention: Automated symbolic orienting. *Visual Cognition*, *20*(3), 244-264.

Ristic, J., Wright, A., & Kingstone, A. (2007). Attentional control and reflexive orienting to gaze and arrow cues. *Psychonomic Bulletin & Review*, *14*(5), 964-969.

Roenker, D. L., Cissell, G. M., Ball, K. K., Wadley, V. G., & Edwards, J. D. (2003). Speed-of-processing and driving simulator training result in improved driving performance. *Human Factors*, *45*(2), 218-233.

Salthouse, T. A. (1992). *Mechanisms of age-cognition relations in adulthood*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Salthouse, T. A. (1996). The processing speed theory of adult age differences in cognition. *Psychological Review*, *103*, 403–428.

Schall, M. C., Rusch, M. L., Lee, J. D., Dawson, J. D., Thomas, G., Aksan, N., & Rizzo, M. (2012). Augmented reality cues and elderly driver hazard perception. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 0018720812462029.

Scialfa, C. T., Deschênes, M. C., Ference, J. D., Boone, J., Horswill, M. S., & Wetton, M. (2012). Hazard perception in older drivers. *International Journal of Human Factors and Ergonomics*, *1*(3), 221-233.

Sekuler, A. B., Bennett, P. J., & Mamelak, M. (2000). Effects of aging on the useful field of view. *Experimental Aging Research*, *26*, 103-120. doi:10.1080/036107300243588

Shanmugaratnam, S., Kass, S. J., & Arruda, J. E. (2010). Age differences in cognitive and psychomotor abilities and simulated driving. *Accident Analysis & Prevention*, *42*, 802-808. doi:10.1016/j.aap.2009.10.002

Tales, A., Muir, J. L., Bayer, A., Jones, R., & Snowden, R. J. (2002). Phasic visual alertness in Alzheimer's disease and ageing. *Neuroreport, 13*(18), 2557-2560.

Tipples, J. (2002). Eye gaze is not unique: Automatic orienting in response to uninformative arrows. *Psychonomic Bulletin & Review, 9*(2), 314-318.

Tipples, J., & Sharma, D. (2000). Orienting to exogenous cues and attentional bias to affective pictures reflect separate processes. *British Journal of Psychology*, *91*(1), 87.

Trick, L. M., & Enns, J. T. (1998). Lifespan changes in attention: the visual search task. *Cognitive Development, 13,* 369–386. doi:10.1016/S0885-2014(98)90016-8.

Verhaeghen, P., & Cerella, J. (2002). Aging, executive control, and attention: a review of meta-analyses. *Neuroscience & Biobehavioral Reviews*, *26*, 849.

Wright, R. D., Richard, C. M., & McDonald, J. J. (1995). Neutral location cues and cost/benefit analysis of visual attention shifts. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale*, *49*(4), 540.

Yesavage, J. A., Brink, T. L., Rose, T. L., Lum, O., Huang, V., Adey, M., & Leirer, V. O. (1983). Development and validation of a geriatric depression screening scale: A preliminary report. *Journal of Psychiatric Research*, *17*(1), 37-49.