Older Adult Multitasking Performance Using a Gaze-Contingent Useful Field of View

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Objective: We implemented a gaze-contingent useful field of view paradigm to examine older adult multitasking performance in a simulated driving environment.

Background: Multitasking refers to the ability to manage multiple simultaneous streams of information. Recent work suggests that multitasking declines with age, yet the mechanisms supporting these declines are still debated. One possible framework to better understand this phenomenon is the useful field of view, or the area in the visual field where information can be attended and processed. In particular, the useful field of view allows for the discrimination of two competing theories of real-time multitasking, a general interference account and a tunneling account.

Methods: Twenty-five older adult subjects completed a useful field of view task that involved discriminating the orientation of lines in gaze-contingent Gabor patches appearing at varying eccentricities (based on distance from the fovea) as they operated a vehicle in a driving simulator. In half of the driving scenarios, subjects also completed an auditory two-back task to manipulate cognitive workload, and during some trials, wind was introduced as a means to alter general driving difficulty.

Results: Consistent with prior work, indices of driving performance were sensitive to both wind and workload. Interestingly, we also observed a decline in Gabor patch discrimination accuracy under high cognitive workload regardless of eccentricity, which provides support for a general interference account of multitasking.

Conclusion: The results showed that our gaze-contingent useful field of view paradigm was able to successfully examine older adult multitasking performance in a simulated driving environment.

Application: This study represents the first attempt to successfully measure dynamic changes in the useful field of view for older adults completing a multitasking scenario involving driving.

Keywords: dual task, time sharing, task switching, attentional processes, mental workload, aging processes, working memory, simulation and training, distraction, driver behavior, useful field of view, gaze-contingent displays

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INTRODUCTION

In today's society, there is an ever-increasing demand to process multiple streams of information, or multitask. In transportation, for example, car manufacturers continue to equip vehicles with new technology so that drivers can have a hands-free cell phone conversation while picking their favorite Internet radio stations as they barrel along the interstate at 80 mph. While the demand for multitasking continues to increase, humans remain quite unsuccessful at it. For example, researchers have found that when drivers attempt to multitask behind the wheel, they demonstrate delayed reaction time when faced with obstacles and impaired target detection (Strayer et al., 2015). Interestingly, general experience does not seem to mitigate these impairments; those who multitask most often show no benefits above nonmultitaskers (Sanbonmatsu, Strayer, Medeiros-Ward, & Watson, 2013).

These increased demands to multitask while driving can be particularly problematic for older adults, in part due to age-related changes in cognition (Reuter-Lorenz & Lustig, 2005). Indeed, researchers have suggested that cognition often declines with age (Hertzog, Kramer, Wilson, & Lindenberger, 2008; Strobach, Frensch, Muller, & Schubert, 2012). For example, healthy older adults tend to respond more slowly and less accurately compared to healthy younger adults on a variety of cognitive tasks (Salthouse, 2009; Verhaeghen, Steitz, Sliwinski, & Cerella, 2003). This can be particularly problematic when considering older adult performance in complex settings such as driving. Indeed, older drivers show increased crash rates per mile traveled at intersections (Sifrit, Stutts, Staplin, & Martell, 2010). It is posited that this age-related increase in crash risk per mile traveled represents a reduced ability to deal with high workload situations, such as scanning an intersection for approaching hazards. Indeed, older drivers show impaired scanning behavior relative to younger drivers, and importantly, their scanning can be improved through training, suggesting that these limitations are not strictly physical (Romoser & Fisher, 2009a, 2009b; Yamani, Samuel, Gerardino, & Fisher, 2016). Compared with younger adults, older adults show increased susceptibility to dual-task costs of conversing while driving through intersections (Gaspar, Carbonari, Kaczmarski, & Kramer, 2015). This mirrors the age-related increase in dual-task costs shown in other driving tasks (Becic et al., 2010; McCarley et al., 2004). Thus, the ability to evaluate changes in cognitive demand as a function of dual-tasking and task complexity is important to understanding how attentional limitations contribute to increased crash risk as well as the nature of older adult multitasking deficits more broadly.

The current research investigated older adult multitasking performance in a driving context. Specifically, we implemented a gaze-contingent paradigm to measure moment-by-moment changes in attention using the useful field of view while older adults drove in a simulator in both easy and hard driving conditions and with a low and high cognitive workload.

Useful Field of View

The useful field of view is the visual field from which information can be extracted in a single fixation (Mackworth, 1965), which is arguably important for successful driving. This phenomenon has been referred to by many different names, such as the *functional field of view* (Crundall, Underwood, & Chapman, 1999), the *perceptual span* (Gildman & Underwood, 2003), and more broadly as *attentional breadth* (Pringle, Irwin, Kramer, & Atchley, 2001). In addition, there is a proprietary task that uses the exact same name as the theoretical construct (i.e., UFOV; Ball, Beard, Roenker, Miller, & Griggs, 1988).

In terms of implementation, the useful field of view has typically been measured by briefly presenting simple stimuli (e.g., letters and numbers) at different retinal eccentricities while instructing viewers to fixate centrally. While foundational for initially guiding early research on the useful field of view, this approach has several limitations. For example, viewers are not free to look around the screen as they might in a more naturalistic setting, thus limiting natural viewing behavior (i.e., eye movements). In addition, these types of approaches are not amenable to more complex settings such as driving because they would mask what is happening beyond the windshield, thus leading to dangerous and unrealistic scenarios. Most importantly, these approaches are static and thus cannot inform on how the useful field of view might change transiently on a moment-to-moment basis in dynamic environments like driving when distracted.

Recently, there have been attempts to measure moment-by-moment changes in the useful field of view during simulated and real driving, though the majority of these have only included younger adults. In these studies, the most common method used for measuring the useful field of view is a peripheral detection task (PDT). These types of tasks usually require drivers to respond quickly and accurately to LED lights at fixed locations across a windshield while driving, and oftentimes, multiple driving-related factors are manipulated, such as driving task difficulty and cognitive workload, to detect real-time changes in PDT accuracy and response time (Crundall et al., 1999, 2002; Jahn, Oehme, Krems, & Gelau, 2005).

This approach of measuring the useful field of view is not without limitations. For example, retinal eccentricity (i.e., distance from the center of vision) is uncontrolled, varying randomly from one target presentation to another. This is problematic because if targets are presented at fixed screen locations while viewers are allowed to move their eyes, then screen eccentricity becomes an uninterpretable variable (Gruber et al., 2014). Although eye tracking allows one to retroactively calculate the retinal eccentricity of the target, these targets are a fixed size and intensity, which confounds variable changes in attention with the fixed drop-off of acuity (as discussed in Ringer et al., 2014).

Gaze-Contingent Useful Field of View

To get around these limitations, we used a gaze-contingent useful field of view paradigm (Ringer, Throneburg, Johnson, Kramer, & Loschky, 2016). The particular instantiation of the gaze-contingent useful field of view

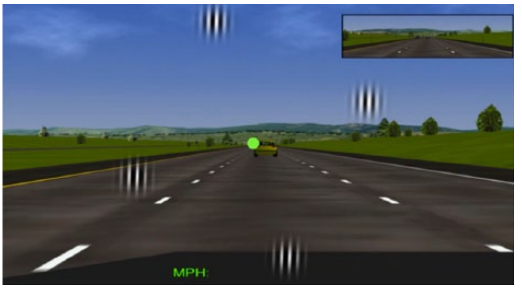

Figure 1. Example screenshot of the Gabor stimuli overlaid on the driving simulator image. The green dot represents the participant's current fixation location (note that this dot did not appear during the actual experiment). The participant's goal was to determine the direction of the Gabor patch stripes' orientation offset from perfect vertical either slightly to the left or slightly to the right. In this case, the four Gabor patches have their stripe orientation (as measured on the unit circle) offset from vertical by roughly 3° to the right. This Gabor orientation discrimination task is intentionally difficult, with the vertical slant to the right or left being very subtle, to better measure the effects of attention. The amount of offset was customized for each participant based on their thresholding performance before they completed the driving conditions.

used in the current study was as follows. First, the attentional measure used was Gabor patch orientation discrimination. Figure 1 shows four Gabor patches (circular striped patches) superimposed on a driving simulator scenario. We used Gabor patch stimuli because sensitivity to patch orientation has repeatedly been shown to be affected by attention (Cameron, Tai, & Carrasco, 2002; Carrasco, Penpeci-Talgar, & Eckstein, 2000). Second, the gaze-contingent display presented stimuli for single eye fixations at specific distances relative to the center of gaze, allowing viewers to freely look wherever they liked, while presenting the Gabor stimuli at specified eccentricities. Third, the Gabor stimuli were psychophysically scaled (for both size and orientation deviation from vertical) to factor out the physiologically driven drop-off of visual resolution with eccentricity. Fourth, the attentional manipulation was twofold, including both a driving-related load (lateral wind: Medeiros-Ward, Cooper, & Strayer, 2014) and a standard cognitive workload (auditory two-back task: Reimer, Mehler, Wang, & Coughlin, 2012). Important for the current research, by using this gaze-contingent useful field of view paradigm, it allows us to tease apart the impact of the physiologically based drop-off of resolution as a function of retinal eccentricity (Curcio, Sloan, Packer, Hendrickson, & Kalina, 1987; Van Essen, Newsome, & Maunsell, 1984) versus the impact of attentional manipulations on the useful field of view (for a detailed review, see Ringer et al., 2016). This is crucial for understanding older adult multitasking performance while driving because there are at least two competing possibilities for how divided attention might affect the useful field of view in real time: tunnel vision interference and general interference.

Tunnel Vision Interference

Researchers have suggested that cognitive distractions can lead to tunnel vision, which would manifest as a narrowing of the useful field of view (Mackworth, 1965; Reimer, 2009; Ringer et al., 2016). Under this account, discrimination for items further from the fovea declines as cognitive distraction increases while discrimination for items closer to the fovea remains relatively preserved. Note that such tunnel vision predictions, while purportedly based on the attentional effects of distraction on peripheral vision, are the same predictions one might make for performance in peripheral vision without any distraction, purely due to the physiological limits of peripheral vision.

General Interference

In contrast to this tunnel vision account, another possibility is that as cognitive distraction increases, discrimination is uniformly poorer regardless of eccentricity (Crundall et al., 1999; Williams, 1988). Under this account, items further from the fovea should have comparable discrimination to items closer to the fovea. Note, however, that to find a truly uniform decrement in performance across eccentricity due only to cognitive distraction, one must control for the known physiological limits to vision as a function of eccentricity. Because the physiological limits of vision with retinal eccentricity are well studied, it is possible to compensate for them. Specifically, with Gabor patches, if one increases their size and orientation offset from vertical as they are presented at further eccentricities, it is possible to equate Gabor orientation discrimination performance at each eccentricity tested (Strasburger, Rentschler, & Jüttner, 2011). Such scaling of Gabor stimuli can either be done using standard equations or empirically by using adaptive threshold estimation techniques to find the sizes or orientation offsets required for individual participants to produce equivalent performance at each eccentricity. One can then test viewers' performance with their threshold-derived, scaled Gabor stimuli with and without cognitive workload. In this way, one can find the true effects of cognitive workload (i.e., multitasking) on the useful field of view without contamination by the effects of the well-known physiological limits of peripheral vision (Gaspar et al., 2016; Ringer et al., 2016).

Current Study

In the current study, we investigated dynamic changes in the useful field of view in older adults to extend previous research on gaze-contingent useful field of view paradigms that focused solely on younger adults. Specifically, Gaspar et al. (2016) had 25 younger adult participants drive in a simulator under high or low levels of cognitive workload while measuring gaze-contingent useful field of view. They observed that cognitive workload impaired Gabor detection regardless of retinal eccentricity. In the current study, we chose to focus on older adults as they offer an interesting population to further test for any interactive effects between cognitive workload and eccentricity because on average, they have poorer executive function and are less likely to exhibit ceiling effects that might have masked any effects in the younger adult study by Gaspar et al. (2016).

In addition, older adults are an important group to study because previous research has shown repeatedly that they have exaggerated multitasking performance declines both in laboratory settings (Kramer & Madden, 2008) and more complex environments (Neider et al., 2011), yet the source of these declines remains underspecified. In other words, it is possible that older adult multitasking performance declines due to a tunnel vision account or a general interference account, and our gaze-contingent useful field of view paradigm is well suited to evaluate this contrast. Thus, the current study has theoretical importance in understanding dynamic changes to attentional breadth for older adults without the confounding effects from the physiological limits of peripheral vision. The current study also has applied importance when considering the ever-increasing demands to multitask that older adults encounter in driving and today's society.

METHOD

Participants

Twenty-five older adults (mean age = 67; age range, 60–82) licensed to drive, with normal or corrected-to-normal vision and normal neurological functioning participated in the study. This sample size was determined primarily from the effect sizes in Gaspar et al. (2016). This research complied with the American Psychological Association Code of Ethics and was approved by the University of Illinois at Urbana-Champaign Institutional Review Board. Informed consent was obtained from each participant, and participants were paid for their participation.

Procedure

Overview. The gaze-contingent useful field of view paradigm involved several interconnected systems, including a desktop driving simulator (DriveSafety), remote eye tracker (SmartEye Pro 5, 60 Hz), and rendering PC that integrated input from the simulator and eye tracker. After providing consent, participants completed a Gabor orientation discrimination thresholding task as well as practice on the auditory two-back cognitive distraction task and the simulated driving task. Then, participants completed four experimental driving conditions that were counterbalanced in terms of cognitive workload (single task vs. dual task) and driving difficulty (no wind vs. wind). Each experimental drive lasted approximately 15 minutes, and participants were instructed to follow a lead vehicle in the center lane of a three-lane highway while maintaining a 50 m gap.

Gabor stimuli. As shown in Figure 1, stimuli consisted of four identical Gabor patches centered on fixation and tangentially spaced 90° apart with a random angular offset. The Gabors were created by removing all hue information and varying the contrast of the underlying image content toward black or white, with luminance clipping occurring at the extremes. The Gabors were also size-scaled such that they linearly increased in size as eccentricity increased to factor out purely visual eccentricity effects on performance. Finally, the four identical Gabors were presented on the corners of an invisible square centered on the current fixation. This was to ensure that at least one Gabor patch would be visible even if a participant's gaze was allocated to a corner of the display during a fixation in which the patches were presented. To make the relative spatial locations of the Gabors unpredictable, the orientation of the invisible square (relative to 0° vertical) was randomly selected from a range of orientations (0°–89°) on each presentation.

Gabor thresholding. To further factor out purely visual eccentricity effects, prior to the main experiment, participants went through an adaptive threshold estimation procedure (Kontsevich & Tyler, 1999) to determine their individualized Gabor orientation discrimination thresholds under single task conditions that would produce 80% accuracy at each of three retinal eccentricities (5°, 10°, or 15°). In this way, any differences across eccentricities under dual task conditions could not be attributed to purely visual factors but instead could be attributed to attentional factors.

Gabor discrimination task. During each of the four experimental drives, participants completed a gaze-contingent Gabor orientation discrimination task. For gaze-contingent stimuli, we defined fixations as beginning when five consecutive samples (at 60 Hz) were within 6.2 cm of their center of mass and ending with two consecutive samples >6.2 cm from the center of mass. In this task, on every 6th to 10th fixation, four identical size-scaled Gabor patches were flashed for a duration of 67 milliseconds. The Gabors were presented at a predetermined retinal eccentricity of either 5°, 10°, or 15° of visual angle from the viewer's current eye fixation position. The participants' task was to determine whether the nearly vertical Gabors were tilted left or right, with responses made by pressing one of two buttons on the steering wheel of the driving simulator. For each participant, the Gabor offsets from vertical were based on their prior threshold estimations at each eccentricity.

Driving task. Drivers were instructed to follow a lead vehicle, leaving approximately a 50 m gap between their vehicle and the vehicles in front of them. We measured how well drivers achieved this aspect of the driving task in terms of their longitudinal vehicle control (i.e., how well they could consistently maintain that gap between their vehicle and the vehicles in front of them). In addition to following a lead vehicle, drivers also needed to stay in their lanes just as they would in the real world. We measured how well drivers achieved this aspect of the driving task in terms of their lateral vehicle control (i.e., how well they could keep their vehicle in the middle of the lane). Both longitudinal and lateral measures of vehicle control have been used in previous driving research (Dozza, Flannagan, & Sayer, 2015).

Cognitive workload (multitasking). Cognitive workload was manipulated using an auditory two-back working memory task (Reimer et al., 2012; Son, Park, & Oh, 2012). In the two experimental drives that included this two-back task, participants heard 1 of 26 randomly selected letters every three seconds and were instructed to verbally indicate (yes or no) as quickly as possible if the letter they heard matched the letter presented two trials back. Except for the initial two trials, there was a 25% chance that the letter presented would be a match. For the remaining two experimental drives, participants drove without any additional tasks. A primary interest of this study was how older adults' dynamic useful field of view might be impacted by cognitive workload (i.e., multitasking).

Driving task difficulty (wind). In addition to manipulating cognitive workload, driving task difficulty was manipulated by the addition of a computer-generated lateral wind in two of the experimental drives. This manipulation allowed for an additional exploration of how older adults' useful field of view might be impacted by dynamic changes in the environment in a way that was different from the multitasking manipulation described previously. Lateral wind was generated using the combination of a constant wind (40 mph) and the sum of three sine waves (all at 25 mph and .077 Hz, .059 Hz, and .032 Hz, respectively), which produced the sensation of wind gusts that drivers had to adjust for in their steering to stay in their lanes (Medeiros-Ward et al., 2014). The wind varied in directionality such that drivers were unable to predict and therefore had to respond to the lateral force. There was no lateral wind in the other two experimental drives.

RESULTS

Gabor Discrimination Task

Our primary interest was in the effects on Gabor orientation discrimination task accuracy, which was our measure of the useful field of view or attentional breadth. Crucial for the current study, accuracy was analyzed across three eccentricities. If Gabor accuracy declined during increased cognitive workload only at far eccentricities but not near eccentricities, this would support a tunnel vision hypothesis. If Gabor accuracy declined during increased cognitive workload across all eccentricities, this would support a general interference hypothesis.

Gabor accuracy was the dependent measure in a repeated-measures ANOVA with eccentricity (5° vs. 10° vs. 15°), cognitive workload (single task vs. dual task), and lateral wind (no wind vs. wind) as within-subjects factors. There was no effect of wind, $F(1, 24) = 1.66$, $p = .21$, $\eta^2_p = .06$, or eccentricity, $F(1, 24) = 0.27$, $p = .76$, $\eta^2_p = .01$ on Gabor accuracy, but there was a main effect of cognitive workload, $F(1, 24) = 4.83$, $p = .04$, $\eta^2_p = .17$. Specifically, Gabor discrimination accuracy significantly declined from the single task (.885) to the dual task (.840) cognitive workload conditions. Thus, cognitive workload decreased older adult drivers' dynamic useful field of view as measured by Gabor accuracy. Critically important for testing between a tunnel vision and a general interference account, cognitive workload did not interact with eccentricity, $F(2, 48) = 0.26$, $p = .77$, $\eta^2_p = .01$, which is more consistent with a general interference account of the effects of older adult multitasking (Figure 2). There was no significant interaction

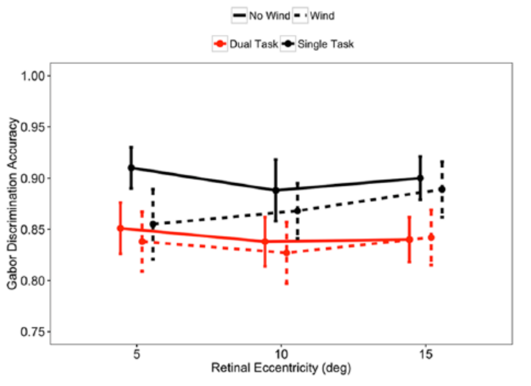

Figure 2. Gabor discrimination accuracy (proportion correct) at 5°, 10°, and 15° as a factor of driving difficulty and cognitive workload. Error bars represent ±1 standard error of the mean. Single task = driving only. Dual task = driving with auditory two-back task.

between wind and eccentricity, $F(2, 48) = 0.78$, $p = .47$, $\eta^2_p = .03$, nor was there a significant interaction between cognitive workload and wind, $F(1, 24) = 0.49$, $p = .49$, $\eta^2_p = .02$. Finally, there was no significant interaction between cognitive workload, wind, and eccentricity, $F(2, 48) = 0.22$, $p = .80$, $\eta^2_p = .01$.

Driving Performance

We also wanted to directly measure the effects of our cognitive and driving loads on simulated driving performance. Using repeated measures ANOVAs, driving performance was measured in terms of lateral vehicle control (i.e., the standard deviation of lateral lane position, or SDLP) and longitudinal vehicle control (i.e., the standard deviation of following distance from the lead vehicle in meters, or SDFD) with lateral wind (no wind vs. wind) and cognitive workload (single task vs. dual task) as within-subjects factors. There was a main effect of wind on SDLP, $F(1, 24) = 79.26$, $p < .001$, $\eta^2_p = .77$, such that it was more difficult to maintain lane position with lateral wind; namely, SDLP was significantly higher when there was wind (.502) compared to no wind (.409). Interestingly, there was no effect of cognitive workload, $F(1, 24) = 0.68$, $p = .42$, $\eta^2_p = .03$, and no interaction between cognitive workload and wind on lane keeping (SDLP), $F(1, 24) = 0.53$, $p = .47$, $\eta^2_p = .02$ (Figure 3).

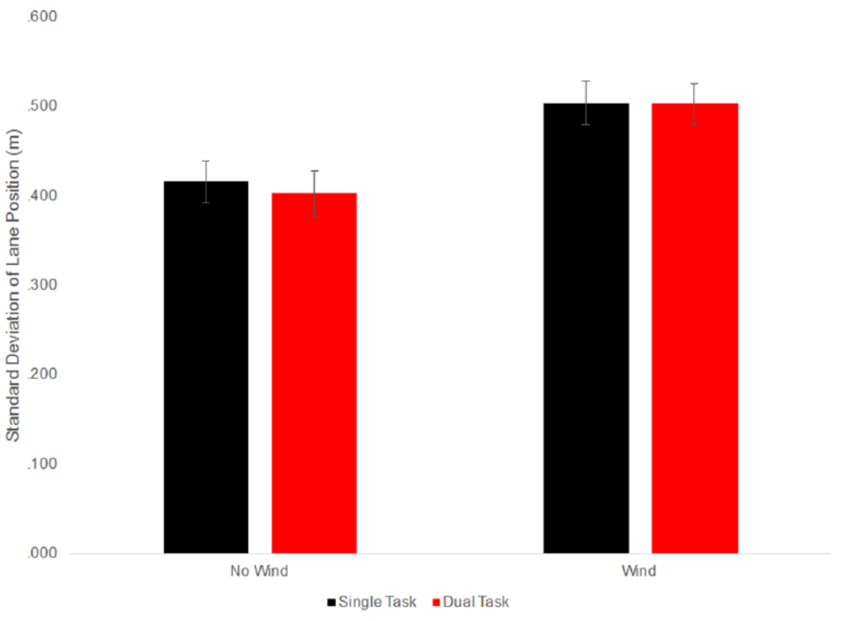

Figure 3. Standard deviation of lane position in the driving task. Error bars represent standard error of the mean. Single task = driving only. Dual task = driving with auditory two-back task.

There was a robust main effect of wind, $F(1, 24) = 15.18$, $p = .001$, $\eta^2_p = .39$, indicating that following distance was more variable with lateral wind; namely, SDFD was greater in the conditions with lateral wind (39.47) compared to when there was no wind (27.58). Also, there was an effect of cognitive workload on following distance, $F(1, 24) = 8.82$, $p = .01$, $\eta^2_p = .27$, in which following distance variability (SDFD) was greater in the dual task workload conditions (37.84) compared to the single task workload conditions (29.20). There was no interaction between cognitive workload and wind, $F(1, 24) = 1.75$, $p = .20$, $\eta^2_p = .07$ (Figure 4).

DISCUSSION

The current research investigated older adult multitasking performance in a simulated driving environment. Specifically, we used a novel gaze-contingent dynamic measure of the useful field of view to measure moment-by-moment changes in the useful field of view as older adults drove in both easy and hard driving conditions and with single and dual task cognitive workloads.

With regard to driving performance, wind affected both lateral and longitudinal vehicle control; however, cognitive workload affected longitudinal vehicle control but not lateral vehicle control. The fact that we found that our cognitive dual task strongly affected longitudinal control, namely, lead car following distance, is consistent with prior studies that have claimed that longitudinal vehicle control is a tactical higher-order task requiring executive function and working memory (Bergen, Medeiros-Ward, Wheeler, Drews, & Strayer, 2013). Specifically, drivers must keep the desired headway active in working memory while monitoring the actual headway, continually compare the two, and then make appropriate decisions about speeding up or slowing down. Given that our cognitive dual task, the auditory two-back task, involves similar executive function and working memory processes, it makes sense that it interfered with the longitudinal vehicle control task. What is surprising, however, is that the two-back cognitive workload did not affect the lateral vehicle control task.

While other studies have found that cognitive workload can affect lateral vehicle control, there

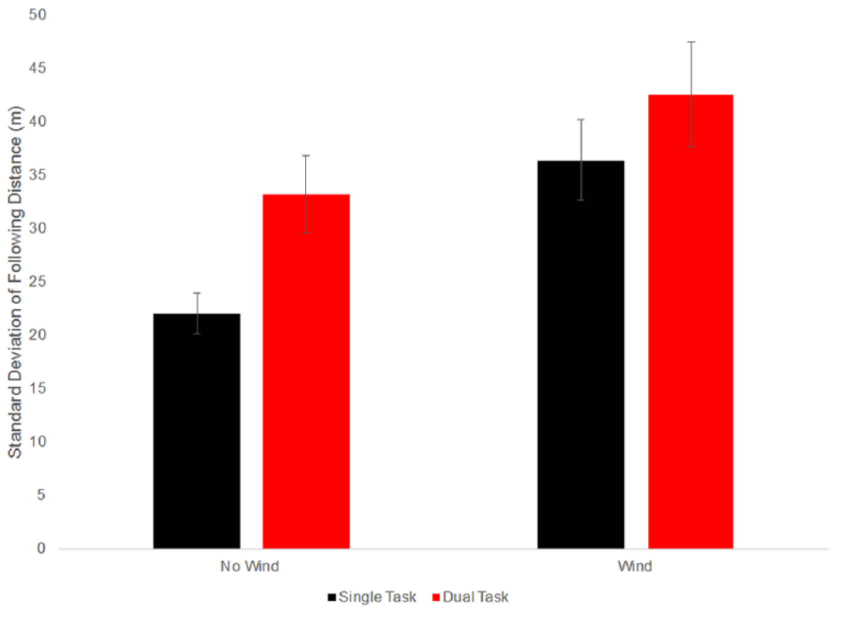

Figure 4. Standard deviation of following distance. Error bars represent standard error of the mean. Single task = driving only. Dual task = driving with auditory two-back task.

are several possible reasons for why we did not find evidence for this in the current study. One possibility could be that our cognitive dual task might have been too easy, in which case older adult drivers might not have experienced a sufficiently difficult secondary task. This seems unlikely given that the average two-back task accuracy was 88%. Indeed, other studies have shown the two-back task to cause considerable cognitive workload (Mitchell, Macrae, & Gilchrist, 2002; Reimer, 2009; Reimer et al., 2012; Ringer et al., 2016). Furthermore, as noted previously, we did find robust effects of the two-back cognitive workload on our longitudinal measure of vehicle control. Thus, another possibility is that lateral vehicle control might not be the most appropriate measure for quantifying cognitive workload. Indeed, in the past, some researchers have found decreases in lateral lane position variability with increased cognitive workload (Atchley & Chan, 2011; Becic et al., 2010) while others have found the opposite (Cooper, Medeiros-Ward, & Strayer, 2013; Merat & Jamson, 2008). Given this discrepancy, more research is needed to better understand measures of lateral vehicle control. Finally, it is possible that this study was underpowered, and thus some effects might have gone undetected both in terms of driving measures and Gabor accuracy.

With regard to our primary hypothesis about dynamic changes in the useful field of view and contrary to a tunnel vision account of multitasking performance, we found evidence that visual discrimination performance suffered equivalently across the entire range of eccentricities measured (from 5° to 15° eccentricity). This is in line with a general interference or domain-general account of multitasking in which as cognitive workload increases, task performance decreases regardless of the eccentricity of presented stimuli. Similar results consistent with general interference have been found in several other studies (Bian, Kang, & Andersen, 2010; Crundall et al., 1999, 2002; Gaspar et al., 2016; Ringer et al., 2016). For example, Bian et al. (2010) had young adults follow a lead vehicle while responding to lights at three fixed eccentricities and found that in dual task conditions, light detection was impaired at all spatial locations. The current study extends this research by using a gaze-contingent paradigm to control for the drop-off in visual acuity at increased eccentricities for older adults.

An important question for future research is whether a foveal load is as detrimental to covert attention for older adults as it is for younger adults or if age-related attentional decrements are exacerbated by target eccentricity, as claimed by Ball and colleagues (1988). In addition, future research should expand the possible theoretical accounts to include models beyond general interference theories and tunnel vision theories (e.g., for an alternative approach involving a zoom-lens model, see Eriksen & St. James, 1986).

While some previous aging research on the useful field of view has found evidence more in line with a tunnel vision theory of interference (Ball et al., 1988), our results are more similar to previous research on functional field losses. For example, Seiple, Szlyk, Yang, and Holopigian (1996) manipulated masking, distractors, and stimulus luminance on a computer-based measure of the useful field of view and found that target detection rates were impaired for older adults across all levels of eccentricity. Our results are similar even though we used a gaze-contingent Gabor discrimination task rather than a stationary target detection task and also a dynamic, driving environment rather than a static visual stimulus display on a computer. One possible reason for the general interference demonstrated in our study could be related to speed of processing, which has been shown to slow for older adults in other vision-based tasks (Hommel, Li, & Li, 2004).

Other studies that have found evidence of tunnel vision with an auditory load may have confounded low-level visual properties, like sensitivity, acuity, and cortical magnification. For instance, Reimer (2009) found that increased N-back difficulty tends to impair overt attention by reducing eye movement dispersion in a driving simulator, but peripheral information was not size-scaled. Conversely, Ringer and colleagues (2016) size-scaled Gabor patches and did not find evidence of tunnel vision with a concurrent auditory N-back task but did show tunnel vision with a foveal rotated L versus T discrimination task. Therefore, the method used in the current study is capable of producing attentional tunneling with the appropriate attentional manipulation (i.e., a foveal load), but more research is needed to better understand the potential combinatory effects of age and working memory load in applied contexts. Future longitudinal studies with larger sample sizes are needed to further explore these possibilities as well as test for other potential underlying mechanisms to inform age-related theories of attention and performance.

To our knowledge, the current study is the first to investigate the effects of multitasking on a population of drivers known to have elevated deficits in multitasking performance using a dynamic measure of the useful field of view in a complex setting. We focused on older adults because much is still unknown about mechanisms underlying older adult multitasking performance. Furthermore, there has been more than a 50% increase in older adult licensed drivers from 1999 to 2015 (U.S. Department of Transportation, n.d.), and in 2014, approximately 16 older adults were killed (648 injured) in crashes on average every day (Centers for Disease Control and Prevention, 2017). Thus, understanding older adult multitasking performance can have societal implications. The current study shows that older adult multitasking performance during driving results in a reduction of the useful field of view and does so with a novel gaze-contingent paradigm that controls for the low-level effects of eccentricity on acuity (Gaspar et al., 2016; Ringer et al., 2014, 2016). More research is needed to replicate these effects with larger samples and extend these findings to other paradigms beyond the useful field of view and to different complex settings for a more complete mechanistic account of older adult multitasking performance.

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KEY POINTS

- This study implemented a dynamic useful field of view paradigm to examine older adult multitasking performance in a simulated driving environment.
- This approach overcomes limitations with previous real-time useful field of view measures in applied settings.
- The present study found evidence to support a general interference account of multitasking rather than a visual tunneling account in the presence of increased cognitive workload.

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