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Research Article

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Control of Vehicle Braking by Younger and Older Drivers: The Effect of Texture and Size Information

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Abstract

In the current study we examined differences in the use of visual information for the control of braking for older and younger drivers. On each trial, drivers controlled braking in a driving simulator during approach to three stop signs. Their task was to apply smooth and continuous braking and stop in front of the stop signs. The initial time-to-contact, initial speed, texture on the ground and size of the stop signs were manipulated. The mean stop distance relative to the stop signs, standard deviation of stop distance, crash rate, mean time-to-contact at onset of braking, and distribution of tau-dot were analyzed. Overall we found that older drivers had larger mean stop distances and lower crash rates as compared to younger drivers. In addition, regulation of tau-dot varied as a function of size for younger but not for older drivers. These results, taken together, suggest that older drivers may use size information differently than younger drivers in braking regulation.

Keywords: Aging; Braking control; Time-to-contact

Introduction

Safe driving performance includes the successful detection and avoidance of an impending collision. Of all crash types, rear end collisions account for a high number of vehicle crashes. For example, data from the NHTSA 2003 General Estimates system indicated that rear-end crashes accounted for 28% of police reported crashes in the United States and is a rate higher than other types of high crash rate events such as loss of control incidents (23%) and improper lane changes (9%) [1]. The frequency and severity of rear-end collisions and its importance to driving safety is evident by the relatively recent introduction of collision avoidance systems within vehicles (e.g. NTSB, 2001) intended to reduce the incidence of rear-end collisions.

Successful safe avoidance of a rear-end collision requires the driver to regulate braking by applying appropriate pressure on the brake at the appropriate time such that the vehicle could decelerate or stop to avoid a collision. Braking too early and too hard would result in stopping short, and braking too late and too soft may result in crashing into a decelerating or stopped leading vehicle. Thus, in order to understand the human factors behind events such as rear-end collisions one must understand how a driver controls braking. It is important to note that driving, including the control of braking, is a visual task. Despite an extensive literature on the human factors of driving performance it is surprising that relatively few studies have examined how a driver regulates braking and specifically what visual information is used by a driver to control braking. The purpose of the present study was to examine whether the use of visual information for the control of braking varies according to the age of the driver. It is well documented that crash rates are higher for older as compared to younger drivers [2]. In addition, the number of older drivers on the road will increase dramatically as a result of aging of the US population. Indeed, data from the Federal Highway Administration indicate that the percentage of 65 and older age drivers on the road will increase from 13% in 2007 to 23% in 2030 as a result of changing age demographics within the United States [3]. These findings suggest that understanding age-related differences in braking control is an important issue for understanding increased risk of crashes with older drivers and roadway safety.

Visual information for braking

As an observer approaches an object, the projection of the object expands. Lee (1976, 1980) showed that the time to contact ($\dot{\tau}$) with an approaching object with constant velocity (the time it takes for an approaching object to reach an observer or another object) is determined by the visual angle of the object and the inverse rate of optical expansion of that object [4,5]. Previous research has demonstrated the usefulness of τ in judging time to collision [6,7]. Furthermore, Lee [4] proposed that the time derivative of τ (tau-dot, or $\dot{\tau}$) could be used to regulate deceleration during braking. Specifically, maintaining $\dot{\tau}$ at a critical value of -0.5 would lead to a perfect stop. Values less than -0.5 would result in a collision and $\dot{\tau}$ values greater than -0.5 would result in stopping before the desired stop location [4]. Thus, a potential strategy to control braking is through regulating $\dot{\tau}$ at the critical value of -0.5.

Previous studies have examined whether drivers use $\dot{\tau}$ to discriminate collisions and regulate braking. For instance, Kim et al. [8] presented observers with displays simulating approach to a square and required observers to determine whether an impending collision was "hard" or "soft". They found that when deceleration was manipulated such that $\dot{\tau}$ was maintained at a constant value, drivers tended to use $\dot{\tau}$ of -0.5 to discriminate between "hard" and "soft" collisions. However, Kaiser and Phatak [9] argued that observers' sensitivity to $\dot{\tau}$ did not necessarily mean that $\dot{\tau}$ was actually used in active braking regulation. Yilmaz and Warren [10] examined the use of $\dot{\tau}$ in active control of braking and manipulated sources of information for distance to a stop sign (ground surface texture and the size of the stop sign). They found that drivers regulate deceleration to null the error between the current $\dot{\tau}$ and the critical $\dot{\tau}$ of -0.5. The presence of ground texture or

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variations in object size did not improve drivers' performance except for the shortest high speed trials. They concluded that this $\dot{\tau}$ strategy was sufficient to regulate braking.

If $\dot{\tau}$ is the only source of visual information used in braking control, then manipulating other sources of visual information should not affect the performance in judging collision events. Andersen et al. [11] tested this hypothesis using a collision judgment task. Drivers viewed scenes simulating approaching an object with constant deceleration and determined whether they would be able to stop before crashing into the object. They found that drivers used $\dot{\tau}$ information when making collision judgments. However, performance was also affected by the initial speed of the driver, size of the impending object and the edge rate information on the ground. They suggested that since the critical value of $\dot{\tau}$ at -0.5 was the only value at which deceleration was constant, drivers might have used an analysis based on constant deceleration rather than constant $\dot{\tau}$. Their findings were extended by Fajen [12] using an active braking control task similar to that in Yilmaz and Warren [10]. Fajen [12] found that both the global optical flow information and edge rate information affected performance in braking, which could not be explained by an analysis based solely on $\dot{\tau}$.

These studies, considered together, have examined the use of visual information in braking regulation of younger drivers. In the current study, we examined whether there was any age-related difference in the use of visual information to regulate braking. Previous studies have found age-related differences in perceptual processes that are related to collision detection. For instance, Schiff et al. [13] found an age-related decrement for older observers in determining the time to contact of an approaching object. Oxley et al. [14] found that when selecting a safe time gap crossing a street, older observers tended to be more conservative than younger observers. DeLucia et al. [15] examined age-related differences in judging time to contact between two objects and between an observer and an object. They found that overall observers underestimated TTC (time-to-contact of an approaching object). However, older observers showed greater underestimation as compared to younger observers. Since underestimation of time to contact suggests that observers believe that less time is available to avoid collisions, these findings suggest that older observers may react early than younger observers when actively regulating braking control.

Andersen et al. [16] examined age-related difference in detecting collision events during deceleration. They found that older observers were less sensitive to collision events as compared to younger observers, especially at high speed. In addition, older observers made more collision judgments when non-collision events were simulated. Both age groups used speed and size information in detecting collision events during deceleration. Their findings suggest that older observers may be at higher risk in detecting collision during deceleration. Andersen and Enriquiz [17] examined age-related difference in collision detection. In their study, younger and older observers were presented simulated 3D scenes with an approaching object that would either collide with the observer or pass by the observer. They found that older observers showed less sensitivity to collision events with shorter presentation duration, longer time to contact and increased object motion speed. When observer motion was simulated, older observers showed greater difficulty in detecting collision events, suggesting that older observers have difficulty discriminating object motion expansion from background expansion.

As discussed earlier, the purpose of the current study was to examine whether there was an age-related difference in the control of braking and to examine whether the performance differences for older and younger drivers was due to the use of different types of visual information. As discussed earlier, previous studies have found age-related decrements in judging time to contact of an approaching object [13]. Thus, it is possible that older drivers, as compared to younger drivers, have decreased performance in regulating braking based on information. On the other hand, previous studies have found an age-related difference in judging collision events during constant deceleration and that this age-dependent performance was related to the use of speed and size information [16]. Studies have also found an age-related difference in the use of information on the ground and age-related difference in judging egocentric distance [18]. Thus, it is possible that older drivers may show an age-related difference in using ground texture and size information in active control of braking.

Experiment

Method

Drivers: The drivers were 14 undergraduate students (6 males and 9 females, mean age=20.9 ± 2.3) and 13 older drivers (6 male and 7 female, age=70.8 ± 5.1) from the Life Society Program at the university. All drivers were paid for their participation, were naive regarding the purpose of the experiment, had normal or corrected-to-normal visual acuity and were licensed drivers for at least 2 years. All drivers were also screened using several perceptual and cognitive tests. The tests included Snellen acuity, contrast sensitivity (assessed using the Pelli-Robson contrast sensitivity chart; Pelli, Robson, and Wilkins, 1988), forward and backward digit span, perceptual encoding, and the Kaufman brief intelligence test (K-BIT). Demographic information of the drivers who participated in the current study and the results of the screening tests are presented in Table 1.

Stimuli: The stimuli were computer generated 3-D scenes simulating driving towards three red octagon-shaped stop signs (Figure 1). One stop sign was located in the center of the roadway and the other two were positioned on both sides. There were two sizes of stop signs. Each side of small stop signs was 0.2 m, and the distance between small stop signs was 0.6 m. Each side of large stop signs was 0.6 m and the distance between large stop signs was 0.9 m. Each stop sign was connected to the ground surface by a red pole with a width of 0.1m and a height of 0.94 m. The center of the stop signs was 1.2 m above the ground, which was the same as the simulated eye height. The ground surface had either a 64×32 or 8×4 random black and white checkerboard texture.

Design: The four-way mixed design included age as the between-

Variable	*Younger*		*Older*	
	M	SD	M	SD
Age (years)^a	20.9	2.3	70.8	5.1
Years of education^a	14.1	1.3	16.4	2.1
Snellen Letter Acuity	10/10.8	1.1	10/12.9	2.3
Log Contrast Sensitivity$^{a, b}$	1.85	0.12	1.60	0.18
Digit Span Forward	11.4	2.7	11.2	2.2
Digit Span Backward^a	8.8	1.5	6.6	1.1
Perceptual Encoding Manuala	84.9	20.7	51.4	22.6
Kaufman Brief Intelligence Test	26.2	7.8	24.3	6.5

^{a}Differences between age groups were significant ($p \leq .05$) for both sets of age groups. b Contrast sensitivity was measured using the Pelli Robson test (Pelli, Robson, & Wilkins, 1988)

Table 1: Means and Standard Deviations of Participants' Demographic Information and Results From Perceptual and Cognitive Tests in Experiment 1.

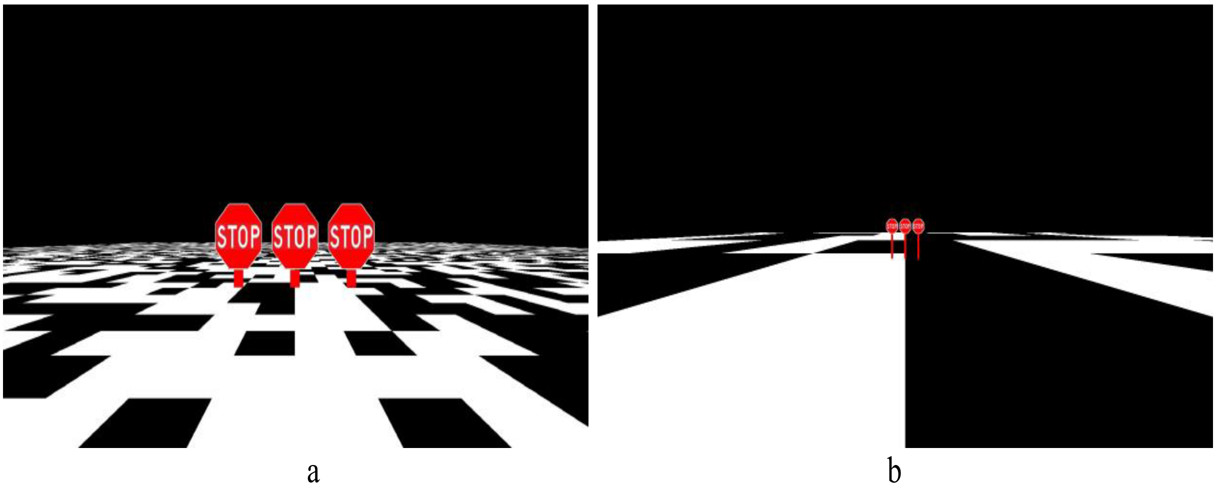

Figure 1: Static image of scenes used in the study. (a) large stop signs with high density ground texture; (b) small stop signs with low density ground texture.

subject variable and three within-subject variables: (1) the texture density on the ground (64×32 or 8×4), (2) initial TTC (3s, 3.5s, or 4s), (3) initial speed (40 kmph, 60 kmph, or 80 kmph), and (4) size of the stop signs (0.2 m or 0.6 m each side). The texture density was blocked and the order of texture density was counterbalanced across drivers within each age group. The mean stop distance to the stop signs, crash rate, and distribution of $\dot{\tau}$ were collected and analyzed.

Apparatus: The displays were presented on a 58-inch (148 cm) flat screen plasma TV (Panasonic TH-58PF12) with a pixel resolution of 1920 by 1080, controlled by a Windows 7 Professional Operating System on a Dell Precision T7500 workstation. The refresh rate was 60 Hz. The dimensions of the display on the monitor were 128.4 cm (W)×72.2 cm (H), subtending a visual angle of 106.4°×73.9° at a viewing distance of 48 cm. A Logitech G25 steering system with acceleration and brake pedals was used for closed loop control of the simulator with deceleration varying from 0 m/s^2 to 10.8 m/s^2.

Procedure: The experiment was run in a darkened room. Each trial started with a preview phase simulating the vehicle motionon a roadway towards three stop signs at a constant initial speed. During t preview phase the drivers did not have control over the brake. The purpose of this preview phase was to enhance the perception of self-motion, which usually requires 5 seconds to occur [19]. Five seconds later, drivers heard a warning tone which indicated that the control input from the drivers was allowed. The task of the drivers was to control the brake to stop as close as possible in front of the stop signs. Consistent with previous studies, drivers were instructed to apply smooth and continuous braking as if they were driving a real vehicle [11,12]. They were also instructed to avoid sudden and jerky brake adjustments and avoid applying full brake pressure at the very last moment.

Dependent Variables: Five dependent variables were collected to measure the performance of braking control of the drivers. These are: (1) the mean stop distance to the stop signs, which measures the constant error in stopping distance; (2) standard deviation of the mean stop distance to the stop signs, which measures the variable error in stopping distance; (3) percentage of crashes, which measures the percentage of trials in which drivers ended up crashing into the stop signs; (4) time-to-contact at onset of braking, which measures the time at which drivers started to actively apply control of braking; and (5) mean , which measures the average that drivers were controlling at during braking control.

Results and Discussion

Similar to Yilmaz and Warren [10], data analysis excluded trials in which drivers showed slam-on-the-brake or bang-bang pattern. Slam-on-the-brake trials were defined as those trials with a quick increase from zero to maximum deceleration value usually towards the end of approach with minimal further adjustments. Bang-bang trials were defined as those trials with alternating zero deceleration and maximum deceleration values during approach. Since two younger drivers and one older drivers showed slam-on-the-brake performance for majority of the trials (>75%), their data were not included in analysis. For the remaining drivers, 14.2% of the total trials were excluded from analysis either due to a slam-on-the-brake response or bang-bang response. This was in line with the 17% exclusion rate in Yilmaz and Warren [10]. On average, the exclusion rate was 15.5% for younger drivers and 12.9% for older drivers. This difference did not reach significance (F(1,22)=1.16, p=0.29). Mean stop distance, standard deviation of stop distance (a measure of consistency in braking performance), onset of braking (time following the preview phase when drivers depressed the brake pedal), and crash rate were collected and analyzed in a 2 (age) × 2 (texture density) × 3 (TTC) × 3 (initial speed) × 2 (size) mixed ANOVA. To examine the relationship between $\dot{\tau}$ and braking performance we calculated the relative frequency of control at different $\dot{\tau}$ values using the following methodology. $\dot{\tau}$ values were derived every 17 milliseconds during the braking control and sorted into 10 different bins between -1.0 to 0. These values were converted to a relative frequency histogram with the mean $\dot{\tau}$ derived and analyzed in a 2 (age) × 2 (texture density) × 10 (bin) mixed ANOVA.

Constant error in stopping distance

There was a significant main effect of age (F(1,22)=11.07, p<.01). The average stop distance for younger and older drivers was 1.2 m and 3.0 m from the stop signs, respectively. There was a significant main effect of initial TTC (F(2,44)=42.05, p<0.01), a significant main effect of initial speed (F(2,44)=63.41, p<0.01), and a significant main effect of size (F(1,22) = 12.15, p<0.01). In addition, we found a significant interaction between age and TTC (F(2,44)=5.30, p<0.01), a significant interaction between age and initial speed (F(2,44)=6.25, p<0.01), a

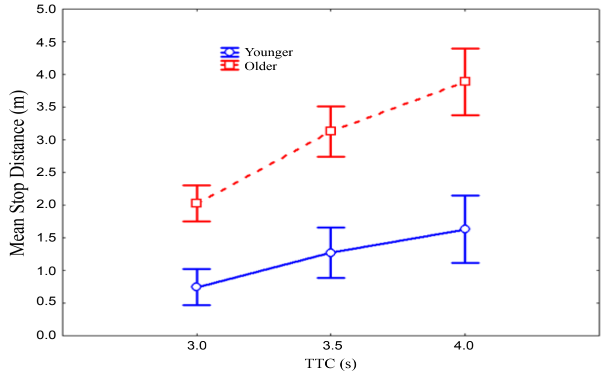

Figure 2: Mean stop distance as a function of age and TTC.

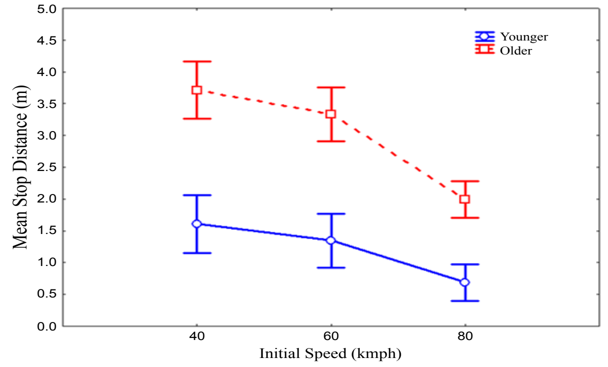

Figure 3: Mean stop distance as a function of age and initial speed.

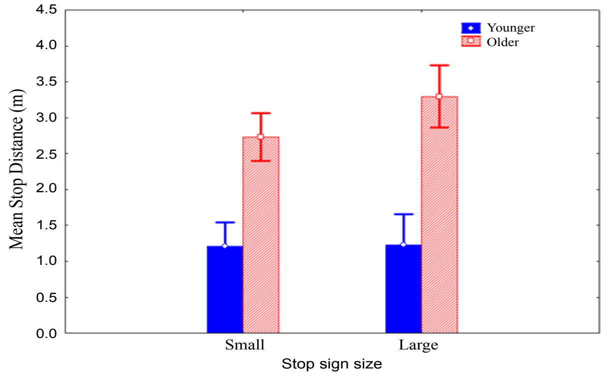

Figure 4: Mean stop distance as a function of age and stop sign size.

significant interaction between age and size (F(1,22)=10.61, p<0.01), a significant interaction between TTC and initial speed (F(4,88)=15.0, p<0.01), a significant interaction between TTC and size (F(2,44)=3.65, p<0.05), and a significant three-way interaction between texture, initial speed, and size (F(2,44)=6.19, p<0.01). As can be seen from Figures 2 and 3, age-related differences in mean stop distance increased with an increase in TTC (Figure 2) and decreased with increased initial speed (Figure 3). For younger drivers, their mean stop distance did not change with the size of the stop signs (F(1,11)<1, p>0.05), whereas older drivers stopped further away from the larger stop signs as compared to small stop signs (F(1,11)=18.0, p<0.01, see Figure 4). Mean stop distance did not vary according to the texture on the ground (F(1,22)<1, p>0.05). No other main effect or interaction was significant.

Variable error in stopping distance

Although the average standard deviation of stop distance for older drivers (0.89 m) was slightly larger than younger drivers (0.78 m) and 0.89 m, this difference did not reach significance (F(1,22)<1, p>0.05). There was a significant main effect of texture (F(1,22)=4.50, p<0.05), a significant main effect of initial TTC (F(2,44)=5.81, p<0.05), and a significant main effect of initial speed (F(2,44)=48.27, p<0.01). As can be seen from Figure 5, standard deviation of stop distance increased with increasing TTC and increasing initial speed. When the low density ground texture was presented on the ground plane, the standard deviation of stop distance was larger than when a high density checkerboard texture was presented on the ground plane. No other main effect or interaction was significant.

Percentage of crashes

The main effect of age did not reach significance (F(1,22)=3.37, p=0.08). On average, older drivers had a crash rate of 7% and younger drivers had a crash rate of 11%. There was a significant main effect of initial TTC (F(2,44)=16.57, p<0.01) and initial speed (F(2,44)=38.88, p<0.01). In addition, there was a significant interaction between age and size (F(1,22)=6.14, p<0.05), between TTC and initial speed ((F(4,88)=16.36, p<0.01), and a significant 3-way interaction between texture, initial speed and size (F(2,44)=7.28, p<0.01). As can be seen

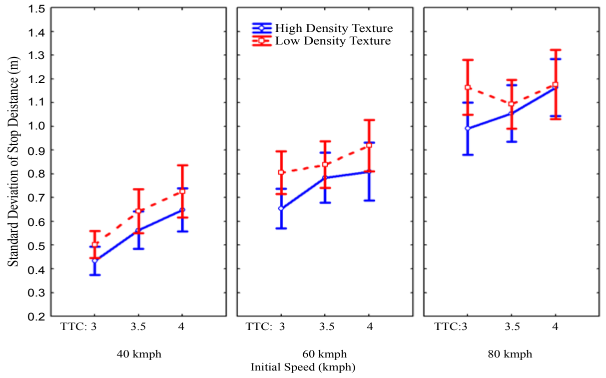

Figure 5: Standard deviation of stop distance as a function of texture, initial speed, and initial TTC.

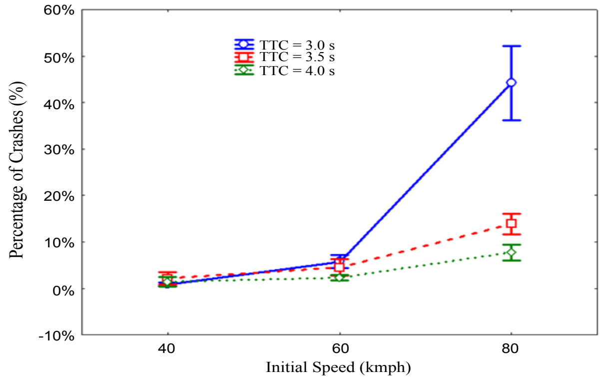

Figure 6: Percentage of crash as a function of initial speed and initial TTC.

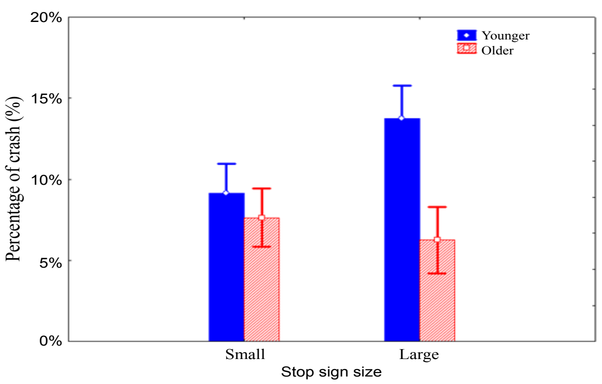

Figure 7: Percentage of crash as a function of age and stop sign size.

in Figure 6, the crash rate decreased with longer TTC and increased with faster speed. The main effect of TTC on crash rate was not significant when initial speed was 40 kmph (F(2,44)<1, p>0.05) or 60 kmph (F(2,44)=2.11, p=0.13). When initial speed was 80 kmph, there was a significant main effect of TTC on crash rate (F(2,44)=18.2, p<0.01). This effect is likely the result of a decreased ability of drivers to accurately determine TTC at higher speeds and overestimating the safety time margin for braking. According to Figure 7, when small stop signs were presented, younger and older drivers showed similar crash rate (F(1,22)<1, p>0.05). When large stop signs were presented, younger drivers had higher crash rate (14%) than older drivers (9%) (F(1,22)=6.72, p<0.05). No other main effect or interaction was significant.

Time-to-contact at the onset of braking

On average, the TTC at the onset of braking was very similar between younger and older drivers and the main effect was not significant (F(1,22)<1, p>0.05). There was a significant main effect of initial TTC (F(2,44)=1456.33, p<0.01), which is not surprising since drivers had less time to brake for shorter initial TTC conditions. The main effect of size was also significant (F(1,22)=11.92, p<0.01). According to this result, when small stop signs were presented, drivers initiated the braking slightly earlier (3.19 s) than when large stop signs were presented (3.23 s). The effect of size did not interact with any other variables. This was not expected given that larger stop signs should appear closer to drivers and thus result in earlier braking.

In addition, there was a significant interaction between age and initial speed (F(2,44)=6.81, p<0.01), between texture and initial speed ((F(2,44)=6.24, p<0.01), between initial TTC and initial speed (F(4,88)=5.78, p<0.01), and a significant 3-way interaction between age, texture density and initial speed (F(2,44)=5.34, p<0.01). As can be seen in Figure 8, when the high density ground texture was presented, there was a significant interaction between age and initial speed (F(2,44)=10.75, p<0.01). That is, at slower speeds, younger drivers tended to initiate braking late (resulting in shorter TTC) as compared to older drivers. When low density ground texture was present, this interaction between age and initial speed did not reach significance (F(2,44)<1, p>0.05). No other main effect or interaction was significant.

Mean $\dot{\tau}$

The average $\dot{\tau}$ of the relative frequency histogram for younger drivers was -0.46, which was significantly smaller than that of older drivers (-0.41, F(1,22)=7.65, p<0.05). There was a significant main effect of texture (F(1,22)=5.68, p<0.05), suggesting that the presence of a low density ground texture resulted in a smaller mean. There was also a significant main effect of initial speed (F(2,44)=3.56, p<0.05). In addition, there was a significant interaction between age and size (F(1,22)=4.67, p<0.05), between TTC and initial speed ((F(4,88)=12.13, p<0.01), and a significant 3-way interaction between texture density, initial speed and size (F(2,44)=3.23, p<0.05). According to Figure 9, when small stop signs were presented, the mean at which drivers were controlling was larger with a high density ground texture present than with low density ground texture present. When large stop signs were presented, the mean $\dot{\tau}$ was larger with a high density ground texture present than with a low density texture present only at slower initial speed.

Figure 10 demonstrates the relative frequency histograms as the percentage of $\dot{\tau}$ for both age groups with small and large stop signs. Two interesting results could be found from this figure. First, younger drivers have the highest percentage of control when $\dot{\tau}$ was -0.5, which is consistent with previous studies for collision judgments and active braking control [10-12,16]. Older drivers, however, have the highest percentage of $\dot{\tau}$ at -0.4. Compared to younger drivers, older drivers tend to regulate $\dot{\tau}$ more frequently at values greater than -0.5 and less frequently at values less than -0.5. Since $\dot{\tau}$ values less than -0.5 would result in a collision, this result suggests that older drivers are more

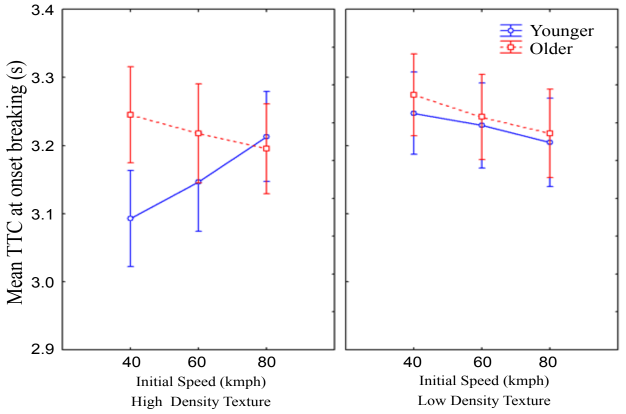

Figure 8: Mean TTC at onset of braking as a function of texture, initial speed, and age.

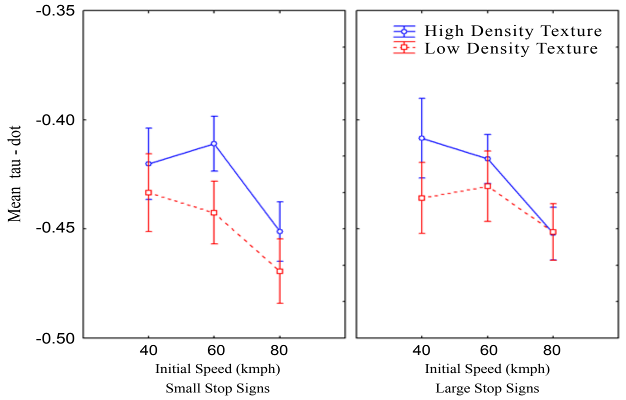

Figure 9: Mean tau-dot as a function of texture, initial speed and stop sign size.

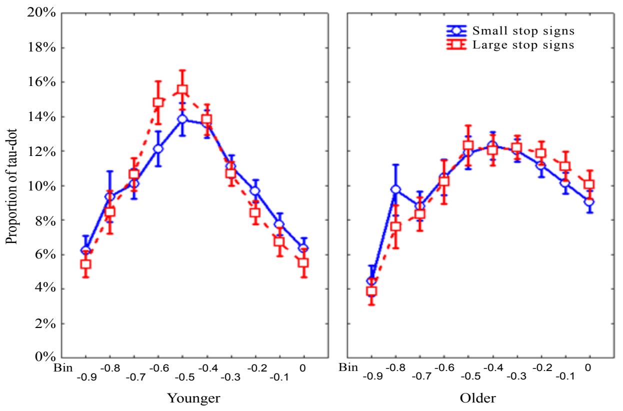

Figure 10: Distribution of tau-dot values younger and older observers were controlling at with small and large stop signs.

conservative than younger drivers in regulating braking. Second, younger drivers' distribution of $\dot{\tau}$ was affected by the size of the stop signs whereas older drivers' distribution of $\dot{\tau}$ was similar regardless of the stop sign size. That is, when large stop signs were presented, younger drivers tend to regulate braking such that $\dot{\tau}$ was more concentrated at the value of -0.5.

Conclusion

In this study, we examined age-related differences in braking control and whether such differences were related to visual information available in the driving scene. We found that overall, older drivers tend to stop further away from the stop signs and had fewer crashes as compared to younger drivers, especially when large stop signs were presented. In addition, older drivers regulated deceleration such that they had a higher percentage of $\dot{\tau}$ at greater values and a smaller percentage of $\dot{\tau}$ at smaller values than younger drivers. Previous studies have found that younger drivers regulated $\dot{\tau}$ at -0.5 in braking control, suggesting that younger drivers used either a $\dot{\tau}$ based analysis or a constant deceleration analysis [10]. Our results suggest that older drivers may regulate $\dot{\tau}$ slightly greater than -0.5. This is probably an indication that older drivers are more cognizant of their decrements in visual capabilities and thus strategically regulate braking with a conservative bias to avoid a collision.

In the current study the texture on the ground was manipulated. There were two purposes for this manipulation. First, texture density is directly related to edge rate information, which has been shown to affect perceived ego-speed [20]. Previous studies have found that edge rate affected performance in collision judgments and active braking control [11,12]. The second reason of manipulating texture on the ground was related to perceived distance on the ground surface. Recent studies have found age-related differences in using ground surface information to organize layout of 3-D scenes. For instance, Bian and Andersen [18] showed that older observers, as compared to younger observers, tend to use less information on the ground surface to determine relative distance between objects in 3D scenes. More recently, Bian and Andersen [21] found an age-related difference in perceiving egocentric distance. According to the constant deceleration model proposed by Andersen et al. [11], judgment of collision events during deceleration was determined not only by but also by the perceived distance between the driver and a collision object. Thus, it is possible that the manipulation of texture would have a differential effect on performance in active braking control for younger and older drivers. Overall, the findings in the current study did not support this hypothesis. Although high density texture resulted in smaller variable error in stop distance and greater mean $\dot{\tau}$ than low density texture, these effects did not vary as a function of age, suggesting that the use of texture information in active control of braking was similar for younger and older drivers.

The current study also examined the use of size information between younger and older drivers in active control of braking. Yilmaz and Warren [10] found that manipulation of stop sign size did not affect performance for younger drivers in braking regulation. Andersen et al. [16] found that both younger and older drivers used speed and size information in detecting collision events during deceleration. In the current study, we found that when large stop signs were presented, older drivers had fewer crashes and stopped further away from the stop signs than younger drivers as compared to when smaller stop signs were presented. That is, older drivers may view the larger stop signs are being closer and thus stopped further away from them. In addition, the stop sign size affected the distribution of $\dot{\tau}$ controlled by younger but not older drivers. This finding suggests that older drivers, as compared to younger drivers, may be more dependent on size information and use this information to estimate closing distance.

The present study demonstrates the types of visual information used by drivers to regulate braking and the conditions in which driving performance declines and the crash risk is increased. This finding indicates the conditions in which advanced warning signals or automated braking could be beneficial in avoiding a collision during braking. Thus, the research has important implications for automotive engineering and the design of new advanced vehicle technologies.

In conclusion, the results of the current study indicate that older drivers had larger stop distances and lower crash rate than younger drivers in active control of braking. This age-related difference in performance was probably due to differential use of size information but not texture information on the ground. The textures on the ground surface did not differentially affect braking regulation for younger and older drivers. The size of the stop signs, however, resulted in different tau-dot distributions for younger but not older drivers. These results suggest that the epidemiological finding of increased crash rates for older drivers may be more dependent on other factors such as reduced attention and the useful field of view or reduced attention in depth during driving rather than a decline in the ability to process visual information for the regulation of braking [22,23].

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