Final Report: Aging Driver And Pedestrian Safety: Parking Lot Hazards Study BDK83 977-12

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Disclaimer

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation or the U. S. Department of Transportation.

Prepared in cooperation with the State of Florida Department of Transportation and the U. S. Department of Transportation.

SI* (Modern Metric) Conversion Factors

Approximate Conversions to SI Units

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
FORCE and PRESSURE or STRESS				
lbf	pound force	4.45	newtons	N
lbf/in^2	pound force per square inch	6.89	kilopascals	kPa
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**

LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
TEMPERATURE (exact degrees)				
^oC	Celsius	1.8C+32	Fahrenheit	^oF
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. Source: http://www.fhwa.dot.gov/aaa/metricp.htm (Revised March 2003)

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16. Abstract. In Task 1, we analyzed pedestrian crash data for parking lots in West Central Florida, finding: 1) Seasonal variation in crash frequency in parking lots with higher frequencies in winter and spring, likely associated with tourist influxes to Florida; 2) Variation in crash frequency during daytime hours with peaks from noon to 6 pm; 3) Greater crash risk (per 1000 population) for all crashes and serious crashes for younger (age 15-19) and older (age 75+) pedestrians, as well as for younger (age 20-24) and older (age 65+) drivers; 4) Greater crash frequencies in smaller than larger parking lots and in residential parking lots; 5) No significant variation in crash frequency by parking space angle or by presence of crosswalks; and 6) Greater frequency of back out crashes for older pedestrians (age 75+) and forward driving crashes for younger (age 14 and below) pedestrians.

In Task 2, an observational study of pedestrian behavior in parking lots, we found: 1) Greater use of crosswalks by all age groups (young, middle, old) in larger parking lots, though no significant age variation occurred in using crosswalks; 2) No significant age variation was seen in lateral distance to parked cars when pedestrians were navigating; and 3) Greater distracted walking by younger than older pedestrians.

In Task 3, a field experiment requiring middle-aged and older pedestrians to navigate through an open parking lot and a parking garage wearing eye-tracking equipment, we found: 1) Age differences in walking speeds when navigating parking lots with older pedestrians, aged 65 and older, walking about 0.6 feet/s slower than middle-aged adults, aged 50 to 64; and 2) No significant age differences in attention patterns when navigating parking lots, as indicated by scanning behavior (e.g., head turns, eye fixation patterns) or in response to a backing out threat (fixation response time, walking path deviation).

We conclude that the most likely reason for the differential crash types in parking lots for older compared to younger pedestrians probably lies in the reduced speed with which older pedestrians can react to hazardous events. Potential countermeasures to improve safety could include age-targeted educational campaigns and development and deployment of collision-avoidance technology. We also recommend that future work focus on developing new ways to assess pedestrian crash exposure in parking lots that take into account walking speed and distance from parking spaces to store fronts.

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Executive Summary

Across the United States, walking is one of the most dangerous modes of transportation with 20.1 fatalities per 100 million miles traveled (Surface Transportation Policy Partnership (STPP), 2004). In 2009, Florida reported the highest rate of pedestrian fatalities, 2.51 deaths per 100,000 residents, nearly twice the national average of 1.33 per 100,000. Compared to other age groups, older adults are significantly more likely to be injured or killed in pedestrian crashes. Although those aged 65 and up make up only about 13% of the population, this age group accounted for 18% of all pedestrian fatalities, more than any other age group (NHTSA, 2009).

We began by conducting a thorough examination of an existing data set to gain a better understanding of the common characteristics, if any, of parking lot collisions (Task 1). Next, we conducted an observational study of younger, middle-aged, and older adult pedestrians navigating parking lots in the Tallahassee, FL, area (Task 2). Finally, we conducted a field study using a mobile eye-tracking device to learn more about pedestrians' allocation of visual attention as they navigated parking lots (Task 3).

Task 1 analyses revealed that the frequency of parking lot crashes, including severe crashes, was relatively constant during the 2004-2008 study period. As has been shown by others, there was significant variation by month, with more crashes in winter months and during spring break (March) and least in summer months. While this overall pattern was observed across all age groups, it was most marked for older adults aged 65 and older. Parking lot crashes were most likely during the noon to 6 pm interval, consistent with commercial business hours. Examining crash frequencies by population distributions for age groups showed that crash rates (per 1000 population) were highest for pedestrians aged 15-19 years, then declined with age until a spike was observed for seniors aged 75+ years. A similar trend was observed for drivers involved in parking lot crashes, though with the peak in youth occurring later at age 20-24 years of age. The high vulnerability of seniors during crashes was underlined when considering pedestrian crashes resulting in fatal or incapacitating injuries; rates held steady from age 15-19 years until an increase starting at age 65-74 years with a doubling at age 75+ years.

When examining types of crash by driver action, considering most frequent types (backing versus forward driving), contrary to expectations, we found that driver age had little influence on whether the crash involved reverse or forward driving. However, older pedestrians age 75+ years were about twice as likely to be hit by a vehicle backing up than driving forward, whereas the reverse was true for pedestrians aged 14 and younger, with no significant variation found for other age groups.

Consistent with earlier studies, the highest ratio of fatal and severe crashes to all crashes was observed for residential parking lots, though the small number of cases in the data set makes interpreting our results difficult for such crash types. This finding is also echoed in the finding that smaller parking lots recorded more serious crashes, despite their being about equal numbers of small and medium lots occurring in the data set. We found no differences in crash frequency or severity by type of parking offered (e.g., angled, straight parking spaces), whether parking lot aisles offered one-way or two-way traffic flow, or whether lots offered crosswalks.

Task 2 analyses of behavior patterns for pedestrians naturally navigating parking lots revealed that crosswalk use did not vary by age of pedestrian but did vary by parking lot type, with most frequent use in large parking lots. Pedestrians used crosswalks about half the time. We assessed the frequency of distracted walking (e.g., cell phone use) finding that only younger or middle-aged (but not older) pedestrians were walking while distracted, with a significantly higher frequency in younger pedestrians. We found no evidence that lateral distances from parked vehicles within walking paths varied by age of the pedestrian. However, path lengths may have varied with age, because older pedestrians were more likely to be navigating to and from handicapped parking spaces. Thus, we found no salient behavioral differences that could account for why older pedestrians may be more at risk from backing up crashes.

Task 3 examined a controlled navigation task within 1) an outdoor parking lot, and 2) a parking garage, where middle-aged and older pedestrians started from the same point and encountered a back out threat in the garage at the same distance while wearing a portable eye tracker. We found no salient differences in attention patterns while navigating, as revealed by head movements when crossing through the outdoor lot. For the parking garage, we found no age differences within eye movement data, such as for fixations in different areas of interest or for reaction time to the backup light event. Nor did we find any significant age differences in lateral separation from parked vehicles when walking or in the path deviation when the vehicle activated backup lights. If anything, older pedestrians were more cautious about approaching a vehicle when the backup lights were activated. The one significant finding was an age difference in walking speed of about 0.6 feet/s.

Together, findings from these studies suggest that the greater risk for older pedestrians in parking lots may be attributable to their slower response to hazards, such as vehicles driven by inattentive drivers, as indexed by their slower movement capabilities (e.g., walking speed) and greater fragility when involved in a crash.

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Chapter 1.

Introduction

Across the United States, walking is one of the most dangerous modes of transportation with 20.1 fatalities per 100 million miles traveled (STPP, 2004). In 2009, Florida reported the highest rate of pedestrian traffic fatalities, 2.51 deaths per 100,000 residents, which is nearly twice the national average of 1.33 deaths per 100,000 (NHTSA, 2010). Until recently, pedestrian incidents that occur in traffic at intersections have been the focus of most research, as well as the target of most new countermeasures designed to protect pedestrians. However, in suburban areas, where many people do not walk on busy streets, a significant number of pedestrian-vehicle collisions occur in non-traffic settings, such as parking lots and residential driveways (NHTSA, 2009). Many of these non-traffic incidents, particularly those involving a serious or fatal injury to a pedestrian, involve a backing vehicle (NHTSA, 2008a).

Parking lots are particularly dangerous pedestrian environments; there are potential hazards in all directions, and both pedestrians and drivers are often busy with other tasks, such as carrying groceries or searching for an empty parking space. Considering this, it is not surprising that an estimated 32% of non-traffic backing crashes involving a pedestrian fatality and 60% of those where a pedestrian was injured occurred in public and private parking lots (NHTSA, 2008a). For older adults, who may be slower to notice and react to potential hazards, parking lots may be particularly dangerous (e.g., Owsley et al., 1998, Maltz & Shinar, 1999). Consistent with this, older pedestrians aged 70 and above have been found to be much more likely than younger adults to be injured or killed in a crash where a vehicle is backing. Although older adults aged 70 and older only made up around 9% of the population in 2007, they accounted for around 26% of back-over fatalities and 18% of injuries. Only children under age 5 had a greater risk of being injured or killed in a back-over crash (NHTSA, 2008a).

Compared to research on the features of and circumstances surrounding traffic crashes involving pedestrians, much less is known about non-traffic incidents. One reason for this is that the main source of information about both traffic and non-traffic crashes are police reports. Because state and local laws governing the reporting of traffic incidents may vary considerably, it is challenging generating accurate estimates of the rate and characteristics of crashes occurring in parking lots, as well as other non-traffic locations. Prior to 2007, when NHTSA developed the Not in Traffic Surveillance (NiTS) system, national data sets did not consistently include information on non-traffic crashes (NHTSA, 2009).

Understanding the factors related to pedestrian-vehicle crashes in non-traffic settings, which include parking lots, is particularly important for states with a large number of older residents. Currently, Florida has one of the oldest state populations in the U.S., with 18% of its population estimated to be age 65 or older, and the number of older citizens in Florida and throughout the nation is predicted to continue to grow (U.S.

Census Bureau, 2011). A more complete understanding of the factors contributing to parking lot collisions involving pedestrians will help advance Florida Department of Transportation's mission to reduce the number of driving-related injuries and fatalities among residents of all ages.

Objectives and Supporting Tasks

Peter Hsu and colleagues from Florida DOT District 7 located in the West Central region covering Citrus, Hernando, Hillsborough, Pasco, and Pinellas counties reported a significant number of serious and fatal crashes for older pedestrians in parking lots between 2004 and 2008. Reducing pedestrian crashes is a goal of the Strategic Highway Safety Plan (SHSP) Vulnerable Road Users Emphasis Area, which covers all surface transportation systems including parking lots. Our goals in this research project were 1) to make use of their data sets to understand why this is occurring; 2) to supplement archival analyses with observational studies of parking lot pedestrian (and motorist) behavior to assess age differences in navigation practices, both as drivers and pedestrians; and 3) to provide micro-level data on pedestrian behavior as they navigate within a parking lot using eye-tracking equipment to understand what they are attending to visually.

In support of these goals, we have conducted three studies using a diverse set of research methodologies to gain a better understanding of both human and design factors related to pedestrian-vehicle crashes in parking areas. In Task 1, we performed a detailed analysis of an existing data set of parking lot crashes that occurred in FDOT District 7 between 2004 and 2008. This data set provided links to both detailed crash records, including copies of the original police reports filed at the time of the crash. In addition to performing a detailed analysis of the features of parking lot crashes listed in the database, we also examined the layout of the "open to sky" parking lots in order to identify design features of parking lots that may relate to the risk of crashes. In Task 2, we observed pedestrians as they navigated parking lots in the Tallahassee area. Past work has found that older adults take longer to notice and respond to potential hazards. In Task 3, we conducted a field study where pedestrians were outfitted with a head-mounted mobile eye-tracking system to learn about potential age differences in the allocation of visual attention as pedestrians navigate parking lots that might contribute to increased crash risk.

The findings from these studies provide critical information about the conditions surrounding pedestrian-vehicle crashes in parking lots, particularly those involving older pedestrians, which will aid the FDOT in developing appropriate guidelines and recommendations for the design of public and private parking facilities. In addition, findings from these studies can be used to guide the design of education programs for both drivers and pedestrians to better inform the public about safe navigation of parking areas.

Chapter 2.

Task 1: Archival Data Analysis of Pedestrian Crash Data Sets.

Task 1 was a detailed analysis of an archival data set consisting of information from crash reports from pedestrian-vehicle crashes that occurred in parking lots in Florida DOT District 7 (West Central, FL). Our preliminary analyses of the data set determined that the type and severity of crashes experienced by older adult pedestrians (age 65+) differed from younger adult pedestrians aged 16 to 64. Specifically, older adult pedestrians were disproportionately involved in crashes involving vehicles that were backing up and were more likely to be severely or fatally injured in crashes compared to younger pedestrians.

The primary aim of Task 1 was to begin constructing an ecology of parking lot crashes, which was used as a basis for planning Tasks 2 and 3, by supplementing our initial exploratory analyses with a more detailed examination of the cases included in the data set. In addition to analyses on information already included in the data set (e.g., age of driver, age of pedestrian, type of parking lot), we also used additional information provided in the included police reports to determine the precise location of many incidents. For those cases where a clear overhead view of the parking lot was available, we used Geographic Information System (GIS) software to record information about the design of the parking area, such as the size of the parking lot, whether parking spaces were angled or straight, if crosswalks were present, and whether parking aisles were one-way or bidirectional.

While human factors, such as inattention, are likely a major contributing factor in parking lot crashes, particularly those involving older pedestrians and drivers, there is good reason to expect that design features of parking areas should also relate to the frequency of crashes. For example, though angled parking spaces may improve traffic flow in parking lots, this ease in maneuvering may also make drivers more likely to back out of spaces quickly, which would give older pedestrians less time to notice and react to vehicle hazards. In addition, the presence of obstacles, such as cart returns or raised medians and landscaping, may also increase risks to older pedestrians. However, other features of parking lots, such as whether crosswalks are provided, may be associated with a lower incidence of crashes.

Method

The data set used in the Task 1 archival analysis was provided by Peter Hsu and colleagues in FDOT District 7. This data set consisted of information taken from police reports from pedestrian-vehicle collisions that occurred in parking lots between January 1, 2004 and December 31, 2008 in five counties in the West Central region of Florida (Citrus, Hernando, Hillsborough, Pasco, and Pinellas counties). In addition to information included in the data set, we also made use of the original police reports (included with data set) to identify the exact locations of crashes so that physical features of parking lots could be coded using GIS mapping software, as well as overhead views of parking lots available through Google Maps. As the availability of clear overhead views in the mapping software was necessary for the classification of parking lot features, cases that occurred in parking garages, those with dense tree canopies, and those that did not include enough information to determine the precise location of the incident were reviewed but no information about the physical features of those parking lots could be coded.

Examination and Recoding of Existing Data Set

Prior to conducting any analyses, we rechecked information included in the original data set and coded additional variables needed for our proposed analyses. First, the original data set only indicated the ages of individuals listed in sections 1 and 2 of police reports, and did not identify which of the individuals involved in the collision was the driver and which was the pedestrian. In addition, when a collision involved more than one vehicle and one pedestrian, only information from the first two individuals included on the police report was listed in the data. For example, if more than one pedestrian was involved in the collision, this could only be determined by looking at the original police report. We created additional variables in the date file that clearly indicated the age of the driver and all pedestrians involved in each crash. Within these variables, we also designated cases where the driver's age was unknown, as the original database had only indicated these with a "0," which did not distinguish missing information from instances where the pedestrian involved in the collision was less than a year old.

Because the circumstances surrounding parking lot collisions was a key variable in the current task, we also checked the information included in the variable indicating the driver's action at the time of the incident (e.g., backing, driving straight). Some of the driver actions listed in the original data file either had considerable overlap or were not specific enough for our proposed analyses. We created a new variable, "driver action," which combined redundant categories and included more refined categories for those that were too broad. Finally, we checked cases in which multiple vehicles were involved to confirm that the information listed for either vehicle 1 or vehicle 2 corresponded with the vehicle that collided with the pedestrian, as there were a number of instances in the original file where either vehicle 1 or vehicle 2 were parked cars that were also involved in the incident.

GIS Coding Procedure

The Geographic Information System software, ArcGIS Explorer was used to code the parking lot locations of the police crash reports (Available: http://www.esri.com/software/arcgis/explorer/index.html). We used the addresses given in police reports, as well as any supplemental information given in the narratives and crash scene drawings included in reports, to determine the precise location of each case we reviewed. For each case where the precise location could be determined and a clear overhead view of the parking lot was available, we used the ArcGIS software to measure key physical features, such as the overall area and the size of parking spaces.

We also coded additional information about parking lots using satellite maps included in this software, such as whether parking spaces were straight or angled.

In cases in which the maps produced within the GIS program were of poor quality, supplemental images were used through Google Maps, Google Earth, or Bing Maps. Supplemental maps were used only to solidify the accuracy of the address provided and find surface-level features; such as crosswalks, regular spaces, handicap spaces, and traffic direction (see Figure 1). For example, if the address provided in the database was for a large grocery store, we verified that this information was generally consistent with what was provided in the narrative and drawing of the crash scene included in police reports. In addition, because the incidents included in the database occurred several years ago, there were some cases where current satellite images did not match the information in the police report. Where possible, we used archival GIS maps or older images available through Google Earth that were dated from around the time the collision occurred. However, these older satellite images were often of poorer quality than more recent ones, so the information that could be coded from these images was sometimes quite limited.

Table 1 lists and defines the specific features that were coded within each parking lot. Factors such as type of lot, straight or angled spaces, locations of handicap spaces and crosswalks, traffic directions, and size were coded for each police reports' parking lot. Using the address listed on the police report, coders could search within the GIS program to produce a satellite map of the location of the specified crash.

Figure 1. Example of a coded parking lot in ArcGIS Explorer.

Table 1. Features coded for each parking lot.

Coded Lot Features	
Type of Lot	Retail, Non-Retail, Residential, Gas Station, etc.
Type of Spaces	Straight, Angled, or Parallel
Number of Spaces	Total number of parking spaces in a given lot (be they regular, handicap, or parallel)
Area of Spaces	Length/width of regular, handicap, and parallel spaces
Location of Handicap Spaces	Close to Entrances, Close to Buildings, etc.
Number of Crosswalks	Total number of crosswalks present in a given lot
Location of Crosswalks	If any: close to entrances, close to buildings, etc.
Number of Aisles	Total number of aisles that contain legal parking spaces; Aisle is defined as a row of spaces in which cars are able to legally park
Area of Aisles	Length/width of aisles
Traffic Direction	Whether the lot contains aisles that are strictly one-way, two-way, or both
Total Area	Area of a given lot, measured in units of square feet

Results

Total Cases Coded

Table 2 shows the total number of cases from each county included in the data set, as well as the number of cases that were coded (see also Appendix A). A large number of cases could not be coded because the address information included in the police report was either incomplete or not detailed enough to determine the precise location of the incident or a clear overhead view of the parking area was not available (e.g., dense tree cover, parking garages).

Table 2. Coded cases by county.

County	Total Cases	Coded	Unable to Code
Citrus	27	14	13
Hernando	53	38	15
Hillsborough	691	353	338
Pasco	154	105	49
Pinellas	469	339	130
Total	**1394**	**849**	**545**

Number of Incidents per Year

The total number of incidents remained consistent across the five year timespan included in the database, $X^2(4, N = 1394) = .70$, $p = .95$, as did the number of severe incidents, which were defined as those involving either a fatal or incapacitating injury to a pedestrian, $X^2(4, N = 254) = 1.95$, $p = .75$ (see Tables 3 and 4). That is, there is no evidence of a shift in the frequency of incidents, either increasing or decreasing, during the time period included in the data set.

Table 3. Number of total cases per year by county.

	2004	2005	2006	2007	2008	Total
Citrus	4	8	3	3	6	27
Hernando	15	11	7	9	11	53
Hillsborough	130	149	150	143	119	691
Pasco	33	23	31	31	36	154
Pinellas	86	96	88	89	110	469
Total	268	287	279	278	282	1394

Table 4. Number of cases involving fatal or incapacitating injuries per year by county.

	2004	2005	2006	2007	2008	Total
Citrus	0	0	1	0	0	1
Hernando	1	2	3	1	5	12
Hillsborough	28	32	27	24	22	133
Pasco	11	4	9	10	4	38
Pinellas	18	13	11	15	13	70
Total	58	51	51	50	44	254

When Parking Lot Collisions Involving Pedestrians Occur

As has been found in other studies of pedestrian crashes, the total number of incidents differed by month, with the most incidents occurring in December and the least in June and July, $X^2(11, N = 1394) = 34.53$, $p < .001$ (see Figure 2). The higher crash frequency during the winter months is likely due to greater traffic in parking lots generated by holiday shoppers, while the peak seen in March may be due to changes in tourism patterns (e.g., spring break). However, although the number of crashes involving incapacitating or fatal injuries to pedestrians followed a similar pattern, differences in the frequency of severe crashes were no greater than what would be expected by chance alone, $X^2(11, N = 254) = 13.31$, $p = .27$ (see Figure 3).

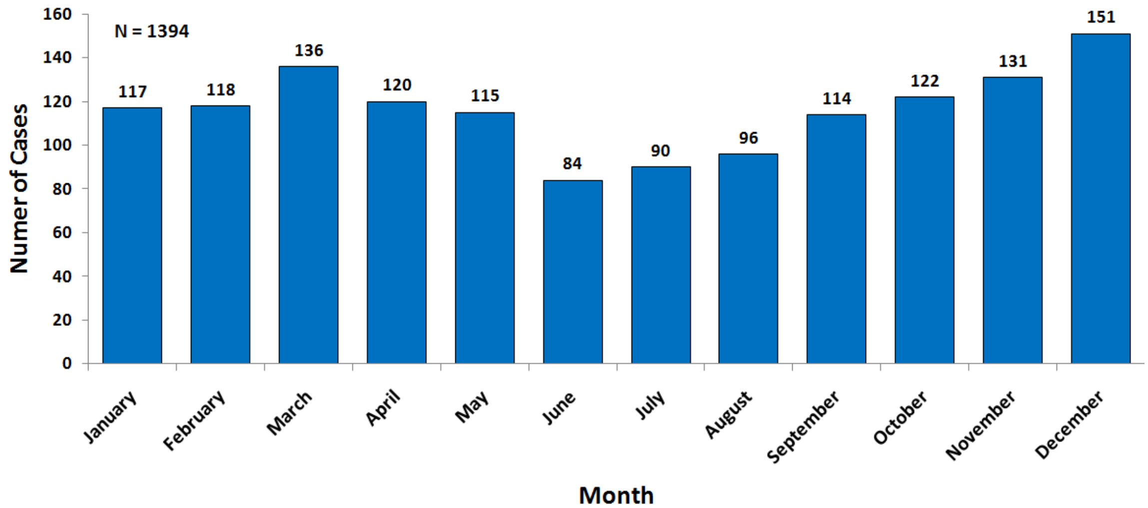

Figure 2. Number of total cases per month.

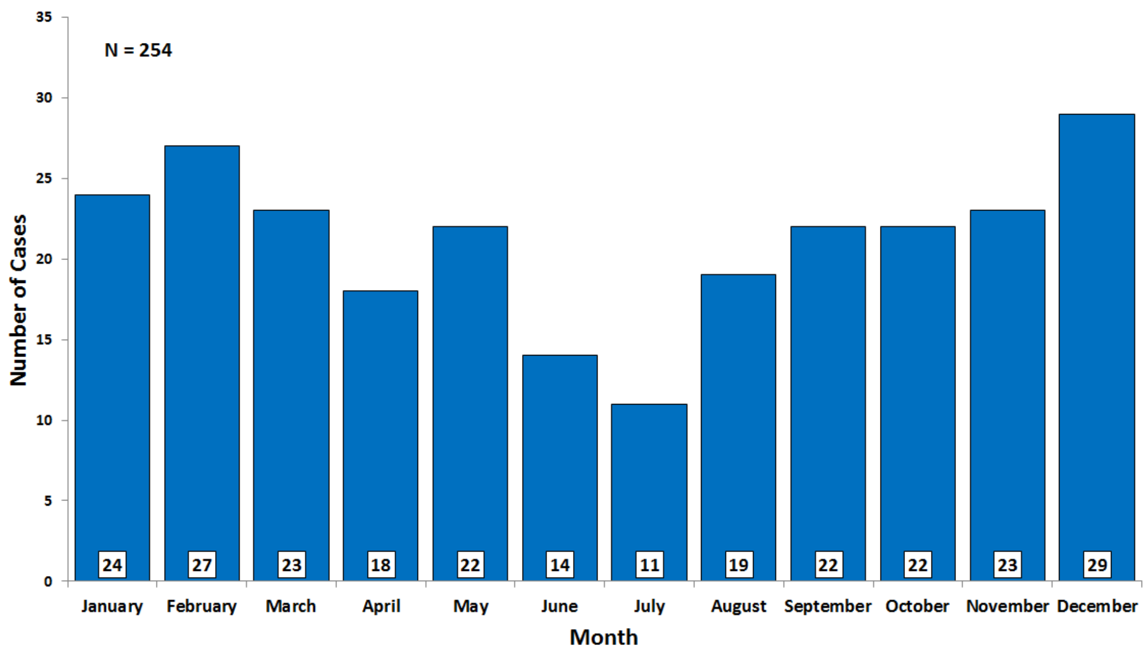

Figure 3. Cases involving fatal or incapacitating injuries to pedestrians by month.

Crash frequencies across the year were examined individually for each of four broad age groupings (14 years and under, 15 to 25, 26 to 64, 65 and older). The general pattern observed in the overall data was seen for each age group, but a larger difference in crash frequencies across the year was seen for pedestrians aged 65 and older (see Table 5), reflecting a significant change across months with the peak in December.

Table 5. Number of crashes per month by pedestrian age group.

Month	14 and Under	15 to 25 Years	26 to 64 Years	65 and Older
January	14	20	49	34
February	12	24	56	26
March	11	25	61	39
April	17	25	60	18
May	16	19	52	28
June	7	13	53	11
July	10	15	50	15
August	9	13	52	22
September	18	26	47	23
October	12	25	57	28
November	15	26	63	27
December	16	22	61	52
Total	157	253	661	323
X^2	10.01	13.13	5.68	49.89*

* $p < .001$

The overall frequency of crashes did not differ significantly across days of the week, (6, N = 1394) = 10.14, p = .12, though there were slightly fewer crashes on Sunday and Monday compared to the rest of the week (see Figure 4).

Although most traffic crashes where pedestrians sustain fatal or incapacitating injuries occur on weekends (NHTSA, 2008b), our data set suggests that non-traffic incidents in parking lots are more likely to happen during a weekday, with the largest number of incidents occurring on Wednesdays and the fewest on Mondays (see Figure 5). Again, possibly due to the relatively small number of cases in our current data set, this difference did not reach conventional significance, X^2 (6, N = 254) = 7.15, p = .31.

In contrast to more severe incidents, parking lot crashes where pedestrians sustained only minor or no injuries were more equally distributed throughout the week, though this difference also did not reach conventional significance, X^2 (6, N = 1140) = 6.86, p = .33. (see Figure 6). Again, similar to more severe crashes, parking lot crashes where pedestrians were not seriously injured were more likely to occur on Saturday and least likely on Sunday or Monday.

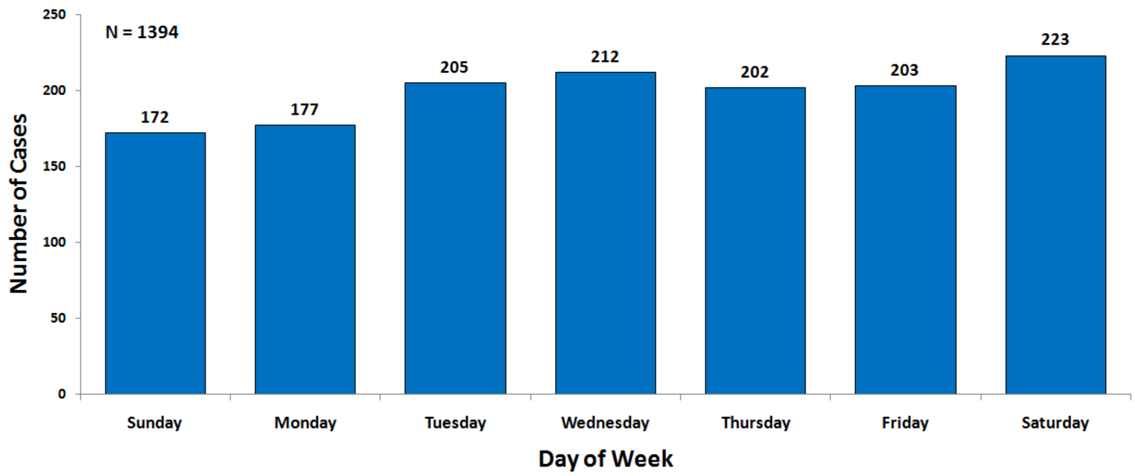

Figure 4. Number of cases by day of the week.

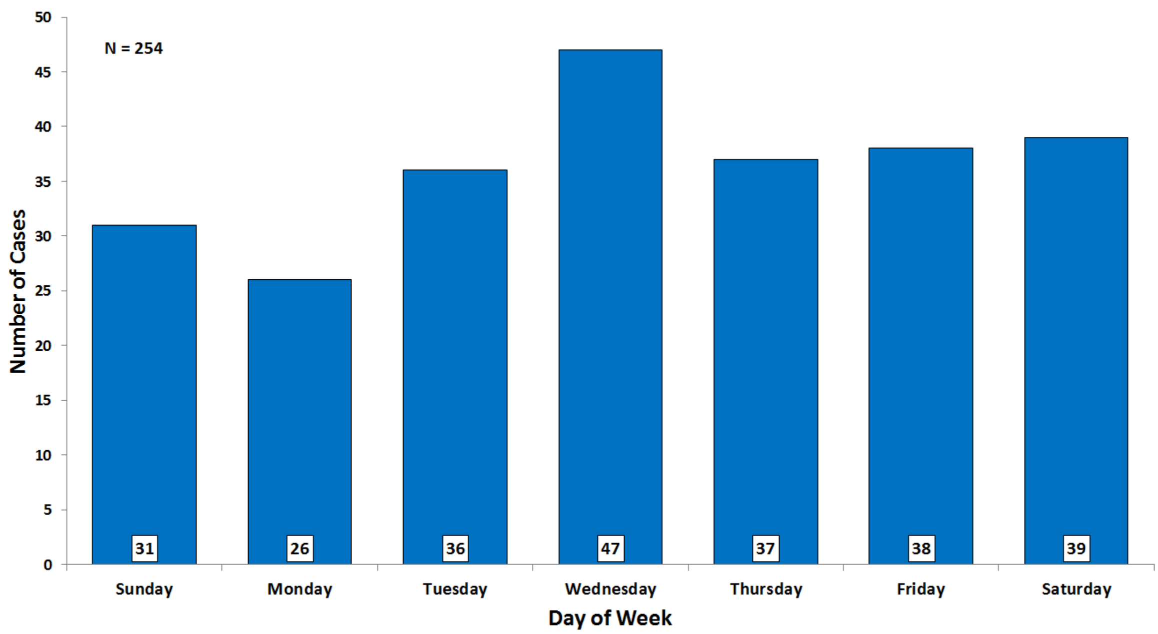

Figure 5. Cases involving fatal or incapacitating injuries to pedestrians by day of the week.

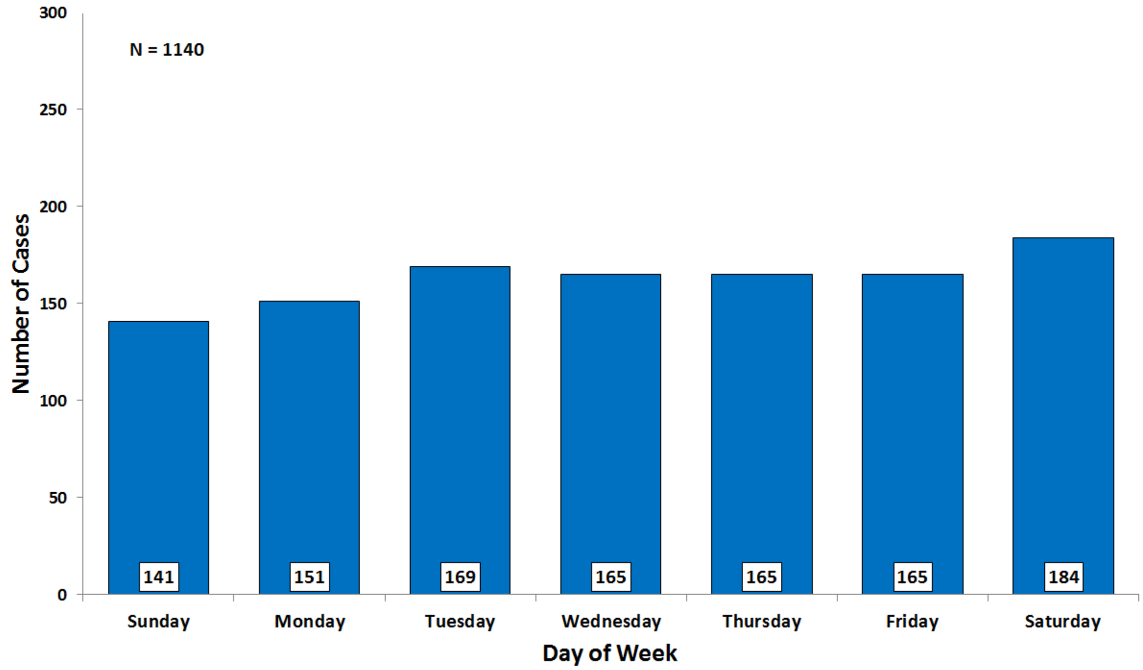

Figure 6. Cases where pedestrians sustained minor or no injuries by day of the week.

The number of total incidents varied across the time of day, with the most incidents occurring between 7 am and 7 pm, X^2 (7, N = 1393) = 553.70, p < .001), see Figure 7. To further examine these differences in crash frequency, we created four equal time categories (1 am to 6:59 am, 7 am to 12:59 pm, 1 pm to 6:59 pm, and 7 pm to 12:59 am). Across all cases, there were significant differences in crash frequencies across all four broad time periods (see Table 6).

Table 6. Number of total cases by time of day.

Time of Day	Overall	Severe	Minor	X^2
1 am to 6:59 am	99	18	81	185.79*
7 am to 12:59 pm	405	80	325	
7 am to 12:59 pm	405	80	325	62.33*
1 pm to 6:59 pm	663	130	533	
1 pm to 6:59 pm	663	130	533	214.81*
7 pm to 12:59 am	226	26	200	

* p < .001

Comparing the frequency of severe crashes, which are defined as those where pedestrians suffered either fatal or incapacitating injuries, to the frequency of incidents where pedestrians were not seriously injured revealed that the frequency of both types of crashes differed significantly by time of day, with most severe, X^2 (7, N = 254) = 149.97, p < .001 and minor crashes, X^2 (7, N = 1139) = 424.19, p < .001, occurring between 7am and 7pm. Unlike traffic collisions involving pedestrians, non-traffic collisions in parking lots were most likely to occur between 12 pm and 6 pm, the hours during which most businesses operate (see Figure 6).

Due to the small number of fatal cases, clear conclusions cannot be drawn about age differences in fatal crashes. However, at least in the current data set, parking lot crashes resulting in the death of the pedestrian were most likely to occur between 12 pm and 3 pm. Figure 8 shows the number of incidents in which a pedestrian was fatally injured by time of day and age group.

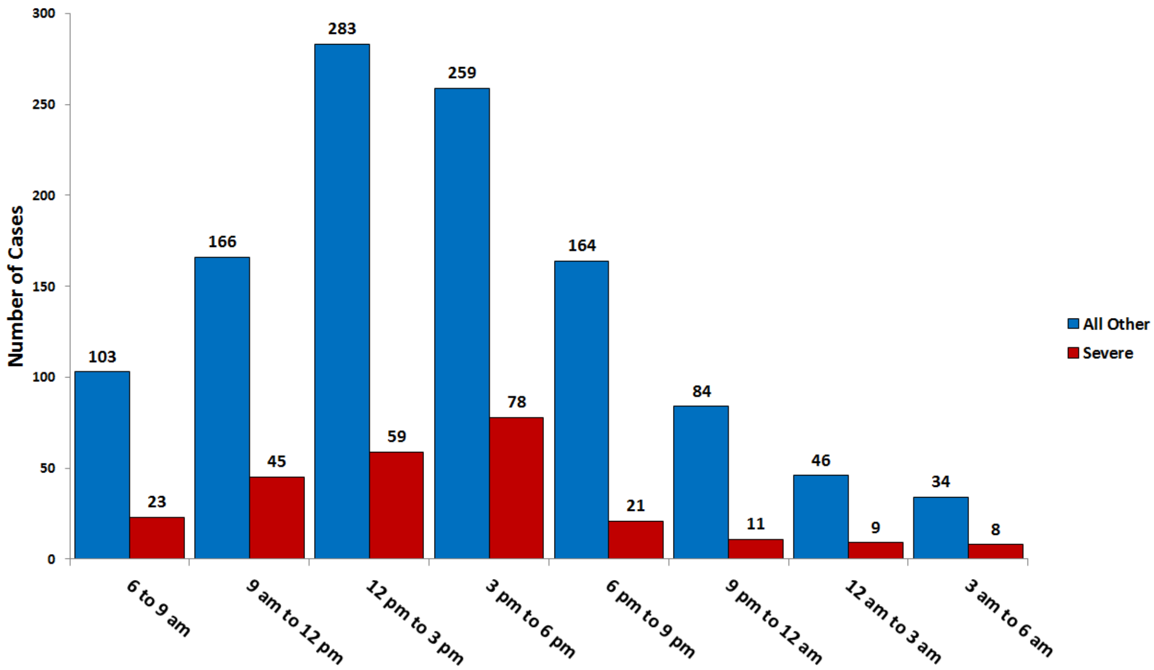

Figure 7. Number of cases by time of day and severity.
*Severe incidents include those where pedestrians suffered fatal or incapacitating injuries.

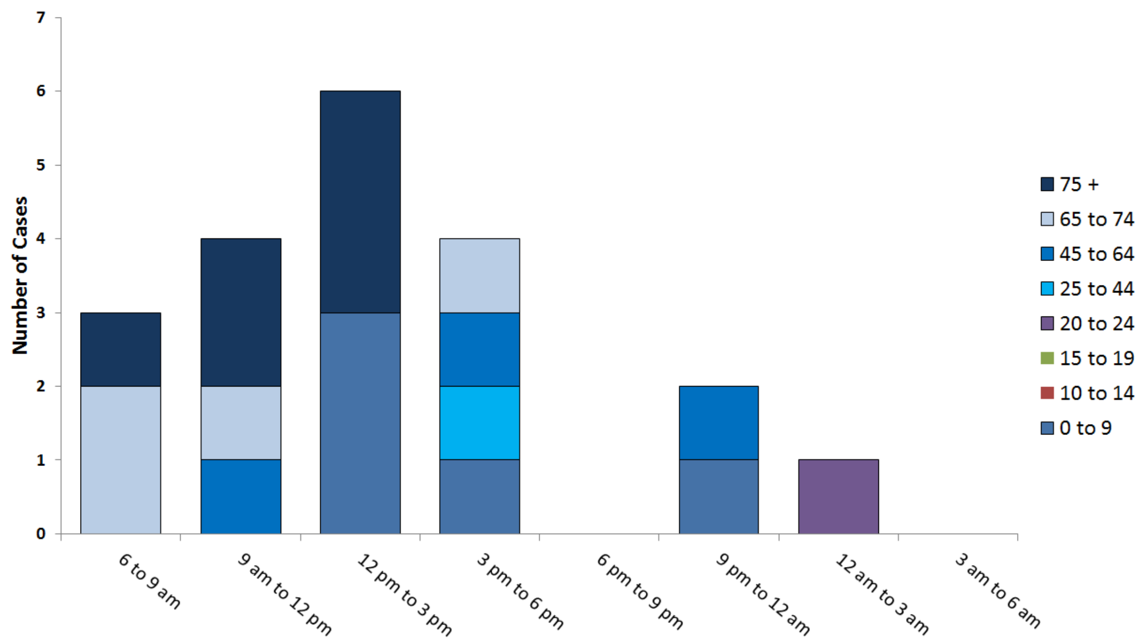

Figure 8. Number of fatal cases by pedestrian age group and time of day.
*There were no fatal cases for pedestrians aged 10 to 14 or those aged 15 to 19.

Frequency of Parking Lot Collisions Involving Pedestrians by Age Group

We examined the number of cases for severe and minor crashes by driver and pedestrian age group. As expected, drivers and pedestrians aged 25 to 64 were involved in the largest number of severe and minor incidents, as they represent the largest population groups in the counties included in the data set (see Appendix B for detailed population figures). There were substantially fewer incidents for the youngest and oldest age groups, likely because fewer individuals in these age groups would be out during the times of day that parking lots tend to be the most crowded (see Figures 9 and 10).

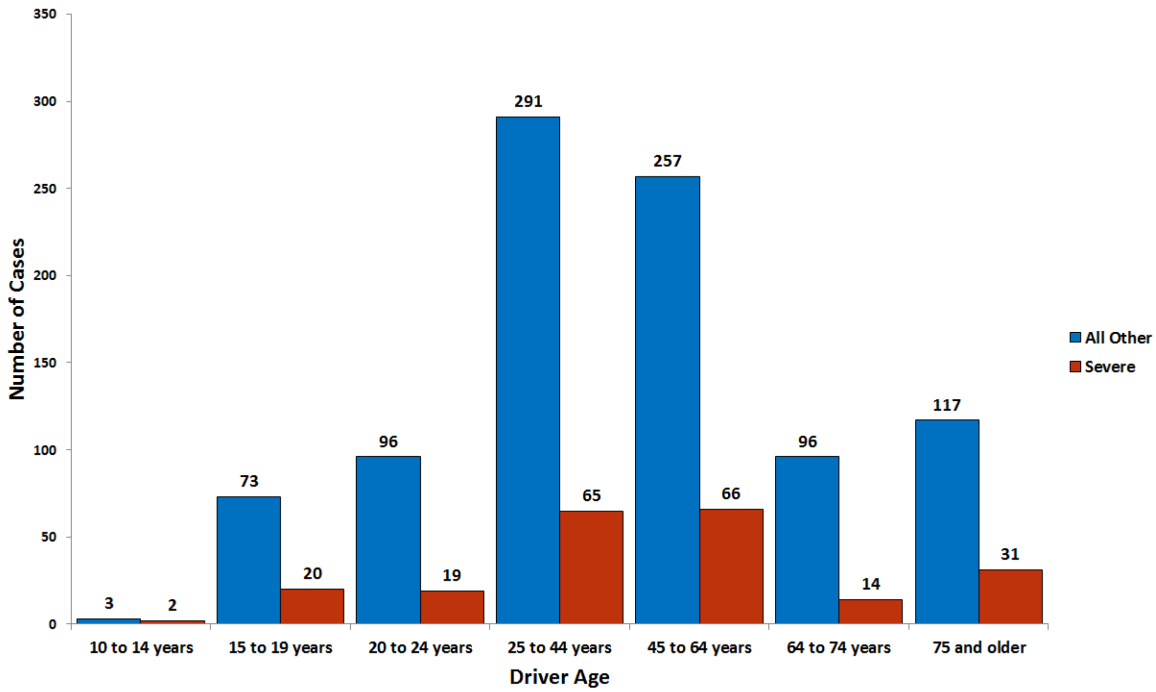

Figure 9. Number of cases by severity and driver age.

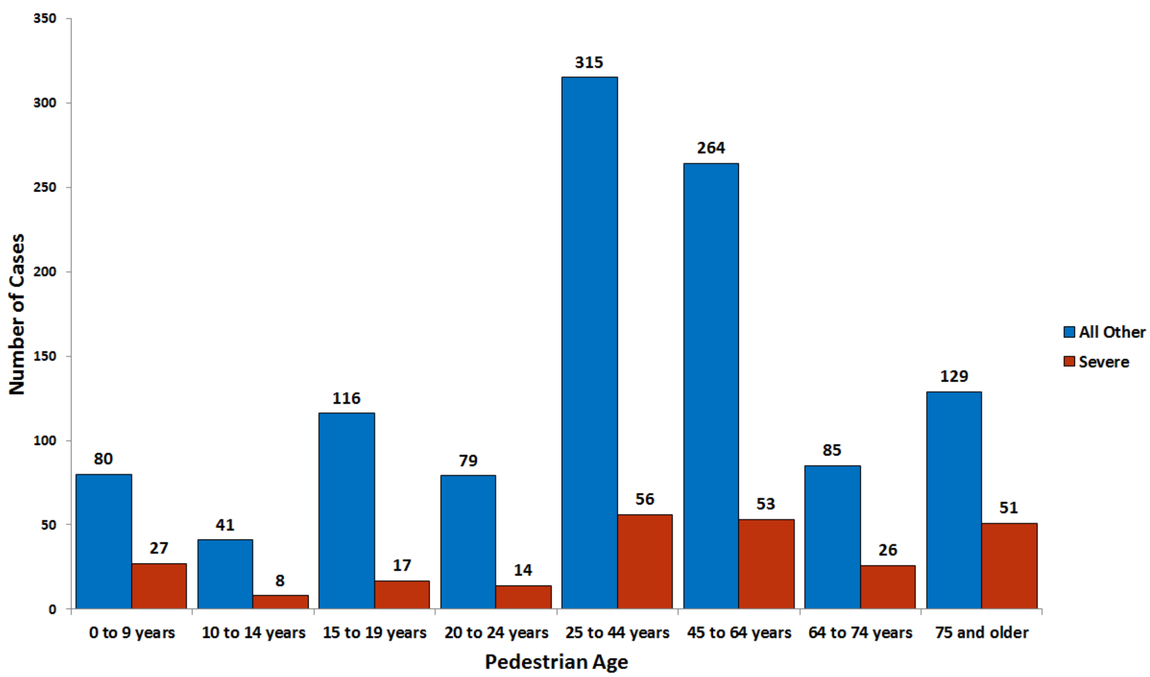

Figure 10. Number of cases by severity and pedestrian age.

When the number of incidents for each age group per 1,000 population is examined, similar to trends seen in other types of collisions involving pedestrians, our data set suggests that children aged 10 to 14 years, younger adults between the ages of 15 and 24, and older adults aged 75 and older have the greatest risk of being involved in parking lot collisions compared to other age groups. Figure 11 shows the average incidence of parking lot collisions per 1,000 population by age group for the years included in the data set based on national intercensal population estimates (U.S. Census Bureau, 2010).

The rate of serious crashes by age group showed a slightly different trend. As was the case for the overall rate of involvement in crashes, older pedestrians and drivers over the age of 75 had an elevated risk of being involved in a parking lot collision where a pedestrian received an incapacitating or fatal injury. However, the risk of being involved in a severe crash does not appear to differ substantially across drivers aged 15 and over (Figures 11 and 12; see also Appendix C for more detailed statistics).

There are some limitations to these calculations that should be considered when interpreting these results. First, as has been noted elsewhere, there is likely inconsistency in the rate at which incidents are reported, and this inaccuracy may not be uniform across age groups (e.g., NHTSA, 2004; 2006a; 2009). For example, because older adults are more likely to be injured in what would be considered minor collisions, the rate of reporting of incidents involving older pedestrians may be higher than for those involving younger pedestrians. Second, due to the small size of the data set, it is uncertain whether these estimates are an accurate reflection of the true rate at which parking lot collisions occur. In a small data set, inaccuracies in the rate of reporting are more likely to influence the precision of risk estimates. Third, there were a significant number of hit and run incidents in the current data set; out of 1394 cases, there were 232 where drivers left the scene, a rate of about 17%, meaning that estimates of the rate at which drivers of different ages were involved in collisions is based on fewer cases overall than were estimates for pedestrians.

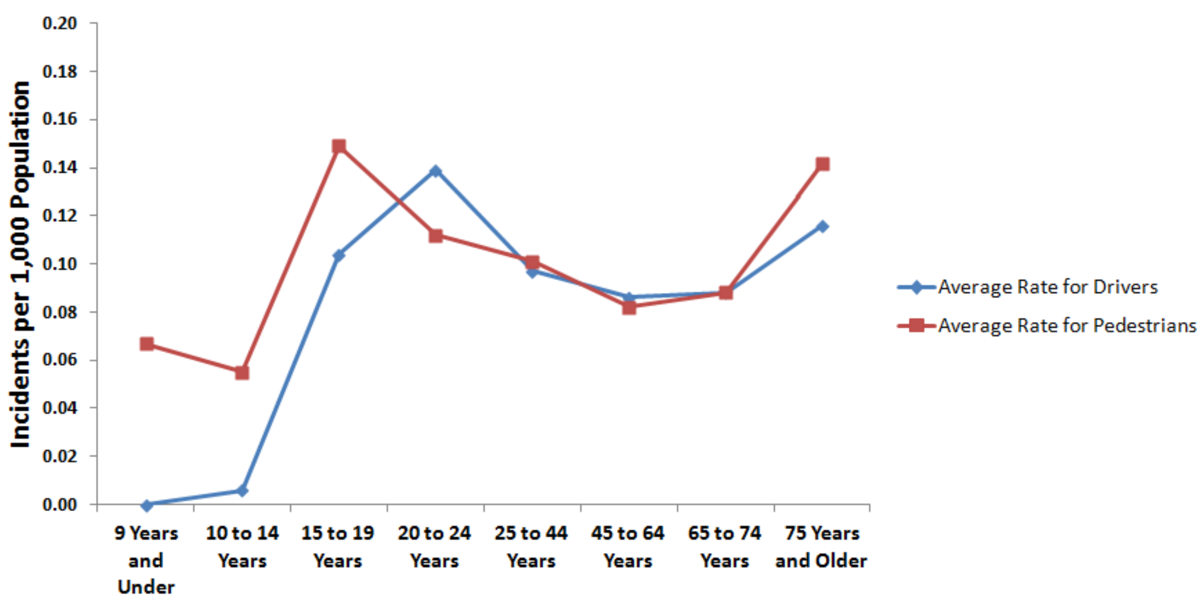

Figure 11. Average number of incidents per 1,000 population of drivers' and pedestrians' involvement in parking lot crashes by age group.
*Based on aggregate population estimates for the five counties included in the data set.

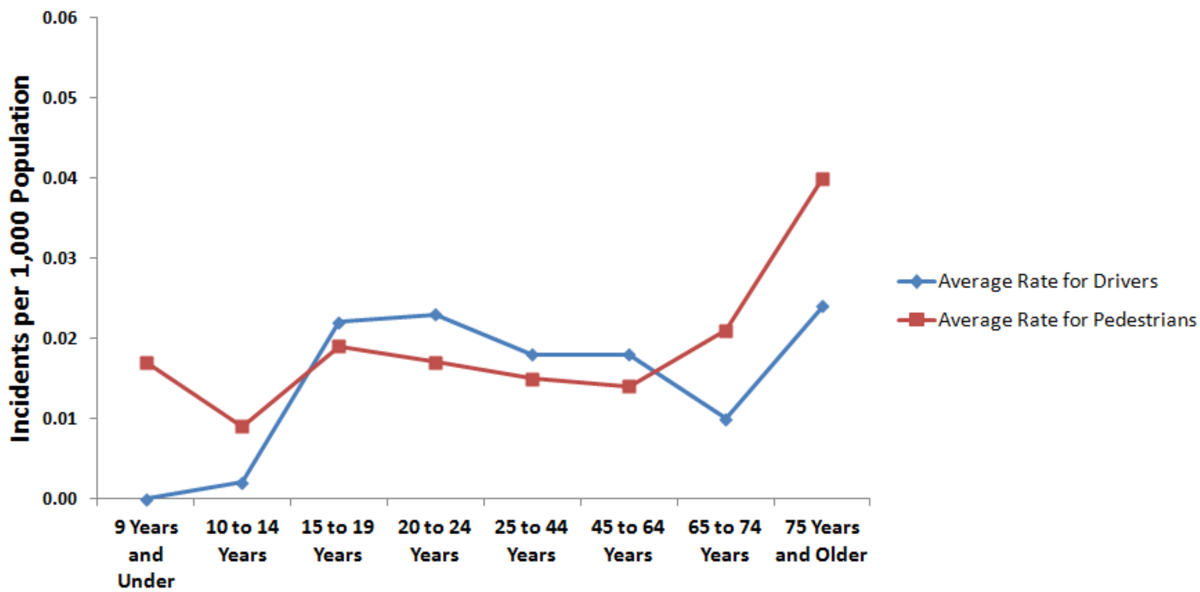

Figure 12. Average number of incidents per 1,000 population of drivers' and pedestrians' involvement in parking lot collisions where pedestrians sustained fatal or incapacitating injuries by age group.

* Based on aggregate population estimates for the five counties included in the data set.

Driver Action When Collisions Occurred

In the current data set, parking lot collisions involving pedestrians were most likely to occur when the driver was either backing or driving forward, with these two types of crashes accounting for 76% of all incidents included in the current data set (see Figures 13 and 14). When incidents where a pedestrian died as a result of their injuries were examined separately, a similar pattern was observed (see Figure 15).

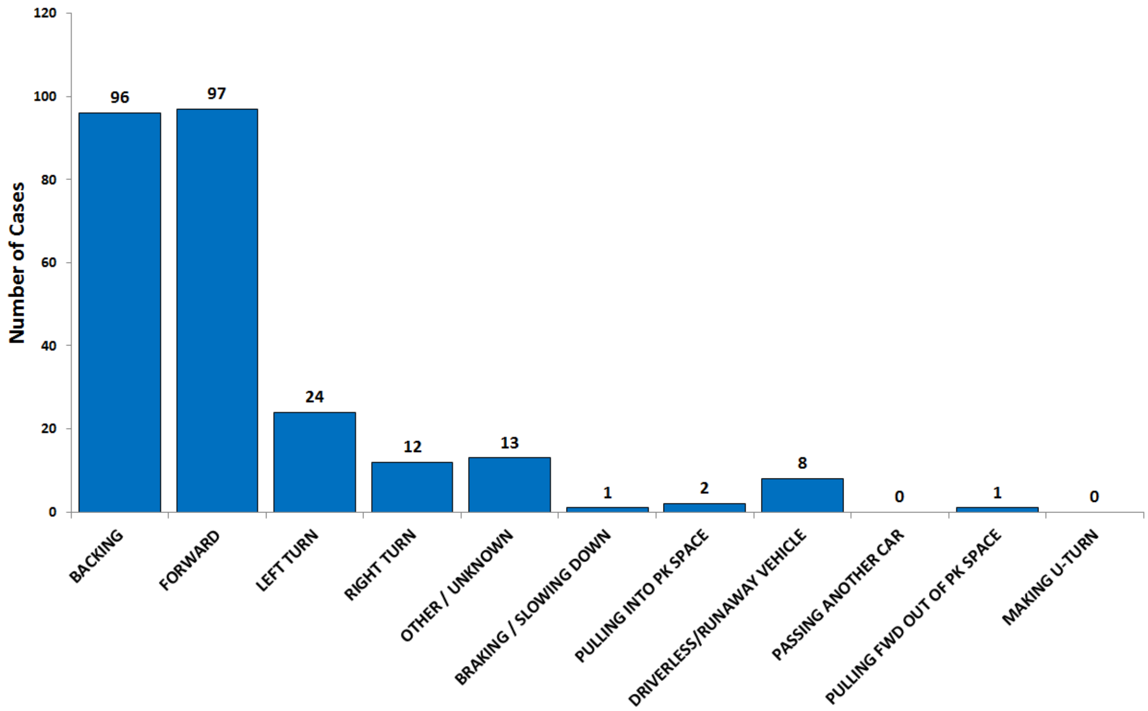

Figure 13. Number of cases where a pedestrian suffered fatal or incapacitating injuries by driver action.

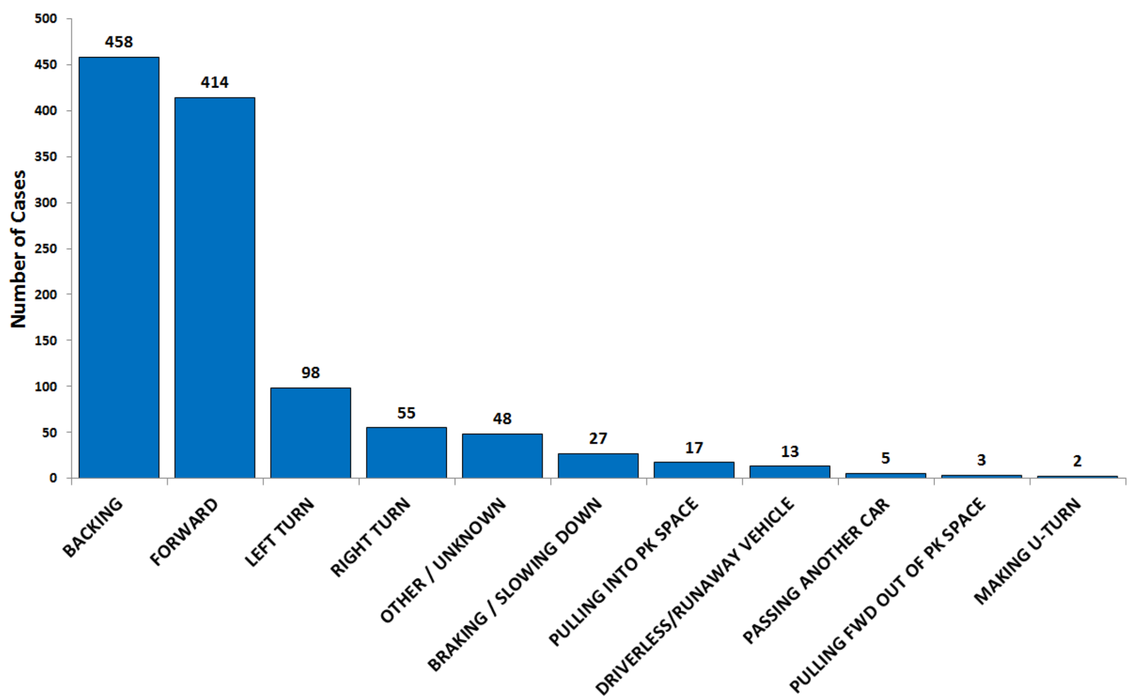

Figure 14. Number of cases by driver action for cases where pedestrians sustained non-incapacitating or no injuries.

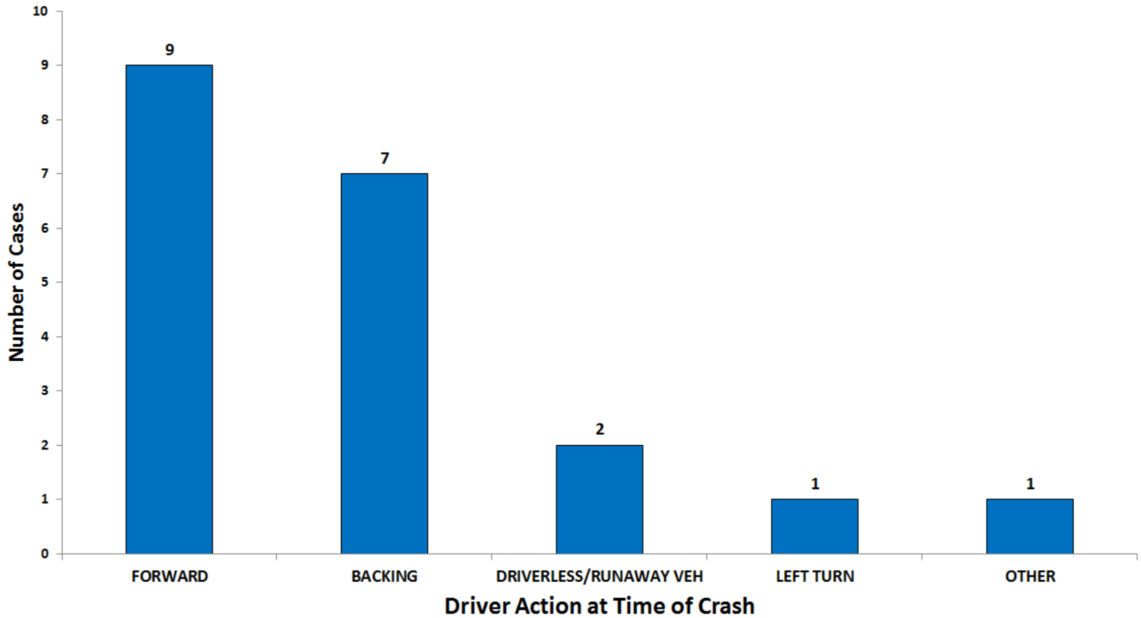

Figure 15. Fatal cases by driver action at the time of the crash.

As noted earlier, most crashes in the current data set occurred when the driver was either backing or driving forward through a parking lot. We examined whether drivers of different ages tended to be involved in different types of crashes. For example, because older adults are less likely to turn their head to check behind their vehicle before backing, relying primarily on mirrors, it is possible that they are more likely to be involved in backing crashes (Dawson et al., 2010). However, based on the current data set, there is no evidence suggesting that older drivers are more likely to be involved in backing crashes compared to other age groups (see Table 7).

Table 7. Number of total incidents for drivers in each age group by driver action at the time of the crash.

Age Group	Backing	Forward	Total Incidents	X^2	p^*
9 years and under	1	0	1	n/a	n/a
10 to 14 years	3	2	5	.20	1.0
15 to 19 years	28	42	93	2.80	.72
20 to 24 years	45	45	115	n/a	n/a
25 to 44 years	139	120	356	1.34	1.0
45 to 64 years	137	119	323	1.27	1.0
65 to 74 years	47	38	110	.95	1.0
75 years and up	55	63	148	.54	1.0
Total	455	429	1151**		

** Bonferroni adjusted p values*
*** Due to the number of cases where the driver left the scene before the police arrived, there were fewer cases where the driver's age was known.*

Table 8. Number of total incidents for pedestrians in each age group by driver action at the time of the crash.

Age Group	Backing	Forward	Total Incidents	X^2	p^*
9 years and under	31	**58**	108	8.19	.03
10 to 14 years	7	**34**	49	17.78	<.001
15 to 19 years	41	**61**	133	3.92	.38
20 to 24 years	39	40	93	.01	1.0
25 to 44 years	**164**	123	371	5.86	.13
45 to 64 years	**119**	110	317	.35	1.0
65 to 74 years	**42**	36	111	.46	1.0
75 years and up	**99**	41	181	24.03	<.001
Total	542	503	1363		

**Bonferroni adjusted p values*

We also examined whether pedestrians of different ages tended to be involved in different types of crashes. As was true for the overall crash frequency, for severe crashes, those where a car was driving forward in a roadway or backing, accounted for 75% of incidents. The pattern for severe crashes, which were those where a pedestrian sustained either a fatal or incapacitating injury, was similar to what was observed for the overall frequency of crashes (see Table 9). Younger pedestrians were more likely to be injured in crashes where a vehicle was driving forward, while older pedestrians were more likely to be injured in a crash where a vehicle was backing.

Table 9. Number of incidents where pedestrians sustained fatal or incapacitating injuries by age group and driver action at the time of the crash.

Age Group	Backing	Forward	Total Incidents	X^2	p^*
9 years and under	9	**15**	27	1.50	1.0
10 to 14 years	1	**6**	8	3.57	.48
15 to 19 years	3	**7**	17	1.60	1.0
20 to 24 years	3	**10**	14	3.77	.40
25 to 44 years	**24**	19	56	.58	1.0
45 to 64 years	**18**	15	53	.27	1.0
65 to 74 years	11	10	26	.05	1.0
75 years and up	**27**	15	51	3.43	.48
Total	96	97	252		

**Bonferroni-adjusted p values*

Number of Cases by Parking Lot Type and Size

Out of the total cases that could be coded, the number of collisions in which a pedestrian was seriously or fatally injured was highest for residential parking lots (see Table 10), which is consistent with other, larger scale studies (e.g. NHTSA, 2008). Although the slightly elevated risk for serious crashes in these types of parking lots may be due to our relatively small sample size, there are some noteworthy features of residential parking areas that could make them risky pedestrian environments. For example, residential parking lots are especially likely to be "multi-use" areas. Another unique feature of many of the residential lots examined in the current study is that they tended to have winding, irregularly shaped roads and parking areas, as opposed to the rectangular, grid-like layout common in the parking lots of most businesses (see Appendix D for examples of residential lot layouts). In the current data set, there was some evidence that fatal incidents were also more likely to occur in gas station parking lots. It is possible that these smaller, relatively busy, multipurpose spaces are particularly hazardous for pedestrians. Due to the small number of cases in the current data set, it is not possible to conduct analyses that allow precise estimates of the rate of collisions as a function of parking lot type. However, based on the overlap between our findings and those of larger scale studies, it seems likely that fatal and severe incidents are more common in these types of lots.

Table 10. Number of coded incidents by severity and lot type.

Lot Type	Inc. Injury	Fatal Injury	All Other Incidents	Total	Percentage Fatal
Retail	79	8	420	507	1.6%
Non-Retail Business	34	1	125	160	.6%
Fast Food	2	0	20	22	0%
Residential	11	3	43	57	5.3%
Unmarked Parking	1	0	6	7	0%
Gas Station	10	2	69	81	2.5%
Other	3	0	12	15	0%
Total	140	14	695	849	1.7%

We also examined pedestrian risk as a function of lot size by dividing lots into three different size categories (see Figure 17, Table 11). Based on the current sample consisting of the 781 cases where an open aerial view of the parking lot was available, small parking lots seem to have an elevated risk of fatal injuries to pedestrians compared to medium and large parking lots. Although there were nearly the same number of small and medium sized parking lots, a greater number of incidents involving a fatality occurred in smaller lots (see Table 12). However, due to the small number of fatal incidents overall, it is uncertain whether this difference actually reflects a true difference in the number of fatal incidents in small versus large or medium sized parking lots.

Table 11. Parking lot size categories.

		Median Number of Spaces[1]	
Lot Size	**Area**	**Regular**	**Handicap**
Small	Under 100,000 ft^2	38	2
Medium	100,000 to 2,000,000 ft^2	551	17
Large	Over 2,000,000 ft^2	5402	98

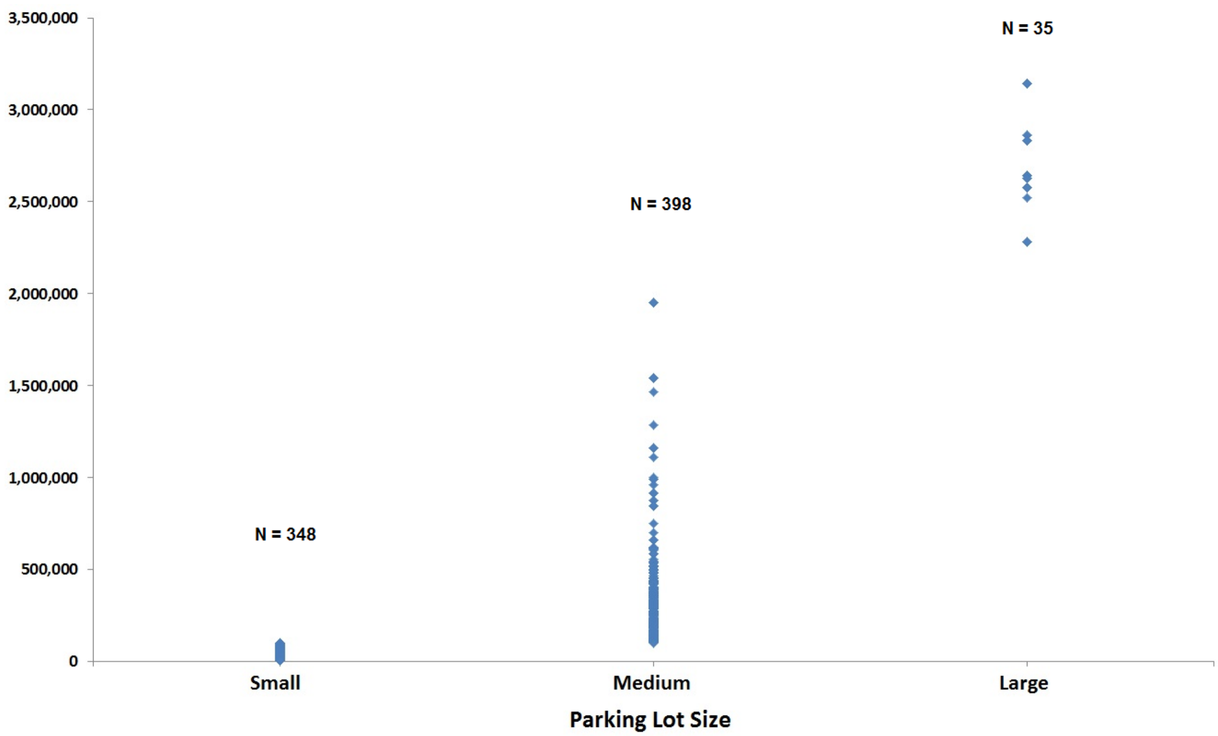

Figure 16. Total area for small, medium, and large parking lots.

[1] The number of parking lots for which parking space counts could be determined is smaller than the number for which total area was available, as some parking lots had heavy tree cover that prevented an accurate count of the number of parking spaces. In addition, many parking areas, particularly smaller lots, had poorly marked spaces or had spaces marked with only a painted symbol or sign. When cars were parked in spaces, these handicap spaces may not have been counted, increasing the amount of error in space counts for smaller lots.

Table 12. Number of cases by business type and lot size.

	Small	Medium	Large
Retail	154	312	24
Non-Retail Business	89	57	0
Fast Food	21	1	0
Residential	9	15	0
Unmarked Parking	0	1	6
Gas Station	71	4	0
Other	4	8	5
Total	**348**	**398**	**35**

Table 13. Number of cases by lot size and severity of injury to pedestrian.

	Fatal	Inc. Injury	Non Inc. Injury	No Injuries	Possible Injury	No Data	Total
Small	5	61	141	29	110	2	348
Medium	3	61	153	31	150	0	398
Large	0	4	14	4	13	0	35
Total	8	126	308	64	273	2	781

*Inc. means incapacitating injuries.

Physical Features of Parking Lots and Crash Frequency

Parking Space Type: One feature of parking lots coded in the current study was whether lots had straight, angled, parallel parking spaces, or a mixture of several types. It is plausible that the type of spaces in a lot may have some influence on the type and frequency of crashes. For example, while angled spaces may improve flow through parking lots, drivers may also tend to back out of angled spaces more quickly than they would from a straight space, increasing the chances of being involved in a collision with a pedestrian.

They type of parking spaces could be determined for a total of 814 parking lots. Based on our GIS coding of these parking lots, we identified six different types of lots: Those with only angled spaces, only straight spaces, a combination of angled and straight, a combination of straight and parallel, those where all three types were represented, and those with unmarked spaces (e.g., grass parking area). Although it would be informative to know whether incidents were more common in parking areas that had one type of space versus another, because the base rate of each type of parking space in the five counties included in the data set is unknown, such analyses cannot be conducted. Instead, we examined differences in the type and severity of crashes for parking lots with each type of space. The frequency of severe crashes was fairly constant across all lot types, suggesting that parking space orientation has a negligible influence on the severity of crashes (see Table 14).

Table 14. Crash severity by parking space type.

	Severe	**Minor**	**Total**	**Percent Severe**
Angled	9	40	49	18%
Straight	76	327	403	19%
Angled & Straight	42	234	276	15%
Straight & Parallel	5	19	24	21%
All 3 Types	4	37	41	10%
Unmarked	5	16	21	24%
Total	**141**	**673**	**814**	

Also of interest in the current study was whether the types of crashes that occur differed as a function of parking space orientation. For example, visibility could be more limited when parking spaces are straight as opposed to angled, leading to a greater risk of backing crashes in those lots. For this analysis, we examined for each parking lot type whether the frequency of backing versus forward crashes differed, as those types of crashes represented the majority of incidents and also tended to be those most likely to involve a fatal or incapacitating injury to a pedestrian. There was no evidence in the current data set that the frequency of backing versus crashes where the car was driving forward differed between parking lots with straight, angled, or a combination of different types of parking spaces (see Table 15).

Table 15. Number and proportion of all cases by parking space type and driver action at the time of the crash.

	Number of Cases				Proportion of Cases		
	Backing	**Forward**	**All Other**	X^2	**Backing**	**Forward**	**All Other**
Angled	15	17	17	.13	30.6%	34.7%	34.7%
Straight	176	144	83	3.2	43.7%	35.7%	20.6%
Angled & Straight	111	95	70	1.2	40.2%	34.4%	25.4%
Straight & Parallel	8	10	6	.22	33.3%	41.7%	25.0%
All 3 Types	19	12	10	1.6	46.3%	29.3%	24.4%
Unmarked	6	9	6	.60	28.6%	42.8%	28.6%
Total	**335**	**287**	**192**		**41.1%**	**35.3%**	**23.6%**

Direction of Aisles: We also coded whether parking aisles were one-way, two-way, or both directions. This was done based on overhead views of parking lots, such as whether there were painted arrows on the road surface. For angled lots, it was assumed that an aisle was one-way if all of the angled spaces were oriented in the same direction. It is possible that the incidence and severity of crashes is influenced by whether aisles are one or two-way. For example, one-way aisles reduce the complexity of the driving environment because traffic would only be coming from one direction, so parking lots with one-way aisles may be safer than two-way aisles.

Based on the current data set, there was no evidence that the frequency of severe crashes differed between parking lots with one-way aisles, two-way aisles, or a combination of both (see Table 16). Again, because the total number of parking lots in the five counties from which the current data set was drawn that had each type of aisle is unknown, it cannot be determined whether the observed differences in frequency of crashes between lot types in the current data set reflects an actual difference in crash rate.

Table 16. Crash severity by aisle direction.

	Severe	**Minor**	**Total**	**Percent Severe**
One-Way Aisles Only	8	43	51	16%
Two-Way Aisles Only	84	408	492	17%
Combination of both	48	217	265	18%
Could not be determined	114	472	586	20%
Total	**254**	**1140**	**1394**	**18%**

Availability of Crosswalks: Crosswalks are included in parking areas with the hope of increasing the safety of pedestrians as they cross the path of traffic by making areas where pedestrians are present more conspicuous. Of interest in the current study was whether or not the presence of crosswalks was associated with reduced crash frequency overall or at least a reduction in the number of incidents where a pedestrian sustained fatal or incapacitating injuries. For parking lots where a clear overhead view was available, either in our GIS software or Google Earth, we coded whether or not parking areas had crosswalks. Not surprisingly, out of the cases that could be coded, a larger proportion of medium and large parking lots had crosswalks (see Table 17). It is likely that the proportion of very large parking lots that have crosswalks is underrepresented in the current data set, as there were only a small number of large parking lots. Of those, several were not typical businesses, such as fair grounds and a car auction lot. The largest retail parking lots, which were most often shopping malls, all had crosswalks.

Table 17. Number of parking lots with crosswalks by parking lot size.

	Had Crosswalks	No Crosswalks / Unable to Determine	Total
Small	48	300	348
Medium	296	102	398
Large	20	15	35
Total	364	417	781

Table 18 shows the number of severe crashes, which were those where a pedestrian suffered a fatal or incapacitating injury, and minor crashes, which were pedestrians sustained only minor or no injuries, for parking lots with and without crosswalks. There was no evidence based on the current data set that suggested significant differences in the number of severe crashes between parking lots with crosswalks and those without crosswalks, X^2 (1, N = 136) = 2.94, p = .09.

Table 18. Number of severe and minor cases occurring in lots with crosswalks compared with those that did not have crosswalks.

	Severe	Minor	Total	Percent Severe
Crosswalks	58	307	365	16%
No Crosswalks / Unable to Determine	78	340	418	19%
Total	136	647	783	17%

Differences in the number of severe crashes were also compared between parking lots with crosswalks and parking lots without crosswalks for those age groups who were most likely to be injured or killed in crashes. The number of severe incidents was equivalent between parking areas with and those without crosswalks (see Table 19).

Table 19. Number of severe versus minor cases by age group for parking lots with and without crosswalks.

Parking Lots With Crosswalks				
	Severe	**Minor**	**Total**	**Percent Severe**
9 years and under	6	17	23	26%
65 to 74 years	9	32	41	22%
75 years and up	12	48	60	20%
Total				
Parking Lots Without Crosswalks				
	Severe	**Minor**	**Total**	**Percent Severe**
9 years and under	5	19	24	21%
65 to 74 years	10	22	32	31%
75 years and up	11	39	50	22%
Total				

Although the presence of crosswalks was not associated with a lower incidence of severe crashes overall, crosswalks may reduce the incidence of backing crashes relative to other crashes because pedestrians may be less likely to walk behind vehicles. To examine this we compared the number of crashes where a vehicle was backing to the number of crashes where a vehicle was driving forward between parking lots with and without crosswalks. This analysis revealed no significant difference in the number of backing versus forward crashes in parking lots with crosswalks, but a significantly higher number of backing crashes compared to forward crashes in parking lots where no crosswalks were present (see Table 19). While this suggests that crosswalks may be associated with a lower incidence of backing crashes in parking lots, it is important to note that there were a larger number of small parking lots represented in the sample of parking areas without crosswalks. It is possible that the difference observed here may only reflect that difference. To examine this, the number of backing versus forward crashes in parking lots with and without crosswalks was examined separately for medium sized and large parking lots only. For medium and large parking lots, there was no evidence that crosswalks were associated with a reduction in the number of backing compared to forward crashes (see Table 20).

Table 20. Number of crashes where the driver was backing versus driving forward for parking lots with and without crosswalks.

All Coded Cases				
	Backing	Forward	X^2	p^*
Crosswalks	138	126	.55	.92
No Crosswalks / Unable to Determine	188	145	5.55	.04
Total	326	271		
Medium and Large Parking Lots Only				
	Backing	Forward	X^2	p^*
Crosswalks	122	112	.43	.51
No Crosswalks / Unable to Determine	46	43	.10	.75
Total	168	155		

**Bonferroni-adjusted p values, taking into account number of comparison tests.*

Although there was no evidence that crosswalks were associated with a reduction in severe crashes or a reduction in the proportion of crashes where a vehicle was backing, crosswalks may still led to a reduction in backing or forward crashes for pedestrians of some ages. For example, for older adults who may take longer to cross the roadway, the increased conspicuity afforded by a crosswalk may reduce the number of forward crashes in which pedestrians of that age group are involved. Based on the current results, there was no evidence that the frequency of backing versus forward crashes differed between parking lots with and those without crosswalks for any age group (see Tables 21 and 22).

Table 21. Number of crashes where a vehicle was moving forward or backward by age group for parking lots with crosswalks.

Age Group	Backing	Forward	Total Incidents	X^2	p^*
9 years and under	8	10	23	.22	1.0
10 to 14 years	2	5	8	1.29	1.0
15 to 19 years	10	16	32	1.39	1.0
20 to 24 years	10	11	25	.05	1.0
25 to 44 years	37	27	86	1.56	1.0
45 to 64 years	23	25	80	.08	1.0
65 to 74 years	13	15	41	.14	1.0
75 years and up	32	14	60	7.04	.06
Total	135	97	355		

** Bonferroni-adjusted p values, taking into account number of comparison tests*

Table 22. Number of crashes where a vehicle was moving forward or backward by age group for parking lots without crosswalks.

Age Group	Backing	Forward	Total Incidents	X^2	p^*
9 years and under	6	12	24	2.00	1.0
10 to 14 years	1	6	8	3.57	.48
15 to 19 years	18	20	49	.11	1.0
20 to 24 years	13	8	25	1.19	1.0
25 to 44 years	67	44	127	4.77	.24
45 to 64 years	41	30	92	1.70	1.0
65 to 74 years	11	12	32	.04	1.0
75 years and up	26	11	50	6.08	.08
Total	183	143	407		

** Bonferroni-adjusted p values, taking into account number of comparison tests*

Conclusions

Based on the coded cases, our findings suggest several conclusions. First, the frequency of crashes in parking lots was relatively stable in the five counties included in the data set between 2004 and 2008. We found that the overall frequency of crashes was highest in December, which would be the time when retail parking lots tend to be very busy and lowest during June, July, and August. The trend for severe incidents, those where pedestrians suffered fatal or incapacitating injuries, followed a similar pattern but differences were smaller in magnitude.

Not surprisingly, we found that parking lot collisions were most frequent between noon and 6 pm, which are the times that are busiest for most businesses and followed a similar trend across age groups. However, there was a slight tendency for incidents involving older adults to have occurred earlier in the day, between 9 am and 3 pm.

Given that older adults are less likely to hold regular jobs, it is likely that they choose to shop during the morning hours when stores are likely to be less busy.

This result (in conjunction with the time of day differences) is suggestive that parking lot traffic may be a mediator of crash frequency, assuming that high tourism months result in increased traffic in parking lots. Similarly, there were no significant trends for crashes to vary by day of week. However, time of day was a significant factor in frequency of injury types, showing similar trends for the two categories of injury type (severe, other).

Consistent with findings that older adults are more likely to be injured or killed in car crashes compared to their younger counterparts, we also found that pedestrians aged 75 and older were at greater risk of being involved in a serious or fatal collision in parking lots compared to other age groups, including children aged 9 and under. For less serious crashes, there was also an elevated risk for pedestrians over age 75, but there was also an elevated risk for younger pedestrians aged 15 to 19.

Drivers aged 15 to 24 years of age and those aged 75 and older were responsible for a disproportionate number of parking lot collisions compared to their representation in the population.

When types of driver activity (backing, forward, type of turn, etc.) are examined, most cases involve backing up or driving forward in the parking lot and the trends are similar for serious and less serious injuries. However, pedestrians age 25-44 and older pedestrians age 75+ are more likely to be involved in a crash associated with a vehicle that is backing up. Children aged 19 and lower show the reverse pattern.

Finally, the type of parking lot was associated with crashes. Smaller and medium lots experienced more crashes than large lots, despite the greater amount of traffic that large lots are likely to experience per unit time that they are occupied. However, without a count of the total number of lots of different sizes in these counties, it is difficult to argue for a greater risk associated with small and medium lots. What we can say is that given that there was a crash at some time on a lot in these counties, small and medium lots are riskier in terms of the severity of the crash. It seems likely that smaller lots will have less effective separation of drivers and pedestrians in lanes and crossing zones than is the case for better-planned large lots in shopping malls.

Task 1 did not reveal evidence that crosswalks reduced the number of crashes where pedestrians sustained fatal or incapacitating injuries, nor was there evidence that crosswalks were associated with a reduction in the number of backing crashes relative to crashes where a car was driving forward. However, there are a number of cases where no benefit was found. First, it may be that parking lot collisions are less frequent at roadway crossings, tending to happen most often in the parking aisles. Based on some of the narratives from police reports, this seems likely. Also, we did not find any evidence that crosswalks benefitted older pedestrians, the age group most likely to be seriously injured in parking lot collisions. Again, this is likely because more crashes occur in parking aisles, as opposed to crossing roadways between the parking area and the front of stores. Finally, another likely reason we did not find any benefit of crosswalks is because pedestrians may not make frequent use of crosswalks when they are provided.

Chapter 3.

Task 2: Observational Studies of Pedestrian Behavior in Leon County Parking Lots.

Because the police narratives examined in Study 1 rarely provided any information about what pedestrians were doing prior to crashes, we were not able to make any strong inferences about age differences in behavior in parking lots. Older pedestrians' increased risk of being involved in crashes where a vehicle was backing may be due to their greater tendency to walk closer to the backs of parked vehicles. Because older adults are more likely to have mobility issues and also to fear falling (Vellas et al., 1997), as they have a greater risk of being injured in a fall, older pedestrians may walk closer to the back of parked vehicles so that they will have something to grab onto should they stumble while walking. However, walking closer to the backs of parked vehicles could put older pedestrians at increased risk of being involved in a backing crash for several reasons. First, as older adults are often smaller in stature, on average, compared to younger adults, they may be less visible to drivers who are backing (Ogden et al., 2004). Second, older adults are slower to both notice and react to potential hazards, meaning that they would require additional time to safely move out of the way of a backing vehicle (e.g., Borowsky et al., 2010). Both of these reasons suggest older adults would be safer if they walked further from, not closer to parked vehicles.

To examine age differences in walking path preference, in Study 2 we observed older, middle-aged, and younger pedestrians as they navigated parking lots in the Tallahassee area, with special attention to pedestrians' overall strategy for navigating parking lots and coping with potential hazards. For example, we not only recorded the path pedestrians took from their car to the store, we also recorded instances where pedestrians stopped or adjusted their path to avoid a backing vehicle or other hazard.

Another question raised in Study 1 was whether the failure to find any benefit of having crosswalks available may have been, at least in part, due to pedestrians not making use of crosswalks. To further explore this, we also recorded whether pedestrians used available crosswalks when crossing the roadways between parking areas and stores.

An issue that may contribute to parking lot collisions, perhaps more so now than it has in the past, is driver and pedestrian distraction. With the popularity of mobile phones continuing to increase with people of all ages, we could see changes in pedestrian behavior related to distraction (see Nagamatsu et al., 2011; Neider et al., 2011). To examine this, in Study 2 we also recorded whether the pedestrians we observed were using mobile phones or engaging in other potentially distracting activities, such as talking with another pedestrian or pushing a shopping cart, while traveling through parking lots.

Method

Materials

Initially, we made use of a custom-programmed Tablet-based interface to code parking lot behavior. However, we discovered a serious programming error during data collection, so switched to a paper and pencil interface that provided the observer with a map of the parking lot being coded.

Procedure

We collected observational data from a total of four locations and partial data from a fifth location (see Figure 17, Table 23). Of the six locations we originally planned to observe, written permission for one location could not be obtained and permission from a second location was delayed so that we only had time to schedule a single observation session for that location.

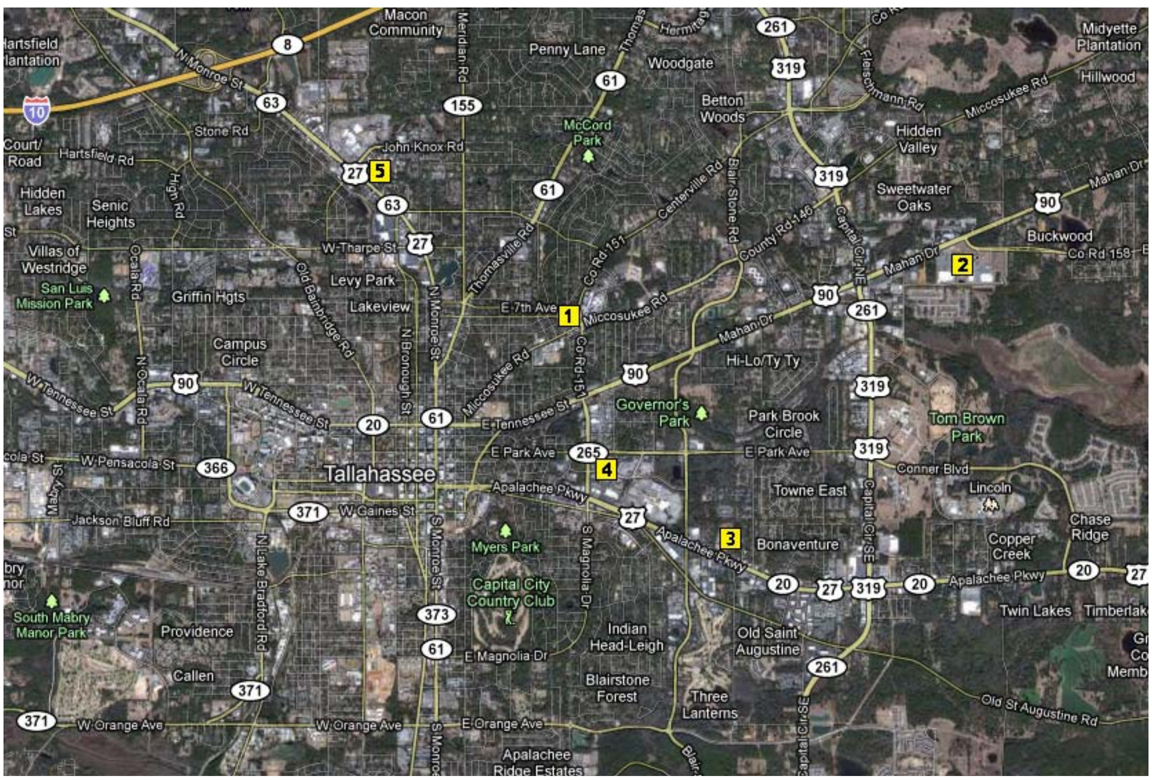

Figure 17. Map showing locations observed for Task 2.

Table 23. Number of observations by age group from each location.

Loc #	Large, Angled Parking	Younger	Middle	Older	Total
1	Winn-Dixie, 111 S. Magnolia	46	72	42	160
	Large, Straight Parking				
2	Wal-Mart, 4021 Lagniappe Way	49	42	47	138
3	Target, 2120 Apalachee Pkwy.	19	16	3	38
	Small, Straight Parking				
4	Walgreen's 1202 N. Magnolia Dr.	56	68	48	172
5	Walgreen's, 2349 N. Monroe St.	42	44	52	138
	Total	212	242	192	646

Coding Scheme

Based on a series of pilot observations sessions and also drawing from information gained in our analysis of crash reports in Task 1, we developed a list of behaviors to observe in Task 2. Table 24 lists the items that were coded by the observers. In addition to each of these, coders also drew each pedestrian's path through the parking lot on an image showing an overhead view of the parking lot. Figure 18 shows sample data from 10 different pedestrians (data was combined from separate sheets).

Observer Training

To ensure that observations were as accurate as possible, all observers were given extensive training on the coding scheme. First, observers were given a "study guide" showing all of the items on the coding scheme and their precise definitions. Then, to help familiarize them with the coding scheme, observers completed at least two practice observation sessions. Following the practice sessions, observers were tested on their knowledge of the coding scheme. The test consisted of four videos of a pedestrian walking through a parking lot. Observers coded the pedestrian's actions, which were scored for accuracy. Observers were given feedback on their coding accuracy, and additional training was provided if necessary.

In contrast to some previous observational studies of pedestrian behavior (e.g. Huang & Zegeer, 2000; 2001), age differences in pedestrian behavior were a focus of interest in the current study. Coders were instructed to estimate pedestrian age, as this technique has been used in a number of other published studies (Singer & Lerner, 2005; Hatfield & Murphy, 2007; Stollof, McGee, & Eccles, 2007; Kim, Brunner, & Yamashita, 2008; Rosenbloom, 2009). Although we did not give our coders highly detailed instructions on estimating pedestrian age, past work has found that observers' estimates of age correlate highly (r = .90) with actual age (Koepsell et al., 2002).

Table 24. Categories coded in the Task 2 observational study.

Item	Definition
Age Group	Apparent age group of pedestrian (younger, middle, older)
Destination	Whether pedestrian was walking to their car or to the store.
Scanning	Whether pedestrian was visibly looking to the left and right, straight ahead, or both.
Cart	Whether pedestrian had a cart. Coded “yes” or “no.”
Distracted	Whether the pedestrian was visibly distracted (e.g., cell phone, interacting with children, etc.). Coded as “yes” or “no.”
Additional Pedestrians	Number of pedestrians walking with the one being coded.
Cars in Lane	Number of vehicles driving down the aisle that pass the pedestrian being coded.
Number of Stops	Number of times the pedestrian stops or pauses as they are walking.
Storefront Cars	Number of cars driving by at the front of the store as the pedestrian crosses.
Backing Vehicle	Vehicle in reverse in pedestrian’s path.
Advancing Vehicle	Vehicle driving forward in pedestrian’s path.
Pedestrian Yields	Number of time the pedestrian yields to either a backing or advancing vehicle.
Pedestrian Adjusts	Number of times the pedestrian adjusts their walking path due to a backing or advancing vehicle.
Pedestrian Dodges Vehicle	“Close call” / “near miss” where the actions of the pedestrian appear to have prevented a collision.
Vehicle Yields	Number of times a backing or advancing vehicle yields to a pedestrian.
Vehicle Adjusts	Number of times a backing or advancing vehicle changes its path to compensate for the presence of a pedestrian (e.g., goes around a pedestrian but does not stop).
Vehicle Fast Brake	Number of times a “close call” / “near miss” occurred where a vehicle stopping appears to have prevented a collision.
Notes	Coder recorded any special circumstances or observations that were not covered by the coding scheme.

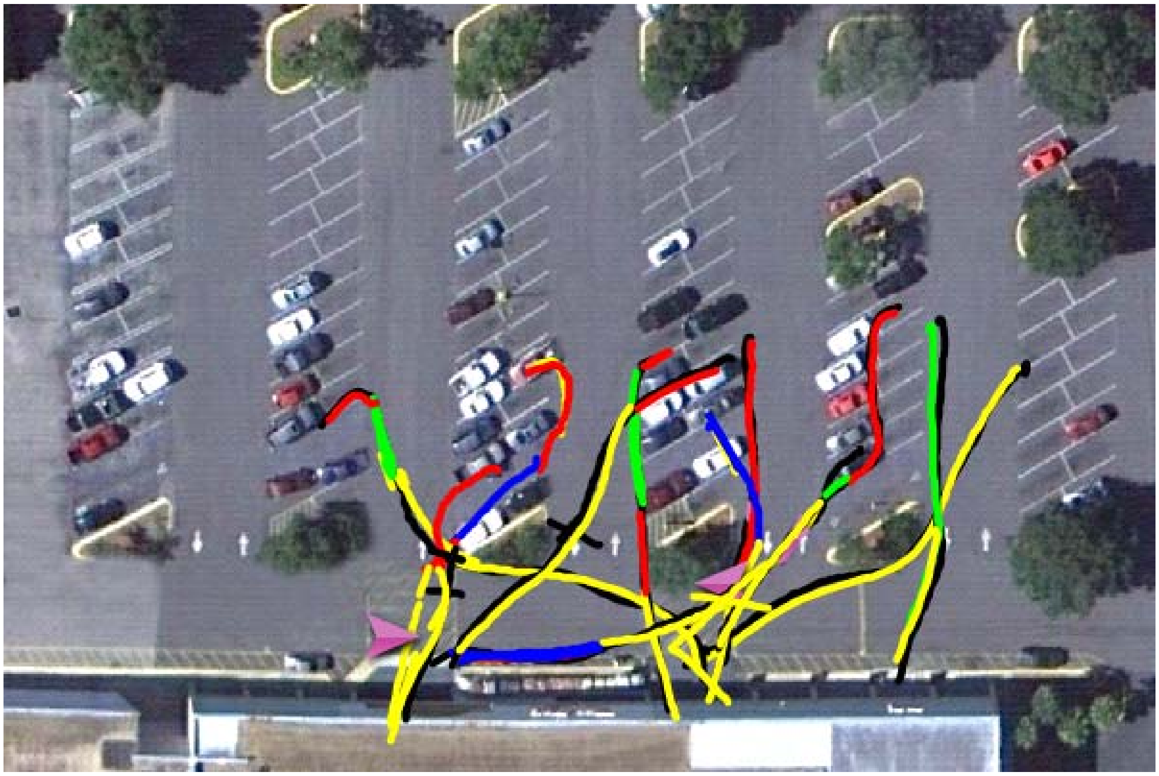

Figure 18. Example of pedestrians' paths at Winn-Dixie on S. Magnolia Drive.

Observation Sessions

Observers were sent out to each location in pairs, and both coders observed the same pedestrian from different vantage points. This was done so that we could be more confident that the information recorded was accurate. Coders were instructed to position themselves in unobtrusive locations near the front of the store and to communicate with one another only to indicate which pedestrian they would observe. Observations were collected over several sessions, with the number of observation sessions per location varying between one and four sessions. Observers collected between 20 and 30 observations per session. Observation sessions for each location continued until we had observed at least 20 younger, 20 middle-aged and 20 older pedestrians. We could not collect complete data from one location, Target on Apalachee Parkway, due to delays in receiving approval from the parking lot owner to conduct observations.

Results

Surprisingly, our analysis of crash reports for Task 1 did not find any evidence that the presence of crosswalks in parking lots was associated with a lower risk of crashes or in a reduction of any specific type of crash (e.g., those where cars were backing compared to driving forward). One reason we may not have found a difference is because pedestrians did not make use of crosswalks when they were available. This would be consistent with other work examining crosswalk use at intersections (e.g., Zegeer et al., 1983; Huang & Zegeer, 2000). In the current study, we examined pedestrians' use of crosswalks across the parking lots we observed. Further analyses also looked at age differences in the use of crosswalks, as well as in other types of risky behaviors (e.g., cutting through empty parking spaces, walking close behind parked vehicles).

Pedestrians' Use of Crosswalks

All of the locations observed in the current study had crosswalks available. Overall, about 55% of the pedestrians observed made use of crosswalks when navigating the parking lots. However, the rate at which pedestrians made use of crosswalks differed substantially across locations (see Table 25). The two parking lots with the highest rate of crosswalk use were Walmart and Winn-Dixie, both of which had fairly large crosswalks located directly in front of store entrances. Out of the 19 pedestrians observed at Target on Apalachee parkway, none used the crosswalks. In contrast to the parking lots at Walmart (see Figure 19) and Winn-Dixie, the crosswalks at Target were small, and while they were located near store entrances, were only convenient to use for those parked in the center two aisles (see Figure 20).

Table 25. Pedestrians' use of crosswalks at each location.

Location	Used Crosswalk	Did Not Use Crosswalk	Percentage Using Crosswalk
Winn-Dixie, Magnolia	59	18	77%
Walmart, Lagniappe	61	7	90%
Target, Apalachee	0	19	0%
Walgreen's Magnolia	13	29	31%
Walgreen's Monroe	0	34	0%
Total	**133**	**107**	**55%**

Figure 19. Parking lot of Walmart on Lagniappe.

Figure 20. Overhead view of Target parking lot on Apalachee Parkway.

Age Differences in Crosswalk Use

Next, we compared the rate of crosswalk use across age groups. Because observers estimated pedestrians' approximate age, there were some instances where coders disagreed about a pedestrians' age group membership (e.g., one coder classified a pedestrian as a middle-aged adult and the other classified the pedestrian as an older adult). Although this was relatively infrequent (38 out of 324 cases), for all analyses of age differences, only cases where both coders agreed on pedestrians' age were used (n = 286). Of those 286 cases, there were 219 where both coders agreed on their coding, which were included in the final analysis. The overall number of pedestrians using the crosswalk did not differ between age groups, χ^2 (2, N = 124) = 1.04, p = .59 (see Table 26). The frequency at which pedestrians of different ages used crosswalks did not differ substantially at any location (see Table 27.

Table 26. Crosswalk use by age group.

Age Group	Used Crosswalk	Did Not Use Crosswalk	Percentage Using Crosswalk
Younger (n=75)	40	35	53%
Middle (n=79)	42	37	53%
Older (n=65)	42	23	65%
Total	**124**	**95**	**75%**

Table 27. Number of pedestrians who used crosswalks at each location by age group.

Location	Lot Type	Younger	Middle	Older	Total	χ^2
Winn-Dixie, Magnolia	Large, Angled	14	23	16	53	2.53
Walmart, Lagniappe	Large, Straight	20	17	21	58	.45
Target, Apalachee	Large, Straight	0	0	0	0	n/a
Walgreen's Magnolia	Small, Straight	6	2	5	13	2.00
Walgreen's Monroe	Small, Straight	0	0	0	0	n/a
Total		**40**	**42**	**42**	**124**	

Overall, pedestrians were significantly more likely to use crosswalks in large compared to small parking lots, χ^2 (1, N = 124) = 78, p < .001 (see Table 28). This parallels findings for crosswalk use at intersections, where pedestrians are much more likely to use crosswalks when there is heavy vehicle traffic (e.g., Zegeer et al., 1983; Huang & Zegeer, 2000). That is, pedestrians are less likely to expend additional effort to walk to locations where there are crosswalks if there is very little traffic.

Table 28. Percentage of pedestrians using crosswalks by age group and lot size.

Age Group	Large	Small
Younger	69%	23%
Middle	69%	10%
Older	86%	23%

Incidence of Risky Behaviors and "Near Misses"

Fortunately, “near misses,” which we defined as instances where a collision was avoided through the action of either the driver or the pedestrian, were infrequent in the current data set. There were no observations of pedestrians having to move out of the path of a backing vehicle and only a single observation where a pedestrian had to quickly move out of the path of a forward traveling vehicle (this was an older adult). No observations of a vehicle having to brake suddenly to avoid a pedestrian were observed for either backing or forward traveling vehicles.

We also recorded other adaptive behaviors of pedestrians, such as adjusting their path due to a backing or forward moving vehicle or yielding the right of way to a backing or forward moving vehicle. These instances were also relatively infrequent compared to the total number of observations recorded, so no analyses were conducted. Raw data is presented in Table 29.

Table 29. Frequency at which pedestrians adjusted their path to avoid a vehicle or yielded to a vehicle by age group.

Behavior	Younger	Middle	Older	Total
Adjusts path due to forward moving vehicle	1	2	1	4
Yields to advancing vehicle	3	2	5	10
Adjusts path due to backing vehicle	0	5	2	7
Yields to backing vehicle	0	1	1	2

Another behavior that may put pedestrians at risk of being involved in a crash is distraction. In the current study, pedestrians were not often distracted by other activities, with observers noting that only 26 out of the 325 pedestrians observed were distracted. However, the likelihood that a pedestrian would be distracted differed significantly across age groups. In the current study, no older pedestrians appeared to be distracted. However, 18 younger adults and 8 middle-aged adults appeared to be distracted, most often using cellular phones, and this differed significantly between younger and middle-aged adults (χ^2 (1, N = 26) = 3.85, p = .05).

Also of interest was whether distractions changed the frequency of compensatory behaviors, such as yielding to or adjusting one’s path to avoid a backing or forward moving vehicle. As expected, distracted pedestrians appear to be less likely to engage in compensatory behaviors (see Table 30). For example, in the current samples, all instances where a pedestrian yielded to an advancing vehicle involved pedestrians who were not distracted by other activities. However, because there were so few observations per cell where compensatory behaviors occurred, normal chi-square analyses could not be conducted. Even when collapsing into a smaller set of categories (forward/backward path adjustment by distracted/not distracted) and using a Fisher’s Exact Test statistic, no significant relationship was observed (p 2-tailed = .24).

Table 30. Frequency at which pedestrians adjusted their path to avoid a vehicle or yielded to a vehicle by age group.

Behavior	Distracted	Not Distracted	Total
Adjusts path due to forward moving vehicle	0	5	5
Yields to forward moving vehicle	0	11	11
Adjusts path due to backing vehicle	1	2	3
Yields to backing vehicle	0	2	2

Pedestrians' Walking Paths Through Parking Lots

In the Task 1 archival data analysis, we found that older adults were more likely than younger and middle-aged adults to be involved in a parking lot crash where a vehicle was backing. For example, one hypothesis for Task 2 was that older adults walk closer to the back of parked vehicles, which they may do so that they are further from vehicles driving down the aisle or so that they can use parked vehicles to steady themselves should they stumble while walking. However, walking closer to the backs of parked vehicles may make older adults less visible to drivers who may be backing and would allow for less time for both drivers and pedestrians to react to hazards. To examine this, we observed pedestrians' walking paths and made note of how far they chose from the back of parked cars. Cases were only included in the analysis if both coders' included path information, occasionally a coder would forget to record this, and if there was a high degree of correspondence between the path information that was recorded. Table 31 shows the number of observations from each age group for which path information was available.

Table 31. Number of cases from each age group where complete walking path information was recorded.

Age Group	Total Cases	Cases With Path Info
Younger	94	74
Middle	104	80
Older	88	62

In the current study we recorded the approximate distance between the pedestrian and parked vehicles by having coders draw pedestrians' path on a map of the parking lot and indicate the part of the lane in which the pedestrian was walking. Figure 21 shows the four lane positions coded in the current study. Lane position 1 was defined as taking a path through empty spaces, which could be considered a high risk behavior. Lane position 2 was defined as being within arm's reach of a parked vehicle, while lane position 3 was defined as near parked cars but not within arm's reach of parked vehicles. Finally, lane position 4 was defined as being in the center of the aisle.

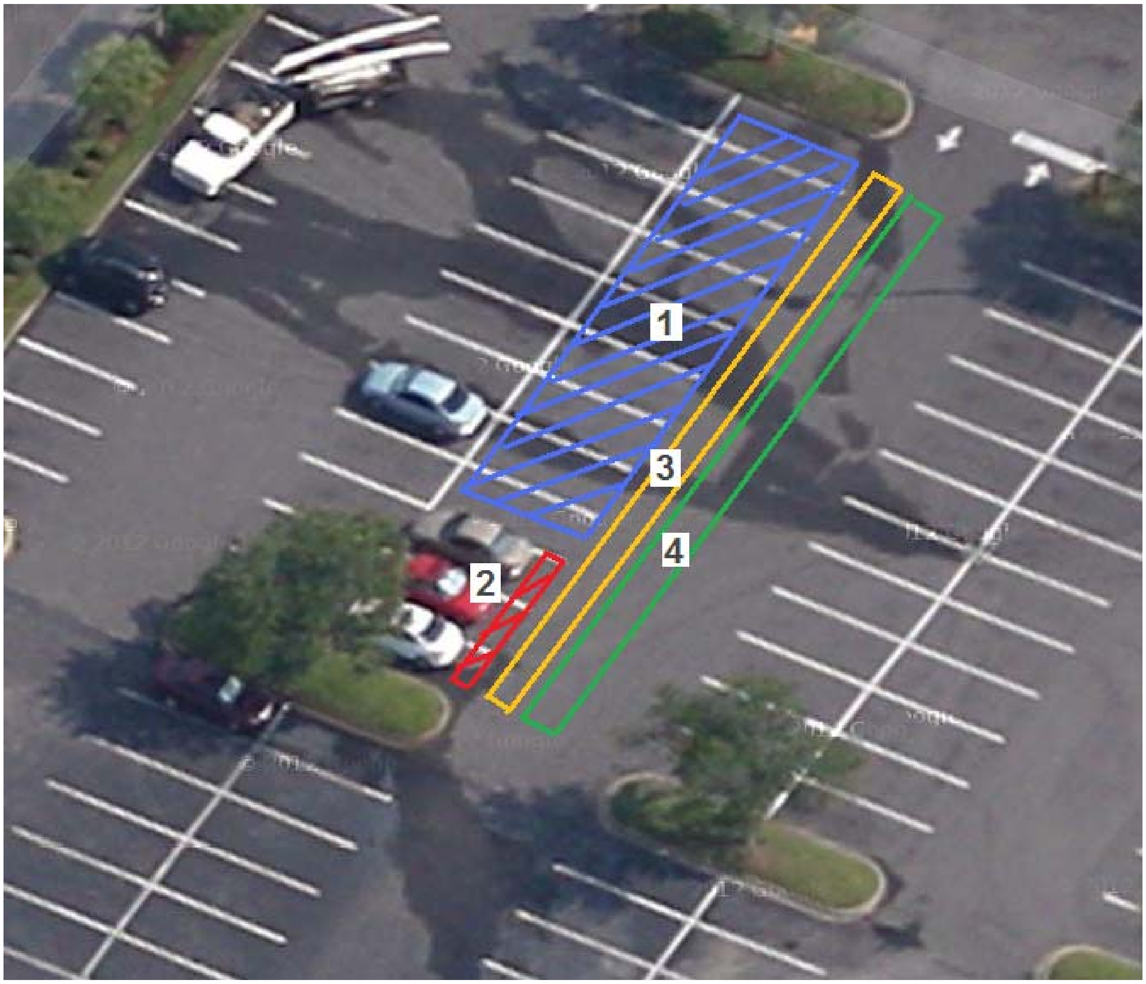

Figure 21. Lane position coding.

One factor that could influence our analyses of age differences in pedestrians' preference to walk closer to the backs of parked cars is that older pedestrians are more likely to be parked in handicapped spaces. Indeed, although relatively few pedestrians observed in the current study were parked in handicapped spaces, significantly more older pedestrians were observed either coming from or going to a car parked in a handicapped space, $X^2(2) = 8.24$, $p = .02$ (see Table 32). Because pedestrians parked in handicapped spaces would spend only limited time traveling through the parking aisles, these pedestrians were excluded from walking path analyses. Separate analyses for those parked in handicapped spaces were not conducted because there were too few cases.

Table 32. Number of pedestrians from each age group who were parked in a handicapped space.

Age Group	Parked in Handicapped Space
Younger	4
Middle	6
Older	15

A Kruskal-Wallis test was conducted to determine whether there were differences in the number of times pedestrians of different ages used each lane position (see Table 33). These analyses revealed no large differences in the frequency at which pedestrians used any of the lane positions. Differences were only observed for lane position 4 in large parking lots, and even these were relatively small and were not in the expected direction: Older and younger pedestrians used lane position 4 more than middle-aged adults.

Table 33. Average frequency at which each lane position was used by age group for pedestrians not parked in handicap spaces.

Large Lots					
Lane Position	**Younger**	**Middle**	**Older**	**X^2**	**p^***
Position 1	.09	.14	.28	2.21	.88
Position 2	.75	.67	.90	2.42	1.0
Position 3	.50	.39	.28	2.81	1.0
Position 4	1.61	1.04	1.34	10.61	.02
Small Lots					
Lane Position	**Younger**	**Middle**	**Older**	**X^2**	**p^***
Position 1	.31	.41	.27	.99	1.0
Position 2	1.23	.84	1.07	5.55	.24
Position 3	.04	.03	.03	.02	1.0
Position 4	.69	.50	.57	2.15	1.0

* *Bonferroni-adjusted p values, taking into account number of comparison tests*

One reason we may not have found age differences in pedestrians' walking path choices may be that pedestrians all walked very different paths overall, most of which were not in a straight line. For this reason it was difficult to obtain a pure measure of participants' "comfort zone" when walking in the parking aisle (refer back to Figure 19). For this reason, this aspect of walking path information will be more accurately gauged in Task 3, where all pedestrians will be walking the same distance from the same start and end points.

Conclusions

In summary, putting together the data from the parking lot crash data set, showing older pedestrians at greater risk from backing up crashes than other age groups, and data from this observational study, we can draw some tentative conclusions. Although older adults are at greater risk for backing up crashes and, presumably, would be safer if they chose crosswalks and kept their distance from parked, potentially backing vehicles, they apparently do not do so at a greater frequency than do other pedestrians. However, in terms of avoiding distraction it appears that older pedestrians do a better job than do their middle-aged and younger counterparts. Such results suggest that any educational campaigns to improve parking lot safety need to be targeted to the types of risks that different age groups incur. Younger and middle-aged pedestrians appear to need to be warned about distraction during navigating, whereas older pedestrians appear to need to be warned about the risk of backing-up collisions.

Chapter 4.

Task 3: Precise Monitoring of Perception and Attention Differences in Pedestrians.

Although Task 2 yielded some useful findings, these were of limited use in accounting for the perceptual and cognitive variables that are likely responsible for injuries and deaths of pedestrians in parking lots. At the core of efficient behavior while navigating in constantly changing environments, such as busy parking lots, is the ability to visually perceive the environment, pay attention to the most relevant information, and engage in behavior that maximizes safety while keeping track of potential hazards. Perhaps the best way to obtain data on these aspects of perception and navigation is the precise monitoring of eye movements in real life traffic situations. The last two decades have seen dramatic progress in eye-tracking technology, now for the first time allowing for the relatively unobtrusive collection of accurate data with walking participants (see one of the best technical solutions at http://www.smivision.com/en/gaze-and-eye-tracking-systems/products/iview-x-hed.html). Several recent publications have focused on the perception of hazards during dynamic traffic situations, focusing on perception, attention and multitasking. To give a few examples, Huestegge et al. (2010) examined the dynamics of detecting a collision hazard and responding by taking evasive action, whereas Borowsky et al. (2010) characterized age-related limitations in hazard awareness during driving. Using eye-tracking methodology has become state of the art in major traffic research institutions around the world. However, the present literature, while very informative, is limited to data collected exclusively from a driver's perspective, with pedestrians primarily seen as a potential hazard.

Building on recent advances in both technology and research theory, we used portable eye-tracking technology to record gaze positions and durations while pedestrians navigated two parking lots on the Florida State University campus. The recordings included a video of the scene with eye movements superimposed, enabling us to monitor pedestrian behavior holistically, combining navigational behavior with perception. Based on these data, we conducted analyses to address several key questions:

1) How do pedestrians scan the parking lot environment in front of them within their immediate "forward cone" area (Kitazawa & Fujiyama, 2010) vs. more distant parts of the visual field?

2) How much attention is given by pedestrians to relevant vs. irrelevant areas and objects within the current scene? This includes specifying the proportions of time spent looking at stationary objects (e.g., parked cars) in anticipation of potential hazards.

In this study, eye movements were monitored to determine participants' allocation of attention. Attention acts like a filter, determining which aspects of a scene are processed and reach conscious awareness (Mack & Rock, 1998). A consistent finding is that salient and important events go unnoticed when attention is allocated elsewhere (e.g., Simons & Chabris, 1999). Thus, if older adults are allocating their attention differently as they navigate parking lots this might explain their greater risk. Recent work suggests that older drivers' increased risk of crashes at intersections can largely be explained by differences between younger and older adults in their strategic allocation of attention, and that through training, older adults can improve their attentional allocation and reduce their crash risk (Pollastek et al., 2012). If similar differences in the allocation of attention to safety-critical events are observed in parking lots, this might explain the differential crash risk of older adults and suggest training programs to reduce inefficient attentional strategies.

Method

Participants

A total of 66 participants recruited from the Tallahassee, FL area, 32 middle-aged adults (mean age = 57.7 years; SD = 3.7) and 34 older adults (mean age = 71.1 years; SD = 4.6) completed Task 3 (see Table 34). Participants were paid $25 for the experimental session.

Table 34. Participants in Task 3.

	Males	**Females**	**Total**
Middle	14	18	32
Older	17	17	34
Total	**31**	**35**	**66**

Materials

For this study we used a SensoMotoric Instruments (SMI) iViewX™ HED mobile eye tracker to record participants' eye movements during the study (http://www.smivision.com/en/gaze-and-eye-tracking-systems/products/iview-x-hed.html, see Figure 22). Eye movement data was recorded by a Lenovo® ThinkPad X200s subnotebook computer that was carried by participants in a small backpack.

Figure 22. Head-mounted mobile eye tracker.

Procedure

For this task, participants wore a mobile eye-tracking device and navigated two parking lots on the Florida State University campus. At the beginning of the experimental session, participants were outfitted with the mobile eye-tracking unit, which recorded what participants saw, as well as where their eyes were directed as they navigated the parking lots during the experiment (see next section for additional detail about the eye-tracking setup procedure). Participants were given an opportunity to become accustomed to walking with the eye-tracking unit and were encouraged to test out their range of motion while wearing the tracker. Next, an experimenter accompanied the participant to the parking area behind the psychology building. The experimenter instructed the participant to walk to the northeast corner parking garage where they would be greeted by a second experimenter (see Figure 23). Due to the eye tracker’s unreliable performance in direct sunlight, eye-tracking data was not collected during this phase of the experiment, but the participants’ chosen path through the parking area was recorded and coded, as was done for the Task 2 observational study.

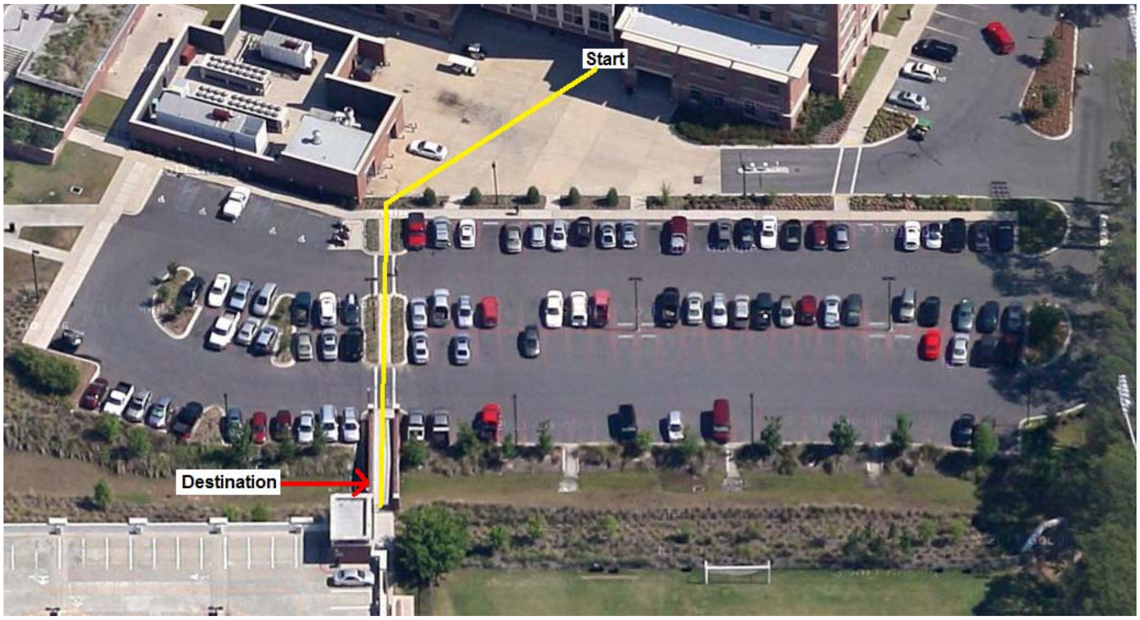

Figure 23. Open parking lot that was used for the Task 3 field study.

The second phase of the experiment, during which eye movements were recorded, was conducted in the parking garage. Upon being greeted by the experimenter stationed in the garage, the eye tracker setup was rechecked and recalibrated if necessary. Next, participants were asked to walk to a traffic cone setup approximately 105 feet down the parking aisle and then return to the experimenter. Because the experiment was conducted during normal business hours, participants were always reminded to remain alert for hazards, as they would in any other parking area. When the participant reached the 5th parking spot, the experimenter signaled a second experimenter waiting in a vehicle to put the vehicle in reverse so that the backup lights were illuminated but did not actually back the vehicle (see Figure 24). In addition to eye movement data, an experimenter also recorded participants' chosen path to the cone and made notes of any compensatory behaviors, such as participants changing their path to avoid the potential threat of the backing vehicle.

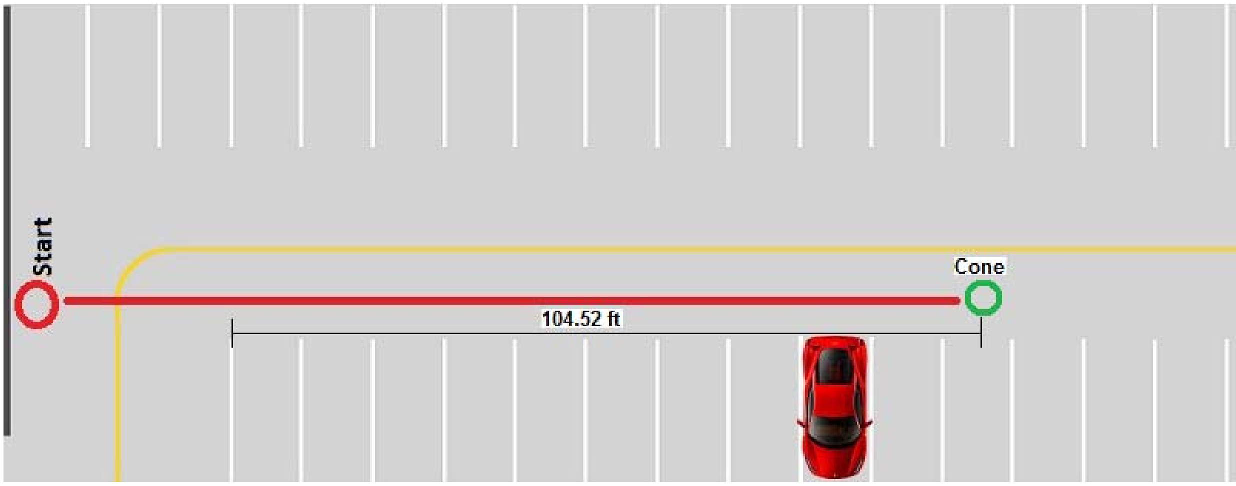

Figure 24. Diagram of garage parking area used for the Task 3. field study.

Eye Tracker Calibration

One issue common to all eye-tracking systems is that the degree of accuracy in recorded information depends critically on the quality of the equipment's calibration. Stationary eye-tracking systems, which are the most common type, require that participants remain at a fixed distance from the stimulus being presented, and the equipment is calibrated to that distance. However, in the current study, a mobile eye tracker was used. Because participants were moving, and the distance of stimuli from the participant varied, we chose a calibration distance that allowed reasonable accuracy of tracking of far objects, those that were between 10 and 20 feet away, as this corresponded with a distance of about one to two parking spaces ahead of the participant.

After participants were outfitted with the eye tracker, the initial calibration of the equipment was done in the hallway outside of the laboratory. Participants were asked to fixate on 5 different points during the calibration sequence, which were pointed out using a laser pointer (see Figure 25). After the calibration sequence was completed, the experimenter verified the accuracy of the setup by asking the participant to look at different objects in the hallway. If the calibration was unsatisfactory, the procedure was repeated.

Every effort was made to select participants who were likely to be good candidates for eye-tracking experiments, as certain types of vision problems make it difficult or impossible to track a person's eye movements (e.g., bifocals, cataracts). However, some participants arrived with visual problems, such as cataracts, that had not yet received a clinical diagnosis of certain problems. As a result, there were a number of participants whose eye-tracking data could not be included in analyses. An exact breakdown of the number of participants with valid data is given in the results section.

Figure 25. Area used to calibrate eye tracker.

Table 35. Variable descriptions.

Variable	**Description**
Reaction Time	The time in milliseconds between the moment the back-out vehicle’s reverse lights activated and the moment when the participant gazed upon the back-out vehicle.
Stop Distance	The number of parking space participants gave between themselves and the back-out vehicle if the stopped for it.
Total Head Turns	The total number of 90-degree head turns participants made while traversing the outside parking lot.
Back-Out Vehicle Stop	If the participant stopped and waited to see if the back-out vehicle to pull out.
Crosswalk Use	If the participant used any of the crosswalks in the outside parking lot.
Walking Speed	The speed in feet per second at which participants walked down the aisle.

Data Coding

Unlike laboratory-based eye-tracking studies in which both the participant and the stimuli they view are stationary, fairly extensive data processing was required to be able to examine participants' allocation of visual attention while navigating the parking area. Much of this involved selecting "areas of interest" (AOIs) for each video that represented key features of the parking area, such as the cars on the right and left sides of the parking area, as well as the vehicle that was the "backing threat" (see Figure 26). Because the mobile eye-tracking unit recorded participants' eye movements superimposed over video (see Figure 27), it was necessary to specify areas of interest individually for each participant.

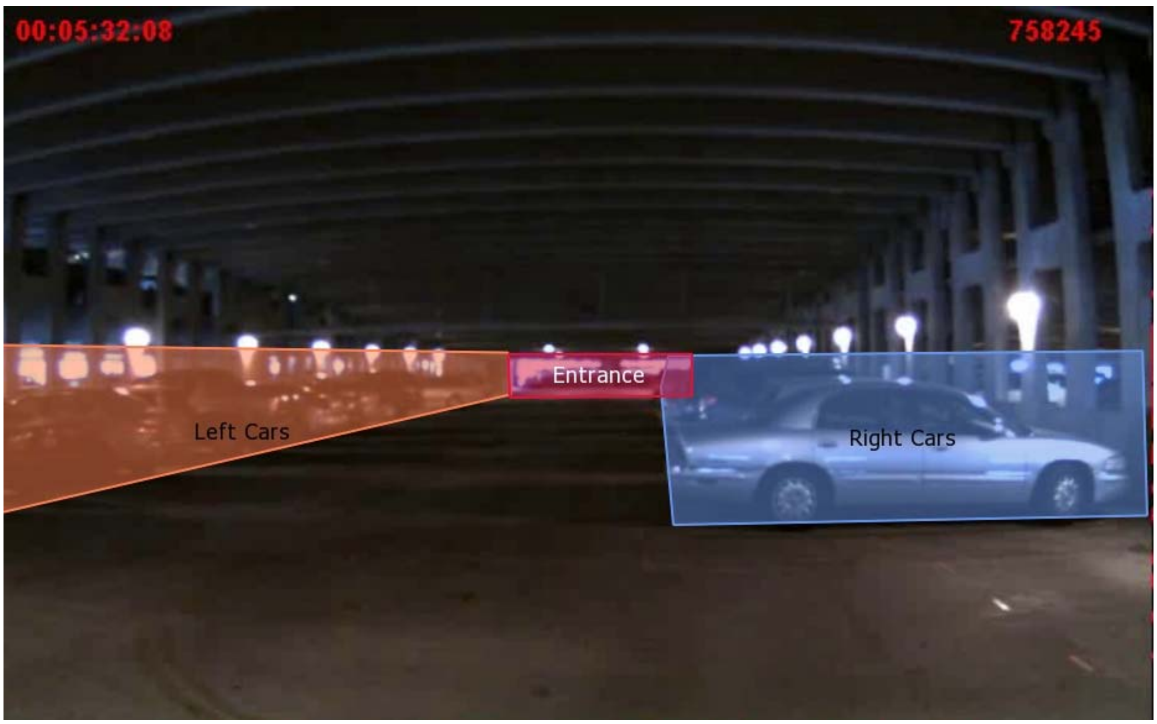

Figure 26. Screen capture showing areas of interest.

Figure 27. Screen capture showing fixations and scan paths from mobile eye-tracking video.

Results

Beyond the issues that arose with the calibration of the eye-tracker (see above), data attrition was also caused by video failure, occlusion of the back-out vehicle, and odd strategies taken by participants (e.g., walking in front of the back-out vehicle). Therefore, the number of participants used in some analyses will differ.

Participants' Parking Lot Navigation Strategies in the Open Lot

For the open parking lot, data from 32 middle and 33 older-aged adults were used in the analyses. Data from one older participant was lost because no video was recorded during the open lot portion of the experiment.

In the current study, we were interested in age differences in visual search strategies that could contribute to older adults' greater risk of being involved in a parking lot collision involving a backing vehicle. One factor that may differ between older and middle-aged adults is the frequency at which they look left and right, as older adults have been noted to do this less frequently in other contexts. To examine this in the current study, we watched the scene video recorded by the mobile eye tracker and coded the number of times pedestrians looked left or right. Overall, in the open parking lot, there was no substantial difference between middle and older-aged adults in the number of head movements made, $t(63) = -.13$ (see Figure 28). As it may have been the case that one age group showed a greater amount of dispersion in the number of head movements made than the other, we compared the frequency distributions in head turns of both age groups (Figure 28). As can be seen in Figure 28, the variance in the number of head turns made by middle-aged participants was slightly larger than that made by older-aged participants; however, as a caveat, it should be mentioned that this difference could simply be due to sampling error.

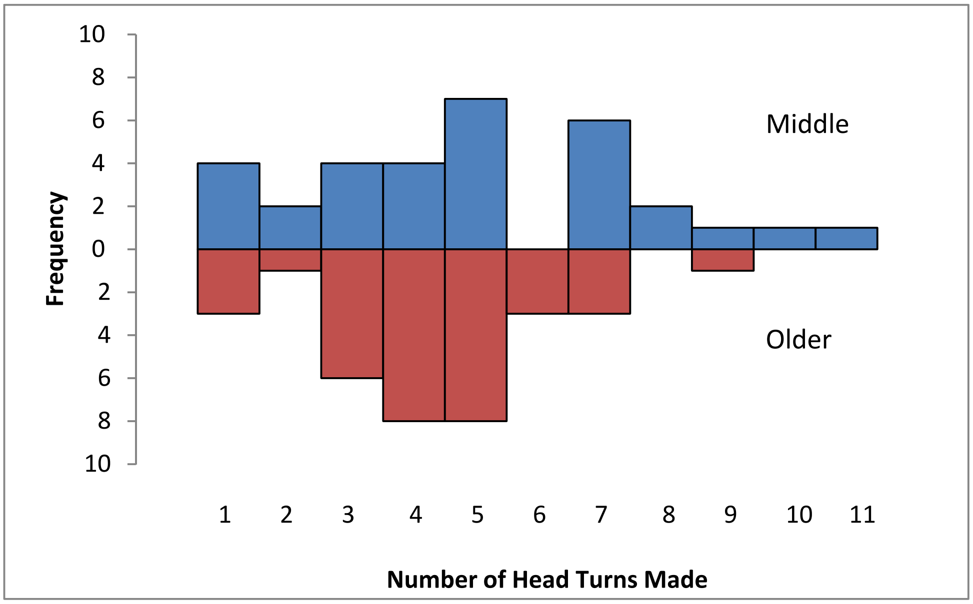

Figure 28. Bihistogram displaying the frequency distributions for the number of head turns made by middle-aged and older participants.

We also examined the frequency at which pedestrians made use of the crosswalk when crossing the open parking lot area. Overall, it was found that older adults did not substantially differ from middle-aged adults in crosswalk use, $X^2(1) = .16$. Although this lot was selected because it was not likely to be busy during the hours of 10am and 2pm, when the study was run, there was occasionally traffic in the lot, so it is likely that our results are representative of participants' naturalistic behavior while navigating other parking lots.

Eye Movement Behavior and Navigational Strategies Used in the Garage

For the parking garage data, participants' reaction times and stop distances to the back out vehicle as well as walking speed were each compared between middle and older-aged adults using a series of two-tailed t-tests while stop frequency was assessed with a chi-square analysis. For reaction time, data from 12 middle and 13 older-aged adults were acceptable for analysis, whereas, for stop frequency, data from 32 middle and 33 older-aged adults were acceptable for analysis. Overall, no substantial differences were found between middle and older-aged adults on reaction time, $t(23) = .20$, or on the distances at which participants stopped at for the back-out vehicle to pull out, $t(38) = -$

1.15. In addition, there was no substantial difference in the likelihood of stopping for the backout vehicle between middle and older-aged adults, $\chi^2(1) = .71$ (see Table 36). As would be expected, there was a difference between middle (M = 4.90, SD = .58) and older-aged adults (M = 4.28, SD = .63) in walking speed (in feet per second), $t(57)$ = 3.90.

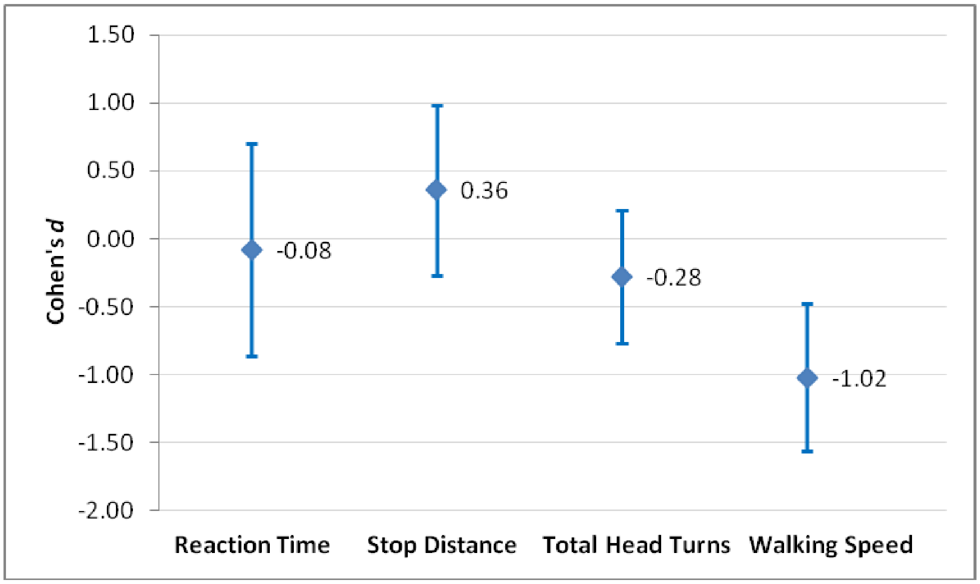

Figure 29. Effect sizes for the mean differences between middle-aged and older adults in reaction time, stop distance, total head turns, and walking speed.
*Negative values indicate a superiority of middle-aged adults on the difference. Error bars represent 95% confidence intervals.

Table 36. Means, standard errors, confidence intervals, and proportions for outside are of interest data.

Variable	Middle Mean(SE)	Older Mean (SE)	Age Group Difference (SE)	95% CI of the Difference	N (Middle, Older)
Reaction Time (ms)	1036 (306)	935 (401)	101 (511)	[-954.85, 1157.29]	12, 13
Stop Distance	1.31 (.16)	1.61 (.20)	.30 (.26)	[-.82, .22]	21, 19
Total Head Turns	4.97 (.47)	4.33 (.32)	.64 (.57)	[.49, 1.76]	32, 33
Walking Speed (fps)	4.90 (.11)	4.28 (.11)	.62 (.16)	[.30, .94]	28, 31
Stopped for Back-Out Vehicle	Yes = 65.6%	Yes = 57.6%	8.0%		32, 33
Used Crosswalk	Yes = 18.8%	Yes = 24.2%	5.4%		32, 33

Eye-tracking

Participants' eye-tracking data was carefully reviewed to determine whether it was appropriate for inclusion in analyses. A number of participants' eye-tracking data was lost due to slipping of the hat on which the tracker was mounted, disrupting the calibration of the equipment. There were also some participants who, for various reasons, were simply not able to be setup on the equipment. Table 37 gives the total number of participants from each age group who had high quality eye-tracking data. There was no evidence that data loss was unevenly distributed across age groups or genders.

Table 37. Participants in Task 3 with valid eye-tracking data.

	Males	**Females**	**Total**
Middle	8	6	14
Older	8	8	16
Total	**16**	**14**	**30**

We divided the garage into 5 distinct areas of interest (see Figure 30) and then calculated the proportion of fixations that fell within each area for every participant. Originally, a finer grained analysis using smaller areas of interest was planned; however, as we were not confident that the tracking capability on the eye tracker was accurate enough for these smaller areas, the larger areas were eventually used. Overall, eye-tracking data from 11 middle and 14 older-aged adults was judged to be of acceptably high quality and were included in the analysis.

We then compared the proportions in each area for middle and older-aged adults using a series of two-tailed t-tests. The results of these tests are shown in Table 38 and Figures 32 and 33. Overall, the area surrounding the back-out vehicle (area 4) and the center of the aisle (area 5) showed the most substantial differences, with older adults displaying a proportion that is up to 22 percentage points greater than middle-aged adults in area 4 ($t(25) = -1.7$, and middle-aged adults displaying a proportion that is up to 27 percentage points greater than older-aged adults in area 5 ($t(25) = 1.36$). Note, however, that the confidence intervals for these differences include 0 as plausible values for the differences in the population, indicating that no differences may actually exist.

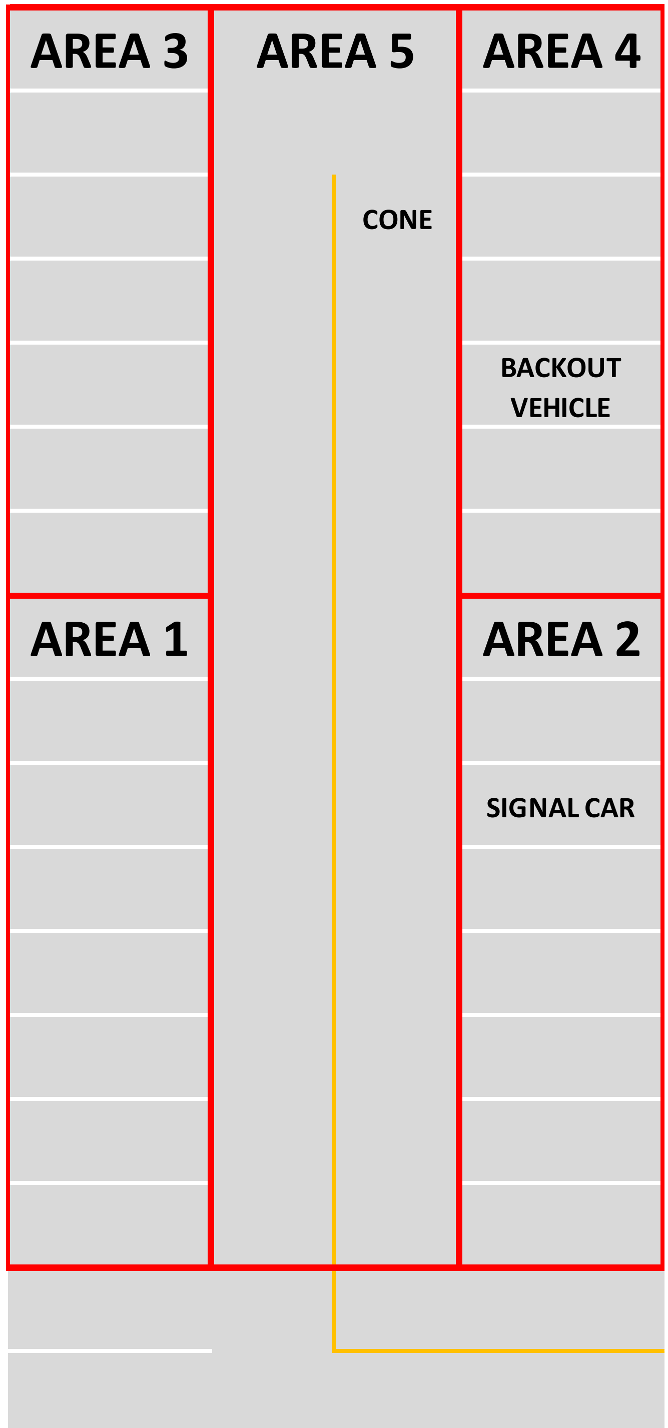

Figure 30. The parking garage separated into the 5 areas of interest (enclosed in red).

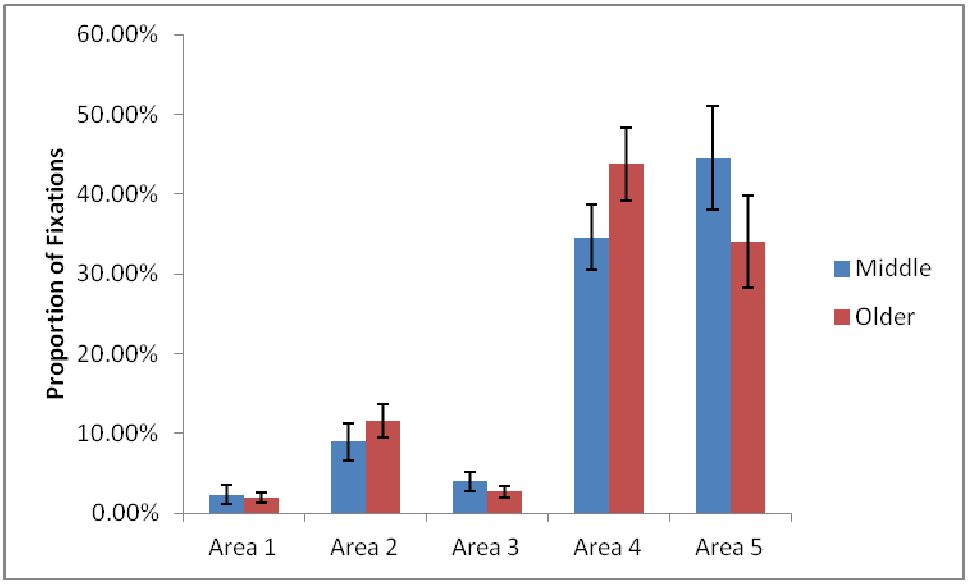

Figure 31. Proportion of fixations made across age groups for each area of interest.
*Error bars represent -/+ 1 standard error of the mean.

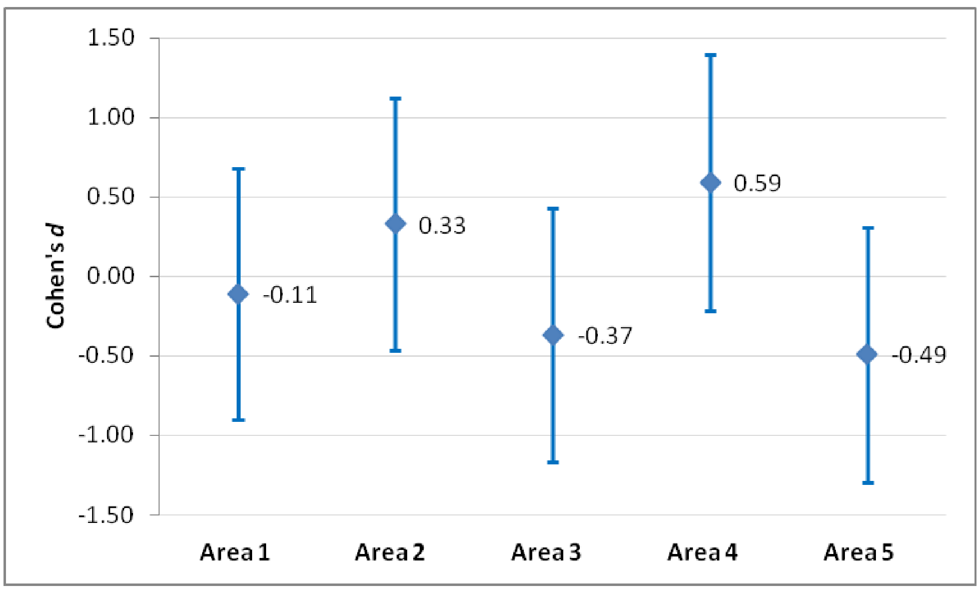

Figure 32. Effect sizes for the mean differences between middle-aged and older adults for the areas.
*Negative values indicate a superiority of middle-aged adults on the difference. Error bars represent 95% confidence intervals.

Table 38. Means, standard errors, and confidence intervals for the area of interest data.

Variable	Middle Mean (SE)	Older Mean (SE)	Age Group Difference (SE)	95% CI of the Difference	N (Middle, Old)
Area of Interest 1 (%)	2.33 (1.17)	1.97 (.69)	.36 (1.30)	[-2.33, 3.05]	11, 14
Area of Interest 2 (%)	8.95 (2.38)	11.57 (2.12)	2.62 (3.19)	[-9.21, 3.97]	11, 14
Area of Interest 3 (%)	3.98 (1.26)	2.71 (.74)	1.27 (1.39)	[-1.60, 4.15]	11, 14
Area of Interest 4 (%)	34.55 (4.07)	43.76 (4.53)	9.21 (6.26)	[-22.16, 3.74]	11, 14
Area of Interest 5 (%)	44.54 (6.50)	34.07 (5.78)	10.47 (8.70)	[-7.54, 28.75]	11, 14

In general, no substantial differences were found between middle and older-aged participants on most variables; however, older-aged adults walked slower than middle-aged adults and tended to gaze more often towards the right side of the aisle, which consisted of a row of vehicles and a back series of columns that allowed visual access to other parts of the garage. Age-related differences in the proportion of fixations in areas 4 and 5 may suggest that older adults pay more attention to vehicles they are walking by as any one vehicle could be a potential threat. In addition, it could be that the older participants were more captured by the potential threat of the backout vehicle, whereas, middle-aged adults paid more attention to potential threats coming from the aisle. Indeed, participants were told that the garage was an active parking lot, and as such, were likely to expect some traffic in the aisle. Alternatively, participants from both age groups may have paid the same amount of attention to each area, however, because of their reduced functional field of view, older participants may have had to rely more on eye movements to maintain attention. Finally, these differences could simply come as a result of sampling error and not actually exist in the population. Indeed, the confidence intervals for areas 4 and 5 include 0 as a plausible value for the population difference.

Walking Path Information

We recorded information about each pedestrian's path as they traveled through the garage, with special attention to the distance at which pedestrians walked from the backs of parked vehicles. The coding sheet used was draw to exact scale using measurements taken of the garage area (see Appendix G for sample coding sheet). Pedestrians' approximate distance from the backs of cars was estimated by measuring the distance between the line drawn for a pedestrian's path and the painted lines for parking spaces. Measured distances then were converted to estimates of the distance, in feet, from which pedestrians walked from parked cars (see Figure 34).

For each participant, we computed the average walking distance from the backs of parked cars for the area before they passed the 5th parking space and the area from the 5th space to the 11th space. Data from one participant was not recorded, and data from four older participants who used "unconventional" strategies (e.g., walked in front of parked cars, crossed over into the other lane), and were also statistical outliers, were also excluded from the analysis leaving a total of 31 middle-aged and 30 older participants. As expected, most participants, regardless of age, deviated their path to increase the distance between themselves and the potentially backing vehicle, $F(1,59) = 24$, $p < .001$, $\eta_p^2 = .29$. However, while there was a slight trend for older adults to walk about 0.7 feet closer to the backs of parked vehicles before the back out event, $F(1,59) = 1.81$, $p = .18$, $\eta_p^2 = .03$, both age groups deviated their paths by about the same amount in response to the back out event, $F(1,59) = .87$, $p = .35$, $\eta_p^2 = .02$ (see Figure 33).

Some participants stopped in response to the back out event, presumably to wait and see if the driver actually would back up. About the same number of middle-aged and older participants stopped in response to the back out event (see Table 39). When the car did not begin backing, participants resumed walking toward the predetermined destination. One possibility is that participants who did not stop may have deviated their walking path more than those who did, increasing the distance between them and the backing vehicle instead of waiting to until it seemed safe to proceed. However, there was no evidence of this in the current data, as participants who stopped in response to the backing threat showed about the same amount of path deviation as those who did not, $F(1,61) < 1$.

Table 39. Number of participants who stopped or did not stop in response to the back out event.

	Stopped	**Did Not Stop**	**Total**
Middle	11	21	32
Older	14	19	33
Total	25	40	65

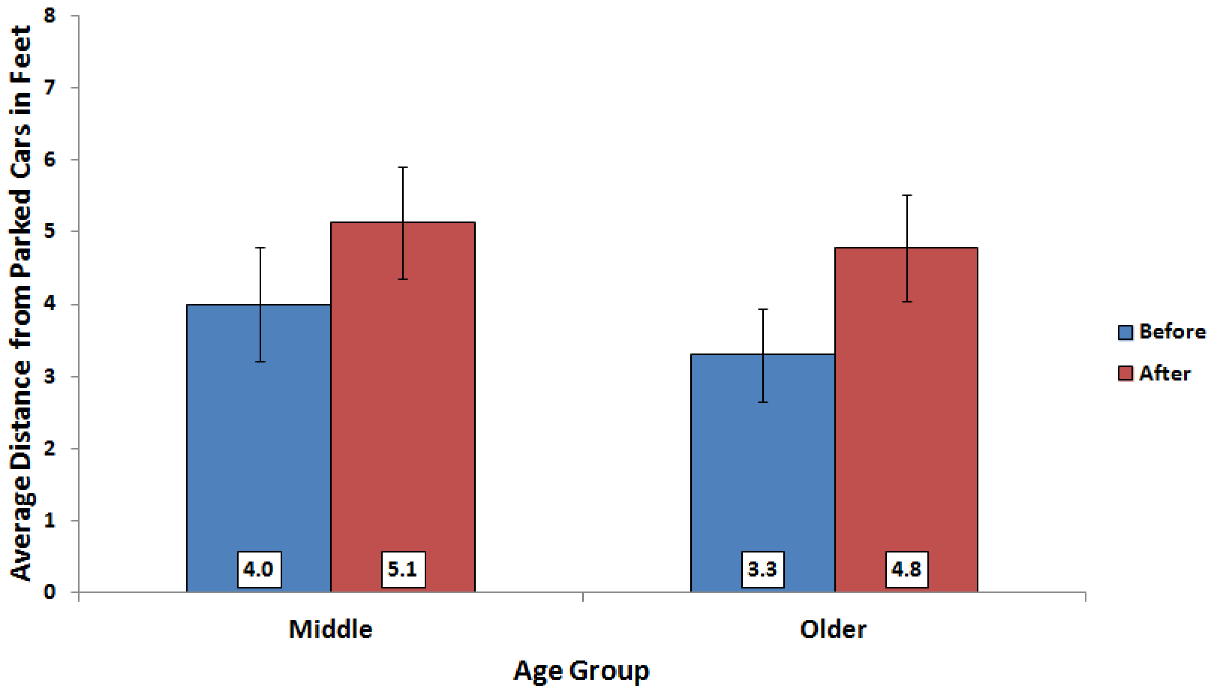

Figure 33. Average walking distance from parked cars by age group and experiment phase.
*Error bars show the 95% confidence interval.

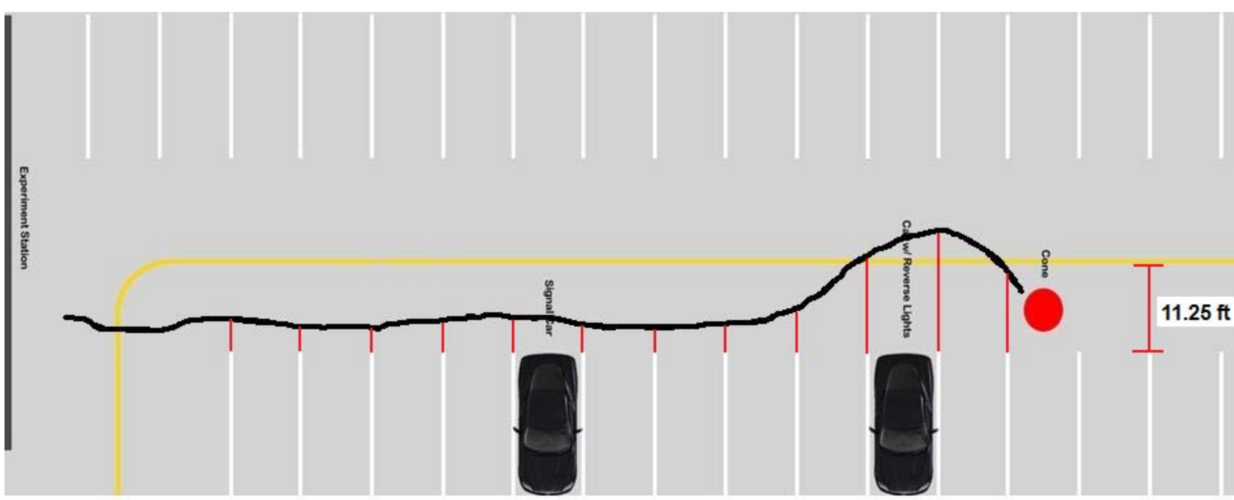

Figure 34. Sample of walking path coding measurements.

Participant Suspicion of Back Out Event

A concern with this or any field study design is that participants do not act as they would outside the experiment. In the current study, special care was taken to create a task that captured critical features of participants' decision processes while navigating parking lots, however, the fact remains that participants were aware they were being observed. To be able to assess potential effects of participant suspicion on the current results, we asked each participant who completed the study whether they were aware that the driver of the backing vehicle was one of our experimenters.

Most participants in the current study did not report that they suspected that the backing event in the current study was part of the experiment (see Table 40). However, there were a number of participants, including slightly more older adults, who did report being suspicious. One possible reason for this is that our older adults may have been more likely to have participated in previous (though unrelated) studies and so have been more likely to suspect that there was more to the experiment than they were told at the outset.

Table 40. Participant suspicion by age group.

	Not Suspicious	**Suspicious**	**Total**
Middle	26	6	32
Older	22	12	34
Total	**48**	**18**	**66**

*Count also includes participants who were ultimately excluded from analyses.

When participants' response to the backing threat was analyzed separately for participants who were suspicious versus those who were not, a slightly different pattern of results was observed for suspicious participants, which also varied between age groups. First, for participants who did not report being suspicious, results were very similar to what was seen overall; participants deviated their path to increase the distance between themselves and the backing threat, $F(1,43) = 15.3$, $p < .001$, $\eta_p^2 = .26$, and this tendency was similar across age groups, $F(1,43) = .37$, $p = .55$, $\eta_p^2 = .01$ (see Figure 35).

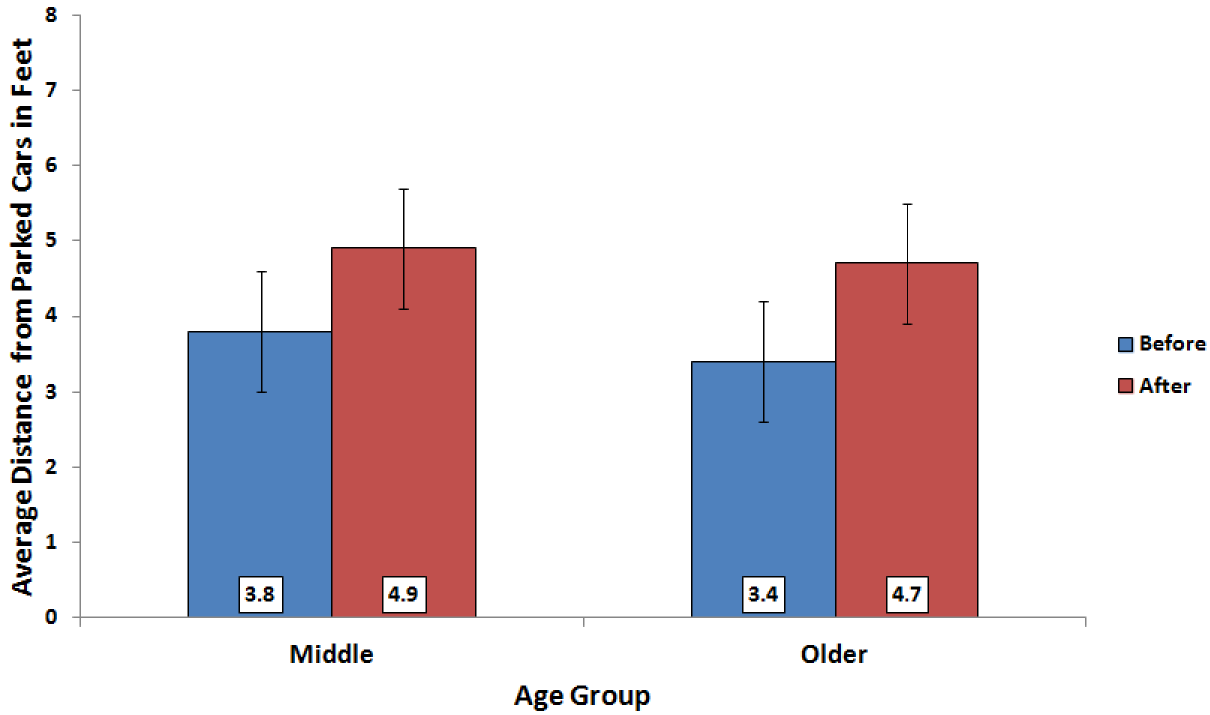

Figure 35. Average walking distance from parked cars by age group and experiment phase for participants who did not report any suspicion.
*Error bars show the 95% confidence interval.

For participants who did report that they were suspicious that the back out event was staged, there was an overall weaker tendency for participants to change their walking path less in response to the backing threat, $F(1,13) = 6.28$, $p = .03$, $\eta_p^2 = .33$, and there was evidence that this tendency may have varied between age groups, $F(1,13) = 3.19$, $p = .10$, $\eta_p^2 = .20$. Specifically, middle-aged adults who reported suspicion did not deviate their path in response to the backing threat, while older adults did do this (see Figure 36). However, due to the overall small number of participants reporting suspicion, caution should be used when interpreting these findings.

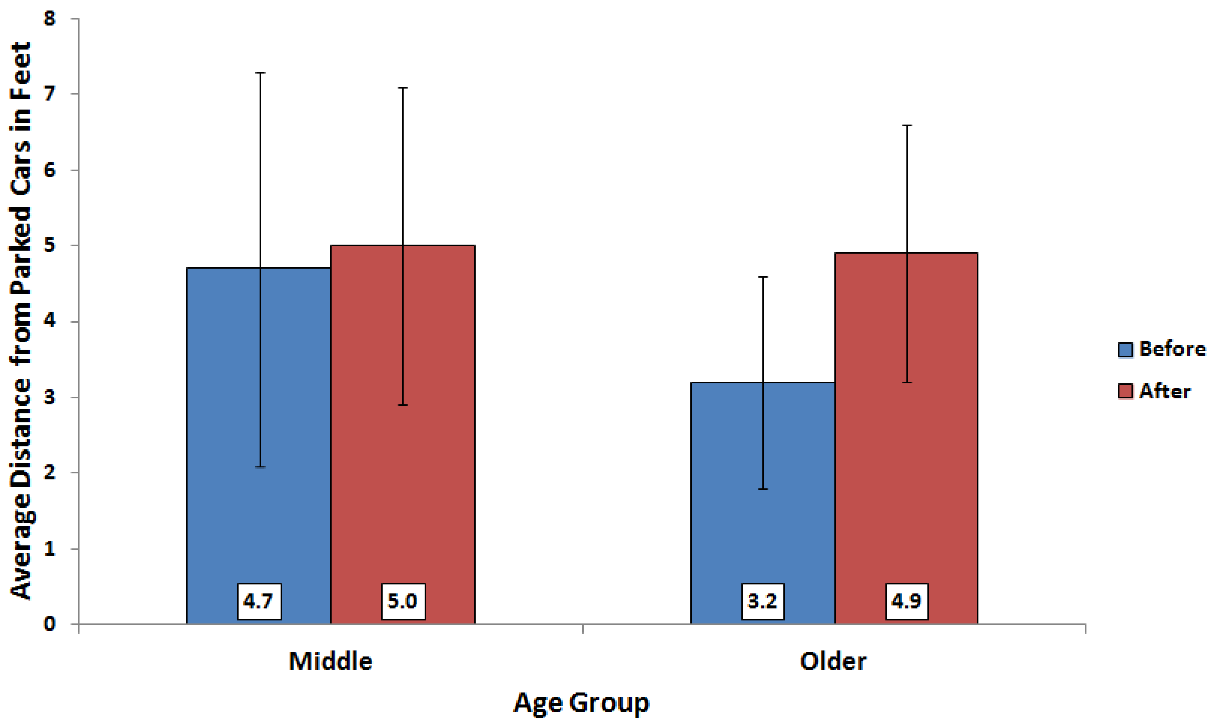

Figure 36. Average walking distance from parked cars by age group and experiment phase for participants who reported suspicion.
*Error bars show the 95% confidence interval.

It is possible that participants who were suspicious that the back out event was part of the experiment may not have taken the potential threat seriously. However, the proportion of participants who stopped in response to the back out event was about the same between participants who reported being suspicious and those who did not report being suspicious (see Table 41 and Table 42).

Table 41. Participants who stopped in response to back out event by reported suspicion.

	Not Suspicious	**Suspicious**	**Total**
Stopped	28	12	40
Did Not Stop	20	6	26
Total	**47**	**18**	**66**

Table 42. Participants who stopped in response to back out event by reported suspicion.

Not Suspicious			
	Stopped	**Did Not Stop**	**Total**
Middle	18	8	26
Older	10	12	22
Total	**20**	**28**	**48**
Suspicious			
	Stopped	**Did Not Stop**	**Total**
Middle	3	3	6
Older	9	3	12
Total	**12**	**6**	**18**

Pedestrians' Visual Attention During Back Out Event

As mentioned previously, upon encountering the back out event, a little over half of the participants stopped, presumably to wait and see if the driver was going to back out. During that time, most participants for whom we had valid eye-tracking data did seem to be looking at the driver (see Figures 37 and 38).

Figure 37. Sample of fixation data from a middle-aged participant after encountering the back out event.

Figure 38. Sample of fixation data from an older participant after encountering the back out event.

Conclusions

There were remarkably few differences in how middle-aged and older pedestrians distributed their attention while walking, as indicated by eye fixation patterns. The only variable that differentiated the way the groups navigated in this fixed path experiment was walking speed. Perhaps part of the reason for observing so few differences is that the two groups were not far apart in age (about 13 years). Also, as seen in the prior observational study, these age groups do not vary much in naturalistic walking behavior.

Previous research has found that older adults tend to search less efficiently compared to younger adults and have poorer control of their visual attention (e.g., Madden et al., 1999; Plude & Doussard-Roosevelt, 1989; Scialfa & Joffe, 1997; Zacks & Hasher, 1997). Based on these findings, one might expect that as older adults navigate parking lots they would be less efficient searching for and detecting potential hazards, such as backing vehicles. However, luminance onsets, like the onset of reverse lights, are one of the most effective means of capturing attention (Boot et al., 2005; Enns et al., 2001; Irwin et al., 2000; Theeuwes, 1994). Furthermore, some research suggests that stimulus-driven attentional control (attention capture) is automatic and robust to age-related differences, while age effects are largely seen in goal-oriented shifts of attention (e.g., Kramer et al., 2000). Age-invariant capture of attention by luminance onsets is consistent with the result that middle-aged and older adults attended to the back out vehicle just as quickly and just as often.

Chapter 5. Summary of the Studies

Benefit of the Project

This project has provided relevant data to aid the formulation of policy and recommendations for the Safe Mobility for Life Program. Some of the findings with relevant policy implications are:

Task 1.

1) Seasonal variation was seen in crash frequency in parking lots with higher frequencies in winter and spring, likely associated with tourist influxes to south Florida.
2) Diurnal variation in crash frequency was found with peaks from noon to 6 pm.
3) Crash risk (per 1000 population) variation for all crashes and serious crashes with greater risk for younger (age 15-19) and older (age 75+) pedestrians, as well as for younger (age 20-24) and older (age 65+) drivers.
4) Greater crash frequencies were found in smaller than larger parking lots and in residential parking lots.
5) No significant variation was seen in crash frequency by parking space angle or by presence of crosswalks.
6) Greater frequency of backing up crashes occurred for older pedestrians (age 75+) and forward driving crashes for younger (age 14 and below) pedestrians.

Task 2.

1) All age groups (young, middle, old) made greater use of crosswalks in larger parking lots, though no significant age variation occurred in using crosswalks.
2) No significant age variation was seen in lateral distance to parked cars when pedestrians were navigating.
3) Greater distracted walking occurred for younger than older pedestrians.

Task 3.

1) Age differences were observed in walking speeds when navigating parking lots with older pedestrians walking about 0.6 feet/s slower than middle-aged ones.
2) No significant age differences in attention patterns were observed when navigating parking lots, as indicated by scanning behavior (e.g., head turns, eye fixation patterns) or in response to a backing out threat (fixation response time, walking path deviation).

Specific Recommendations Based on Study Findings

1). Task 1 found that there were crash frequency variations by month and suggest that potential educational interventions, such as public service announcements, be targeted to high risk months (winter, spring break) to alert pedestrians (many of whom may be tourists) to the risks in parking lots and how to navigate safely. Given the greater crash risk for both older drivers and pedestrians (age 75+ years) and younger drivers (age 20-24 years) and younger pedestrians (age 15-19 years), educational campaigns could concentrate on those age bands. Also, given that use of crosswalks did not vary by age though crash risk did, educational campaigns might wish to try to increase crosswalk use, particularly for the most at-risk age groups. Finally, given the greater risk to older pedestrians of backing up crashes, they might be encouraged to give themselves a greater lateral distance from parked vehicles when walking down an aisle, though this strategy might leave them at greater risk of being hit by an inattentive forward-moving driver.

Our studies suggest the most likely reason for the differential crash types in parking lots for older compared to younger pedestrians probably lies in the speed with which older pedestrians can react to dangerous events. The main finding to be explained from the archival data analyses is why older pedestrians are more likely to be seriously injured or killed in parking lots by cars backing up than by cars moving forward. From study 2, which observed navigation behavior in parking lots, it was reasonably clear that the paths pursued were fairly similar as a function of age. In fact, in terms of exposure to crash risk, it appears that because older pedestrians are more likely to be parking in handicapped parking spaces, they likely have shorter paths to destinations than other age groups at least in the larger parking lots we observed. However, given that crashes may occur at higher frequency in smaller lots, we cannot be confident that older pedestrian exposure is truly lower. Older pedestrians also seem to be more cautious than other age groups in terms or risk taking, as evidenced by lower prevalence of walking while distracted (e.g., by using a mobile phone). Hence, having ruled out path differences (study 2) and attention allocation differences (study 3), we are left with the conclusion that speed of responding is the most likely explanation. Evidence favoring such a conclusion is the slower walking speed (study 3) and the well-known difference in general speed of information processing for older compared to younger adults (e.g., Jastrzembski & Charness, 2007).

One likely scenario for a backing up crash is that a driver is distracted and fails to notice a pedestrian in the backup path, perhaps after verifying initially that the path is clear. The general advice that one should be looking over a shoulder while backing up may be difficult to follow if there are head mobility limitations (more likely to occur with older drivers). An alert pedestrian may notice the backup lights and move quickly to evade the vehicle. An older alert pedestrian may notice the backup lights but not move quickly enough to avoid a collision. Inattentive pedestrians of any age may fail to register the backing up vehicle.

2) Given the problems associated with backing up a vehicle, for driver and pedestrian alike, it would be useful to encourage drivers to exercise greater caution when backing, including looking twice and also scanning for pedestrians. Rear backup cameras or other alerting systems in their vehicles may also prove to be useful, enabling even inattentive drivers to be alerted to an impending crash. However, the efficacy of these systems continues to be evaluated (see NHTSA, 2006b), and they should not serve as a driver's sole means of detecting hazards while backing (see also AAA, 2007). Future development and deployment of collision-avoidance technology (e.g., collision detection coupled with automated braking, autonomous parking for vehicles) may also help to prevent back-up crashes.

3). As analyses in Task 1 and Task 2 make clear, more research is needed to provide better metrics of risk for pedestrians in parking lots. By using survey data on driving behavior, it is possible to compute a risk index such as crashes per million miles driven for drivers of different ages. It would be helpful to collect data on age-related rates of navigation through parking lots together with path length (time and distance, given age-related differences in walking speed) in order to develop a similar index for pedestrian crashes (such as crashes per unit time of exposure or crashes per mile navigated).

4). Further research should be conducted on how specific design features of parking lots may contribute to crash risk. Such data might enable parking lot designers to achieve a better balance between optimization of parking spaces, traffic flow, and safe separation of pedestrian and vehicle traffic.

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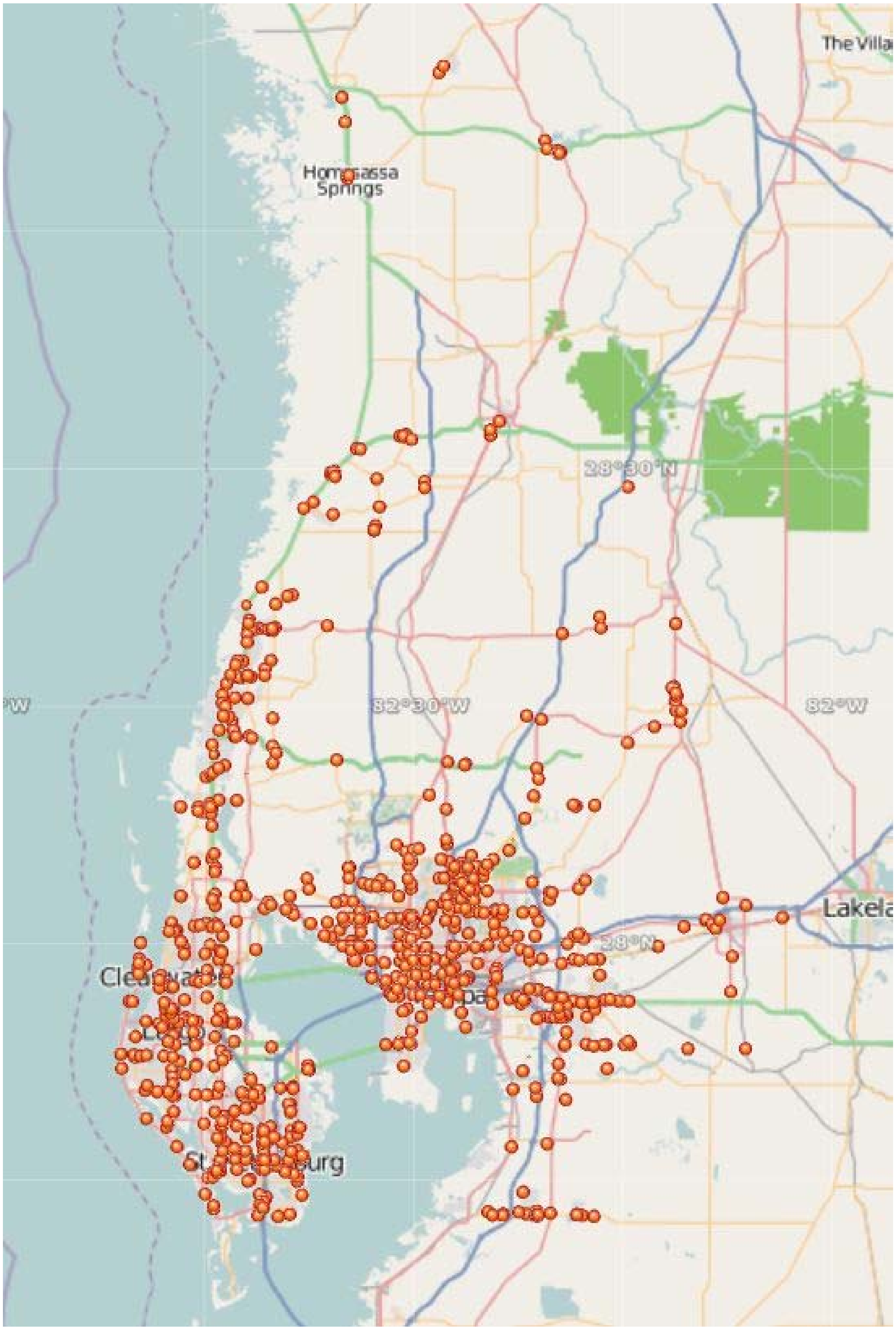
Appendix A. Locations of GIS coded cases



Appendix B. Population Estimates by Age Group for Counties Included in Data Set

Aged 9 Years and Younger					
	2004	2005	2006	2007	2008
Citrus	10,345	10,611	11,031	11,458	11,618
Hernando	14,980	16,024	16,947	17,957	18,149
Hillsborough	148,699	153,009	156,618	157,403	158,338
Pasco	44,794	47,450	49,917	52,122	53,356
Pinellas	90,556	89,546	88,148	87,059	86,028
Total	311,378	318,645	324,667	328,006	329,497

Aged 10 to 14 Years					
	2004	2005	2006	2007	2008
Citrus	6,875	6,856	6,993	6,897	6,926
Hernando	8,914	9,195	9,598	9,898	10,095
Hillsborough	80,493	81,942	82,635	82,453	82,151
Pasco	24,819	25,913	26,913	27,662	28,205
Pinellas	53,590	52,457	51,094	49,426	48,205
Total	176,695	178,368	179,239	178,343	177,590

Aged 15 to 19 Years					
	2004	2005	2006	2007	2008
Citrus	6,738	7,061	7,208	7,413	7,367
Hernando	8,241	8,925	9,463	9,883	10,167
Hillsborough	76,799	80,498	84,039	85,835	87,122
Pasco	22,668	24,106	25,563	26,844	27,540
Pinellas	50,630	51,865	52,270	52,368	52,174
Total	167,080	174,460	180,549	184,350	186,378

Aged 20 to 24 Years					
	2004	2005	2006	2007	2008
Citrus	4,653	4,827	5,102	5,396	5,427
Hernando	6,575	6,927	7,249	7,661	7,643
Hillsborough	80,861	83,190	85,427	86,958	87,909
Pasco	18,588	19,581	20,498	21,686	21,956
Pinellas	46,877	47,248	47,213	46,913	46,682
Total	159,558	163,778	167,495	170,621	171,625

Aged 25 to 44 Years					
	2004	**2005**	**2006**	**2007**	**2008**
Citrus	22,705	23,088	23,591	23,982	23,857
Hernando	30,634	32,425	34,162	35,420	35,702
Hillsborough	335,571	343,783	349,474	348,093	346,204
Pasco	97,984	103,725	108,896	112,656	112,927
Pinellas	235,676	231,500	226,591	221,118	216,509
Total	724,574	736,526	744,720	743,276	737,207

Aged 45 to 64 Years					
	2004	**2005**	**2006**	**2007**	**2008**
Citrus	37,847	39,969	41,835	42,886	43,110
Hernando	39,411	42,397	44,992	46,502	47,297
Hillsborough	258,525	270,372	281,293	289,434	296,637
Pasco	101,718	108,945	115,288	119,876	122,773
Pinellas	255,673	262,748	268,384	271,948	274,877
Total	695,178	726,436	753,798	772,653	786,702

Aged 65 to 74 Years					
	2004	**2005**	**2006**	**2007**	**2008**
Citrus	21,573	22,003	22,433	23,022	23,801
Hernando	20,689	20,967	21,497	21,763	22,415
Hillsborough	66,583	68,371	69,502	71,349	74,352
Pasco	44,292	45,249	45,961	46,897	48,809
Pinellas	89,313	88,744	87,373	88,035	91,028
Total	244,454	247,339	248,772	253,073	262,413

Aged 75 Years and Older					
	2004	**2005**	**2006**	**2007**	**2008**
Citrus	19,104	19,376	19,633	19,920	20,016
Hernando	20,149	20,296	20,490	20,807	20,969
Hillsborough	60,694	61,989	62,838	63,161	64,060
Pasco	46,785	46,875	46,493	45,836	45,747
Pinellas	105,990	105,318	103,109	101,757	100,955
Total	254,726	255,859	254,569	253,488	253,755

Information from U.S. Census Bureau:
http://www.census.gov/popest/data/intercensal/county/files/CO-EST00INT-AGESEX-5YR.csv

Appendix C. Incidents per 1,000 population by Age Group and Year

Pedestrians: All Incidents						
	2004	**2005**	**2006**	**2007**	**2008**	**Average**
9 Years and Under	0.077	0.085	0.055	0.055	0.064	.067
10 to 14 Years	0.045	0.062	0.084	0.039	0.045	.055
15 to 19 Years	0.156	0.149	0.15	0.13	0.161	.149
20 to 24 Years	0.107	0.098	0.125	0.117	0.111	.112
25 to 44 Years	0.106	0.106	0.107	0.101	0.083	.101
45 to 64 Years	0.066	0.102	0.069	0.084	0.089	.082
65 to 74 Years	0.094	0.069	0.08	0.111	0.088	.088
75 Years and Older	0.137	0.117	0.161	0.118	0.177	.142
Average	0.099	0.099	0.104	0.094	0.102	

Drivers: All Incidents						
	2004	**2005**	**2006**	**2007**	**2008**	**Average**
9 Years and Under	0	0	0	0.003	0	.0006
10 to 14 Years	0.006	0.011	0.006	0	0.006	.006
15 to 19 Years	0.078	0.092	0.111	0.125	0.113	.104
20 to 24 Years	0.157	0.183	0.107	0.105	0.14	.138
25 to 44 Years	0.094	0.114	0.085	0.105	0.085	.097
45 to 64 Years	0.089	0.07	0.102	0.075	0.095	.086
65 to 74 Years	0.094	0.101	0.084	0.063	0.095	.087
75 Years and Older	0.122	0.113	0.082	0.126	0.138	.116
Average	0.080	0.086	0.072	0.075	0.084	

Pedestrians: Severe Incidents						
	2004	**2005**	**2006**	**2007**	**2008**	**Average**
9 Years and Under	0.029	0.022	0.009	0.015	0.009	0.017
10 to 14 Years	0	0.017	0.011	0.011	0.006	0.009
15 to 19 Years	0.018	0.017	0.011	0.022	0.027	0.019
20 to 24 Years	0.025	0.006	0.024	0.012	0.017	0.017
25 to 44 Years	0.017	0.022	0.015	0.011	0.012	0.015
45 to 64 Years	0.020	0.014	0.012	0.016	0.010	0.014
65 to 74 Years	0.025	0.012	0.024	0.024	0.019	0.021
75 Years and Older	0.039	0.031	0.047	0.043	0.039	0.040
Average	0.022	0.018	0.019	0.019	0.017	

Drivers: Severe Incidents						
	2004	**2005**	**2006**	**2007**	**2008**	**Average**
9 Years and Under	0	0	0	0	0	0.000
10 to 14 Years	0.006	0	0.006	0	0	0.002
15 to 19 Years	0.018	0.011	0.017	0.027	0.038	0.022
20 to 24 Years	0.050	0.043	0.006	0.006	0.012	0.023
25 to 44 Years	0.022	0.022	0.013	0.015	0.016	0.018
45 to 64 Years	0.016	0.014	0.023	0.022	0.014	0.018
65 to 74 Years	0.008	0.012	0.003	0.012	0.015	0.010
75 Years and Older	0.047	0.012	0.020	0.024	0.020	0.025
Average	0.021	0.014	0.011	0.013	0.014	

Appendix D. Sample Overhead Views of Residential Parking Areas Coded in Task 1.

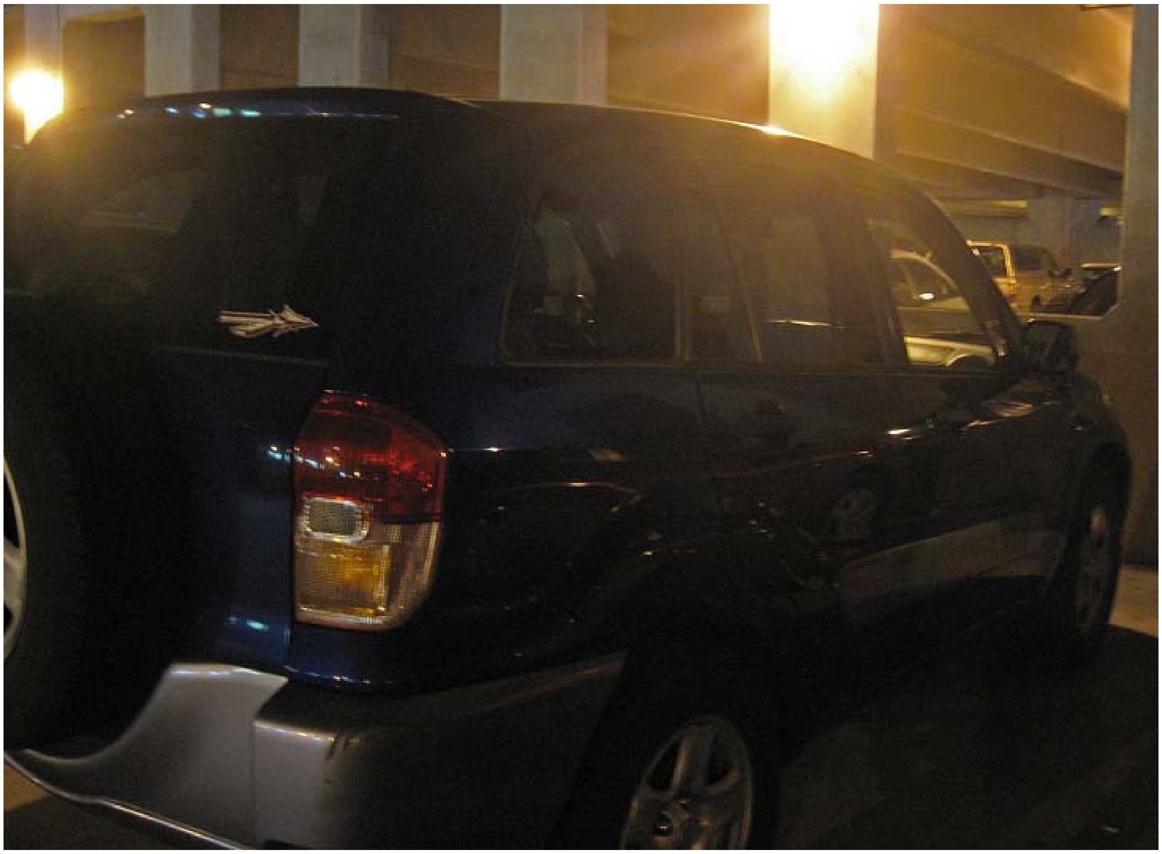
Case#: 75289544
4813 Bristol Bay Way, Tampa, FL
Google Maps: http://g.co/maps/j32je

Case#: 75174275
8700 Orange Leaf Court, Tampa, FL
Google Maps: http://g.co/maps/dkst9

Case# 76266895
4733 Waters Avenue, Tampa, FL
Google Maps: http://g.co/maps/cuvr7

Appendix E. Task 3 Field Testing Location

Appendix F. Task 3 Vehicles Used in Back Out Event.



Appendix G. Sample participant coding sheet

Participant #: ________

Date: ____________

Lane Position	
1 – *Blue*	Empty Spaces
2 – *Red*	Arm's reach of cars
3 – *Green*	Not arm's reach, not center
4 – *Yellow*	Center of Aisle

Notes: ________________