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Perception and Action in Virtual Environments: Human performance in virtual driving simulators.

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VI.B Experiment 2: Forward Looking Blindspots (FLBs). *A report of A-Pillar induced field-of-view obstruction and driver performance in a simulated rural environment.*

VI.B.1 Abstract

The most common reference to the concept of a driver's "blindspot" is a region of the driving field to the left and right rear of the vehicle. This paper seeks to address issues with the physical design of vehicles and the driver's interaction with the vehicle, which produce hazardous conditions to the forward regions of the vehicle. I believe this to be a much more critical issue since this vector produces a much more dangerous situation due the nature of potential collisions with vehicles traveling at right angles to one another and to some degree with pedestrian traffic.

The "A-pillar" is a support post found in nearly every vehicle on the road. This structure and associated structures such as mirrors, can produce a field of obscured vision spanning large areas in a drivers field of view. Due to the nature of human attention, scanning behavior and perception, this forward looking blindspot (FLB) is largely

unnoticed and uncompensated for. In recent automotive engineering designs there has been minimal effort to correct this problem. It is also possible to correct this issue in driver training, yet this is also rarely done. This experiment clearly indicates the potential for collisions based upon driver scanning behaviors, complacency, and automotive design.

FLBs occur when the driver's field of view is compromised as a result of the obscured line of sight produced by the support pillar on either side of the windshield, also known as the A-pillar. This differs from the "traditional" concept of the rear-view blindspot. This obscured region enables an approaching vehicle to remain hidden for an extended time due to coincident acceleration or deceleration. This interaction holds serious implications for real world events as well as research results in traffic interactions and automotive design.

This study analyzed the relationship between the size of the FLB, the approach behaviors (speed, response) of two vehicles approaching an intersection at right angles, and driver behavior relative to an accident-likely event.

The wrap around simulator (WAS) at the University of Minnesota Human Factors Research Lab (HFRL) is a large dome like structure with wrap around screens and multiple projectors that produce a forward field of view image of approximately 130 degrees about an instrumented vehicle. At each simulated intersection, the manner in which the participants scanned the virtual environment was observed and scored in four categories or levels:

I. Eyes fixed- peripheral vision only

II. Eyes only scan- left/right, no head motion.

III. Eye/head scan – head rotates but no change in position

IV. Active scan – head moves around left/right, forward/back (looking around A-pillar*)*

Participants were also scored as to target vehicle acquisition and collision. Acquisition increased at each increased level of scanning and the collision rate decreased at the "active" scanning levels (III & IV). Signage (yield) at intersections produced no significant correlation with the acquisition rate, collision rate, or scanning level.

It would appear that in the interaction between automotive design, traffic systems and driver behavior, the complacency or resulting inactivity of the driver's scanning behavior can produce a common and hazardous driving condition. This issue applies to automotive and pedestrian traffic as well, and explains to some degree why pedestrians often seem to appear in the road as one initiates a left or right turn.

VI.B.2 Introduction

We not only have an innate trust in what we see is in fact what is real, but we have a brain that will even fill in the gaps of the missing visual field in order to avoid this lack of veracity. As stated in ``Maurice Merleau-Ponty", F.A. Olafson states "*perceptual error...has a surprising resemblance to veridical perception*" or perhaps more eloquently…"*You cannot depend on your eyes when your imagination is out of focus.* " - Mark Twain. This issue becomes a bit more serious when the "perceptual error" occurs at high speeds in heavy machinery.

Intersections rank high on the most dangerous locations on U.S. roads list. The National Highway Traffic Safety Administration (NHTSA) estimates that almost 2 million crashes occurred at intersections in 1994 (about 30% of all crashes), causing over 6,700 fatalities and many severe injuries. There are more intersection collisions than any other crash type, as reported by Hendricks and colleagues. (1999); 723 crashes involving 1284 drivers were investigated from four selected sites in the country from April 1, 1996 through April 30, 1997 using the National Automotive Sampling System (NASS) protocol. Crash causes were attributed to either driver behavior or other causes. In 99% of the 723 crashes investigated, a driver's behavioral error caused or contributed to the crash. Of the 1284 drivers involved in these crashes, 732 drivers (57%) contributed in some way to the cause of their crashes. Hendricks and colleagues (Ibid) identifies the six primary factors involved. Of these six, driver inattention ranked #1 at 22.7%, speed ranked # 2 at 18.7%, perceptual error ranked #4 at 15.1% and decision error was #5 with 10.1% (alcohol was #3 and sleeping "incapacitation" was number #6). It is perhaps difficult to differentiate between inattention and perceptual error. We tend not to pay attention to something we do not perceive. As simple categories, the data are clear. Data cannot easily address the complexity occurring when these factors interact.

In relation to the A-pillar blindspot issue, of the 99% of the crashes which were attributed to driver behavioral error, about 30% can be attributed to a case of "looked but did not see" conditions at intersections or intersecting paths. NHTSA reports that in turning/merging type situations, older drivers are over-represented with 50% of the incidents occurring in the group over 55 years of age, and 25% over 70 years of age. Drivers in the 35-54 year age group appeared to be involved as a result of an inappropriate traffic scanning technique.

Relative specifically to the VE road and perpendicular intersection arrangement of this study, the review of Hendricks and colleagues (Ibid) review notes some of the more salient features as;

1-participant driver did not see this vehicle and accelerated into the intersection, usually with the colliding vehicle approaching from the right.

2-older drivers were over-represented with 35.7% of the drivers involved being over 70 years of age and 42.8% being over 50,

3-drivers in the 35 to 54 age group appeared to be involved as a result of using inappropriate scanning techniques.

4-Younger drivers under 35 were involved as a result of performing cursory traffic checks.

5- it occurred usually in clear sunny conditions.

Issue 1 is sensible if you consider the angle of the field of view obstruction, which will be discussed shortly. Issue 2 may be one involving any number of possible physiological limitations from neck stiffness to medications. Issue 3 is composed of a large group of habituated drivers with ~17-36 years of driving experience, which may possibly work against them in terms of familiarity and habit. Issue 4 may be as simple as it seems, a lack of experience. And lastly issue 5, which is not to surprising if you consider that headlights have extremely high conspicuity and are tough to conceal for great distances even behind a building or perhaps a tall corn crop

Treat and colleagues (1979) found that overall, human factors caused or contributed to 93% of the crashes investigated. He listed the three major human factors most frequently reported as improper lookout, excessive speed, and inattention. These findings have been supported by other crash studies by Lohman and colleagues (1978) , Perchonek (1978), who used a refined classification scheme to give structure to otherwise nearly intangible human factor data in alcohol related crashes, and by Tharp and colleagues (1970), who addressed accident analyses issues such as large trucks being removed too quickly from accident scenes. In an earlier paper mentioned in Lohman (1978), he used age categories (youth, adult, elderly) and frequency of occurrence and found that youths were over represented in the unsafe driving categories of following too closely, speeding, and traveling left of the center line. This could be due to perceptual skill differences or simply one of age-related driving mentality. As previously stated, it is difficult to organize, categorize and analyze crash data and human behaviors.

Whether a matter of a lack of perceptual skill or of perceived threat, improper lookout and inattention may both be due to a state of complacency. Factors producing this complacency may be as simple as route familiarity or even seat comfort. Whereas these findings assess a rank order and categorization of the reasons for the collisions, there may be no good reason to assume the error to be strictly one of driver behavior or complacency. It may still be one of human error, but compounded by error in the human engineering of the A-pillar, the side mirrors, and/or any other structure placed in the forward field of view of the driver. If a threat is hidden there is no motivation for increased vigilance.

Research that directly focuses on the problem of forward looking blindspots (FLBs) is sparse. These FLBs are generated by interruptions in the field of view by the A-pillar of a car as it approaches an intersection. As can be mathematically demonstrated, these blindspots can comfortably "hide" the presence of even very large vehicles. The size of these obstructed fields of view allows vehicles to remain hidden from one another's view for extended periods if the acceleration or deceleration of the two vehicles occurs while approaching an intersection at right (or near right) angles. This issue is further exacerbated if the behavior of one vehicle signals to another that they are aware of their presence by slowing, for example at a yield sign, when in fact the slowing vehicle is unaware of the other's presence.

These FLBs can obscure the presence of the other vehicle all the way to intersection. In such specific conditions, a collision is a high probability. One study that addresses this issue is by Rumar (1990). Rumar notes that ergonomics and human factors contributions to the design and use of energy absorbing techniques have reduced the injuries of car occupants dramatically, but we have been less successful in reducing the actual risk of collisions occurring. Rumar goes on to note that when drivers are asked why the accident occurred, they often claim they either saw the car too late to avoid collision or did not see the other car at all. This issue has received little empirical attention in the research literature or even general discussion.

Two stages of software were initially developed for this experiment. The first was a simple demonstration program described in the following section, and the second was the actual simulated environment used in the wrap around simulator (WAS) in the University of Minnesota's Human Factors Research Lab. Before proceeding with software development, the existence and scope of the FLBs were determined under real world conditions by simply going to a large open lot, having one individual walk in an arc at 30 and 60 meters and noting the areas which were obscured from the “driver’s” point of view. The sizes of the obscured regions were in agreement with the trigonometric calculations, even though the real world experiment involved binocular vision, which I suspected might decrease the size of the blind-spot area. At the distances normally encountered in traffic intersection interactions this was not an issue. A major overall issue with the testing of a problem of this nature is the variability found in human/car system. Every type and model of vehicle has its own specific configurations. This can be the A-pillar design, the mirror placement, the seat height, and so forth. Combined with the morphology (particularly the height) of the individual driving and their idiosyncratic method of scanning traffic, the system is open to a vast number of possible FLB configurations. The WAS uses only one type of vehicle which makes it a bit simpler. I needed only to ascertain the participant’s personal field of view in order to manipulate the virtual environment with which they would interact. This left only the variability in the driver’s scanning behaviors as one of the critical system variables.

VI.B.3 Methods

VI.B.3.a Participants

In a driving study it is easy to be systematically biased by age. Data from “Traffic Safety Facts” (NHTSA, 1999) provides the crash rate per 100,000 drivers for crash types including fatal, injury, and property-damage. Younger drivers, particularly ages 16-20, are greatly over-represented in crashes. Once again this may be an issue of skill or attitude. The crash rate for all drivers in 1999 was 5,980 drivers per 100,000. The crash rate for ages 16-20 was 15,356 per100,000. The population for this study came primarily from the 25-34 year old group (7,047 per 100,000 crash rate) with a range from 21 -60 years old overall (3-5,000 per 100,000), which should provide somewhat conservative collision rate data in this aspect.

In this study, the participant population consisted of 28 volunteer participants (16 male, 12 female). The population mean age was 29 years. The mean number of years the participants had driving was 9.18.

VI.B.3.b VE calibration

The virtual environment (VE) consisted of two scenarios, calibration and trial. Figure VI.9 illustrates the view from the driver's seat during the calibration phase. Figure VI.10 illustrates two sample views from the trial phase. Figure VI.10 is the actual driver view of the first intersection in the trial sequence. This particular intersection involved no interaction with the other "vehicle".

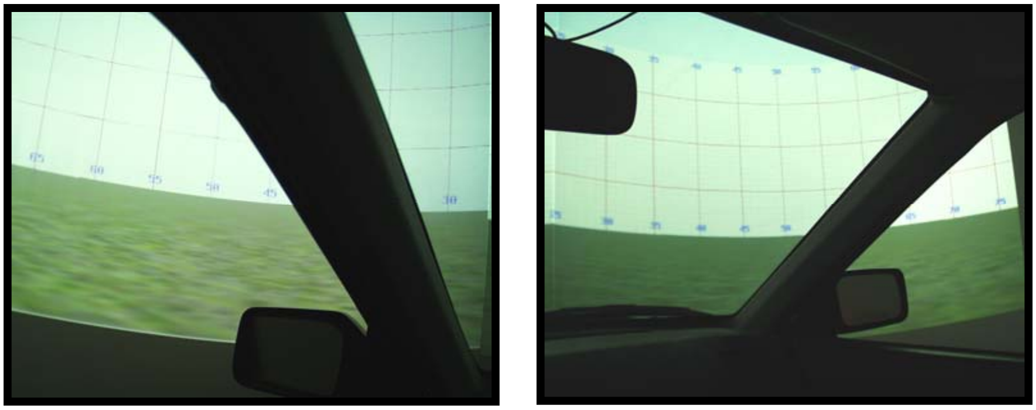


Figure VI.9 Virtual environment calibration screens, Left (driver side) and Right (pa

Figure VI.10 Virtual environment trial scenes, driver view forward and right A-p

VI.B.3.c Calibration scenario

The calibration phase consisted of a large virtual "wall" upon which was displayed a numbered grid (Fig. VI.9). It was set up as if the test car was situated inside of a large virtual environment (VE) cylinder.

The numbers are at the bottom of the grid were situated at approximately eye level. The participants were shown a diagram explaining which set of numbers was being requested(indicated by arrows in fig. VI.11). These numbers are entered into the trial scenario parameters and are used to produce the FLBs for each participant's set of trials. This procedure was repeated for both the driver and passenger side A-pillars. The size and position of the FLB differed for each participant relative to their morphology (particularly height and leg length) since the angle of view and position of the A-pillar changes relative to head position.

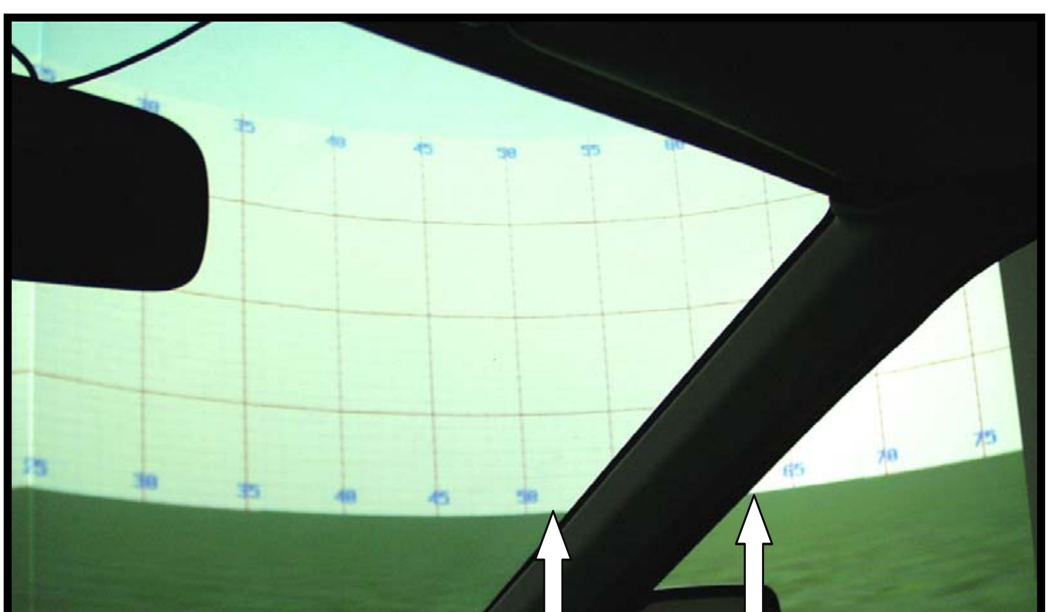


Figure VI.11 Forward looking blind spot (FLB) calibration screen, right A-pillar view.

VI.B.3.d Trials

The trial phase consists of a straight road with 9 right-angle intersections, the first being a non-trial stop sign, marking the beginning of the test road (Fig. VI.10). This provided a brief familiarization period for test participants. The trial phase is composed of two conditions each with two levels, producing four basic conditions: yield / no yield, and "stimulus" VE vehicle slaved or un-slaved to the driver's car in the WAS (hereafter termed the RW car).

I. Yield with slaved vehicle
II. Yield with un-slaved vehicle
III. no Yield with slaved vehicle
IV. no Yield with un-slaved vehicle

Based on the idea that "yielded" intersections (those with a yield sign facing the RW car) might produce an car-car interaction resulting in a sustained period of "hiding-in-the-blindspot" for the VE car, half the intersections displayed a "Yield" traffic control sign.

If the RW car were just about to “expose” the VE car at the intersection, slowing for the yield might keep the VE car in the FLB for a bit longer.

Each trial condition was repeated twice per participant producing a total of eight trial intersections per session for each participant. Order effect was controlled for using a Latin square design.

The simulated vehicles had two conditional behaviors, slaved and un-slaved. Slaved vehicles began their approach to the intersection when the RW car, travelling at approximately 88.5 kilometre/hour (55 mph), was at a predetermined distance (~300m) from a intersection. The slaved VE car then proceeded at a VE road speed that kept it in the FLB of the RW car until the RW car was within 30 meters of the intersection where it was then “un-slaved”. The VE car then proceeded through the intersection independent of the speed or behavior of the RW car, such as braking or acceleration.

An un-slaved vehicle begins its approach to an intersection when the RW car is at a given distance from the intersection. The un-slaved vehicle then proceeds at a VE road speed that is predetermined (~88kph.), independent of the speed of the RW car. The direction of approach (from left or right) of the VE vehicle is distributed between the repeated conditions.

VI.B.3.e Data acquisition

Data pertaining to heading, road speeds, gas pressure, brake pressure, and “global” position coordinates were recorded directly by the computer and exported as a text file. Scanning data were collected by direct observation by the investigator riding as passenger and by video cameras located inside of the test car. Only road speed was used for the analysis as it is a product of gas/brake pressures and change in position and was thought to be a reliable indicator of decreased complacency.

Each participant was videotaped from the front aspect, from the right rear and directly ahead at the VE screen (Fig. VI.12).

Camera data were then used to cross check and confirm observed scanning behaviors and road incidents.

Figure VI.12 Onboard camera views inside RW car.

VI.B.3.f Data analysis

Data analysis consisted of chi-squared analysis (including binomial tests), of the following variables:

1. Scanning level (grouped as independent nominal levels), coded;

   I. fixed gaze, predominantly forward, no head motion

II. eyes scanning, no head motion

III. eyes scanning coupled with left/right head motion

IV. eyes scanning coupled with full left/right, forward/backward head motion

2. Acquisition - Was the virtual vehicle detected by the driver?

3. Collision - Did the driver collide with the virtual vehicle?

as well as Pearson Correlations and descriptive analyses of yield conditions (defined below).

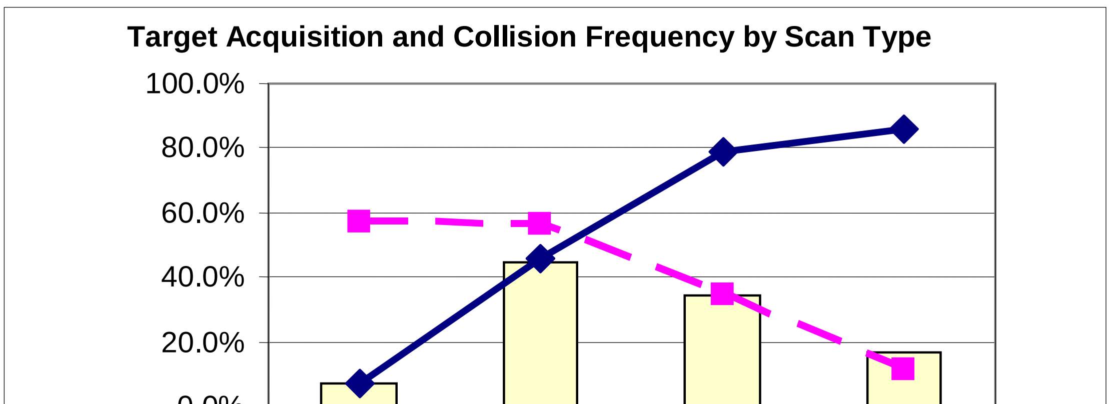
A collision was recorded when the RW car and VE car intersected whether visibly or “virtually”, as would occur when the VE car collided with the rear of the RW car according to Cartesian coordinates. The latter situation might produce an example of “collided-but-not-acquired”. Acquisition was slightly more subjective. If an obvious reaction in response to seeing the VE car was not indicated (sudden braking, swerving, comment, etc.), the participant would asked if they recalled the particular intersection incident during the post test debriefing.

Whether or not the intersection was “Yielded” was an independent variable also analysed. Scanning levels were grouped according to above coding for analysis relative to acquisition and collision. Because this was a simulated environment it was possible to have a collision and not be aware of it. The other observations consisted of any comments from the participants or aberrant driving behaviors we observed.

<u>VI.B.4 Results and Observations</u>

VI.B.4.a The FLB

It is very easy to hide a vehicle in the FLB on either side if the head is in a fixed position. If undetected by the driver a vehicle approaching from the left was obscured until the point of impact and even then the simulator driver often remained unaware of the collision. When questioned about specific incidences where the collision occurred with no evidence of course correction or physical response, the drivers often indicated no awareness of the incident. This suggests a possible peripheral vision limitation. Other than the lack of haptic feedback due to the collision, which in the RW would clearly indicate a collision, the driver was occasionally scanning in the opposite direction. If the simulated vehicle was detected too late by the driver, there was a brief moment of awareness of imminent collision when the vehicle was approaching from the side but there was usually too little time to react.



Scan type >>	I	II	III	IV
Scan type freq.(N=224)	6.3%	43.8%	33.9%	16.1%
Acquisition frequency	7.1%	45.9%	78.9%	86.1%
Collision frequency	57.1%	56.1%	34.2%	11.1%

Figure VI.13 Scanning level (type) frequency across all trials, all subjects and percentage c
collision rate by scan type category. (N =224). Scan types (I, II, III, and IV) are defined on

VI.B.4.b Scanning behaviors, acquisition and collisions

Figure VI.13 demonstrates the apparent interaction between acquisition and collision relative to scanning level. The most frequent level of scanning as indicated by bars was level II (eyes scanning, no head turning) at 48%..As the level of scanning increased the incidence of acquisition increased and the collision rate decreased. The decrease in collision was not significant until head motion (translation) was involved at level III.

No significant difference was found based on signage (“yield”, defined on page 77) (Table VI.7). Yield signage may have even exacerbated the problem of acquisition in some cases, due to increasing the un-slaved target vehicle’s time in the “blind” region or by the slaved vehicle responding with a matching decrease in speed (if there was one) of the test vehicle and thus remaining obscured.

The participants driving behavior in this study was essentially consistent with their real world behavior. This was determined by the information on their questionnaires and by comments made to the researchers. A few of the drivers were by their own description “active scanners". These participants in particular had very few, if any, collisions. Other participants sometimes expressed mild anger at being tricked or fooled into a collision, which was not the case. It is simply that the A-pillars are very effective at obscuring the view of drivers to the point that even repeated scanning without an actual displacement of the head is insufficient to reveal the approaching test vehicle. Note in Figure VI.13 that even though acquisition of the target vehicle was achieved 86% of the time at scan level IV (active displacement of the head), there was still an 11% collision rate.

The comment was often made that the car just "appeared" at the intersection. The "appearing" cars were easily visible for perhaps 10 seconds prior to the collision by anyone not seated in the driver's seat. Several participants never altered their scanning behaviors sufficiently even after repeated collisions. Figure VI.13 illustrates the increase in target acquisition rates and the decrease in collision rates relative to scanning level.

Tables VI.4, VI.5, and VI.6 are Spss outputs which code scanning levels I, II, III, and IV as 0, 1, 2,and 3 respectively. Table VI.4 is a chi-square analysis of the expected frequencies.

As illustrated in figure VI.13 and table VI.4, there was a higher than expected number of level II, and III scans relative to the hypothesized distribution (25%/level). When examined for proportional significance (Table VI.6), acquisition and collision rates differed significantly from the hypothesized distribution ($p<.05$).

Table VI.4 Chi square analysis of scan level frequency.

Scan-type

	Observed N	Expected N	Residual
0	14	56.0	-42.0
1	98	56.0	42.0
2	76	56.0	20.0
3	36	56.0	-20.0
Total	224		

Test Statistics

	Scan-type	acquired	collide
Chi-Square [a,b]	77.286	11.161	6.446
df	3	1	1
Asymp. Sig.	.000	.001	.011

a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 56.0.

b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 112.0.

. Table VI.5 Binomial test of scanning level and acquisition/collision.

Binomial Test

		Category	N	Observed Prop.	Test Prop.	Asymp. Sig. (2-tailed)
acquired	Group 1	0	87	.39	.50	.001[a]
	Group 2	1	137	.61		
	Total		224	1.00		
collide	Group 1	0	131	.58	.50	.013[a]
	Group 2	1	93	.42		
	Total		224	1.00		

a. Based on Z Approximation.

Crosstab

Count

		acquired		Total
		0	1	
Scan-type	0	13	1	14
	1	53	45	98
	2	16	60	76
	3	5	31	36
Total		87	137	224

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	46.338[a]	3	.000
Likelihood Ratio	49.628	3	.000
Linear-by-Linear Association	41.531	1	.000
N of Valid Cases	224		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.44.

Table VI.6 Fishers LSD (Least Significant Difference) comparisons of acquisition and collision rates across scanning levels. (coded 0,1,2,3 for levels I, II, III, IV respectively).

Multiple Comparisons

LSD

Dependent Variable	(I) SCANTYPE	(J) SCANTYPE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
ACQUIRE	.00	1.00	-.3878*	.12514	.002	-.6344	-.1411
		2.00	-.7180*	.12738	.000	-.9691	-.4670
		3.00	-.7897*	.13795	.000	-1.0616	-.5178
	1.00	.00	.3878*	.12514	.002	.1411	.6344
		2.00	-.3303*	.06694	.000	-.4622	-.1984
		3.00	-.4019*	.08536	.000	-.5702	-.2337
	2.00	.00	.7180*	.12738	.000	.4670	.9691
		1.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Fishers LSD comparisons of acquisition and collision rates across scanning levels

VI.B.4.c Complacency

Our simulated environment was barren and visually sparse aside from road signs, roads, and the occasional shrub. While participants were aware that other vehicles were present, they exhibited a very high level of complacency. This complacency may be represented by the frequency of "eyes only" scanning at levels I and II illustrated in Figure VI.13. The participant's style of driving and scanning usually changed after the first collision or near miss, sometimes only briefly, to a more active form of scanning behavior. Even with this change in behavior, some collisions still occurred. This could be due to the either the effectiveness of the A-pillar in obstructing the view or a conflict in veridical perception. The car was within the field of view, but with no expectation of its presence, there is perhaps limited awareness. This would explain the occasional opinion of participants that cars were being made to appear at the intersections.

VI.B.4.d Correlations

No significant correlation was found for the yielded intersections (r =.032, p=.630). In fact, it should be noted that "yield" produced no significant results under any of the variables; scan type, acquisition or collision (Table VI.7). Significant correlations are indicated at the .01 level (2-tailed) between scanning level and acquisition (positive .432) as well as scanning level and collision (negative.324). Acquisition rate and collision were negatively correlated and significant at the .01 level (2-tailed).

Table VI.7 Correlations between Scan level, acquisition, collision and yielc

Correlations

		SCANTYPE	ACQUIRE	COLLIDE	YIELD
SCANTYPE	Pearson Correlation	1	.432**	-.324**	.032
	Sig. (2-tailed)	.	.000	.000	.630
	N	224	224	224	224
ACQUIRE	Pearson Correlation	.432**	1	-.165*	.046
	Sig. (2-tailed)	.000	.	.013	.495
	N	224	224	224	224
COLLIDE	Pearson Correlation	-.324**	-.165*	1	-.009
	Sig. (2-tailed)	.000	.013	.	.893
	N	224	224	224	224
YIELD	Pearson Correlation	.032	.046	-.009	1
	Sig. (2-tailed)	.630	.495	.893	.
	N	224	224	224	224

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

VI.B.5 Discussion

The results presented in figure VI.13 suggest that the FLB produced by the A-pillar can be overcome by the scanning method employed by the driver. If a collision is to be avoided the driver must incorporate an active style of scanning involving a displacement of the head and subsequently a displacement of the FLB. "Eyes-only" scanning (level II) seems to improve the acquisition of an intersecting vehicle but not soon enough to avoid a potential collision. It is apparent that the A-pillars and other forward field of view obstructions such as mirrors pose a potentially hazardous situation to interacting drivers. It should be noted that the conditions were manipulated to produce these hazardous conditions in a virtual environment. As previously mentioned, Hendricks D. L. and colleagues (1999) found that of the 99% of the crashes which were attributed to driver behavioral error about 30% can be attributed to a case of “looked but did not see” conditions at intersections or intersecting paths. It is doubtful that after a “looked but did not see” accident situation, a driver would be in a state of mind where they could recall the level of scanning they employed prior to the collision. The high level of “eyes only” scanning behaviors is common in everyday driving but may also be an artefact of testing in a VE.

Though there exist certain social/moral behaviors that test participants are prone to abide by, the VE is still an unreal (or perhaps *unnatural)* environment and there is no way to hide this fact from an individual being tested. Therefore the complacency inferred in the results may be artificially higher than in the RW. Yet in the RW we become familiar with specific routes. We interact numerous times with potentially hazardous situations with no repercussions. The layout of a specific RW scenario may in fact be an open scene with no obscured fields of view. A situation where one can see for miles in every direction does not exactly motivate an individual to increase vigilance for invisible traffic.

Many of the newer vehicles are now incorporating wider fields of view by moving the A-pillars back. This is usually expressed as a design issue addressing easier ingress and egress from the vehicle or as a frame stiffness issue. Manufacturers also emphasize comfort (read- complacency). Seating is usually constructed with comfort of the seat and headrest emphasized.

Lastly, only a fraction of RW intersection interactions may produce a similar critical decision type situation. One should also be aware that I did not incorporate every possible interaction condition, and that in the RW these varied interactions occur each and every day countless times. This should demonstrate that despite the contrived nature of the experiment, the numerical potential for death and injury in the RW remains extremely high.

VI.B.6 Conclusions

Two basic approaches for dealing with the driving safety challenge of FLBs. First, with respect to driver training, it is not sufficient that drivers be taught, "look left, look right, look left again" before proceeding into an intersection. Recall the 14% non-acquisition rate for fully active scanning (level IV) in Figure VI.13. An awareness of the weaknesses of human perception should be nurtured. Once we are made aware of the ability of our brains to fill in for missing visual information or to distort partial visual cues, it is possible that a lessened sense of complacency while driving may result.

The second is an engineering approach. Either the vehicle itself must be re-engineered to provide for better vision or the road/intersection must be redesigned in order to re-orient the vehicle as it approaches the intersection. This could be accomplished by something as simple as a small deviation in the lane position. Active warning flashers may produce the desired effect, but this would be prohibitively expensive and prone to acclimatization. Also, a warning without evident (visible) threat has limited meaning.

One should keep in mind that the vehicle used in this experiment had small mirrors and drove in a straight line. Large vehicles (buses, trucks, etc.) often have an even larger FLB. An equally critical issue not addressed here is that of the turning vehicle at pedestrian intersections. Pedestrians are predominantly vertical, as are A-pillars. A final observation of note is the significance, or actually lack thereof, of the effect of yield signs.

The intent of the yield sign is to communicate the right-of-way to traffic. The effect may go beyond this intent. Communication between vehicles occurs over long distances. Beyond flashers and brake lights, our primary means of communication is the vehicle itself. If one observes a “yielded vehicle slowing at an intersection one may think to oneself something along the lines of “…they’re slowing… they must see me.” This may tragically not be the case. Many drivers have inexplicably pulled out in front of an oncoming car. This has possibly been due to the reasons presented in this paper. This communication of slowing by the “yielded” car may induce complacency of the “un-yielded” car. One may ask if no yield at all in this situation might be safer than none at all in rural low volume traffic settings. It is particularly in rural settings that the effect of complacent scanning behaviors may occur. It is, however, not limited to these regions. Any traffic location where a sense of false security exists is potentially hazardous. We assume people will stop at a four-way stop, primarily because we assume we are visible to the other driver. We assume that with a clear field of view that we are aware of any potential oncoming vehicle threats. This is not necessarily the case. One need only check the local news for inexplicable crashes of this nature.

The following is a paraphrased report from Volvo, Sweden. 2002

> *“Volvo has recently released it’s "Safety Concept Car," or SCC. The SCC has been constructed to improve the sightlines for the driver by providing more visual information.: “…most of the critical information a driver needs to make decisions behind the wheel, comes from visual input through the car's windows and windshield. The SCC attempts to maximize this input by adapting the vehicle to each individual's driving position.” “…There are no significant blind spots to the front, thanks to see-through "A" pillars framing the windshield. The pillars are covered in optically correct Plexiglas, framed around a box steel construction. Yes, there are still box sections to look through, but any obstruction, such as a small child (who may normally be lost behind fat A pillars found in today's cars) can still be seen.”*

FLB’s are an issue which is in need of being addressed by both the automotive engineering community as well as the driver training community. Certainly injury and death occur all too often due to the limitations in vision to the rear of the vehicles, but when one considers the cumulative effect of collisions involving vehicles travelling at approximately right angles (i.e. trains, buses, cars, bikes, etc.) the resultant collision forces can far exceed that of a collision occurring in the same direction of travel.

VI.C Experiment 3: Deer Avoidance. The assessment of real world enhanced deer signage in a virtual environment.