External Viewing of Vehicle Contents Under Various Tinting and Illumination Conditions

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The purpose of the study was to determine the degree to which motor vehicle window tint films impede a police officer's ability to see clearly into a stopped vehicle. Three hundred twenty subjects were asked to view the contents and occupants of one of four experimental cars. One car had no aftermarket tint film, and the other three had aftermarket tint films tinted to various degrees. Although similar experiments have been conducted, all of those experiments yielded equivocal results because of methodological flaws. The present experiment was an attempt to correct some of those problems and to simulate standard procedures used during traffic stops by the Virginia State Police. In general, the study found that the abilities of subjects to detect occupants and objects in vehicles were substantially diminished as the degree of window tinting increased. However, at night the detrimental effects were substantially reduced when headlights and a spotlight were shone on the vehicle, as would be the case in a traffic stop.

The aftermarket tinting of motor vehicle window glass raises at least three distinct traffic safety concerns. First, the driver of an automobile may encounter situations in which visibility is impeded by tinted windows. Second, visual communication between drivers and pedestrians, cyclists, or other drivers may be impaired. Third, the safety of police officers who must approach a stopped car on foot may be endangered. Tinting may impede an officer's ability to detect weapons, contraband, or threatening acts by the driver or passengers. This last concern motivated the current experiment.

Three studies and one demonstration have investigated the influence of tinting on the ability to identify objects within a parked car. One study was sponsored by tint film manufacturers (*1*), and the others were conducted by police departments (*2–4*). The study sponsored by manufacturers found no detrimental effects from window tinting, even for tinting films with transmittance values as low as 20 percent. The studies sponsored by police departments found that window tinting greatly reduced the abilities of officers to identify objects inside the experimental cars. These conflicting results are likely due to differences in the study designs. More important, all of the studies suffered from serious design flaws that make it difficult to draw any generalizations.

PURPOSE AND SCOPE

The purpose of the study described here was to determine to what degree tinted window films impede an officer's ability to see clearly into a stopped vehicle. Similar experiments have all yielded equivocal results because of serious methodological flaws. The present experiment was an attempt to correct those methodological problems. Every attempt was made to make the procedure for approaching the vehicles used in the experiment as similar to standard police procedures as possible. The experiment was limited to testing the procedures used by police in Virginia.

Although the experiment was designed to control for differences other than transmittance, the generality of the results is somewhat limited. First, only three levels of tinting were tested. Second, ambient light differed somewhat on different testing days and nights. More important, light reflectance, which could not be measured and controlled, affects the ability to see clearly into a vehicle. Reflectance is so situation specific that it is impossible to make broad conclusions that apply to all conditions. In the current experiment assessments were made at five different testing locations to minimize effects that might be specific to a particular location or a vehicle's orientation to a reflection source such as the sun.

METHODS

In the present study observers attempted to identify the interior contents of vehicles tinted to have various levels of light transmittance. Standard police procedures were simulated, and viewing occurred during daytime, dusk, and nighttime hours and during nighttime hours with the use of auxiliary lighting. Under standard police procedures officers park their vehicle about 6.1 m (20 ft) behind the vehicle being stopped, with the headlights pointing slightly more toward the driver side door. The officer then attempts to ascertain the number of occupants. The officer then walks toward the vehicle, stopping at the rear of the driver side of the vehicle, and determines if the trunk is latched. The officer then approaches the driver side of the vehicle at a distance of about 0.5 m (1.5 ft), stopping just behind the driver side door so that it cannot be opened into him or her. During the approach the officer scans the back seat and its passengers but concentrates on the driver. At night the officer rests a spotlight on his or her shoulder away from his or her dominant hand and uses it to see into the interior of the vehicle.

The 160 male and 160 female volunteers who participated in the study were primarily undergraduate students who were passing by the testing locations on the grounds of the University of Virginia. Others were students enrolled in an introductory psychology course who participated to fulfill a course requirement. All subjects were asked if they needed eyeglasses to drive. If they stated that their driver's license stipulated that they wear glasses, they were asked to

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wear them during the testing. If they did not have their glasses with them, they were excluded from the study.

All four test vehicles were 1987 Dodge Aries K four-door sedans. All had identical blue exterior paint, dark blue interiors, and black dashboards. The only difference among the vehicles was the degree of window tinting on the side and rear windows.

Table 1 shows the target and actual transmittance values for the four test vehicles. Actual levels differ from the prescribed levels to some degree. Because tint film is applied over factory glass tinted to different transmittance levels, the resulting level of light transmittance is multiplicative. For instance, a 50 percent aftermarket film applied over an 82 percent factory tinted window theoretically results in a total transmittance of 41 percent ($0.50 \times 0.82 = 0.41$). Since the same aftermarket film is applied to factory glass with different levels of tinting, different results are achieved with different vehicles. In this case the prescribed and actual transmittance values were reasonably close, with the actual transmittance slightly higher than the prescribed transmittance except for Vehicle 3, in which the actual transmittance values were quite a bit lower than ordered. No aftermarket tint film was applied to Vehicle 0, Vehicle 2 represented the maximum reduction in transmittance allowed by Virginia law, and the transmittance values chosen for Vehicle 1 represented intermediate levels. The prescribed levels of tinting for Vehicle 3 represented the maximum reduction of transmittance allowed by any state in the nation, that being Florida.

The objects placed inside the vehicle were arranged in the same way for each test episode. Three mannequins were seated upright in the vehicle: one in the driver's seat, one in the front passenger's seat, and one in the back right passenger's seat. The mannequin in the driver's seat held a pair of scissors in the left hand. Its hands were arranged such that the right hand was placed by its right side and was covered slightly by the right pant leg. The left hand, holding the scissors, was positioned at the bottom part of the steering wheel. Five common objects of various colors and sizes were arranged on the back left seat and back left floor: a black flashlight, a yellow highlighter pen, and a red soda can were placed on the seat, and a pink spiral notebook and a white tennis shoe were placed on the floor.

A stopwatch was used for all timing. Tests without auxiliary lighting took place during the months of October through December 1993. Testing occurred at three different times of day (midday, 2:00 to 3:30 p.m.; dusk, 5:00 to 5:45 p.m.; and night, 6:00 to 7:30 p.m.) and in five different locations on the grounds of the University of Virginia. During April 1994 additional tests were conducted with auxiliary lighting at night to simulate a police stop in which the police cruiser's headlights and the officer's flashlight would shine light into the stopped vehicle. Headlights were shone into the vehicle being viewed, and observers used a handheld spotlight to look into the vehicle. Each observer saw only one car, and the identification rate was determined by examining the performances of different groups of subjects.

Six performance measures were taken:

1. Mannequin detection: detection of the number of mannequins seated upright in the vehicle from a viewing distance of 6.1 m (20 ft) behind the vehicle;
2. Confidence rating: the level of certainty reported about the number of mannequins detected;
3. Distance at certainty: how close to the vehicle the subject needed to be to state with confidence that there were three mannequins;
4. Detection of driver's hand positions: detection of the position of the driver's hands when looking into the front side window and standing approximately 0.5 m (1.5 ft) from the front window;
5. Detection of object in driver's hand: detection of the object that the driver was holding in the left hand when looking into the front side window and standing approximately 0.5 m (1.5 ft) from the front window; and
6. Rear seat object detection: detection of the five objects that were on the backseat and back floor of the vehicle on the driver's side when looking into the back side window approximately 0.5 m (1.5 ft) from the vehicle.

The main independent variables of interest in the study were level of tinting (factory, 50 percent/50 percent, 50 percent/35 percent, and 35 percent/20 percent transmittance windows) and viewing condition (midday, dusk, night, and night with auxiliary lighting). Although testing occurred in different locations, this variable was introduced only to minimize situation-specific effects. Preliminary analyses suggested that there were differences in locations for the different tasks, but these differences were not systematic. That is, one particular testing location was not associated with systemati-

TABLE 1 Transmittance Values for Test Vehicles

	Target [a] (%)			Actual [b] (%)	
Vehicle	Windshield	Front Side	Rear/ Rear Side	Front Side	Rear Side
0	*	*	*	88	88
1	*	50	50	53	53
2	*	50	35	53	38
3	*	35	20	40	13

[a] Target transmittance is the intended transmittance aftertint film is applied over a factory-tinted window.

[b] Actual transmittance for the rear window could not be determined because the measuring device can be used only on an automobile window that will open.

* No aftermarket tint film was applied.

cally better performance than another location across all of the tasks. Thus, the analyses presented exclude the location variable.

Each of the six dependent measures was submitted to a 4 (tinting level: Vehicles 0, 1, 2, and 3) × 4 (viewing condition: midday, dusk, night, and night with auxiliary lighting) analysis of variance (ANOVA). Both factors were manipulated between subjects.

RESULTS AND DISCUSSION OF RESULTS

Mannequin Detection

Figure 1 shows the effect of tinting on detecting the number of mannequins seated upright in the vehicle from 6.1 m (20 ft). For viewing at night with auxiliary lighting there was a decline in performance as the tinting level increased; however, this trend was not statistically significant [$F(3, 79) = 1.6, P = .19$].

The ANOVA for comparison of the effect of tinting for all four viewing conditions revealed a main effect of tinting [$F(3, 319) = 15.3, P < .001$]. As shown in Figure 1, the trend was a decline in performance as tinting level increased. Dunnett's one-tailed t test (5) compared each level of tinting with that of the control level (Vehicle 0) and revealed that performance with Vehicles 2 and 3 was different from performance with Vehicle 0 but that performance with Vehicle 1 was not different from performance with Vehicle 0. The main effect of viewing condition was also significant [$F(3, 319) = 7.2, P < .001$]. Each of the six performance measures was submitted to a preliminary ANOVA. Dunnett's test compared each of the viewing conditions with that of the control condition, that is, midday viewing, and revealed that performance was worse at dusk, night, and night with auxiliary lighting compared with that at midday. However, the significant tinting level × viewing condition interaction [$F(9, 319) = 2.4, P < .05$] qualified this effect further. Performance declined as transmittance level decreased from 35 percent (Vehicle 2) to 20 percent (Vehicle 3) when viewing occurred at night without auxiliary lighting and at dusk. However, there was no decrement in performance from 35 to 20 percent transmittance when viewing occurred at midday and at night with auxiliary lighting. In other words performance declined when viewing the most heavily tinted car at dusk and at night, but performance was not worse with the most tinted car when viewing occurred at midday and at night with auxiliary lighting. Thus, the use of auxiliary lighting at night overcame the effect of heavy tinting. The overall model explained 23 percent of the variance in responses [$F(15, 319) = 5.9, P < .001$].

Confidence Ratings for Mannequin Detection

Unlike mannequin detection performance, confidence or certainty about the number of mannequins reported from a viewing distance of 6.1 m (20 ft) behind the vehicle was affected by tinting when viewing occurred at night with auxiliary lighting. Figure 2 shows that confidence in reports dropped significantly as tinting level increased [$F(3, 79) = 8.7, P < .001$]. Dunnett's test compared each level of tinting with that of the control level (Vehicle 0) and revealed that confidence when viewing the most tinted vehicle was significantly lower compared with the control level but that confidence with the other two tinting levels was not different from that with the control level. The overall model explained 33 percent of the variance in responses [$F(7, 79) = 5.1, P < .001$].

The analysis that compared the effect of tinting for the four viewing conditions revealed a main effect of tinting [$F(3, 319) = 28.7, P < .001$] and a main effect of viewing condition [$F(3, 319) = 8.4, P < .001$], but no interaction. As shown in Figure 2, confidence decreased as tinting level increased, and confidence was generally greater at midday and lower at night. Dunnett's test revealed that confidence ratings with Vehicle 2 and Vehicle 3 were lower than

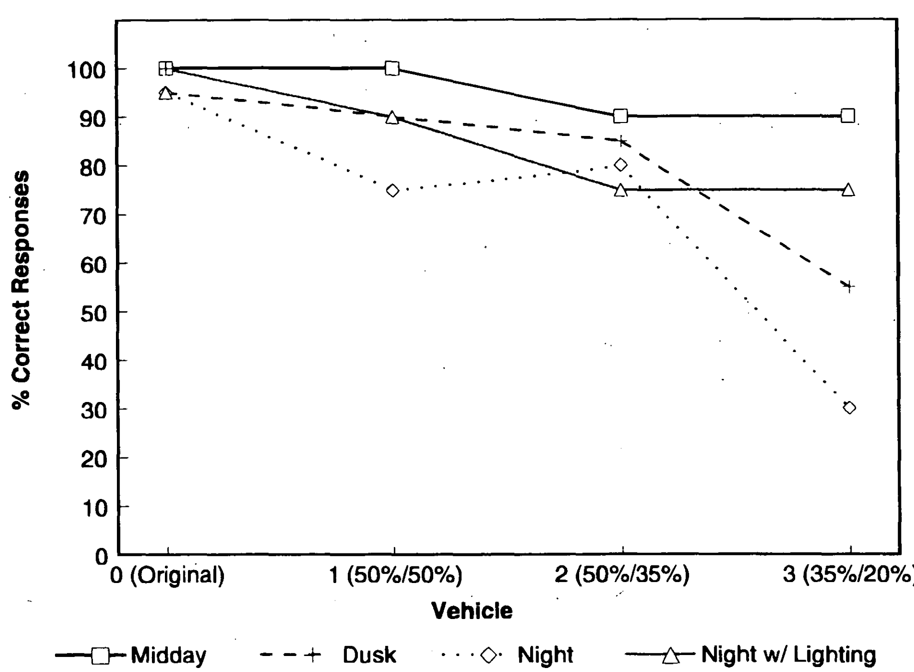

FIGURE 1 Effect of window tinting and viewing condition on mannequin detection.

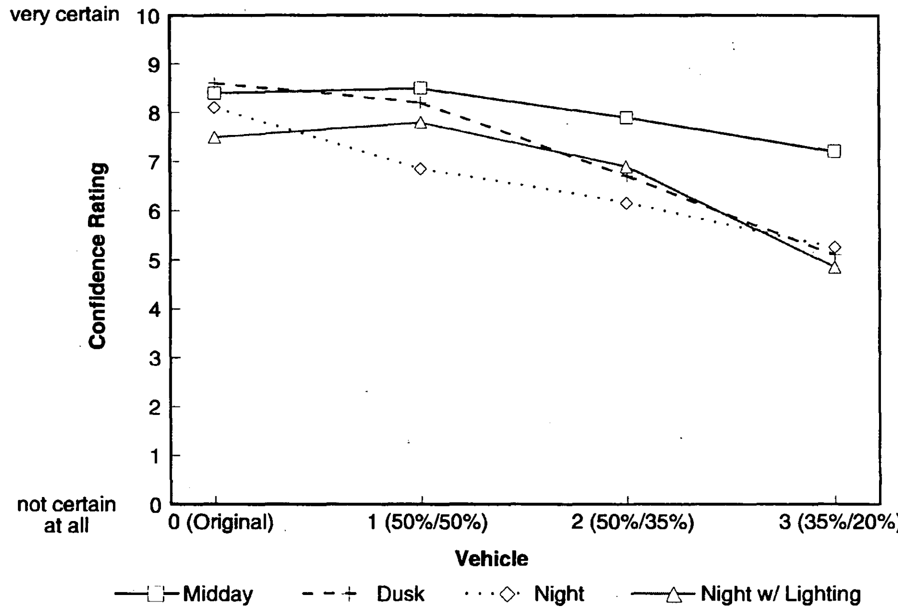

FIGURE 2 Effect of window tinting and viewing condition on confidence ratings.

those with Vehicle 0. Ratings with Vehicle 1 were not different from ratings with Vehicle 0. The overall model explained 29 percent of the variance in responses [$F(15, 319) = 8.3$, $P < .001$]. Dunnett's test also revealed that confidence at midday was higher than that at dusk, night, or night with auxiliary lighting.

Distance at Certainty

The analysis that compared the effect of tinting for all four viewing conditions revealed a main effect of tinting level [$F(3, 299) = 22.8$, $P < .001$]. As shown in Figure 3, the trend for all four viewing conditions was a decrease in distance as tinting level increased. That is, subjects needed to be closer to the more tinted vehicles to be certain about the number of mannequins. Dunnett's test revealed that in comparison with the control vehicle (Vehicle 0), subjects needed to be significantly closer to all of the other vehicles, implying that even lower levels of tinting can lower confidence about reports of the number of occupants inside a vehicle. The main effect of viewing condition was also significant [$F(3, 299) = 2.9$, $P < .05$]. That is, the distance at which subjects became certain about the number of mannequins was generally greater when viewing occurred at mid-

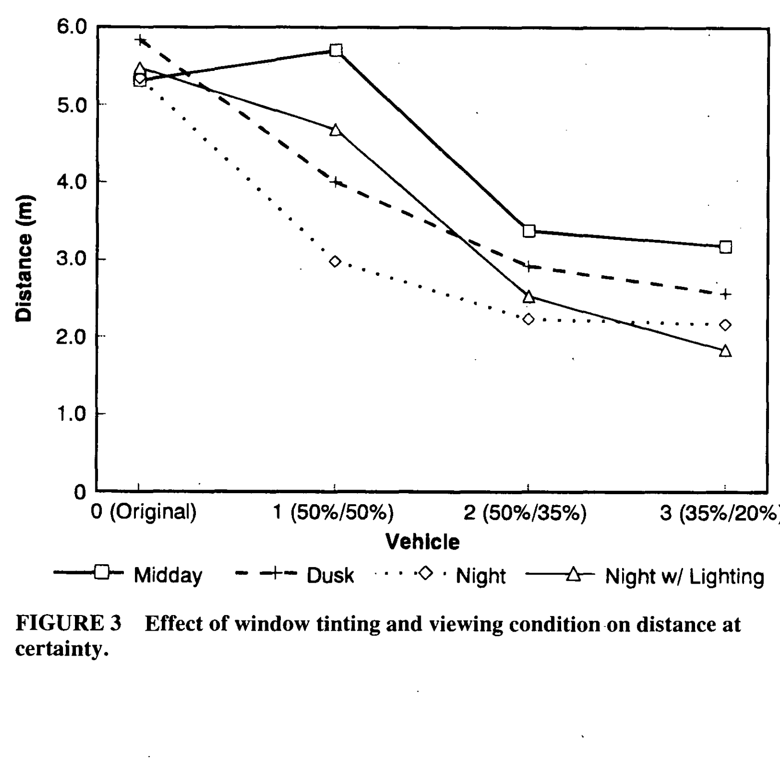

FIGURE 3 Effect of window tinting and viewing condition on distance at certainty.

day and was lower at night. In fact, Dunnett's test revealed that distance at certainty at night was significantly lower than distance at certainty at midday. However, this distance at dusk or at night with auxiliary lighting was not significantly different from this distance at midday. The fact that the tinting level × viewing condition interaction was not significant, however, implies that greater tinting lowered confidence in all viewing conditions. The overall model explained 23 percent of the variance in responses [$F(15, 299) = 5.7$, $P < .001$].

Detecting Positions of Driver's Hands

Subjects were good at detecting the positions of the driver's hands with the use of auxiliary lighting regardless of tinting level (Figure 4). The effect of tinting was not statistically significant [$F(3, 79) = 0.8$, $p = .49$].

The ANOVA that assessed the effect of tinting for all four viewing conditions revealed a main effect for viewing condition [$F(3, 319) = 33.0$, $P < .001$], but no main effect for tinting and no interaction. As shown in Figure 4, detection of the positions of the driver's hands was much worse at night without auxiliary lighting compared with that under the other three viewing conditions. Dunnett's test revealed that only performance at night without auxiliary lighting was worse than performance at midday. The other two viewing conditions were associated with levels of performance similar to that achieved at midday. The overall model explained 27 percent of the variance in responses [$F(15, 319) = 7.4$, $P < .001$].

Detecting Object in Driver's Hand

With the use of auxiliary lighting subjects were very good at reporting the object that the driver was holding in the left hand. Only one subject failed to detect the object. Tinting had no effect on performance [$F(3, 79) = 1.0$, $P = .4$].

Figure 5 shows the effect of tinting on performance for the four viewing conditions. Detecting the object held in the driver's left hand was not affected by the level of tinting but was affected by viewing condition [$F(3, 319) = 35.1$, $P < .001$]. Dunnett's test revealed that the use of auxiliary lighting at night yielded performance comparable to that at midday. However, performance at dusk and at night without auxiliary lighting was significantly worse than that at midday. The overall model explained 27 percent of the variance in responses [$F(15, 319) = 7.6$, $P < .001$].

Detecting Objects in Backseat and Back Floor

The use of auxiliary lighting allowed subjects to report, on average, 3.45 of 5 objects on the backseat and back floor of the vehicle. As shown in Figure 6, tinting had no effect on performance. The use of auxiliary lighting overcame the effects of window tinting, even with the most tinted vehicles [$F(3, 79) = 0.6$, $P = .65$].

Figure 6 shows the effect of tinting on object detection for the four viewing conditions. The main effect for tinting was significant [$F(3, 319) = 56.3$, $P < .001$], indicating that fewer objects were detected with the more heavily tinted vehicles. In fact, Dunnett's test revealed that performance was worse with all levels of tinting compared with that with the control level (Vehicle 0). The main effect for viewing condition was also significant [$F(3, 319) = 232.0$, $P < .001$], indicating that the fewest objects were detected at night with no auxiliary lighting and the most objects were detected at night with auxiliary lighting. The significant tinting level × viewing condition interaction [$F(9, 319) = 13.6$, $P < .001$], shown in Figure 6, indicates that tinting affected object detection at midday and at dusk so that fewer objects were detected when the windows were more tinted. Object detection was consistently high at night with auxiliary lighting and consistently poor at night without it. The overall model

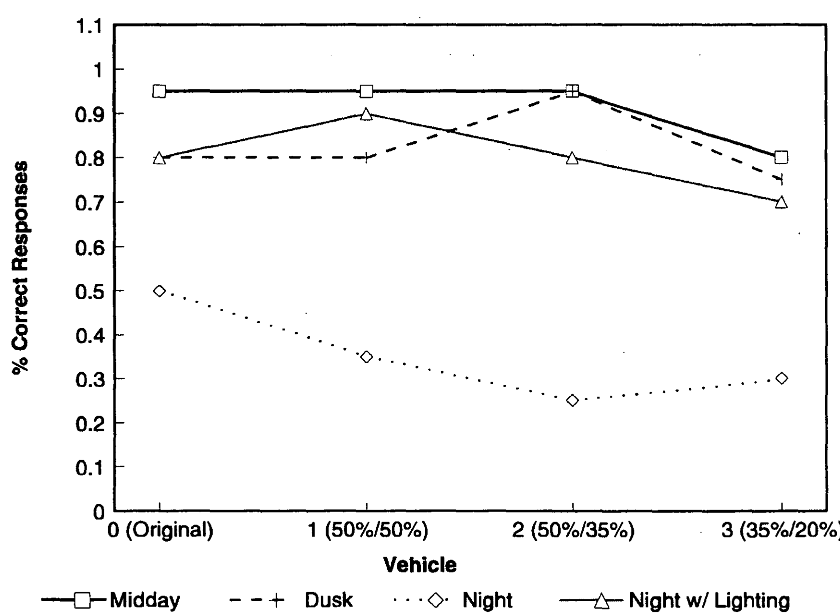

FIGURE 4 Effect of window tinting and viewing condition on detecting positions of driver's hands.

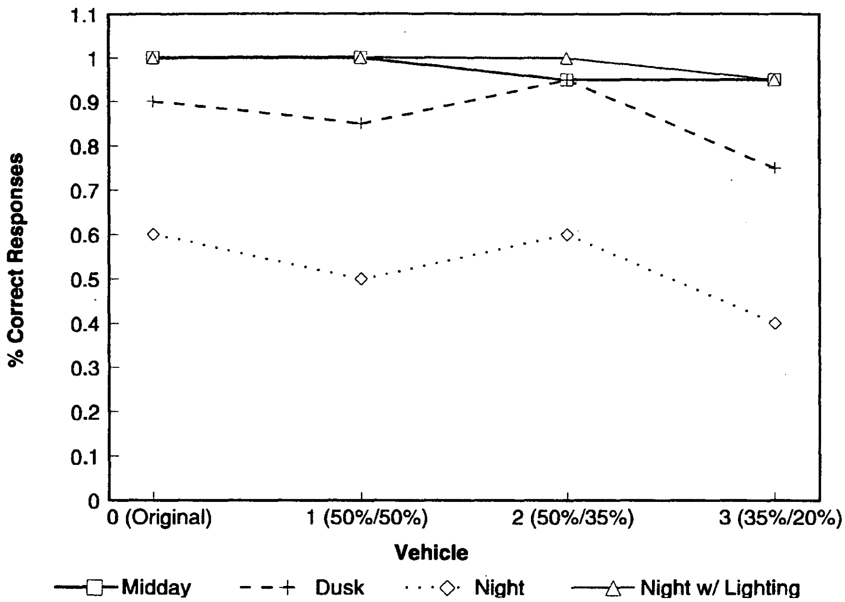

FIGURE 5 Effect of window tinting and viewing condition on detecting object in driver's hand.

explained 76 percent of the variance in responses [$F(15, 319) = 65.8, P < .001$].

SUMMARY AND CONCLUSIONS

In general, higher degrees of window tinting made seeing inside a vehicle more difficult. Window tinting impaired performance of four of the six tasks in the study (mannequin detection, certainty in mannequin detection, distance at certainty, and object detection). For all of these tasks the heaviest tinting level (Vehicle 3 representing the maximum level for any state) significantly impaired performance relative to that with no tinting. The maximum legal level allowed in Virginia (Vehicle 2) also significantly impaired performance of these four tasks relative to that with no added tinting. An intermediate level of tinting (Vehicle 1) impaired performance of only two of these four tasks (distance at uncertainty and object detection) relative to that with no tinting. The four tasks that were

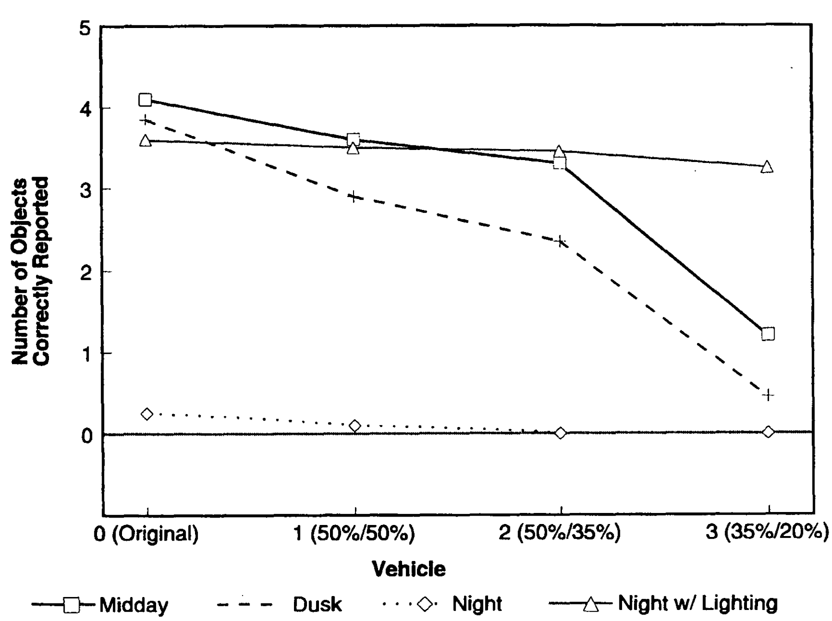

FIGURE 6 Effect of window tinting and viewing condition on object detection in backseat and back floor.

impaired by window tinting all involved looking into the vehicle through the rear window or the rear side windows. The two tasks that were not affected by window tinting (detecting the position of the driver's hands and detecting the object held in the driver's hand) involved looking into the vehicle through the front side window, which had the least amount of tint film applied relative to the amount applied to the other windows of the same vehicle (Table 1). In sum tinting affected looking into a vehicle through the back windows but not through the front side window. Also, the legal limits of window tinting allowed in Florida and Virginia significantly impaired an individual's ability to see inside those vehicles through the rear windows.

Not surprisingly, poor viewing conditions (night and dusk viewing) impaired subjects' ability to see inside vehicles. All six of the tasks used in the study were negatively affected by poor viewing conditions. Viewing the vehicle contents at night without the use of auxiliary lighting was significantly worse than viewing the contents during midday for all of the tasks. Many of the tasks were also more difficult when viewing occurred at dusk than when viewing occurred at midday (mannequin detection, certainty in mannequin detection, detecting the object held in the driver's hand, and object detection). However, only two of the tasks were more difficult when viewing occurred at night with the use of auxiliary lighting than when viewing occurred at midday (mannequin detection and confidence in mannequin detection). In other words the use of auxiliary lighting at night significantly improved performance relative to viewing at night without auxiliary lighting for four of the tasks. In fact, for two of the tasks (mannequin detection and object detection) the use of auxiliary lighting overcame the effects of heavy window tinting.

The experimental results indicate that the detrimental effects of window tinting on viewing people and objects within a stopped vehicle at night are greatly reduced by the use of auxiliary lighting. Performance at night with the use of auxiliary lighting was not affected by window tinting in terms of the accuracy of any of the judgments about what was inside the vehicle. The level of window tinting did not influence mannequin detection, reporting the positions of the driver's hands, reporting the object held in the driver's hand, or reporting the objects on the backseat and back floor.

Window tinting levels did affect the subjects' confidence in their judgments about the number of occupants in the vehicles. At the initial 6.1-m (20-ft) viewing distance, subjects' confidence in the accuracies of their judgments about the number of mannequins in the vehicles decreased with the degree of window tinting. Moreover, the distance from the vehicle at which subjects felt confident in this judgment decreased with the degree of window tinting.

Relative to nighttime viewing without auxiliary lighting, auxiliary lighting significantly improved the accuracy of performance on all of the assessments of vehicular contents: mannequin detection, detecting the positions of the driver's hands, detecting the object in the driver's hand, and object detection. Only confidence and the distance at which subjects felt confident were not affected by the use of auxiliary lighting.

The use of auxiliary lighting to detect objects within the vehicles from close range dramatically improved performance. Subjects who used auxiliary lighting at night to detect objects in the backseat and on the back floor detected more objects than subjects performing under all other viewing conditions, including midday viewing. In addition, nighttime performance with the use of auxiliary lighting was better for the task of detecting the weapon in the driver's hand compared with performance at dusk.

It is tempting to conclude that police officers might do well to use auxiliary lighting during daytime and dusk hours when approaching a stopped vehicle with tinted windows. This conclusion cannot be made, however, without performing an empirical study since the effectiveness of auxiliary lighting may interact with the overall level of ambient illumination that is present at different times of day.

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