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POSITION OF LOW-BEAM  
HEADLAMPS ON THE  
PERCEIVED DISTANCE OF  
VEHICLES**

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16. Abstract <p>Current U.S. regulations require that if vehicle low beams and high beams are provided by separate headlamps arranged horizontally, "the lower beam shall be provided by the most outboard headlamps." One possible rationale for this is that drivers may use the angular separation between headlamps as a cue for the distance to an oncoming vehicle. The present study was designed to investigate this rationale by evaluating the extent to which peoples' nighttime distance judgments are influenced by low-beam headlamp separation. We performed two field experiments, in which the subjects had to make judgments about the distance to a vehicle seen in the oncoming lane of a two-lane road at night.</p> <p>In both experiments, headlamp separation influenced perceived distance, with narrower separation being associated with longer perceived distance. However, the effects on perceived distance were not as great as would be expected if distance perception depended on lamp spacing alone. This suggests that drivers are using other distance cues as well.</p> <p>Relaxing the current restriction on low-beam location might result in both reduced average headlamp separation and increased variability in that spacing. While drivers could in principle adjust their distance judgments for a reduction in the average spacing of headlamps, increased variability would probably result in them relying less on headlamp spacing than they currently do. Given that drivers seem to make use of other distance cues as well, the effect of such a change on the overall quality of their distance judgments cannot be determined by these experiments.</p> <p>The current results do not support lifting the restriction on low beams to the outboard location. They suggest that to do so would reduce the potential value of a distance cue that drivers currently use at night.</p>					
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## Introduction

Current U.S. vehicle regulations require that if vehicle low beams and high beams are provided by separate headlamps arranged horizontally, “the lower beam shall be provided by the most outboard headlamps” (FMVSS, 1994, p. 228). Although the rationale for this requirement is not made explicit, there are at least two possible reasons for it. One is that when drivers are approaching another vehicle at night, they may use the nearest illuminated headlamp on the approaching vehicle (which in normal meeting situations is a low beam) as a marker for the edge of that vehicle. Thus drivers might steer their vehicle too close to an approaching vehicle if the low-beam headlamps on that vehicle were located inboard of the high-beam headlamps.

Another possible reason for the restriction is that motorists may use the visual angle separating the low-beam headlamps as a cue to the distance of an oncoming vehicle. There are other cues to the distance of a vehicle at night—for example, the angle subtended by the width or height of an individual lamp—but the angle between lamps may be an especially important distance cue, especially at greater distances. The potential value of headlamp spacing as a cue to distance depends on that spacing being consistent across vehicles, and on drivers being familiar with the typical spacing distance. Currently, even with the outboard restriction in place, there is a certain amount of variability in low-beam headlamp spacing. Relaxing the outboard requirement probably would have two consequences. One would be a decrease in average low-beam headlamp separation, and the other would be an increase in the variability of that separation because of a mixture of vehicles with inboard low beams and vehicles with outboard low beams.

The present study was designed to investigate the latter of the two possible rationales for the restriction, by evaluating the extent to which peoples’ nighttime distance judgments are influenced by low-beam headlamp separation. We performed two field experiments, in which the subjects had to make judgments about the distance to a vehicle seen in the oncoming lane of a two-lane road at night. Although both experiments were designed to measure effects on distance perception, they involved different specific tasks. This was so that the findings, to the extent they were in agreement, could be more confidently generalized. One experiment required subjects to make an explicit estimate of the distance to an opposing stationary vehicle, and the other required them to indicate the last possible moment they believed they could safely initiate a left turn in front of an oncoming vehicle. Unlike the first task, the second task does not involve a direct measure of distance perception. However, it is a useful complement to the first task because it is more like tasks that drivers perform in normal driving, and it should strongly reflect

subjects' perceptions of the distance to the oncoming vehicle (along with, possibly, their perceptions of the vehicle's speed).

Both experiments used the same stimulus vehicle. It was equipped with two sets of low-beam headlamps (inboard and outboard) and two pairs of parking lamps (also mounted inboard and outboard). Each time the subjects viewed the vehicle, one pair of each type of lamp was turned on. Thus, their distance judgments can be used to evaluate not only the extent to which low-beam headlamp separation served as a distance cue, but also whether parking lamps could convey the relevant distance information, independent of the location of the headlamps.

## Experiment 1: Distance Estimation

### *Method*

#### *Subjects*

Twelve paid subjects participated in this study. There were seven younger subjects (ranging from 16 to 24 years old, with a mean of 20), and five older subjects (ranging from 59 to 70, with a mean of 64). In the younger group there were five males and two females; in the older group there were three males and two females. All subjects were licensed drivers.

#### *Task*

The task in this experiment was to make numerical estimates of the distance to a stationary vehicle positioned ahead and in the adjacent lane. In order to partially calibrate their estimates, subjects were shown the stimulus vehicle at 100 m and told that they should consider that distance to be 100 units. However, they were not told that the example distance was in fact 100 m or that they should attempt to estimate distances in meters. They were told to simply choose whatever numbers reflected their perception of the distance to the opposing vehicle, trying to keep the numbers proportional to their perception of distance. Thus a distance that appeared half the example distance should be assigned a value of 50, and a distance that appeared one and a half times the example distance should be assigned a value of 150. This is a standard technique in the study of perception, generally referred to as magnitude estimation (e.g., Marks, 1974). Subjects' magnitude estimates are normally found to be quite systematic, although not necessarily calibrated to, or even linearly related to, measurement in conventional units.

#### *Vehicles*

Two vehicles were used in the study. A 1992 Nissan Altima served as the observer vehicle. It remained stationary for the duration of each session. A 1992 Toyota Corolla served as the stimulus vehicle. A lamp rack on the front of the Corolla allowed presentations of low-beam headlamps and parking lamps at inboard and outboard positions (see Figure 1). The locations of the headlamps were chosen to be representative of current automobiles in the United States with four-lamp headlighting systems, based on



measurements of an informal sample of 20 such vehicles. The outboard low-beam locations were based on current low-beam locations, and the inboard low-beam locations were based on current high-beam locations. The vertical position of the parking lamps was chosen to be representative of sedans with the parking lamps mounted below the headlamps, and the horizontal positions were chosen so that the spacing of the parking lamps would be as similar as possible to the spacing of the headlamps. (The housings of the parking lamps necessitated the small differences in horizontal spacing shown in Figure 1.)

#### *Test site*

The experiment was conducted on a straight, level section of a two-lane road, with no fixed lighting (see Figure 2). The test site had very light traffic during the evening hours, when the study was conducted (averaging about five cars per hour). Whenever a nonexperimental vehicle entered the area, testing was suspended until the vehicle had passed and was no longer visible. The road surface was dry asphalt.

#### *Stimulus conditions*

Each stimulus consisted of a presentation of a pair of low-beam headlamps (Type 2A1) and a pair of parking lamps. All four combinations of the two positions of the headlamps (inboard or outboard) and the two positions of the presence lamps (inboard or outboard) were used (see Table 1). The test vehicle was positioned at distances of 25, 50, 75, 100, 150, 200, 250, and 300 m ahead of the observer vehicle (see Figure 2). The factorial combination of two headlamp positions, two parking lamp positions, and eight distances resulted in  $2 \times 2 \times 8 = 32$  unique stimulus conditions.

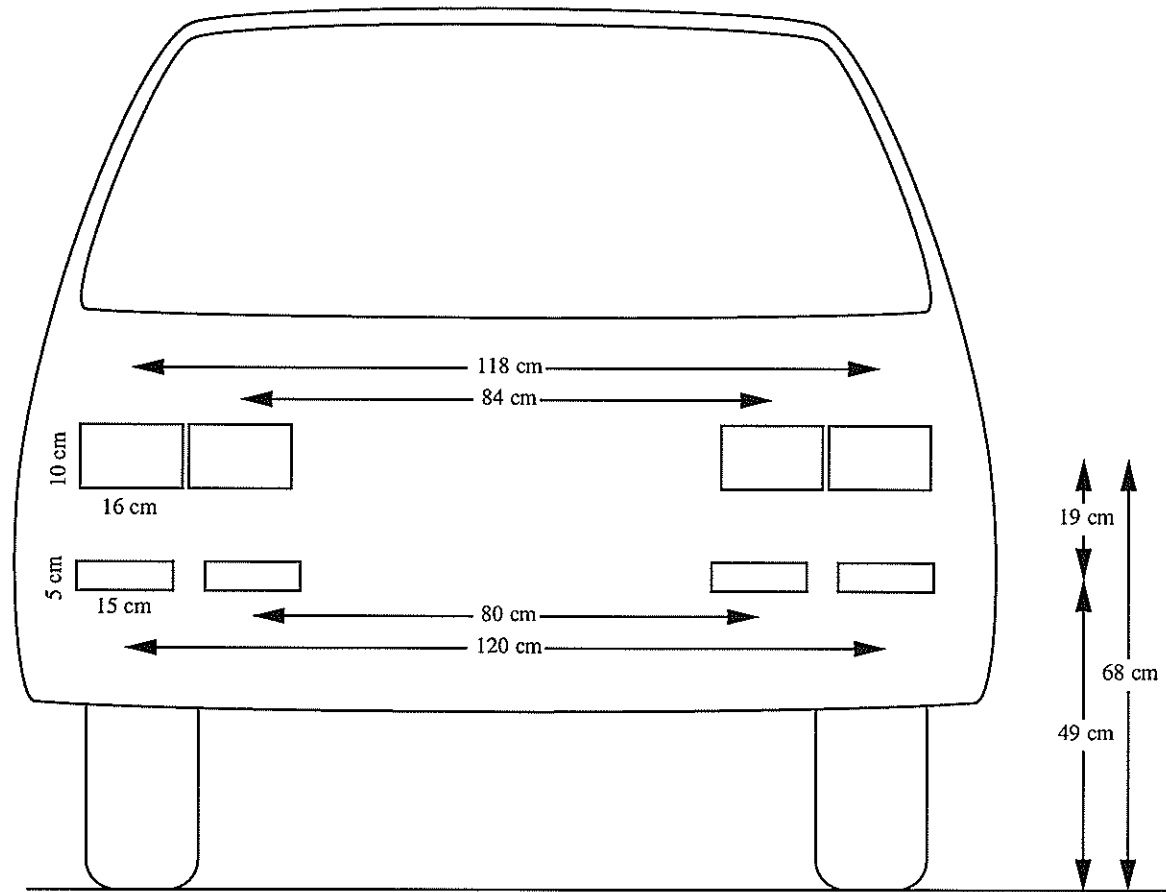


Figure 1. A view of the front of the stimulus vehicle, showing locations and sizes of the illuminated areas of the low-beam headlamps and parking lamps. The distances shown by the arrows are relative to the centers of the lamps.

Table 1.  
The four combinations of the headlamps and parking lamps used in Experiment 1.

Condition	Outboard Headlamps	Inboard Headlamps	Outboard Parking Lamps	Inboard Parking Lamps
1	On	Off	On	Off
2	On	Off	Off	On
3	Off	On	On	Off
4	Off	On	Off	On

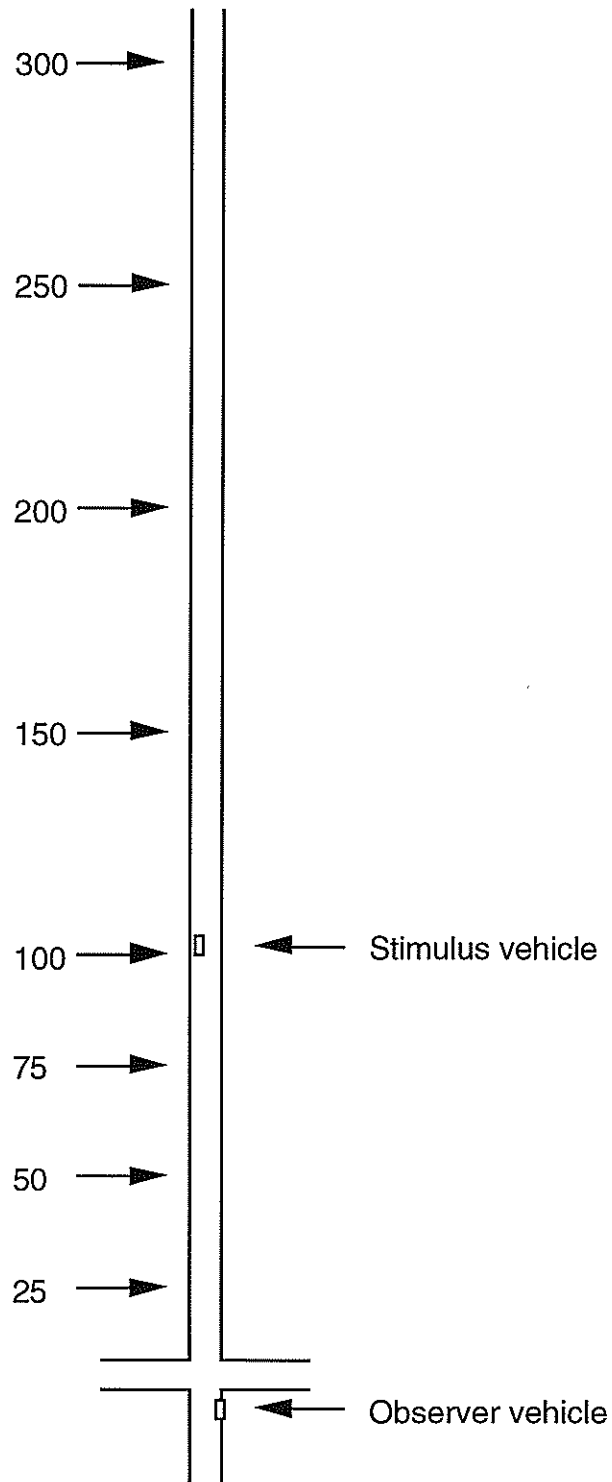


Figure 2. The field setup for Experiment 1, drawn approximately to scale. The observer vehicle was positioned as shown, just before an intersection and partly onto the right shoulder. The eight positions at which the stimulus vehicle was positioned are shown by arrows, with numbers indicating the distances in meters.

*Photometry*

Table 2 shows the illuminance at the eyepoint of the subject in the driver's seat of the observer vehicle for seven of the eight tested distances (the 250-m condition was inadvertently not measured). These readings were taken through the windshield. Prior to these measurements, all headlamps had been visually aimed on an aiming screen, and then slightly reaimed on the basis of preliminary measurements of the lux values at the subjects' eyepoint. This reaiming was done to ensure that the lux values for the inboard and outboard pairs were approximately equal, but slightly biased toward the inboard value being higher. This was so that small remaining differences would not lead to a prediction that the inboard pair of lamps would look further away on the basis of light values. It is not clear that intensity is likely to affect distance perception. Prior research on the effects of rear lamp intensity on distance perception has yielded mixed results (Moore, 1952; Rockwell & Safford, 1968). However, we wanted to be sure that any small effects of intensity that might exist would lead to a prediction opposite to the prediction based on lamp separation as a distance cue (i.e., that the smaller separation of the inboard pair would make the vehicle appear farther away).

Table 2.  
The illuminances reaching the eyepoint of the driver of the observer vehicle at seven of the eight tested distances.

Distance (m)	Inboard Headlamps (lx)	Outboard Headlamps (lx)	Inboard/Outboard Ratio
25	3.005	2.552	1.18
50	1.071	1.008	1.06
100	0.556	0.509	1.09
150	0.239	0.217	1.10
200	0.188	0.151	1.25
300	0.085	0.069	1.23

## *Procedure*

Subjects were run in groups of three, all sitting in the observer vehicle. One subject sat in the driver's seat, one in the front passenger's seat, and one in the middle of the back seat, looking straight ahead between the two subjects in the front, thus allowing all three subjects to experience similar, unobstructed views. One experimenter sat in the rear seat throughout the experiment to give the subjects instructions, and to signal by radio to another experimenter in the stimulus car when the subjects had completed their estimates for each trial. The observer vehicle was always stationary, located as shown in Figure 2. It was positioned partly onto the right shoulder so other vehicles could pass more easily on the infrequent occasions that they passed through the test site. The low-beam headlamps of the observer vehicle were on throughout the study.

Subjects were first shown the stimulus vehicle in the 100-m position with the outboard headlamps and outboard parking lamps illuminated. They were told to consider this distance to be equal to 100 (although they were not told that the distance was actually 100 m, or to estimate distances in meters). They were told that on subsequent trials they would see the vehicle at various other positions and that they should make numerical estimates of the distances to those positions. The instructions emphasized that they could use whatever numbers they chose, but that they should try to make the numbers proportional to their perception of distance. Thus if a distance appeared twice as great as the example distance they should assign it a value of 200, and if it appeared half as great they should assign it a value of 50. The numerical example was given only once, at the beginning of the session (although the 100-m distance was re-presented, mixed with the other distances, without being identified).

The subjects were instructed to have their eyes closed and heads bowed while the stimulus vehicle was moved into position before each trial. When the trial was ready to begin, the experimenter would say "Please open your eyes." Subjects would then open their eyes, raise their heads, and write down their distance judgments based on their first impressions of the distance. Each subject had a small flashlight and a response sheet.

The subjects would say "finished" when they had completed their rating. When all subjects had completed their ratings, the experimenter asked them to "bow your heads and close your eyes" until the next trial began. During this time, the stimulus vehicle moved to the next position. The experimenters attempted to make the delays between trials approximately equal, independent of the distance the car moved, in order to minimize the possibility that subjects would get clues about relative distances from the amounts of time between trials.

Each experiment session consisted of 32 trials (2 locations of headlamps, times 2 locations of presence lamps, times 8 distances), and lasted about one hour. Data collection started approximately one half hour after sunset. The moon was below the horizon throughout all sessions.

The twelve subjects in this experiment also participated in Experiment 2. The order of the experiments was balanced across the four groups of three subjects. Two groups were run in Experiment 1 first, and the other two were run in Experiment 2 first.

## *Results and Discussion*

An analysis of variance indicated that magnitude estimates of distance were significantly affected by headlamp spacing,  $F(1,8) = 22.05$ ,  $p = .0016$ , but not parking lamp spacing,  $F(1,8) = 0.068$ ,  $p = .80$ . The interaction between headlamp and parking lamp spacing was not significant,  $F(1,8) = 1.64$ ,  $p = .24$ . These effects are shown in Figure 3. The mean distance estimates for the inboard and outboard headlamp conditions, averaged over all actual distances, were 130 and 108, respectively. Thus, headlamp spacing affected distance judgments in the direction predicted by the hypothesis that subjects use the angular separation of the two headlamps as a distance cue: more narrowly spaced lamps appeared further away. Parking lamps do not seem to affect subjects' judgments, possibly because they are too dim relative to headlamps.

Magnitude estimates of distance were strongly related to actual distance, as shown in Figure 4. The effect of distance was highly significant in the general analysis of variance,  $F(7,56) = 65.77$ ,  $p < .001$ . Mean magnitude estimates are approximately linearly related to actual distance, but the overall tendency is for subjects to use numbers that are less than proportional to the example they were shown at the beginning of their sessions (a value of 100 assigned to a distance of 100 m).

The interaction of distance and headlamp spacing was also highly significant,  $F(7,56) = 6.66$ ,  $p < .001$ . This interaction is shown in Figure 5. The absolute difference in mean magnitude estimates due to headlamp spacing increases with actual distance. When the effect of headlamp spacing is expressed in terms of the ratio between estimates in the two spacing conditions, as in Figure 6, the change in the headlamp effect with distance is less marked, but there is still a tendency for larger effects of greater distances. This may be because when vehicles are at long distances, distance cues other than the angular separation of headlamps are relatively weak. At shorter distances, a variety of other distance cues may become more effective.

There are a number of candidates for such cues, although the present study does not provide evidence about which, if any, of them are important. For example, objects that are below the eye height of the observer (as most headlamps are) will have lower angular elevation relative to the horizon at shorter distances. The angles subtended by the dimensions of individual lamps are another possibility. Because those angles are always small relative to the angle between lamps, they may be useful as distance cues only at relatively short distances, beyond which the angle between lamps is still large enough to be useful.

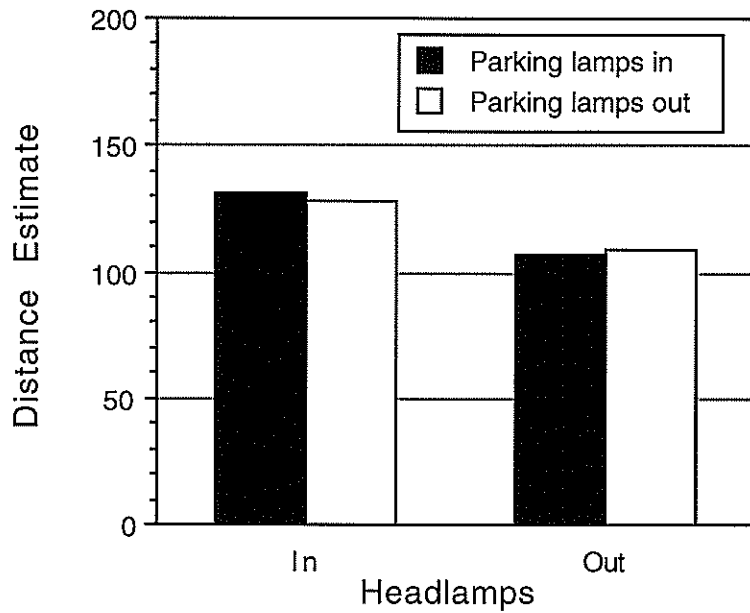


Figure 3. Mean magnitude estimates of distance for each combination of headlamp and parking lamp position.

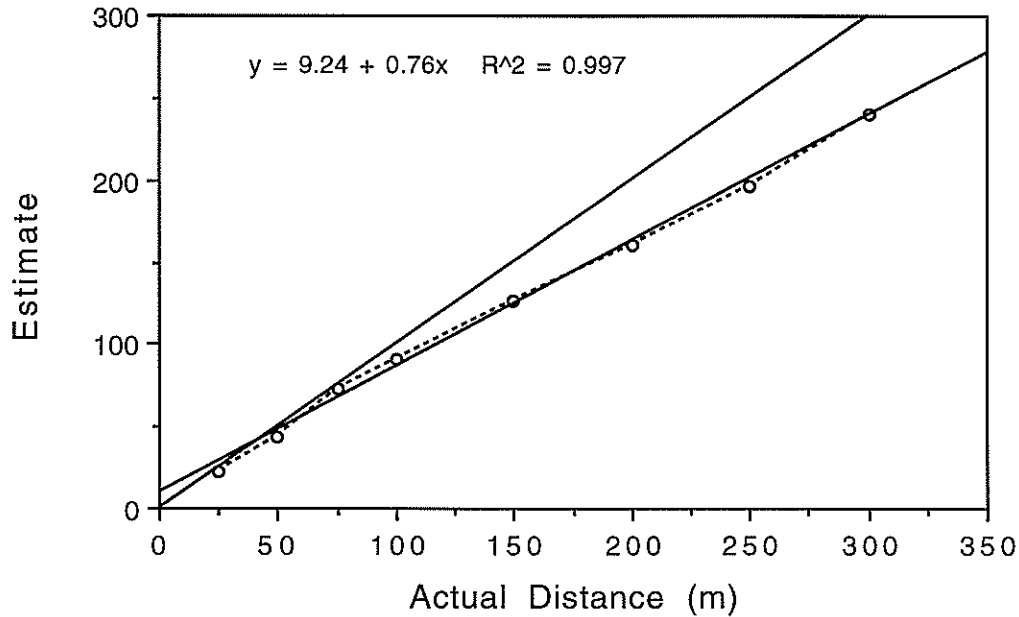


Figure 4. Mean magnitude estimates versus actual distance. The solid line through the data points is the best fitting linear regression function. The other solid diagonal line indicates where data would fall if subjects' estimates were perfectly calibrated to the example shown at the beginning of the session (an estimate of 100 for a distance of 100 m).



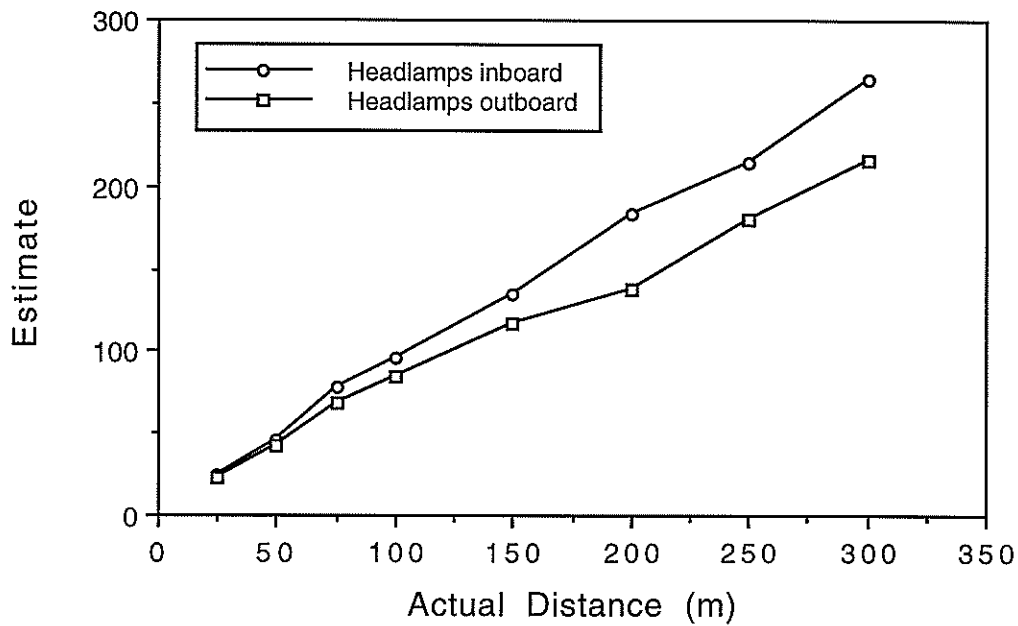


Figure 5. The interaction between headlamp position and actual distance. The absolute difference in magnitude estimates due to headlamp spacing increases with actual distance.

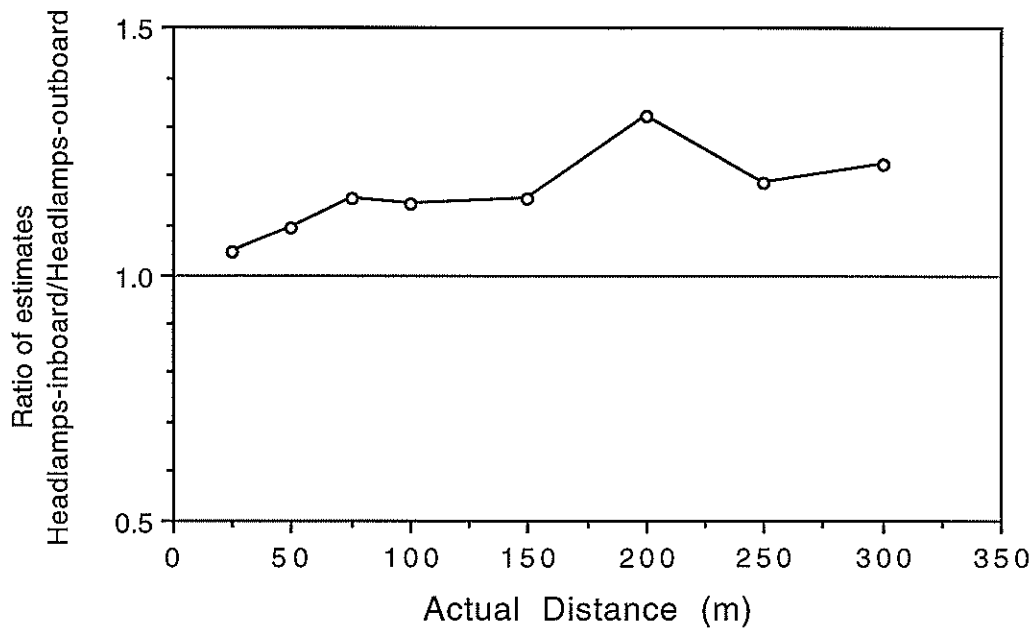


Figure 6. The effect of headlamp position on magnitude estimates of distance, in terms of the ratio of estimates for the inboard position to estimates for the outboard position. By this measure, the increase in the effect of headlamp spacing with distance is less marked than in terms of the absolute magnitude estimates shown in Figure 5, but there is still a tendency for larger effects at greater distances.

## Experiment 2: Minimum Gap

### *Method*

#### *Subjects*

The same subjects participated as in Experiment 1.

#### *Task*

In this experiment, subjects were asked to observe an approaching vehicle and press a hand-held button to indicate the last possible moment at which they believed they could safely initiate a left turn in front of it.

#### *Vehicles*

The same vehicles were used as in Experiment 1.

#### *Test site*

The site was the same as in Experiment 1. However, because the procedure was different, this experiment used a longer section of the road (see Figure 7).

#### *Stimuli*

The same four combinations of two headlamp positions and two parking lamp positions that were used in Experiment 1 (see Figure 1 and Table 1) were also used here. Because this experiment involved a moving stimulus vehicle, the distances used in Experiment 1 do not apply. We used two approach speeds, 50 and 70 km/h. Thus, there were eight unique stimuli, defined by the factorial combination of three stimulus variables, each with two levels: position of the headlamps (inboard, outboard), position of the parking lamps (inboard, outboard), and speed of the approaching vehicle (50 km/h, 70 km/h).

## *Procedure*

As in Experiment 1, the subjects were run in groups of three, all seated in the observer vehicle. On each trial, the subjects watched as the stimulus vehicle turned onto the road from a side road 570 m ahead (see Figure 7). It quickly accelerated to one of the two approach speeds (50 or 70 km/h), and then maintained that speed as it approached and passed the observer vehicle. The subjects were instructed to push a hand-held button at the last possible moment at which they believed they could safely initiate a left turn in front of it. The times between when each individual subject pushed his or her button and when the stimulus vehicle passed the observer vehicle were measured. These times, along with the two different approach speeds, were used to calculate the accepted gaps in terms of distance. The subjects' vehicle was positioned just before a cross street to make it easier for them to imagine the task of making a left turn (see Figure 7).

Each experimental session consisted of 16 trials (two repetitions of each of the eight unique stimulus conditions), and lasted about 30 minutes.

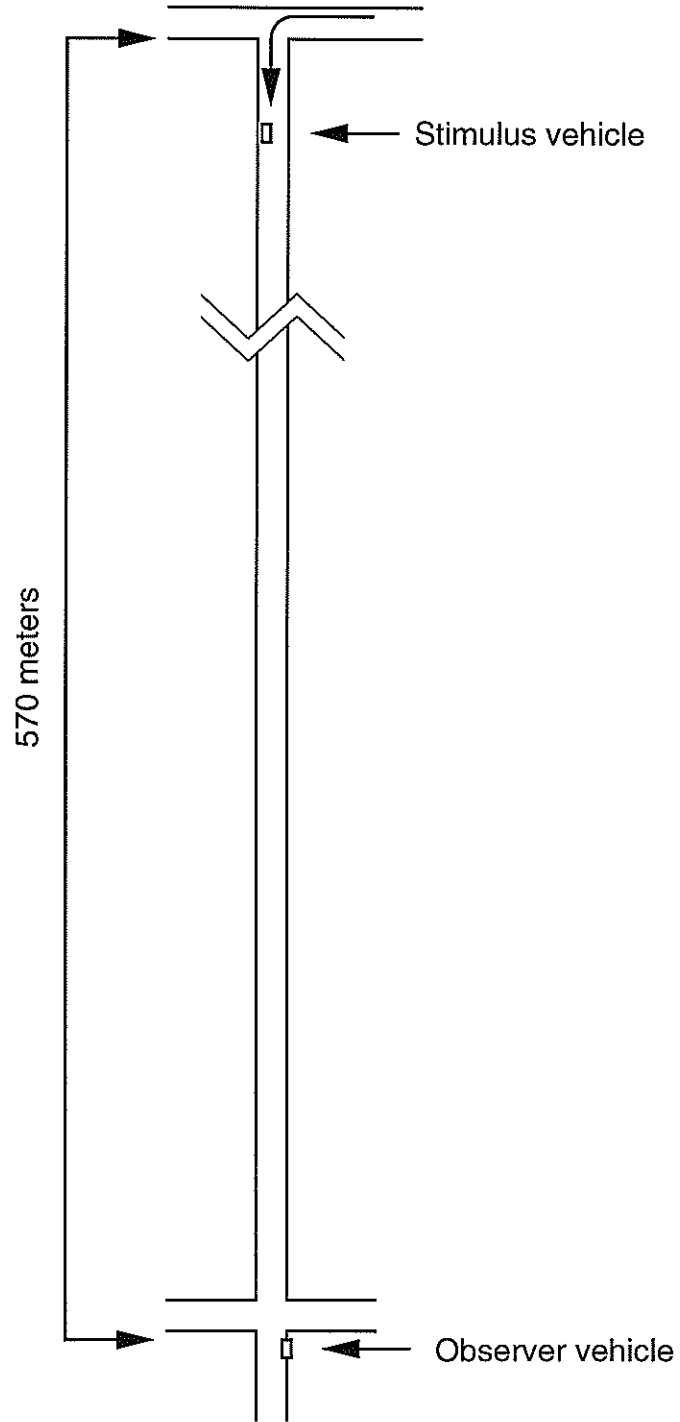


Figure 7. The field setup for Experiment 2. The curved arrow shows the path of the stimulus vehicle as it entered the test road and began to approach the observer vehicle.

## *Results and Discussion*

An analysis of variance indicated that minimum accepted gaps were significantly affected by headlamp spacing,  $F(1,8) = 5.95$ ,  $p = .041$ , but not parking lamp spacing,  $F(1,8) = 1.08$ ,  $p = .33$ . The interaction between headlamp and parking lamp spacing was not significant,  $F(1,8) = 0.011$ ,  $p = .92$ . These effects are shown in Figure 8. The mean accepted gaps for the inboard and outboard headlamp conditions, averaged over the two speeds, were 6.08 s and 6.67 s, respectively. The effect of headlamp spacing is consistent with the hypothesis that subjects use the angle between lamps as a distance cue. The narrower spacing resulted in accepted gaps that were briefer in time and shorter in distance. Assuming that subjects had a subjectively constant distance criterion for an acceptable gap, the narrower spacing resulted in distances appearing relatively long.

Approach speed had a significant effect on gap acceptance,  $F(1,8) = 34.07$ ,  $p = .0004$ , but it did not interact with headlamp spacing,  $F(1,8) = 1.08$ ,  $p = .33$ . The mean accepted gaps for the 50-km/h and 70-km/h approach speeds, in terms of time and distance, are given in Table 3. Perhaps the simplest model of how subjects ought to behave when approach speed varies is that they should always accept gaps that are constant in terms of time. This is based on the idea that the time it takes for the turning driver to initiate the turn and then clear the path of the approaching vehicle is the only relevant parameter. It should not matter whether the approaching vehicle reaches the crossing point at time  $t$  with a speed of 50 km/h or speed of 70 km/h; it only matters that it arrives at time  $t$ . Subjects in this experiment are clearly not performing according to that prediction. However, the prediction that accepted gaps should be temporally equal across approach speeds assumes that subjects perceive those speeds accurately, which may not be the case. A full explanation for the effect of approach speed on gap size probably depends on understanding how subjects perceive not only distance but also speed.

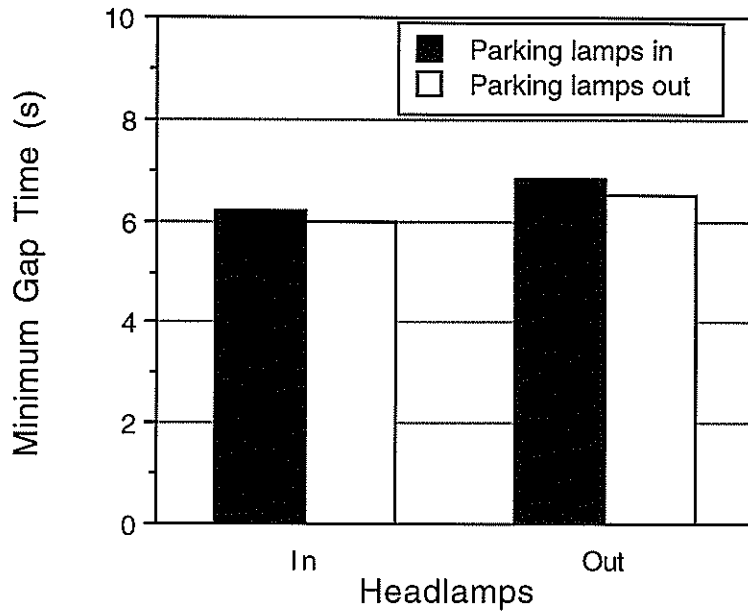


Figure 8. Minimum gap time for each combination of headlamp and parking lamp position.

Table 3.  
The mean minimum gaps accepted for the two approach speeds, in terms of both time and distance.

Approach speed	Minimum gap	
	Time (s)	Distance (m)
50 km/h	7.17	99.6
70 km/h	5.59	108.6

## General Discussion

### *Comparison across the two experiments*

The results of the two experiments reported here are consistent in that they both indicate that narrower headlamp spacing causes vehicles to appear farther away. Both experiments also indicate that parking lamp spacing has no appreciable effect on distance judgments. The consistency of these findings across two different tasks supports the conclusion that headlamp spacing affects distance perception itself, rather than a more limited aspect of how subjects make their judgments on either task alone. Table 4 shows the magnitudes of the effects of headlamp spacing on distance perception for each of the two experiments. The magnitudes are similar, although not identical.

### *Comparisons to a predicted value*

The estimates for the effects of headlamp spacing on distance perception can be compared to a quantitative prediction based on the hypothesis that the angular separation between headlamps is the only cue to distance used by the subjects. Figure 9 illustrates how to derive such a prediction. Assume that an observer sees a pair of headlamps at an actual distance of  $D$  separated by a spacing  $S$ . Also assume that  $S$  is the typical spacing distance for headlamps, and that the observer knows this from past experience. Further assume, for this hypothetical illustration, that all headlamps are separated by exactly this spacing. In the real world there is already a range of spacing distances rather than one fixed distance, but this example can be applied to average spacing and average distance perception, provided that drivers find the spacing of headlamps to be consistent enough to be a useful cue to distance.

Table 4.  
A comparison of the effects of headlamp spacing on distance estimation (Experiment 1) and gap acceptance (Experiment 2).

Headlamp location	Distance estimates	Minimum gap times
Outboard	108	6.67 s
Inboard	130	6.08 s
Perceived-distance ratios (inboard/outboard) <sup>1</sup>	1.20	1.10

<sup>1</sup> For both tasks, this index is meant to reflect the extent to which the perceived distance for inboard headlamps is longer than for outboard headlamps. In the case of distance estimates, the index is simply the ratio of outboard/inboard. In the case of gap times, the index is the ratio of inboard/outboard because accepting a relatively short gap is presumed to be due to it being *perceived* as relatively long.

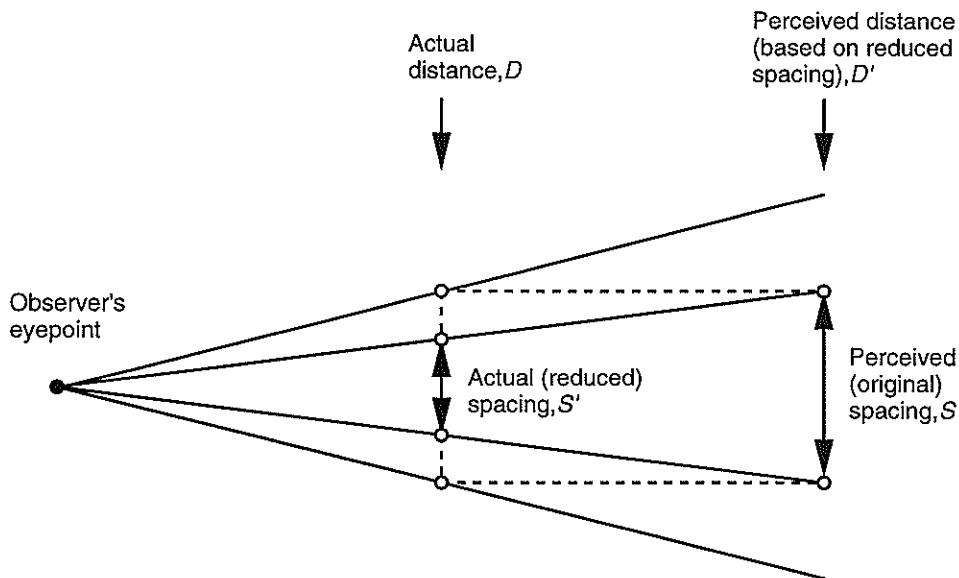


Figure 9. The relationships among perceived and actual spacing and distances, assuming that the observer's distance perception is based entirely on the visual angle subtended by a pair of lamps, and that the observer does not compensate at all for a reduction in the original spacing of the lamps.



Assume that the headlamp spacing is reduced from  $S$  to  $S'$ , and that the observer is unaware of this change and makes no compensation for it in his or her judgment of the distance to the lamps. Because the observer now sees a smaller angular separation between the lamps, and believes the spacing of the lamps is still  $S$ , he or she must conclude that the distance has increased to a value  $D'$ , as if the lamps in Figure 9 had been moved to the right along the horizontal dotted lines, rather than inwardly along the vertical dotted line. As indicated in the diagram, either movement would account for the change from the visual angle between the lamps that was originally observed to the new, narrower visual angle. The actual value that would be expected for the new distance estimate can be calculated by inspection of Figure 9. By similar triangles, the ratio of the actual distance to the perceived distance will be equal to the ratio of the reduced spacing to the original spacing:

$$\frac{D}{D'} = \frac{S'}{S}$$

Thus the expected perceived distance to the more narrowly spaced lamps would be:

$$D' = \frac{S}{S'} D$$

The center-to-center spacings for the headlamps (shown in Figure 1) were 118 cm and 84 cm. In this case the factor by which distance perception should be increased is:

$$\frac{S}{S'} = \frac{118 \text{ cm}}{84 \text{ cm}} = 1.40$$

The average effect actually observed in each of the present experiments is smaller than that prediction (a factor of 1.20 for distance estimates, and 1.10 for gap acceptance). A possible explanation for this discrepancy is that, although the angular separation of headlamps clearly influenced subjects' distance judgments, other (more veridical) cues also contributed. This line of argument suggests that even at relatively long distances, at which the angular separation of the headlamps might be expected to be the predominant distance cue, subjects' judgments are still influenced by multiple distance cues. Figure 6 indicates that, although the effect of headlamp separation does seem to increase with distance, even at 300 m the effect is smaller than the prediction based on headlamp angular separation alone.

### *Mean and variability of headlamp separation*

The results of this experiment indicate that the visual angle subtended by headlamps does affect drivers' distance judgments. Relaxing the current U.S. restriction on low-beam position might therefore be expected to affect distance judgments. The simplest prediction about that effect is that when headlamps are more narrowly spaced, vehicles will appear further away than they otherwise would. However, the overall effect of relaxing the restriction may be somewhat more complex, given that the current restriction not only keeps the mean separation distance across vehicles relatively high, but also, by ensuring uniformity, keeps the variability in separation across vehicles relatively low. If relaxation of the low-beam restriction resulted in all new vehicles having inboard low beams, then the final effect, after complete retirement of the older vehicle population, would be a reduction in mean headlamp spacing with perhaps no change in the variability of spacing. However, at least during the transition period, and indefinitely if new vehicles were produced with both inboard and outboard low beams, the variability of headlamp spacing would be increased. That change in variability might also affect drivers' distance judgments, because it would reduce the reliability of headlamp angular separation as a distance cue.

As mentioned in the Method section of Experiment 1, the headlamp separation used in these experiments were based on mean low- and high-beam separations obtained from an informal sample of 20 current automobiles in the United States with four-lamp headlighting systems. The same data can be used to estimate the variability in headlamp separation for current vehicles in the United States. Figure 10 shows three histograms based on the sample: the 20 low-beam separations, the 20 high-beam separations, and a random mixture of 10 values from each of the other two sets. The variability within either high- or low-beam separations is small relative to the means. This fact, together with the difference between high- and low-beam means, results in the variability of the mixture distribution being large relative to its own mean. Because the sampling method for these data was informal, and because the data include only automobiles rather than the full variety of vehicles that a driver might encounter on the road at night, the values in Figure 10 should not be considered definitive. However, they suggest that there might be a substantial increase in the variability of headlamp spacing, and a corresponding reduction in the value of that spacing as a cue to distance, if low beams were used in both inboard and outboard positions.

If the average spacing of low-beam headlamps was reduced consistently (a change that might be represented by the difference between the top and middle panels of Figure 10) it is possible that drivers would recalibrate their expectations about the relationship between

the angles subtended by pairs of lamps and distance. Such a change might therefore have no long-term effect on distance perception. In contrast, increased variability of spacing, such as a change from the top panel to the bottom panel of Figure 10, would fundamentally reduce the potential value of spacing as a cue to distance. If drivers recognized the increase in variability, they might learn to rely less on headlamp spacing. In principle, they could recalibrate their judgments to the mean spacing of a distribution such as that in the bottom panel of Figure 10, but the uncertainty of those judgments would be increased.

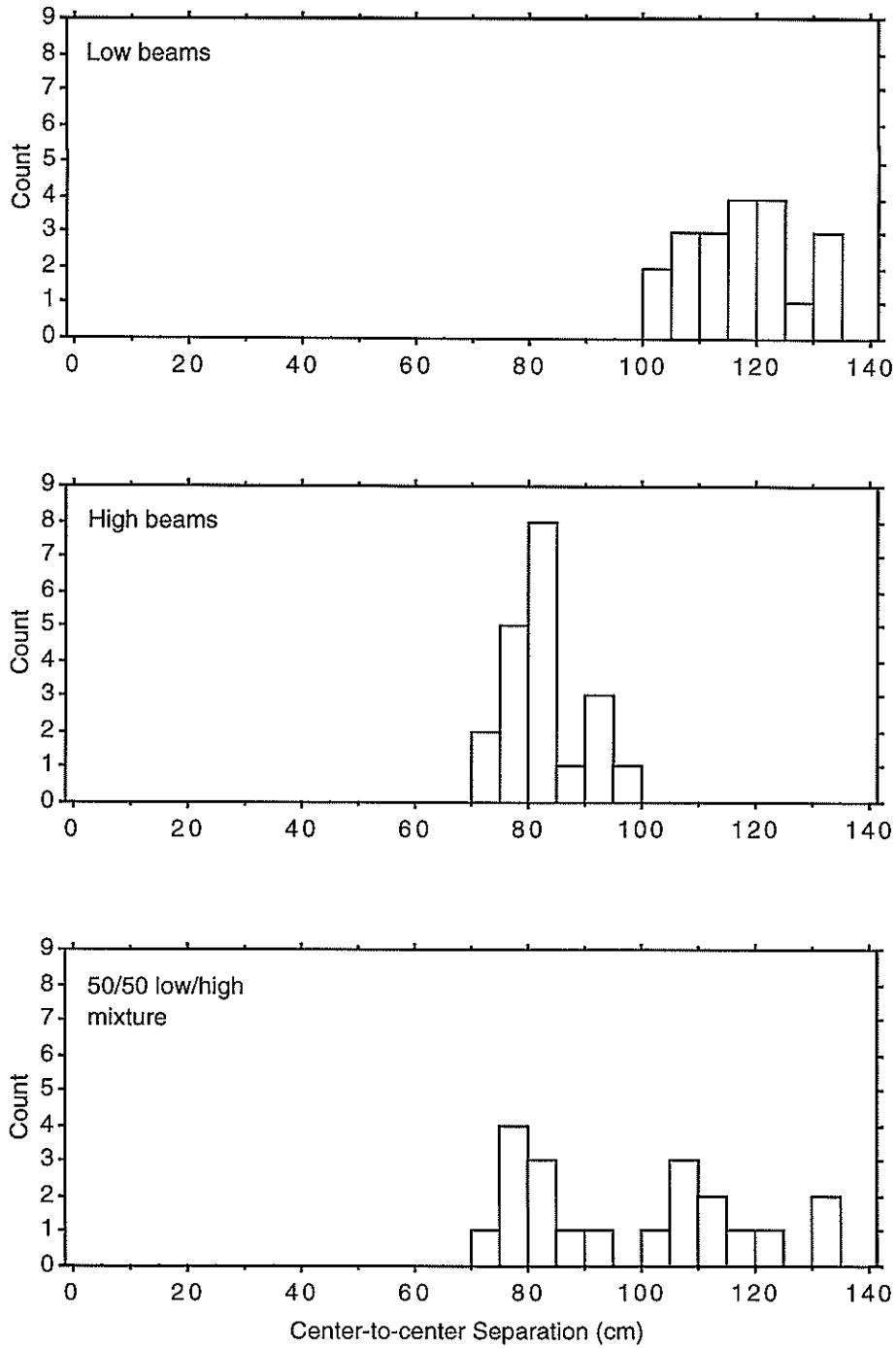


Figure 10. Histograms of center-to-center separations of high and low beams on 20 automobiles in the United States with four-lamp headlighting systems. The bottom panel shows a 50/50 random mixture of the upper two distributions.

## Summary and Conclusions

In each of two experiments, headlamp separation influenced perceived distance, with narrower separation being associated with longer perceived distance. This suggests that drivers are likely to use the angle subtended by low-beam headlamps as a cue for the distance to an oncoming vehicle at night. However, the effects on perceived distance were not as great as would be expected if distance perception depended on lamp spacing alone. This suggests that drivers are using other distance cues as well. The effect of headlamp spacing on distance perception in Experiment 1 was greatest at longer distances, suggesting that the degree to which drivers rely on headlamp separation, versus other cues, increases with distance.

Relaxing the current restriction on low-beam location might result in both reduced average headlamp spacing and increased variability in that spacing. While drivers could, in principle, adjust their distance judgments for a reduction in the average spacing of headlamps, increased variability would probably result in them relying less on headlamp spacing than they currently do. Given that drivers seem to make use of other distance cues as well, the effect of such a change on the overall quality of their distance judgments cannot be determined by these experiments.

The current results do not support lifting the restriction on low beams to the outboard location. They suggest that to do so would reduce the potential value of a distance cue that drivers currently use at night.

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