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Abstract

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A PHOTOGRAPHIC METHOD FOR
MEASURING THE FIELD OF VIEW
FROM WITHIN 1978 MODEL AUTOMOBILES

PACIFIC UNIVERSITY COLLEGE OF OPTOMETRY

A PHOTOGRAPHIC METHOD FOR MEASURING THE FIELD OF VIEW FROM WITHIN 1978 MODEL AUTOMOBILES

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This doctoral thesis is presented in partial fulfillment of the requirements for the degree: Doctor of Optometry.

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ABSTRACT

In this study conducted at Pacific University College of Optometry, thirty 1978 model cars are measured with a new but simple photographic method to determine the field of view from the driver's seat. The horizontal field through the windshield ranged from 78 to 103 degrees, with a mean at 92.2 degrees. Other aspects of the visual design of the autos were studied with the new method and the data presented.

INTRODUCTION

A fast and accurate method of measuring fields of view from within automobiles is described and developed to reduce the time needed to make the measurements. We believe that the time spent on-site is more important than the time which one must spend processing the data. With this method, a photographic darkroom will be the place where part of the data processing is done. Analysis of the data can be done wherever it is convenient. It is our objective to keep equipment to a minimum which will make our method more attractive to workers in the field of visual science.

There ar two broad areas of application for this method of visual field measurement. The first is in the sectors of government and industry that are concerned with the design of motor vehicles. This includes cars,trucks, boats and planes. By providing a method by which large numbers of vehicles can be assessed for visual field size, we hope to increase the awareness of this important factor in vehicle design. The second area of potential use involves Optometric practitioners and researchers, particularly in the field of low vision. Since many low vision devices restrict the field of view, it would be desirable to have a convenient method of finding out what the patient's field needs really are. Using our photographic method, researchers can rapidly study the field requirements of a person or group of people. For example, the field requirements of people in a nursing home could be assesed rapidly and without disturbing the inhabitants.

Our most specific goal is to make our field measurement method so easy that we will someday see a car's angular field of view become a standard specification in automotive and consumer publications which advise car buyers on how to select the best car for their needs.

BACKGROUND

Research into fields of view has been notably limited to motor vehicles. Various people have been carrying on studies of this aspect of automotive design for at least two decades, although interest in this particular area has never been very great.

The currently available methods of measuring field of view often require some highly specialized equipment which is custom designed and built by each researcher independently. Certainly a rapid, accurate method of field measurement could be of use to any manufacturer of motor vehicles. More specifically, the smaller companies who have limited capital and facilities might find such a method useful. Naturally it is likely that some imaginative thinking will result in other applications of the metnod. Hopefully, when and if this method becomes widely used and standardized, it will encourage the development of simple and effective standards for field of view in vehicles.

The next question that arises is what kind of visual fields are necessary for the safe operation of a particular motor vehicle? Most of the research on this question has been related to automobile driving. On a practical basis, there are certain areas of and automobile that may be considered non-essential to visibility. These areas are the floor area, directly beneath the driver, and bounded by the four wheels, and the roof area, above a certain angle from horizontal. This angle is usually given as 25 to 30 degrees. With respect to the horizontal field of view, some preliminary studies indicate that a driver's ability to position a car on the road is not significantly impaired until the field is restricted to less than 25 degrees horizontally. However, other visually related tasks, such as spotting and reacting to peripheral objects were not considered. Danielson (1957), based on his experience with simulated blindness, reported no major difficulties in driving with a 40 degree horizontal field.

Another area of consideration is the blind area directly surrounding the vehicle. Accidents usually arise from this as a result of not seeing a youngster when the car is first set in motion. In GreatBritain the Ministry of Transportation statistics show that 1.5% of fatal accidents to children under five occur in this manner. Obviously this blind area increases when a car is driven by a shorter person.

The factor of speed complicates the problem of determining some kind of minimal field of view. It has been demonstrated that as speed is increased a driver's usable field of peripheral vision contracts. This is attributed to a "smearing" of stationary objects in the peripheral field. (Hockenbeamer 1952). Aberg (1977) reported that subjects do not decrease speed as a response to constricted peripheral fields. Thus what constitutes a sufficent peripheral field at 20 mph may be inadequate at 55. The main adaptation made to restricted fields, as reported by Aberg, is a corresponding increase in head movements. As the visual fields narrow, the amount of compensation increases.

There are presently very few standards for minimum fields of view for any motor vehicles. For autos in England, the Society for Motoring Manufacturers and Traders has specified that the left windshield post should not be less than 25 degrees from straight ahead of the driver and shouldn't occupy more than 4 degrees. The size of the post can be increased one degree for each 5 degrees beyond the required 25 degrees from straight ahead. This assumes some sort of standard driver position in front of the steering wheel. It is easy to see how the angular position of the post can vary with the driver's position relative to the center of the car. Allen (1962) has shown that most drivers sit very close to their door, presumably to use the armrest. One can see also how variations in driver height can vary the degree of field obstruction from rearview mirrors and high dashboards.

In 1955, the National Safety Council reported that an obstruction to vision contributed to one out of eight traffic accidents. In about 40% of these cases, vision was obstructed by some object that was a part of the vehicle.

Obviously, setting visual field standards is a very complex task. It is logical to assume however, that the larger the field of view, the better the driver's ability to perceive and react to important stimuli in the environment around his vehicle. It has been shown that driver's tend to scan the traffic environment in an active and systematic way. (Robinson 1972).

An innocent appearing field obstruction may disrupt the scanning process and cause an important visual cue to be missed. This may be a critical factor when the driver and vehicle are in a high risk situation such as city or freeway traffic.

Robinson (1972) reported also that stress on the visual information processing system was increased when a driver had to take visual input from two locations that were separated by a large visual angle. An example of this is when the outside mirror is located too far back on the side of the car so that the driver must turn his head significantly to make use of it.

Quantitative measurements of fields of view have been made using several different methods. King and Sutro (1961) designed and constructed a goniometer, which measures angular size. The values obtained were plotted onto polar coordinate graph paper which gave a 360 degree representation of a cars's fields of view in all directions. In most current automobile designs, high seatbacks and headrests make a full circle field study very difficult. Cowgill (1977) used this method in light aircraft. He reported considerable difficulty in moving one's body around inside the vehicle when the seat is occupied by the goniometer.

General Motors has developed a method in which the window area is projected onto a large curved screen in front of the car. This is accomplished by using two lightbulbs placed to simulate the position of both of the driver's eyes. In this manner, the field visible to one or both eyes can be charted on the screen from the resulting pattern of light and shadow.

The problems associated with these methods are obvious. Special equipment must be constructed. In the case of the GM method, an entire room must be reserved for the screen. In addition to the expense involved in the equipment, there is a large amount of time needed to take the measurements. No wonder that field studies are not more common.

GOALS OF THIS STUDY

During the course of the study we were concerned with the following goals. One: to establish the usefulness and practicality of the photographic method. Two: to make the following four measurements on a sample of 1978 cars. A) The angle from the driver's visual axis to each side post. B) The angle blocked by each side post. C) The angular size of the inside rearview mirror. D) The angle between the outside mirror and the driver's visual axis. Three: to find the mean values and ranges for the above values.

SUBJECTS

The subjects for this study were 30 automibiles from dealer's showrooms and lots in the Portland area. All were of the 1978 model year. The variety of cars was made as broad and representative as possible within certain limits. Pickup trucks and two seat sports cars were not included. All cars in the study group were capable of carrying four to six passengers. In the cases where a manufacturer makes a single body type under more than one name, we tried to pick a single car that would represent the entire family.

EQUIPMENT

Nikkormat 35mm camera, Asanuma 17mm wide angle lens, Sunset hand held light meter,(since the camera did not have one), a tangent calibrated wall chart, camera tripod, Tri-X 35 mm film, 8x10 photographic printing paper, Vivitar enlarger, darkroom chemicals and equipment.

METHODS

CALIBRATION

Each camera-lens combination must have its own calibration scale. Once this has been produced, the photographs can be measured with a millimeter rule and the resulting length values can be converted to degrees from the calibration graph or chart.

To begin, the camera with lens is placed on a tripod precisely one meter from a blank wall. A horizontal line through the center of the camera's field is placed on the wall using pins and black string or thread. Using a tangent table or calculator, pieces of black tape are placed at distances from a center point which corresponds to a given number of degrees from the center of the field. For example, the tape placed in the center of the field represents the zero point. The next piece of tape will represent a point ten degrees off axis. The tangent of ten degrees is .176 and since the camera is one meter from the scale, we place the tape at 17.6 centimeters from the center mark. More pieces of tape are placed in this manner until the entire horizontal field of the lens is marked off in units of five degrees. The units will take up larger distances toward the ends of the scale due to the nature of the tangent scale. The 45 degree marks will be one meter to each side of center. To increase accuracy, the camera to wall distance should be measured from the first nodal point of the lens rather than from the camera body. This point can be found about two centimeters back from the front of the lens. A more precise location for this point can be measured on an optical bench, but this is not considered necessary for this purpose.

When the scale is complete and the camera is lined up, several exposures are made. We also included some exposures with the camera turned vertically to see if the distortion would be the same in all meridians (it was). The exposed film is then developed normally and taken to the enlarger when dry.

One frame of film is placed in the enlarger. The enlarger head is raised and lowered and the focus adjusted until the image is projected to a convenient size and well focused. We decided to use a size of 20 centimeters between the 40 degree marks. A piece of 8x10 paper is exposed at that magnification and developed. The resulting picture and negative become the calibration reference for that lens and camera. We then measured the print to find the number of millimeters that corresponds to each division on the wall scale. See Fig 1-3 and Table 1. Since the camera distorts the image in a non-linear manner, it is not practical to compute a millimeters to degrees equation for every lens and camera that one might want to use, We chose to use a graph which shows the number of degrees that corresponds to a given length measurement on the photograph. Fortunately, distortion is symmetrical around the center of the photo. This allowed the use of a single graph, but all measurements must be made from the center of the photo because of this distortion factor. We found it helpful to construct a table from the graph which allowed more rapid conversion of the data from millimeters to degrees in the analyses process.

DATA GATHERING

The camera was taken to several car dealers to measure the important visual angles of the automobiles. The procedure was quite simple and required about two minutes per car. Since the 17mm lens would not photograph the entire windshield area on most cars, we found it necessary to make two exposures. A reference point was placed on the windshield which would be in both photographs and allow the values from the two photos to be added together to get the total horizontal field size.

Upon entering the car, researcher 1 seated himself comfortably in the driver's seat and moved the seat as far to the rear as it would go. This procedure was used to standardize the distance from the dashboard which would otherwise be free to vary and affect the results directly, rendering the study worthless. Researcher 1 (R1) was always the one to take the photo from the driver's seat since driver height and posture must be held constant. R1 was 5 ft. 10 in. tall and alsays assumed the same relaxed driving posture in each car.

After assuming the standard position, R1 place a 1 inch piece of tape at the spot on the windshield which corresponded to his subjective visual axis. Accuracy of placement was found to be within one centimeter on a repeated placement test.

R2 watched R1 from outside the car on the left side. R2 used a yardstick to identify the vertical plane which R1's eyes were placed when in the standard position. With the yardstick held firmly in alignment, R1 then moved his head back until the camera could be brought up to the position previously occupied by his head. Withe the aid of R2, the camera was place with the lens reference point at the point that would be between the driver's eyes in the standard position.

With R2 watching the camera placement, R1 lined up the center of the camera's viewfinder with the piece of tape on the windshield and snapped the first picture. The camera was then rotated horizontally to the right and the second picture taken. This photo had to include the tape and the right windshield post.

It was found to be very important to have two people working together on this procedure to avoid any longitudinal movement of the camera between the two exposures which would have a serious effect on accuracy.

DATA ANALYSIS

The film exposed at the data collection site was returned to the darkroom and developed in a normal manner. The photo lab was then prepared for printing the photographs. First, the enlarger height and focus were set to the exact place at which the calibration photo had been made during the calibration phase. This was done by simply placing the calibration negative into the enlarger and adjusting it until the projected image was precisely the same size as the calibration print. In our case, the distance between the 40 degree marks was set at 20 centimeters. The negative is then removed without disturbing the enlarger setting. Each print is then made at that same setting. With thirty cars in the study, we had to print sixty photos. Each one was done on a sheet of 8x10 paper for easy measuring.

To measure the photos, we drew an X from the corners of the print. See figures 4 and 5. Any error in aligning the negative in the negative carrier will appear at this step and that photo must be rejected since the center of the photo cannot be located with certainty. The center should correspond with the piece of tape on the windshield in the photos of the left side of the car. A small discrepancy can be tolerated as long as measurements to the outside mirror are made from the tape on the visual axis rather than from the geometric center.

The following distances were measured on each pair of photos and converted to degrees. A1, tape to inside edge of left post. A2, tape to outside edge of left post. A3, tape to vertical line through inside edge of outside mirror. B1, tape to center of photo. B2, photo center to inside of right post. B3, photo center to outside of right post. B4, center of photo to line drawn down from left edge of rearview mirror. B5, center of photo to line drawn down from right edge of rearview mirror. B6, center of photo to horizontal line drawn from top of rearview mirror. B7, center of photo to horizontal line drawn from bottom of rearview mirror.

Measurement A3 was a direct measurement of the horizontal distance to the outside mirror. This is the angle through which the driver must turn his head to see cars behind him in the outside mirror. The angular width of the windshield was determined by adding measurements A1, B1, B2. The width of the left post was found by subtracting A1 from A2. The width of the right post was found by subtracting B2 from B3. The horizontal angle occupied by the inside rearview mirror was found by subtracting B4 from B5. The vertical angle occupied by the inside mirror was found by subtracting B7 from B6.

These values for the 30 subject automobiles are summarized in tables 2 and 3.

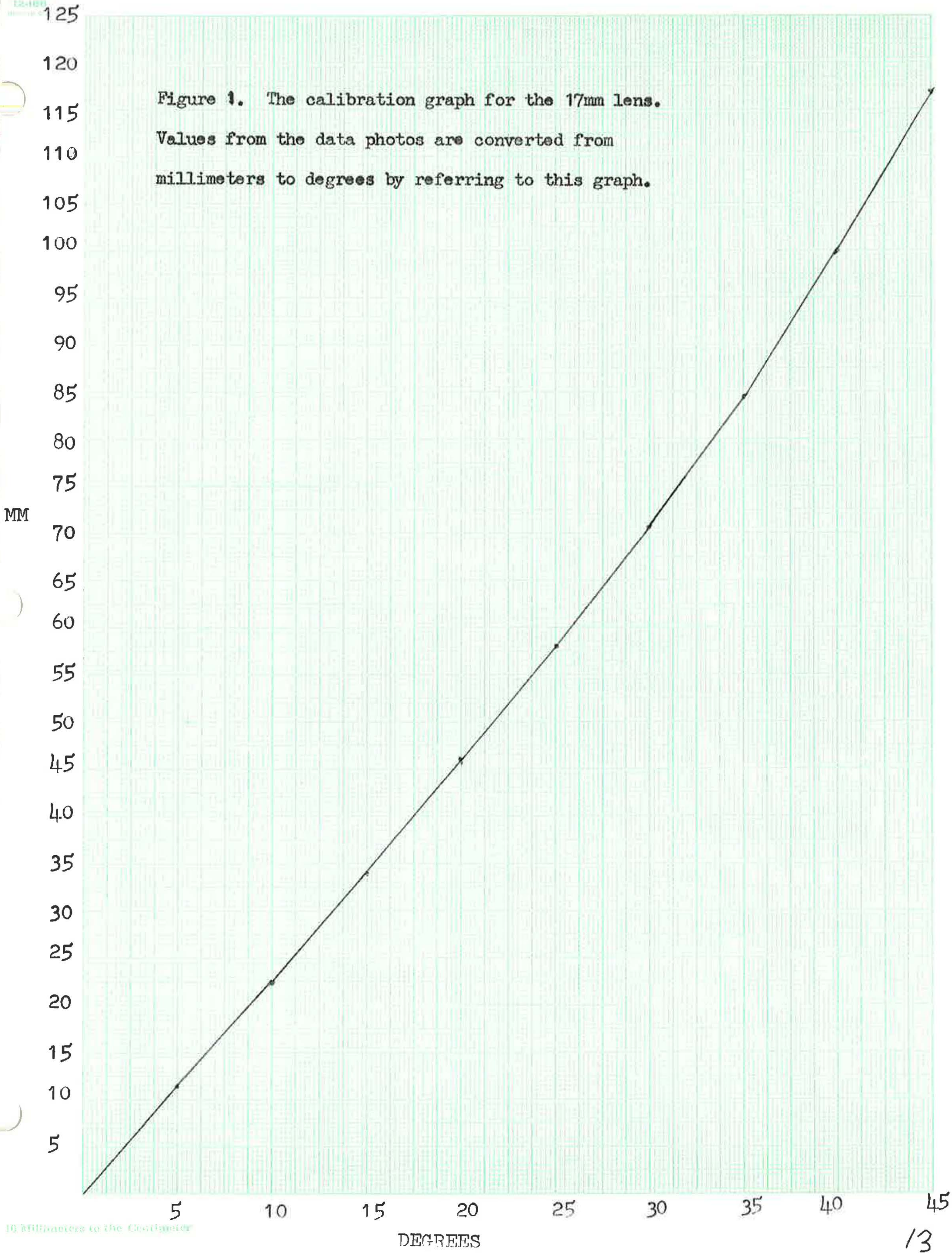


Figure 1. The calibration graph for the 17mm lens. Values from the data photos are converted from millimeters to degrees by referring to this graph.

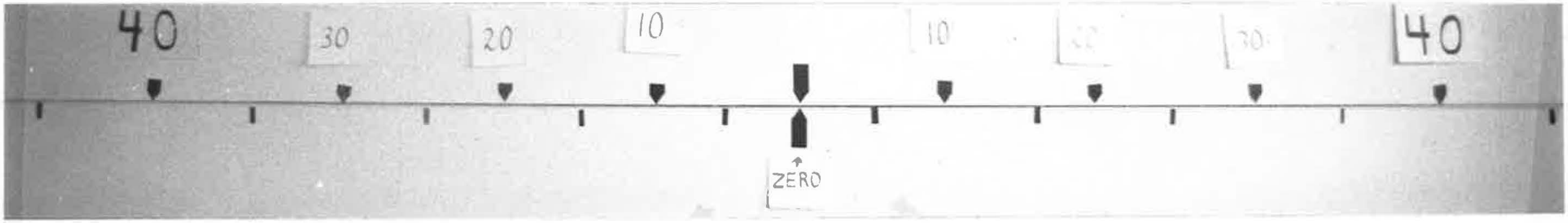


Figure 2. The calibration print for the 17 mm lens. Camera in horizontal position.

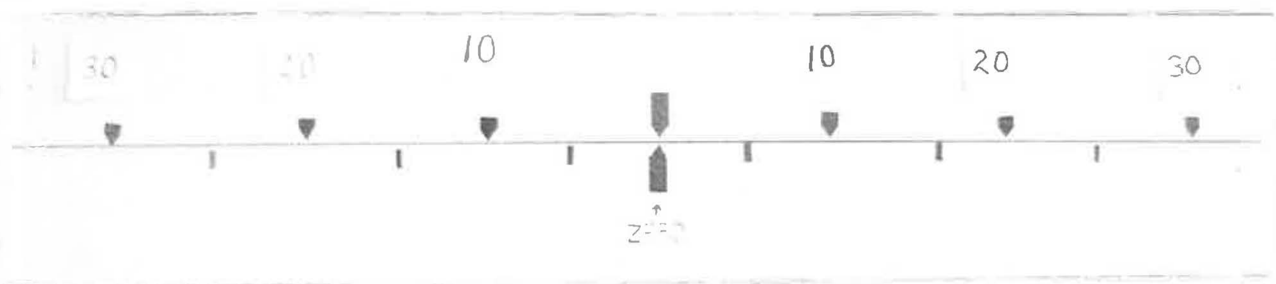


Figure 3. Vertical calibration print for 17mm lens.

Figure 4. Data photo of left side of 1978 Dodge Magnum. Arrows indicate measurements for visual angle through windshield to the left of the tape and measurements for the angle between the tape and the outside mirror.

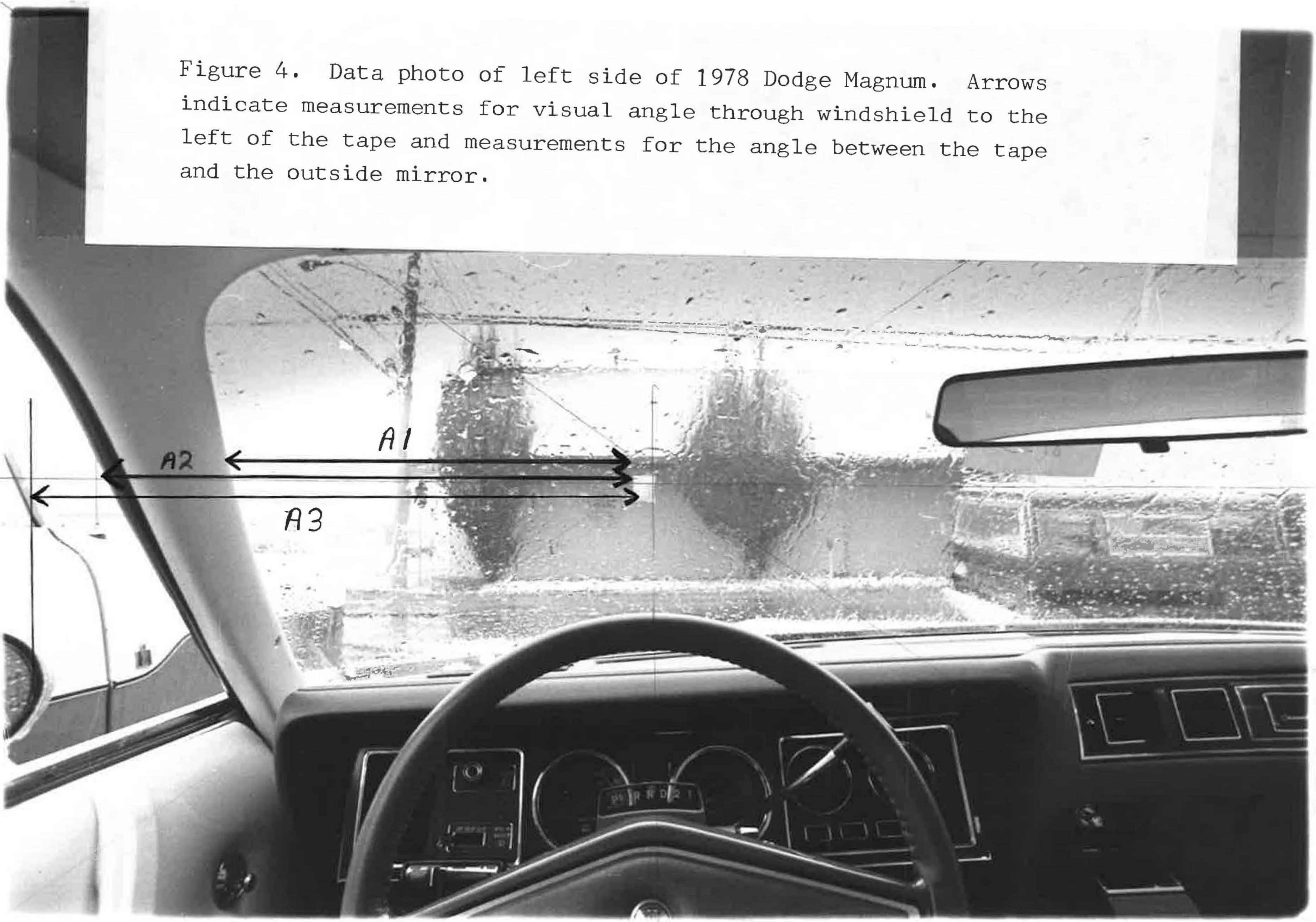


Figure 5. Data photo of right side of 1978 Dodge Magnum. Arrows indicate measurements for angle subtended by inside mirror and the angle of view through the windshield to the right of the tape.

TABLE 1

Measurements of the calibration print for the 17 mm lens. These values represent the degree of distortion in each of four directions from the center of the calibration scale. Print magnification corresponds to a value of 20 centimeters between the 40 degree marks.

DEGREE MARK	DIRECTION FROM CENTER*			
	RIGHT	LEFT	UP	DOWN
5	11.5 mm	11.5mm	12.0mm	11.5 mm
10	22.5	22.5	23.0	22.5
15	34.0	34.0	35.5	34.0
20	45.5	46.0	46.0	46.0
25	57.5	58.0	58.0	58.5
30	70.5	70.5	70.5	70.5
35	84.0	84.5		
40	100	99.5		
45	117	117		

* To nearest .5 millimeter.

TABLE 2

Total horizontal field size and left and right windshield post sizes. Measurements taken at eye level. All values are in degrees.

Dodge Colt	78	9	6
Dodge Aspen	96	8	6
Dodge Magnum	95	8	6
Buick Riviera	99	9	6
Buick Century	89	10	6
Buick Regal	94	8	5
AMC Pacer	94	9	8
AMC Concord	103	8	8
Datsun 510	95	9	6
Datsun 280-Z	85	7	7
Pontiac Sunbird	86	11	6
Pontiac Firebird	97	7	7
Datsun B-210	86	11	4
BMW 2000	86	9	7
Cadillac Fleetw.	96	8	6
Honda Accord	92	11	7
Honda Civic	94	10	8
Ford Mustang II	91	11	5
Ford Granada	96	8	5
Ford Pinto	85	10	6
Ford T-Bird	95	7	4
Ford Fiesta	85	11	7
Saab 99GL	96	8	5
Toyota Corolla	92	11	9
Toyota Corona	80	11	9
Toyota Celica	97	9	7
Opel Isuzu	95	10	6
Plymouth Arrow	95	12	8
Plymouth Horizon	99	11	6
range	78-103	7-12	4-9
mean	92.2	9.4	6.3
S.D.	5.9	1.5	1.3

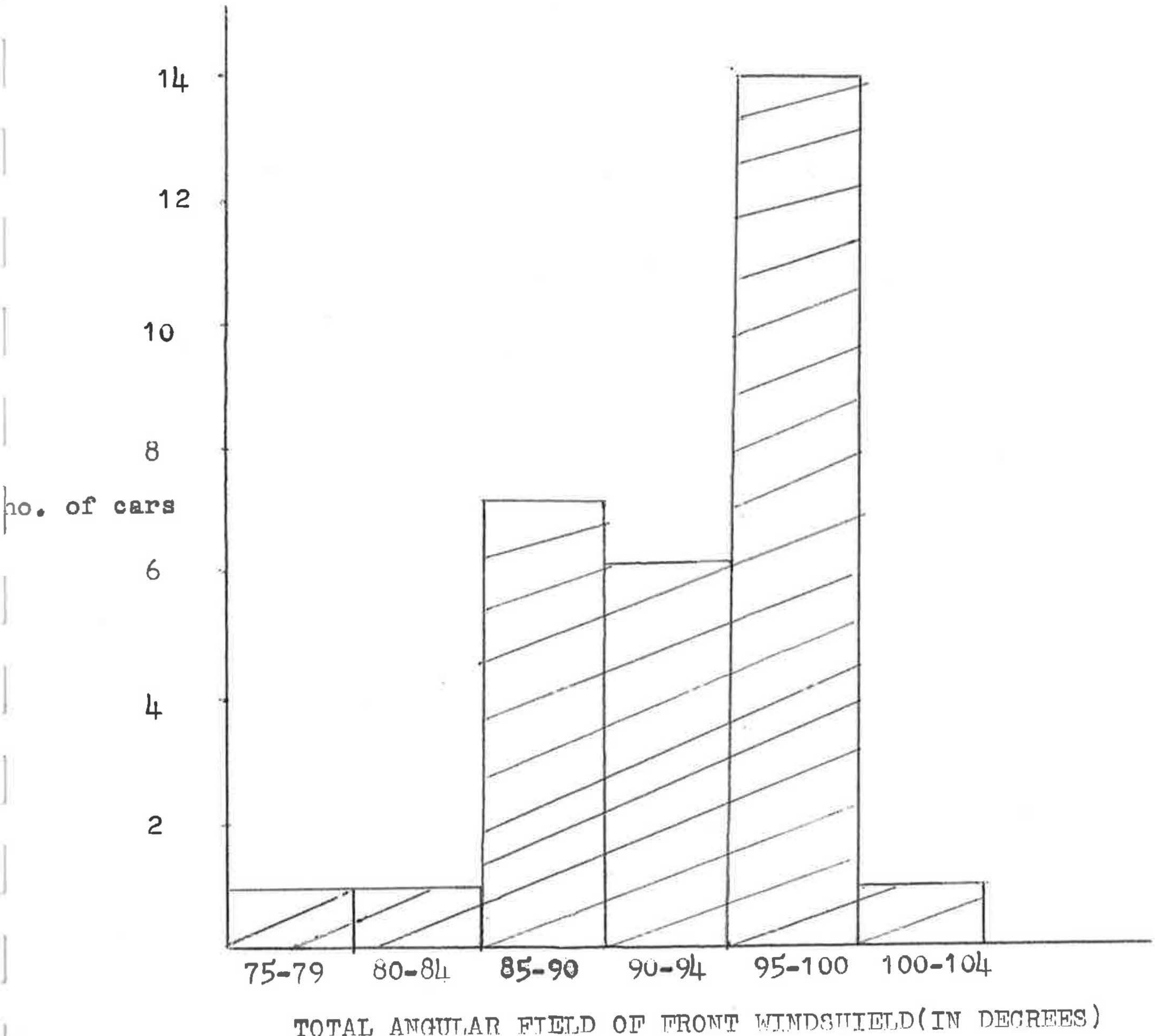
TABLE 3

Vertical and horizontal angular size of inside rearview mirror and the angle between the outside mirror and the driver's vis. axis. All values are in degrees.

CAR	INSIDE M. VERT.	INSIDE M. HORIZ.	ANGLE TO OUTSIDE MIRROR
Dodge Colt	3	20	38
Dodge Aspen	6	29	44
Dodge Magnum	5	28	44
Buick Riviera	5	28	47
Buick Century	6	27	44
Buick Regal	6	25	42
AMC Pacer	5	24	45
AMC Concord	6	31	45
Datsun 510	7	27	41
Pontiac Sunbird	8	24	49
Pontiac Firebird	4	32	46
Datsun B-210	6	29	40
BMW 2000	8	22	46
Cadillac Fleetw.	6	29	41
Honda Accord	8	22	40
Honda Civic	8	27	41
Ford Mustang	6	23	50
Ford Granada	5	22	46
Ford Pinto	8	15	42
Ford T-Bird	5	25	46
Ford Fiesta	7	28	35
Saab 99GL	13	23	40
Toyota Corona	7	32	38
Toyota Corolla	8	17	34
Toyota Celica	8	25	--
Opel Isuzu	8	29	41
Plymouth Arrow	6	24	36
Plymouth Horizon	8	29	41
Datsun 810	6	25	37
Datsun 280-Z	6	19	36
range	3-13	15-32	34-50
mean	6.6	25.3	42.0
S.D.	3.7	4.2	4.5

TABLE 4

Frequency distribution of the total horizontal field through the windshields of 30 1978 model automobiles.



DISCUSSION

To determine the accuracy produced by the photographic method, we constructed a rather crude goniometer. This was placed in the automobile at the position of our standard driver's eyes. A camera tripod was used to hold the instument. Many difficulties were encountered with this method, but the results indicated that the photographic data was accurate to about two or three degrees. A more detailed analysis of this inter-method correlation was not warranted due to the lack of reliability of our goniometer. A more elaborate and expensive goniometer will be needed to validate the photographic method for uses requiring high reliability. At this time, the photo data can be used to compare any two cars in this study, since the known variables were held constant.

Researchers who intend to use our data in the future will encounter a serious problem. There is no easy way to standardize the position of the driver's eyes. We were able to hold this reasonably constant by using the same person and the same posture in each car. Unfortunately, this person will not be available for future research. What is needed is an ariculated mannequin that can be adjusted to assume a standard position behind the wheel of any vehicle. A camera could be built in to the mannequin's head or it could be placed in the car after the proper position has been determined.

We also noticed the fact that the angular size of the inside rearview mirror varies as the mirror orientation (rotation) is changed. In the future, the mirror should be set to a standard position or else actually aimed at the eyes of the driver or mannequin.

Our most valid finding was the measurement of the horizontal visual field through the windshield at eye level. We found that 90% of the cars were between 85 and 100 degrees of visual angle. The average was 92.2 degrees. The narrowest field was found on the Dodge Colt which measured 78 degrees. The AMC Concord was the widest at 103 degrees.

The cars which had the outside mirror placed farthest forward seemed to have the smallest angle between the mirror and the driver's visual axis. This is also related to the position of the seat. A 34 degree angle was the minimum and was found on a

Toyota Corolla. The Ford Mustang II had the largest angle at 50 degrees. Anyone driving a car like that should have the ability to look in two directions at once or should at least have very good peripheral vision. It would seem to be a simple matter to move the mirror farther forward on the car, but this is usually prevented by the windshield pillar or vent windows which would block the view of a mirror placed farther forward.

CONCLUSION

The photographic method of measuring automobile fields of view can be at least as useful as previous methods. It was shown to be quite easy and fast. A more precise check on the accuracy of this method should be made before any attempt is made to combine this data with that from other methods of field measurement.

The major problem we encountered is the same for all methods. That is the lack of lack of standardization which would make comparisons of different cars a valuable technique. Until a standard driver position and standard measuring points are established and agreed upon, workers in the area of automobile fields of view will be considerably handicapped. The second problem in this area is that there are no guidelines by which to judge the relative importance of large or small fields in different parts of the window area. The closest thing to a field comparison that we have today is the data on total glass area that is sometimes published for new cars.

At some time in the future, perhaps the necessary work will be done to standardize automotive field measurements. At that time the photographic method will be quite useful due to its inherent rapidity and ease of use.

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