Visual Efficiency in Monocular Driving

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It is estimated (7) that 2 percent and 5 percent of the drivers on the roads today are effectively monocular. There are at present almost no regulations concerning the safety restrictions, if any, which should be placed upon such drivers. Moreover, those few suggestions which have been made appear at best unsystematic and at worst unrealistic. This is so largely because our understanding of the nature of driving efficiency in general, and of monocular driving efficiency in particular, is very meager. The present paper is directed to this issue.

Psychological and physiological factors are always coordinated in such a manner as to determine the general confidence with which one approaches a physical task such as driving, and, being much more significant than the purely mechanical difficulties involved, the psychological forces largely determine the efficiency of one's performance in relation to safety criteria. The severely handicapped yet mature driver will recognize his unique limitations and act accordingly. The accident prone driver is so prone only because of the psychological meaning which driving has for him, e. g. its very obvious power implications. It is not the eye which perceives, but rather the total integrated self.

The contribution of visual prowess to driving safety has been rather fully documented (2, 3, 7, 8, 9, 10, 11, 13, 14, 15, 27, 28, 30, 33, 35). But the fundamental psychological events seem much less understood (exceptions: (16, 18)). The question of exactly what a driver experiences on the road when handicapped by some physical disability has received perhaps less attention than it ought to. Furthermore, clinical tests of visual efficiency are not always valid measures of actual performance in the field. Consequently, the present study was undertaken for at least two reasons: to familiarize the author with the experience of the monocular driver and with certain of the more significant problems with which he may be confronted; and to develop certain safety procedures which may be of service to a monocular driver in his everyday driving.

● BETWEEN November, 1953 and December, 1954, the author has driven approximately 5,000 miles with one eye occluded, sometimes the right eye and sometimes the left. Most of the critical driving conditions were sampled: city driving (e. g. in New York and Boston), highway driving (e. g. on the Merritt Parkway), short hops and long hauls, daylight, dusk, and late evening drives. No specific attempts were made to change my normal driving habits, so that any changes which were made had to be deliberately introduced in the interest of safety. These changes were thus highlighted, and could be recorded for study and discussion. Except when noted, all observations refer to monocular experiences in the visual fields of both the right and left eyes.

RESULTS

The monocular driver's visual field is illustrated in Figure 1. It is immediately clear that the basic organization of visual space is monocular. Segregation of forms, relative direction and distances, and the externality of objects are all basic aspects of monocular visual experience. The contributions of binocular fusion are generally overemphasized, perhaps because of the recent success of stereoscopic devices, but binocularity adds only a superficial aspect to visual experience. We may call this aspect "solid seeing," the feeling of solidity which objects have, of "thingness," of absolute depth (the etymological meaning of stereopsis), and oppose to it the perception of relative depth which certainly exists in the monocular visual world. Thus, we may more fruitfully break down our discussion into rather specific questions.

1. Are the Loss of Binocular Stereo-Cues and the Contraction of the Visual Field the Only Things Which We Need to Consider in Understanding the Monocular Driver?

The fact (Figure 1) that the lateral and vertical positions of an object remain the same for monocular and binocular drivers is of far greater significance; it is this fact which enables the experienced monocular driver to handle his car in complete safety.

2. What Is the Relative Magnitude and Significance of the Loss of Visual Field?

This varies somewhat with the shape of the face, e.g. the height of the bridge of the nose, but approximates, in general, a shift from about 190 degrees down to about 150

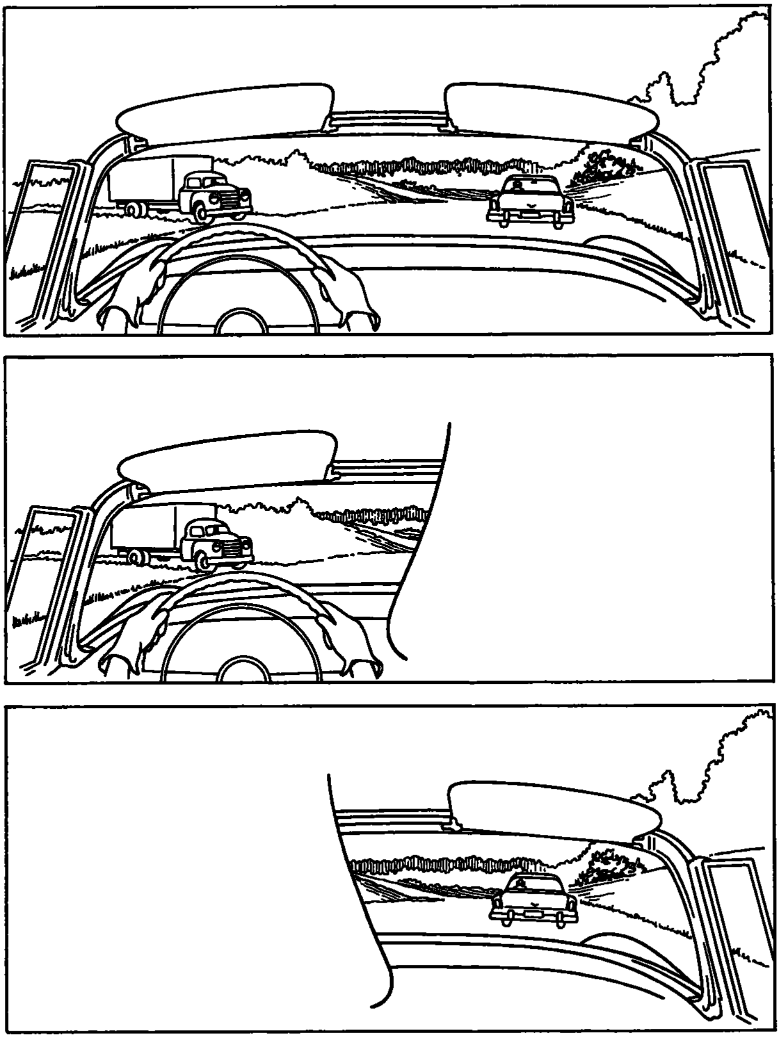

Figure 1. The monocular driver's visual world (A) as seen with the left eye, (B) as seen with the right eye.

degrees. The significance of this may partially be seen in the finding of Fletcher (13) that out of 71 cross-road accidents in monocular drivers, 61 occurred on the side of the defect (see also Figure 1).

3. Does It Make Any Difference Which Eye Is Lost?

There is some evidence (26) p. 447, that loss of the dominant (sighting) eye brings with it a slightly greater spacial disorientation and defect in stereo-acuity than loss of the passive eye, but the present author was unable to conform this. However, a very different asymmetry did arise. If one looks at two lights of different intensities, one in each eye, the resulting impression of brightness contrast of the image fused in the brain will be somewhere between that of the two lights when viewed separately (the so-called Fechner effect). Now we make a distinction between two kinds of blindness: one in which the patient is conscious, i. e. sees a blackness or scintillating greyness before the blind eye (positive blindness); and one in which the patient sees nothing at all before the blind eye (negative blindness). The former is the type of blindness which results from monocular occlusion, as in the present study, and from peripheral eye injuries; the latter more probably results from damage to the optic nerve or to the brain itself (a less common cause of monocular vision). Thus, in any case of positive blindness, the interference of the grey visual field before the blind eye with that visual field before the good eye (by decreasing the contrast) would be particularly annoying in recent blindness and in those patients with intact retinas where the complete dominance of the seeing eye is still challenged (21). In fact, the author observed that when his dominant eye (right) was occluded, the blind field might not only fuse with and lower the contrast of the normal field (left eye), but it might entirely suppress it, leaving him momentarily totally "blind." However, whereas the shielded eye may dominate throughout the short period of the experiment in the case of occluded binocular subjects, in long-term monocular subjects the good eye will eventually become dominant and the Fechner effect cease (24) p. 399.

If one's left eye is good and one's right eye is blind (Figure 1A): one may feel confident in passing cars on one's left, e. g. those going in the other direction from oneself on a two-lane road, but only under extreme circumstances, e. g. a stalled or parked vehicle, should one pass a car on one's right, for one simply cannot see it. When driving on a dual highway, it is a continual strain to drive in the left lane, for the position of all the cars one is passing on one's right, or which may pass you on that side when your lane becomes jammed up, must remain ambiguous and serve as a constant source of serious concern. The author has repeatedly found it intolerable to drive in this manner for more than a few minutes; in cities it is especially disconcerting, because one is, in effect, always doing just this. This is almost certainly the greatest single danger in city driving for the monocular driver. And, although the monocular's confidence in the other driver's ability to stay neatly within his own lane may well increase with time, and the tension thereby abate, nevertheless the danger does not. Moreover, parking for such a driver is a particular chore, although not nearly as dangerous because of the slow speed at which one is moving.

It is interesting to note, and in accord with well understood psychological mechanisms, that the apparent significance of having cars pass one on one's blind side, where the leading role of responsibility is taken by the other driver, is much less than when you yourself assume this responsibility by initiating and carrying through the act of passing. Moreover, the large number of accidents which occur on the right side due to faulty timing when cutting back into lane (15) attests to the obvious inadequacy of the perception of this responsibility even in binocular drivers. This suggests that one perhaps takes on a greater psychological responsibility in driving when blind in the right eye than when blind in the left (reversed, of course, in England). This is clearly a point for further study.

If one's right eye is good and one's left eye is blind (Figure 1B): one may confidently pass cars going in the same direction as you are, because you pass them on your right and they can be kept constantly in view. However, this is quite dangerous when it is possible that other cars may be approaching, e. g. on a two or three-lane road, because such vehicles approach close on one's left and cannot be seen unless you turn your glance away from the car you are trying to pass. Similarly, of course, starting up from the curb is a very special problem, and the danger is quite real because one is blindly entering a fast-moving lane.

4. Does the Monocular Driver Have Specific Problems in Daylight Driving?

The crucial visual cue of monocular daylight driving is the surface gradient. This is also true of the pilot, and of binocular vision in general when the significant objects lie beyond the range of binocular vision (say, roughly, 700 feet). Surfaces, e.g. icy road-beds, rear-ends of trucks, soft shoulders, are perceived when patterns of shadow and color are perceived. Disorientation of skiers, pilots and others in very thick snowstorms, and of automobile drivers particularly in fog, is notoriously a function of their having no real visual surfaces with which to orient themselves.

Thus, the depth of orientation of a daytime monocular driver may be helped, as in the author's experience, by attention to these surface gradients. The issue in such orientation is not so much how far away is the object, say a truck, but rather where am I with respect to it. One is always located at the beginning of a surface gradient. Nearby, the texture of the road, the blades of grass, the telephone poles, fenceposts, etc., are all clearest, most individualized, most separate. At the horizon, or the most distant point towards which one is steering, all these textural qualities vanish — one can no longer distinguish the different patterns on the road or in the neighboring terrain. An object thus takes its egocentric position (i.e. position with respect to the self) from the fact that it overlies and occludes a certain region of this gradient. The farther one is from the object, the less discreet are the aspects of the surrounding surface texture.

A second cue which the monocular driver may use in daylight driving is that of linear perspective. Consider the situation when there are two guide lines on the road, one on the right side as well as the usual one on the left. The self is again at the beginning of the convergence of these lines (e.g. the edges of the road in Figure 1). The point of aim is the convergent point of the pattern, and the egocentric position of an object is given by its juxtaposition to a specific region of the converging lines. It was the author's experience that his efficiency in steering was markedly increased when two such lines were available. In fact, a short vertical rod attached to the hood or fender of the car directly in front of the driver would serve a very similar function, when the line on the right side is missing, by giving the driver a second reference with which to orient himself. Such an orientation becomes necessary when the contour between the edge of the road and the shoulder is not sharp, in which case although the lateral position of the edge is seen exactly as in the binocular driver, its actual distance from the driver tends to be ambiguous. Such guide lines are thus to be particularly recommended in the case of monocular drivers, because of their aid in distance orientation and their contribution to steering efficiency.

Another perspective cue is the perspective of motion (17, 18). As one approaches an object it appears to grow in size, and the rate of this expansion increases as one gets nearer to it. Furthermore, one seems to move past nearby objects at extraordinary visual speeds in comparison to the rate at which one seems to approach these objects from a distance. Brown has found that visual velocity is a function of the rate of change of relative contours, and such changes are always greatest for nearby objects. Thus the same physical velocity seems faster along a straight and narrow city street than along a similar open road across a plain. Brown has also shown that the apparent velocity of an object varies inversely with its distance from the observer, in exact accord with the present author's qualitative experience. This phenomena may be a source of fright or uneasiness until one recognizes it as a manifestation of the generally inefficient monocular depth localization. For example, in the complex case of an approaching vehicle, the true speed of its appraoch may not be realized until it is superimposed, because of the increasing angle at which it appears, on the commonplace stationary environment of streets and scenes which then serve as visual frames of reference. Of course, the distance at which such a superimposition is possible depends on how far to the right or to the left the approaching vehicle is. If it is approaching at right angles to the road, as at an intersection, then the distance is at its maximum; if it is approaching parallel along a two-lane road, then this distance is at a minimum. Thus, motion perspective is more commonly recognized with respect to objects moving past one at some large angle, e.g. the truck in Figure 1, than for objects which are coming directly along one's path of motion at some very small angle, e.g. the car in Figure 1. But the point of aim, i.e. the point towards which one steers does not expand, it remains visually fixed. Attention to this center and the surrounding patterns of motion may help to localize oneself both in depth and in lateral position, by clarifying one's direction from and one's rate of approach to any momentary steering goal.

However, there is an inherent danger in the excessive use of this cue. If one attends exclusively to the unexpanding point of aim, i. e. the steering goal, one may become fascinated by the rushing motion of irregular patterns and gradients on the side, somewhat like when one stares into a waterfall or a fire and finds it hard to turn away. Clark et al (p. 1) state: "Fascination appears to be fundamentally a matter of heightened attention, but some experiences also included compulsive types of the behavior and blocking." It is not simply the monotony of the road which encourages fascination, but many more complex factors. The author, for example, not unlike some of Clark's subjects, has often found himself fixating on the rear of a car and attempting to keep it symmetrically centered in his field of view, until suddenly he was too close to the car and had to apply his brakes abruptly. Furthermore, it is likely that the monocular driver may be seeking even greater reassuring anonymity in the use of his car than the driving situation usually entails, and thus may tend to fixate more rigidly such significant steering cues as the car in front, or some other point of aim.

Happily, of course, these patterns generally shift and flex with the changing patterns of the terrain, with the road population, the illumination, and so on; but then their efficient use as driving guides requires alertness and constant attention. The apparent complexity of the motion perspective cues may be somewhat reduced with the help of motion parallax. When two objects appear at equal distance, and if it is important to know whether or not this is actually true, one can move one's head from side to side a few times, and the nearer object will seem to move laterally much more so than the farther object.

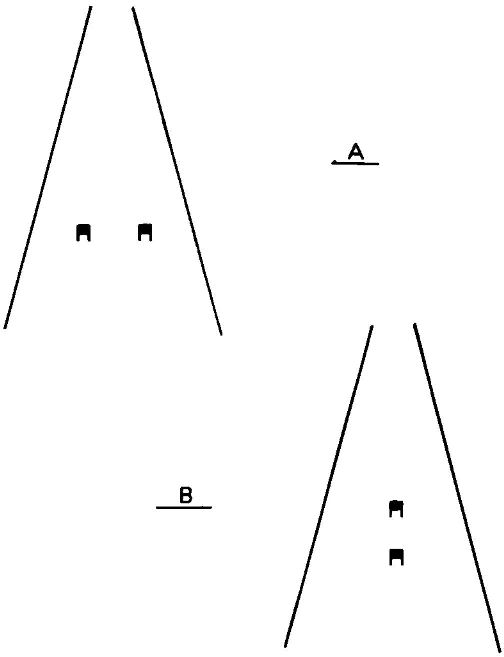

Figure 2. The effect of height on apparent distance.

A second type of motion parrallax requires careful attention to the rate of change of angles in the monocular visual field. Since the self is at the bottom of the visual field (e. g. at the origin of all the gradients), all real objects between the self and the horizon lie at different apparent heights. Different horizontal distances are, by linear projection, equivalent to different heights. For example: as a car approaches, it can be seen to move downwards if one attends to the changing angle between the edge of one's own car and that of the approaching vehicle. Essentially, one projects the two moving objects onto a stationary ground, e. g. the highway, and then uses the changing size of this ground between these two objects as a clue to changing distance. Similarly, if there are two or more objects involved, comparisons between the various changing angles and their respective rates of change will immediately establish a confident egocentric localization. Although this is a highly intellectualized cue, and requires real practice in daylight driving, it is much easier for the monocular driver to learn than for the binocular driver, because the convergence function in the binocular will operate against it. The present author has found this to be one of the most significant aids for steering efficiency. It is particularly important when following another car in one's own lane. In this latter instance, one may exaggerate the parallax by following the car somewhat asymmetrically, so that as the distance between oneself and the car changes, not only does a change in height appear, but also a change in lateral position.

5. Does the Monocular Driver Have Specific Problems in Night Driving?

As we have noted, under daylight conditions, it requires an overt intellectual effort to perceive height changes as distance changes, but under night levels of illumination this becomes the rule. What is lost under low illumination is most of the perspective information from gradients and motion patterns. At night one steers primarily by alignment and not by aim; and the interpretation of depth changes as height changes occurs almost too easily. In Figure 2 we represent the illusion, which may occur with varying degrees of realism, of the road seeming to stand almost vertically somewhere in front of the driver; it seems to proceed from the bottom of the perspective field, i. e from the driver, its origin, up to the top of the perspective field, i. e. to its vanishing point or point of aim. Thus (Figure 2A) we see that the horizontal displacement of two objects gives no information whatsoever as to the relative distances of these objects. However (as in Figure 2B), the vertical displacement of the two objects in the perspective field gives compelling information as to their relative distances. In general, this cue may be quite helpful (as noted above), but sometimes it is a source of disturbance. For example: the high lights of a nearby truck will appear farther away than the low lights of a more distant car; the high traffic lights which appear over the tops of vehicles will seem further away than the low vehicles which, for example, may actually be stopped at these lights; it has happened to the present author that light reflections at various heights in the windshield were projected out into space and seen as real objects at various heights, and so distances, with respect to the actual headlights or taillights which were causing these reflections in the first place. In view of these illusions, it may be advantageous to standardize the heights of taillights, headlights, street lamps, and traffic signals, so as to reduce the need for guessing just what and where they are.

Another crucial problem in night driving is glare. Glare factors are clearly magnified in monocular driving (1). The obvious reason seems to hold: with a decreased visual field a glare source of a given size, once seen, will quite simply dominate a greater percentage of that field. And the common techniques for amelioration, such as blinking, turning one's head, shielding one's eyes, and so on, seem only to add to the danger. Any interference with the vision in the remaining eye will be of extreme harm. It is not really important (7, 8, 9) whether the monocular retina is more sensitive to glare than the binocular retina, the issue is whether or not glare is psychologically more traumatic to the monocular individual considered as a whole. It has been the author's experience that this is so. It is not unlikely that part of this increase sensitivity to glare is due to a slight pupillary dilation in the functioning eye, caused by reflex response to the dark field (positive blindness) before the occluded eye (20); although it may well be that this reflex will fade and gradually cease to operate at all in long-term monoculars. However, regardless of the cause, the overwhelming significance of glare was one of the most important determining factors of the author's monocular driving habits. It was simply impossible, on a two-lane road, to continue driving in the face of a car using its high beams. Particularly annoying was the continual glare from city street lights, e. g. in Times Square, New York, or from headlights in heavy evening traffic. Indeed, in the author's opinion, these conditions represent the only driving situation where one must very seriously caution the monocular driver.

Probably related to this are the problems of the absolute visual threshold (the smallest intensity of light which is just visible) and of dark adaptation (the gradual increase in the light sensitivity of the eye in the dark). For example, in shifting his gaze from the bright dials (inside) back to the dark road (outside), the author has felt the need for a short period of adaptation. This observation may be of importance in view of the experimental finding of Cook (5) p. 69, that if both eyes of a binocular observer were dark adapted, the binocular light threshold is about one-half the monocular threshold. This, of course, may not hold for negative monocular blindness (see above, No. 2), and we are certainly not fully justified in extrapolating (as DeSilva does) to all long-term monoculars with either positive or negative blindness. However, until we have dark adaptation curves available on these latter subjects we are forced to fall back on this type of work for confirmation of findings from the road.

6. Is the Monocular Driver Particularly Subject to Visual Illusions?

Directly related to the loss of confident distance perception for nearby objects is the greater prevalence of visual illusions. One of the most important of these is the tendency of monoculars to underestimate distances. For example, Guilfoyle states (p. 432): "The ground seems invariably nearer to me than it really was" so that to land correctly after my accident I had to learn to fly ". . . straight into the ground" (23, 25, 26, 32). Similarly, although the underestimation of distances is seldom as dangerous in the driver as in the pilot, the present author has often slowed down much sooner than necessary, or stopped quite far from a light, or followed a leading car in traffic at far greater distances than was usual for him.

Other illusions, however, are more startling. The road, for example, may seem to be coming up at one instead of lying flat; it tilts up to the edge of the hood or steering wheel. This occurs in a compelling manner in spite of the usual tendency for a monocularly viewed plane to rise up gradually to eye level in the distance (Figure 2).

The cross-lines may grow markedly in size as they approach, especially if one is driving too fast (6). The guide lines at the edge of the road may appear to converge towards one (in contrast to the operation of perspective) and, with the center line, to "rush" up to one's face.

When one stops suddenly as for a light, after staring for some time at the rapidly approaching road, stationary objects such as houses, trees, or hillsides, may seem to move away from one, just as the sides of a waterfall seem to go up as the water comes down — an after-image of motion (22). If one looks too long out of the side of the car, the landscape may seem to be moving while one is standing still. Under such conditions, a driver may become lax in his awareness of his own responsibility for all the motion which is actually present in the field, because it is now somehow visually located outside of himself.

These illusions are harmful because they increase the discrepancy between the driver's interpretation of the road and the actual road conditions, and thus prevent him from correctly anticipating succeeding events. However, if one can anticipate such illusions, their occurrence need not be upsetting. They occur most frequently in early dawn, at twilight, when one is tired, or when one has been driving for a long time. When they appear, simply slow down and relax your eyes. Constantly shift your glance over the road, do not fixate any given object or pattern longer than necessary, watch the car in front, read its plate number, glance at the cars approaching, take notice of the makes of the car or of the number of passengers, glance back to the first car, look into rearview mirror, check the road in the distance, and so forth.

7. Are the Posted Speed Limits Safe for Monocular Drivers?

A monocular driver may be said to be moving psychologically faster than a binocular driver going at the same physical speed. This is particularly important if it can be shown, as the author felt, that monocular visual reaction times are longer than the equivalent binocular reaction times. For example, Poffenberger has shown (although for only three observers) that finger response time to visual stimuli is approximately 0.015 seconds faster for binoculars than for monoculars. More recently, Richmond and Ebert have concluded on a large sample (using flashing visual acuity targets) that "form speed perception for both eyes is twice that of monocular vision" (31) p. 151. In addition, we may call attention to Teichner's recent conclusion on the simple reaction time (34) p. 141: "For visual . . . RT's (reaction times) the greater the extent of the stimulus in space," i. e. the greater the number of receptors stimulated," the faster the speed of reaction up to some limit"

8. Is There Any Special Danger from Windshield Defects?

Obstructions on the windshields are quite hazardous, because they contract the monocular visual field even more. The increasingly popular practice of placing state tax stamps, inspection stickers, tourist labels and the like, on the front windshield is to be deplored. Even the operation of the windshield wipers may be disturbing; the author has had to slow down whenever he tested their use, with or without additional hazard of actual rain.

9. Are Special Mirrors a Solution?

Individually designed wide-angle, one-piece, rear-view mirrors may be of some help in broadening the field of view. This is particularly so, because, as the mirrors are now conventionally placed, neither the inside mirror nor the outside mirror (depending upon which mirror is on the same side as the blind eye) may be seen without turning one's head from the road. Thus, simply a slight shift in the position of these mirrors may help. The author has also found that a standard central mirror with two independently rotatable side wings is of definite value, although its proper use entails much more practice than a single wide mirror.

GENERAL SUMMARY

There is nothing in the author's experience which would warrant the denial of a license simply on the basis of monocularity. The suggestion (2, 30, 33) that we wait approximately a full year before we permit monocular driving to be attempted is entirely too severe even in the case of professional drivers. A month or two at most would be adequate in general, with some driver's needing much less. The significance of monocular blindness, as of all physical deficiencies, varies enormously with the individual. The phenomenological importance of the physical limitation, being a function of its visibility to others, its psychological penetration into the personality core (particularly impressive in those patients who have not even realized that they are effectively monocular), and many other complex psychological factors, will almost exclusively determine the subject's behavior in situations relative to the handicap. The purely physical limitations are secondary. For example, for some patients a slight dimming of vision may be psychologically more disastrous than total monocular blindness, particularly if it is associated with an obvious facial disfigurement. Such a person may be more cautious in driving, although less necessary, than some patients with only one eye, for whom greater caution is imperative. Thus, no recommendations, such as speed limitations and night-driving restrictions, can be made to any patient without first taking the personal meaning of the physical limitation into consideration. In view of my own experience, I simply cannot be as generally pessimistic as others have been on this issue. Monocular driving did not seem to be particularly hazardous after a few days of practice. It is quite possible that those of us who have never tried monocular driving have thereby built up a certain awe of it which is not really justified, nor shared by those who do so regularly.

Recommendations: (1) An approximate 20/20 correction in the good eye, with strictly enforced insistence that the glasses be worn. If the patient cannot be corrected to about 20/20, the granting of a license will be particularly hazardous unless there are very favorable extenuating circumstances (28). (2) No constriction at all in the visual field of the good eye (also recommended by Black). (3) No other physical handicaps of safety significance, such as slow reaction times, loss of limbs, or seriously impaired hearing. (4) It may be of value to have a pamphlet on hand at licensing bureaus, to be freely distributed to monocular drivers, which includes a general discussion of certain of their special driving problems and makes suggestions as to particular safety procedures which they may follow.

References

1. Albers, E.C. and Sheard, C., The Tolerance of Light in Nonphotophobic Individuals. Amer. J. Ophthal., 1936, 19: 407-412.

2. Black, S., An Approach to Road Accidents from the Visual Aspect. Optician, 1953, 125: 455-460 and 464.

3. Brody, L., Personal Factors in Safe Operation of Motor Vehicles. N.Y. Univ. Center for Safety (as cited in Darcus, n.v.), 1941.

4. Clark, B., Nicholson, M.A. and Graybiel, A., Fascination: A Cause of Pilot

Error. U.S.N. Sch. Aviat. Med. Res. Rep. 1953, Proj. No. NM001-059.01.35.
5. Cook, T.W., Binocular and Monocular Relation in Foveal Dark Adaptation. Psychol. Monog. 1934, 45(3): 1-86.
6. Dallenbach, K.M., The Elastic Effect: An Optical Illusion of Expansion. Amer. J. Psychol. 1953, 66: 634-636.
7. Darcus, H.D., Faulty Vision and the Driver. Traffic Quart. 1953, 7(2): 198-211.
8. DeSilva, H.R., Frisbee, W.H., and Robinson, P., One-Eyed Drivers. Sight-Saving Review, 1938, 8: 174-183.
9. DeSilva, H.R., Robinson, P. and Forbes, T.W., Some Psychological Factors in Accident-Repeater Drivers. J. Abnorm. Soc. Psychol. 1939, 34: 124-128.
10. Duke-Elder, S., Neeley, J.C. and Riddell, W.J.B., Symposium: Visual Requirements in Relation to Modern Travel. Tr. Ophthal. Soc. U. Kingdom. 1953, 73: 287-
11. Eno, Personal Characteristics of Traffic-Accident Repeaters. Eno Foundation of Highway Traffic Control, Saugatuck, Conn., 1948, (as cited in Darcus, n.v.).
12. Fechner, C.T., Ueber einige Verhaltnis des binokularen Sehens, Abh. math. -phys. Kl. kgl. Sächs, Ges. Wiss. 1861, 5: 416-, n.v.
13. Fletcher, E.D., Visual Problems in Motor Vehicle Operation. Optom. Ext. Prog. (Calif.) 1948, 2: 17-21 and 23-27.
14. Fletcher, E.D., Motorist's Vision: Finding in Visual Acuity Studies. Optom. Ext. Prog. (Calif.), 1953, 6(1): Chap. 5.
15. Fletcher, E.D., Motorist's Vision. Optom. Ext. Prog. (Calif.), 1954, 6(4): 21-28 (Appendix).
16. Garrett, J.F. (ed). Psychological Aspects of Physical Disability. Washington, D.C.: U.S. Goverment Printing Office, for the Dept. of Health, Education, and Welfare, 1953.
17. Gibson, J.J., The Perception of the Visual World. New York: Houghton Mifflin Co., 1950.
18. Gibson, J.J. and Crooks, L.E., A Theoretical Field-Analysis of Automobile Driving. Amer. J. Psychol. 1938, 51: 453-471.
19. Guilfoyle, W.J.Y., Experiences of a Uniocular Pilot of Aircraft. Tr. Ophthal. Soc. U. Kingdom. 1938, 57: 431-433.
20. Horowitz, M.W., An Analysis of the Superiority of Binocular over Monocular Visual Acuity. J. Exp. Psychol. 1949, 39: 581-596.
21. Hughes, H., An Investigation of Ocular Dominancy. Brit. J. Physiol. Optics. 1953, 10: 119-143.
22. James, W., The Principles of Psychology. New York: H. Holt and Company, 1905.
23. Jongbloed, J., Landing Carried Out by an Experienced Aviator with the Use of One Eye Only. Acta Brevia Neerl. Physiol. 1935, 5: 123-125.
24. Judd, C.H., Records of Convergence and Divergence. Psychol. Rev. (Monogr. Suppl.) 1907, 8(34): 370-423.
25. Kyrieleis, W., Einaeugige als Fluzeugfeuhrer. Mitt. a.d. Geb. d. Luftfahrt-Medizin. 1942 3: n.v.
26. Livingston, P.C., Debatable Ground in the Matter of the Monocular and Uniocular Pilot of Aircraft. Tr. Ophth. Soc. U. Kingdom. 1938, 57-434-447.
27. Mason, P.E., Minimum Visual Requirements for Safe Driving. J. Missouri State Med. Assoc. 1935, 32: 367-, n.v.
28. Mindt, W., Vision and Road Safety. Optician, 1954, 128: 455-458.
29. Poffenberger, A.T., Reaction Time to Retinal Stimulation, with special reference to the time lost in conduction through nerve centers. Arch. Psychol. 1912, No. 23: 1-73.
30. Raski, K., On the Visual Faculty Required for Driving Licenses. Acta Ophthal. 1953, 31: 521.
31. Richmond, P. and Ebert, E.C., Speed of Visual Perception. U.S.N. Med. Bull. 1933, 31: 150-151.
32. Rose, H.W., Monocular Depth Perception in Flying. J. Aviat. Med. 1952, 23: 242-245.

33. Schwartz, F., Der Einäugige als Motorfahreugfuhrer Schweiz. Med Wchr. 1939, 69: 1145-1147.
34. Teichner, W. H., Recent Studies of Simple Reaction Time. Psychol. Bull. 1954, 51: 128-149.
35. Viteles, M. S., Visual Standards and Flight Performance. J. Aviat. Med. 1947, 18: 528-547.