FILTER STUDY OF THE EFFECT OF CERTAIN TRANSMISSION FILTERS ON VISUAL ACUITY WITH AND WITHOUT GLARE

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SYNOPSIS

Practically every state in the Union has some legal standard of visual acuity for pilots, railway engineers, street-car operators, bus and commercial vehicle operators, as well as lay drivers. It is assumed that superior vision is a factor in safe driving and every effort has been made to increase the size of signs, improve legibility, and otherwise make it easy for one to observe accurately. It is axiomatic that anything which interferes with clear vision will increase the hazards of driving, particularly at night when illumination at best is inadequate.

Glare or extraneous light falling into the eyes of a driver will reduce his visual efficiency. Even turning on the dome-light will greatly confuse a driver and cause him to lose his orientation with respect to movement of his car. The high beams of an oncoming car are alleged to be particularly detrimental to vision. Experimentally this deleterious effect on semi-scotopic vision has been shown to bear a certain relationship up to about the equivalent of 1.25 foot candles of light at the eye after which no great objective effect is to be noted until the amount of light is doubled. In other words, part of this effect seems imaginary and mostly subjective. Some drivers can stand much more light than they care to stand without evidence of deterioration in visual acuity and consequent visual efficiency.

Various methods have been suggested to reduce glare, notably the use of Polaroid. But automotive industry does not seem ready to accept this solution. A few enthusiasts have proposed and actually marketed types of glass which they claim will increase visual acuity at night. The larger companies have not shared this enthusiasm, which is contrary to all the evidence concerning effective vision.

This study is based upon an experiment in which 44 varieties of glass, ranging in color from violet to deep red and having transmission coefficients of visible light from .05+ to .86+

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percent, were measured to secure a representative set of 20 filters for design of an experiment to determine the effect of filters on visual acuity throughout the spectral range. In all cases there was a decrement in visual acuity with the introduction of a filter, regardless of color or wave length of the type used. Although some colors reduced glare, they also reduced visual acuity to the same degree. At no point in the spectral range was any significant difference found. Hence, in light of present knowledge it is concluded that any media introduced between the eye and a stimulus object or situation on the roadway as a means of reducing glare is not to be recommended for night-time or any other condition which lowers acuity when maximum visual efficiency is desired.

In recent years there have been numerous theories advanced concerning the effect of certain wave-band filters on visual acuity. Most research workers in the field do not accept the general hypothesis that it is possible to cut out light and yet retain acuity. However, it is possible that when facing a strong luminant, glare effect for certain individuals may be reduced more than acuity by filters. The loss due to glare might conceivably be greater than the loss due to the filter, thus creating a net gain in seeing efficiency.

Before this problem may be attacked directly, it is necessary to determine the relationship between acuity decrements and the density of interposed filters of known characteristics.

In a pilot study of this nature by Lauer, Fletcher, and Winston (1949), it was found that the objective measurements of acuity, with and without filters, showed only losses, both with and without opposing light. In the experiments only three lenses were used, having transmission factors of 57.9, 60.2 and 86.3. Fourteen subjects in all were used, each being partly dark adapted as expected of a driver meeting cars at night.

An attempt was made in the present experiment to extend the previous study by using more subjects, a wider range of filters, more rigid controls, and typical transmission filters throughout the spectral range of visible light.

Method and Procedure

The design of the experiment was primarily functional in nature and was set up to determine what relationship, if any, exists between the loss in acuity and density of filters and whether a differential effect may be produced between various wave-length ranges of the visible spectrum. The main hypothesis: Vision is proportionally decreased by the interposition of any type of filter according to its transmission factor of visible light. Corollary hypothesis: Visual acuity is proportionally reduced under normal conditions of seeing when a filter is placed before the eyes.

From a set of 44 available filter samples, 20 were selected according to color, percentage of light transmission, and difference in characteristic wave length to provide an adequate range of test filters. The characteristics of all the filters were not known at the time of the experiment although curves on several given by Lauer, Fletcher, and Winston were available.

Due to imperfections, one of the filters, made of plastic, proved to be very inefficient under conditions of opposing light. This filter was not considered in the final calculations.

Eleven subjects of near-normal vision were selected, and 15 separate sets of observations made, using one eye at a time. The vision of all subjects was accurately measured by the Clason acuity meter and corrections made to equate what differences may have existed before treatment of the data.

The test filters were presented in random order, so far as color and transmission coefficients were concerned. Only persons having 70 percent vision, or above, in one, or both eyes, were used in the experiment. Acuity of each eye was determined by standard methods. Half the measurements were run with the opposing light condition first, and half were run with the normal condition of vision being measured first.

An average of three readings was calculated for each setting of the acuity meter, and the mean was entered as the measure. The readings were divided by the subject's normal acuity to correct for individual ocular differences.

The order of stimulus presentation was controlled by systematic rotation to offset fatigue and practice effects.

The subjects ranged in age from 12 to 53, and all measurements were made with monocular vision to control the angular effect of the opposing light, arbitrarily set at 4 degrees declination from the optical axis of the eye. (It was established by Lauer and Silver [1945] that this angle is near the critical point when meeting a car on the roadway.) The eyes were light-adapted at approximately 8-15 foot candles of daylight illumination in this series of observations, although the observer was looking into a dark tunnel while making the determinations.

Apparatus

The measurements were made in the driving laboratory at Iowa State College, using the specially-designed darkened booth described by Lauer and Silver (1941). A Clason acuity meter was used to make all the measurements, since the test image can be gradually enlarged to the point of threshold discrimination with a reasonable degree of accuracy. Four trials were made for each separate measurement in order to obtain a more stable index of acuity. The measurements given have a reliability of approximately +.94. A Ferree and Rand acuity meter was used as the opposing light source and was set to give approximately 1-2 foot candles of light at the eye. The aperture was restricted to give a narrow beam of light. The filters had been carefully tested by means of a specially designed apparatus using a Weston photronic cell with Viscor filter, which passes only visible light.

Treatment of Results

In order to determine the effect of decreased light transmission on acuity levels, the means of all subjects for each filter were computed and plotted against the transmission coefficients shown on the X-axis of the graph (See Fig. 1.) This was done for both the normal condition and with opposing light. The curves show a non-linear relationship and a distinct difference with and without the opposing light. The total decrease in acuity was approximately 14 percent at the upper range of filter transmission for normal vision and 27 percent with the glare source of

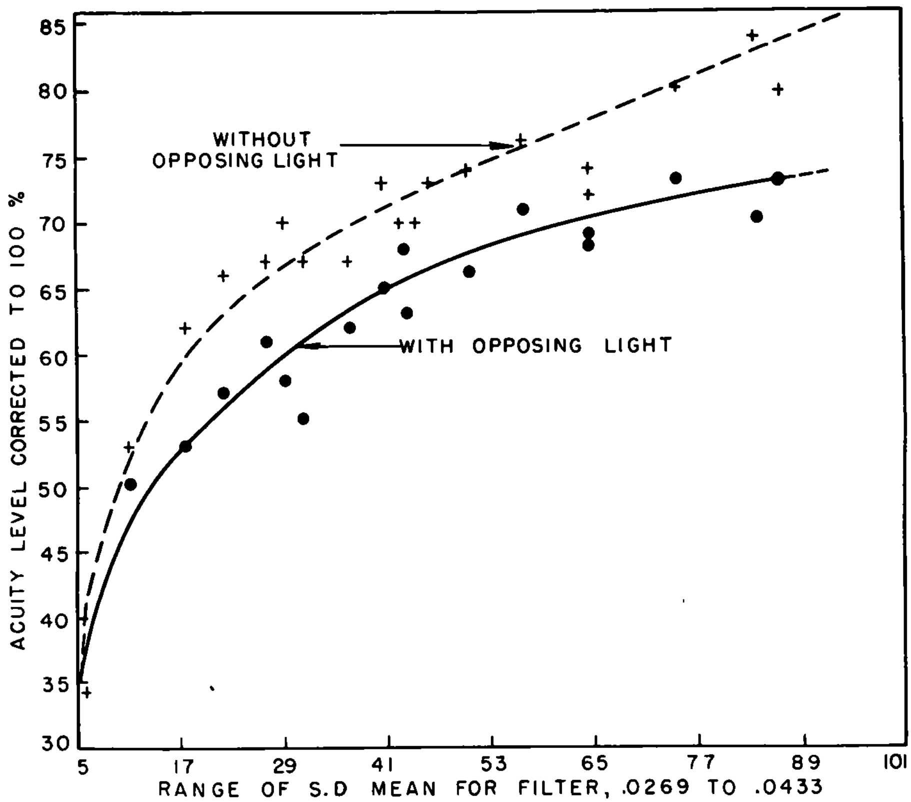

Figure 1. Percent Transmission of Filters

interference. At the lower range there was a general drop of about 65 percent with little differentiation between the two conditions set up.

After this curve was constructed it was used to set up the expected values of filter interference in order to make comparison of bands of wave-length transmission grouped according to qualitative classifications: neutral colors, violet, blue, green, yellow and orange, and red.

The ratio of expected to observed values for each filter was calculated and averaged for each group of filters, both with and without glare source. These data are shown in Tables 1 and 2. Statistical differences could not be shown between the different bands of wave lengths. Although there was an insufficient number of cases to show differences, no obvious irregularity occurred, with the exception of the green band which seems to give lower readings under both conditions, indicating somewhat poorer characteristics as a filter to be used before the eyes in low illumination.

Results and Conclusions

A study of 20 filters, representing as many specific wave bands throughout the visible spectrum, was made to determine the relationship between the filter-transmission factor and visual acuity in low illumination with the test object viewed through the filter. Fifteen sets of measurements were made of visual acuity under normal conditions, and

Table 1

Relation Between Wave Band of Filters and Visual Acuity
No Opposing Light

Spectral Groups	Filter Number	Trans-mission Factor	Acuity Actual	Acuity Expected	Ratio of Actual to Expected	Ratio[1] of Actual to Expected by Spectral Groups
	1	.222	.66	.630	1.05	
Neutral	13	.437	.70	.722	0.97	
	9	.457	.73	.725	1.05	1.020
	10	.177	.62	.600	1.04	
Purple	8	.271	.67	.660	1.02	1.030
	17	.059	.34	.350	0.97	
	2	.110	.53	.523	1.01	
Blue	5	.408	.73	.712	1.02	
	36	.572	.75	.762	0.99	0.998
	20	.309	.67	.680	0.98	
Green	3	.649	.74	.778	0.95	
	30	.506	.74	.740	1.00	0.976
	31	.644	.72	.775	0.92	
Yellow-	38	.751	.80	.800	1.00	
Orange	44	.863	.80	.821	0.97	0.963
	6	.366	.67	.700	0.96	
	21	.290	.70	.666	1.05	
Red	34	.436	.70	.724	0.97	
	40	.847	.84	.820	1.02	1.000

1. Need be 1.00 + or - .08-.10 to be significant.

fifteen were made with opposing light or glare source, for a total of 600 separate observations. Each observation was a mean of from 3-5 trials. The results from 19 filters, or 570 observations, were used as the basis of calculation to obtain the conclusions:

1. The relationship between acuity and filter transmission factor used is not linear but follows a curve of the general form

$$y = be^{+ax}.$$

2. The over-all average loss of 9.83 percent was noted with 1-2 foot candles impinging upon the light-adapted eye looking into a dark chamber. The absolute loss at the upper range was appreciably higher but bears a definite relationship throughout the range.

3. From preliminary analysis of the data there seems to be no spectral range giving significantly different results, unless it should be in the

Table 2

Relation Between Wave Band of Filters and Visual Acuity
Opposing Lights

Spectral Groups	Filter Number	Trans-mission Factor	Acuity Actual	Acuity Expected	Ratio of Actual to Expected	Ratio[1] of Actual to Expected by Spectral Groups
	1	.222	.57	.566	1.01	
Neutral	13	.437	.63	.660	0.96	
	9	.457	.66	.665	0.99	0.985
	10	.177	.53	.536	0.98	
Purple	8	.271	.61	.595	1.03	1.005
	17	.059	.35	.365	0.95	
	2	.110	.50	.475	1.05	
Blue	5	.408	.65	.650	1.00	
	36	.572	.71	.691	1.02	1.005
	20	.309	.55	.610	0.90	
Green	3	.649	.69	.708	0.97	
	30	.506	.66	.675	0.98	0.950
	31	.644	.68	.708	0.96	
Yellow-	38	.751	.73	.720	1.01	
Orange	44	.863	.73	.731	0.99	0.987
	6	.366	.62	.632	0.98	
	21	.290	.58	.601	0.96	
Red	34	.436	.68	.660	1.03	
	40	.847	.70	.730	0.96	0.983

1. Need be 1.00 + or - .08-.10 to be significant

band of wave lengths designated as green. Slightly greater losses than expected were noted in this band, although the differences are not statistically significant.

4. From this study there seems no indication that filters before the eyes can in any way aid vision at low levels of illumination. The results indicate deleterious effects in practically every instance.

5. Some earlier indications of a purely psychological, or apparent, effect of brightness of certain filters seem in evidence from subjective accounts given but are not born out by the objective data.

6. The study supports the primary hypothesis set up but not as a linear relationship.

7. The corollary hypothesis is supported in a general way but not as a linear relationship.

8. The conclusions offered are given subject to limitations of the number of subjects used and the conditions of the experiment. Consistency of results indicates a certain degree of reliability throughout the experiment, which bolsters the conclusions offered.

References

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