IDEA

Innovations Deserving
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Safety IDEA Program

Color-Corrected Motor Vehicle Headlight, Rearview Mirror, and Windshield For Glare Control

Final Report for
Safety IDEA Project 01

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TRANSPORTATION RESEARCH BOARD
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INNOVATIONS DESERVING EXPLORATORY ANALYSIS (IDEA) PROGRAMS MANAGED BY THE TRANSPORTATION RESEARCH BOARD

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COLOR CORRECTED MOTOR VEHICLE HEADLIGHT REAR VIEW MIRROR, AND WINDSHIELD FOR GLARE CONTROL

FINAL REPORT

Safety IDEA Project SAFETY-01

Prepared For

Safety IDEA Program

Transportation Research Board

National Research Council

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EXECUTIVE SUMMARY

This report documents the work done in a Safety IDEA research project on the visual effectiveness of Neodymium Oxide doped headlights, rear view mirrors, and windshields in reducing glare and improving vision. This research project had two stages: clinical optometric experimentation under controlled conditions, and a subjective road test.

Truck divers with commercial driver's licenses were recruited by advertising in local newspapers on Long Island. The subjects were all given a standard optometric examination. Of the 30 subjects, who were paid for their participation in the study, 29 needed a new optometric prescription. Another 14 had significant eye pathologies. Subjects were both male and female and ranged in age from 29 to 75, with just 2 subjects under 40 years in age.

After completion of the standard optometric examination, subjects were run through a series of 9 tests involving vision tasks that might be expected of a motorist. These tests involved the ability to identify lettering through various types of windshield and mirror glass, the ability to discertain colored signs at low light levels, and the ability to see yellow turn signals. Other tests compared stereoscopic depth perception, and the length of time after images remain after exposure to glare.

Subjects were then divided into two groups after completion of the controlled optometric tests. One group received new standard headlights on their vehicle, and the other group received new Neodymium Oxide doped headlights. Subjects were then asked to drive 23.6 miles at night, going south, and turning around and going back north to the starting point, on a 6 lane divided expressway on Long Island. To eliminate any possible interference from road lights, the route chosen was a road without artificial highway illumination.

Subjects were asked to agree or disagree with a series of statements concerning the quality of the headlight lighting, and to estimate ultimate seeing distances of the large green highway signs in low beam and high beam. All data from the optometric testing and the road test was put through a series of rigorous statistical tests.

Several tests showed a significant improvement in visual performance in favor of the Neodymium Oxide doped glass used in the headlight, rear view mirror, and windshield:

1. Subjects were asked to read lettering projected between two tungsten halogen lamps. Statistically significant differences were found with the subjects better able to read the lettering through the Neodymium Oxide doped windshield glass than through standard windshield glass (Test 3).

2. Subjects were asked to read lettering in a rear view mirror without the presence of a glare source and with the presence of a glare source. There was no statistically significant difference between the performance of the Neodymium Oxide doped mirror versus the standard or undimmed electrochromic mirror, but it was significantly better than the dimmed electrochromic mirror (Test 4).

3. An after image was created by projecting a glare source through a sheet of glass onto the subject’s eyes for a short period of time. The after image decay time was 17 percent shorter for the Neodymium Oxide doped glass compared with a neutral density filter of the same light transmittance (Test 9).

4. In the road test, subjects found that the Neodymium Oxide doped headlights were easy on their eyes, that the red colors were redder, that the blue color was bluer, and that yellow signs were easy to read. These results were statistically significant (Test 10).

All three applications of Neodymium Oxide doped glass to the motor vehicle industry are sufficiently advanced in product development for potential implementation. Presently, Neodymium Oxide doped headlights are being sold in the aftermarket by the Federal Mogul Corporation. Neodymium Oxide doped flat glass can be made in sufficient quantity for use in rear view mirrors and in windshield glass. There are no known technological hurdles for their immediate implementation.

I CONCEPT AND INNOVATION

It has long been recognized that the visual discomfort of the glare from headlights from vehicles coming in the opposite direction of travel is a major problem in illuminating engineering.

This dilemma is a challenging problem because of the difficulty of resolving the tradeoff between illumination intensity and glare control. Increasing headlight intensity results in greater sight distances in open road driving, but oncoming drivers will complain about the glare and their reduced visibility. There is also an increase in the elderly population, particularly in the age group over 85 years old, who are more susceptible to glare from headlights than are younger drivers.

A novel approach to reducing night time headlight glare for motorists, and in particular, truck drivers, is to add Neodymium Oxide, a rare earth compound, to the glass of a headlight lamp, the rear view mirror, and the windshield. Neodymium Oxide can be used for tungsten halogen and high intensity discharge motor vehicle headlights.

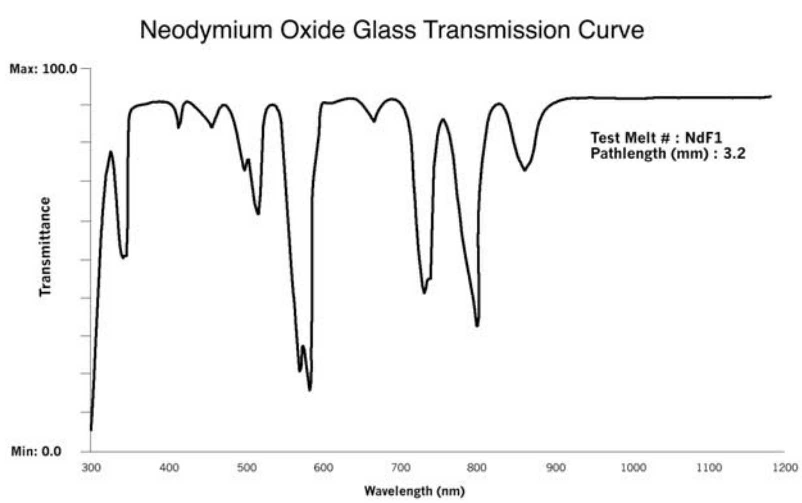
The scientific basis for the research is as follows: Neodymium Oxide, as a component of glass, filters out yellow light between 565 and 595 nanometers. Filtering of the yellow light reduces glare (Cohen and Rosenthal, Dannmeyer). Filtering of the yellow light from the spectrum improves color saturation of the viewed objects, particularly of the primary colors red, green, and blue. The improvement in color saturation, color contrast, and color rendition appears to be rather striking, particularly at low levels of illumination.

Figure 1 provides a transmission curve for a piece of Neodymium Oxide doped glass with a total light transmission of 70 percent, as provided by Schott Glass Technologies, Duryea, Pennsylvania. Federal Motor Vehicle Safety Standards require a minimum normal transmittance of 70% for windshields. The graph shows a maximum absorption of yellow light of 85 percent at 586 nanometers.

Neodymium Oxide doped glass is also potentially useful in reducing the glare from the rising or setting sun when driving east or west. There are a number of major roads where accidents tend to occur in the same location from time to time due to the sunlight glare. Additionally, the glare from the rising or setting sun can be caught in the rear view mirror, obscuring one's ability to see.

The problem of glare from headlights continues to attract the attention of regulators and others who are concerned with motor vehicle safety. NHTSA has received several thousand comments on the issue in response to a request for comments in Docket No. 01-8885.

Figure 1



II INVESTIGATION

The purpose of this research was to quantify the possible reduction in glare and improvement in vision from the use of Neodymium Oxide doped headlights, rear view mirrors, and windshields through clinical optometric research and field trials in the form of a road test.

The office of Dr. Gordon Harris was used for the clinical optometric research. The office was set up with equipment and instrumentation specifically equipped for the research tasks.

Subjects were recruited through advertising in various local papers. Advertising was aimed at truck drivers who had current commercial driver's licenses. A total of 30 subjects were recruited for the research. Ages ranged from 29 to 75, with only two subjects being under 40 years of age. Although the advertising was aimed at truck driver's, several subjects were school bus drivers, who are required in New York State to have a commercial drivers license. Subjects were both male and female.

All subjects were first given an optometric examination to determine their best vision under optimal viewing conditions. With this prescription, the subjects were run through a series of 9 different vision tasks, which were designed to duplicate seeing tasks that might be expected of a motor vehicle driver.

While the optometric examination was free, subjects who needed new prescription glasses were required to pay for them.

With these new prescription glasses, following the clinical vision tests, subjects were instructed go to Centre Service, a motor vehicle repair shop in Syosset, New York, to obtain a new set of headlights for their personal vehicles. The repair shop divided the panel of subjects in half, and one half received new standard tungsten halogen headlights, and the other half received new "TruView" headlights which have Neodymium Oxide in the glass, as manufactured by the Wagner Lighting Products division of the Federal Mogul Corporation.

With the new headlights installed in their vehicles, subjects were instructed to drive from the north to the south on New York State Route 135 (the Seaford-Oyster Bay Expressway) from Jericho Turnpike to Sunrise Highway, turn around, and drive back north to Jericho Turnpike. Subjects were asked to drive at night using the new headlights. Subjects were not told which group they were in.

The nine different tests for the clinical portion of the research, and the field (road) test, are described below:

1. Distance Vision Under Varying Illumination Levels

Distance vision was tested through a Neodymium Oxide doped glass and a standard windshield glass. A sample of Neodymium Oxide doped glass with a total light transmittance of 70 percent was obtained from Schott Glass Technologies, Inc., Duryea, Pennsylvania, and its transmittance curve is shown as Figure 1 on page 2. Pilkington (England) supplied a piece of Siglasol windshield glass with a total light transmittance of 78.6 percent. The Neodymium Oxide doped glass did not have the plastic interlayer which is included in standard motor vehicle windshield glass. In practice, the plastic interlayer absorbs about .5 percent of the light transmitted through the glass.

Distance vision was tested at three levels of illumination: 200, 2,000, and 20,000 millilux (1,000 millilux = 1 Lux) of direct illumination projecting a standard vision chart 14 feet in front of the subject at the far end of the optometric examination room. The light level was adjusted using a diaphragm aperture. The overhead room lighting was turned off during the test.

All vision was tested through the subject's best correction. Vision was recorded as 20/50, 20/40, 20/30, 20/20, or 20/15. When subjects were able to read all but several letters on a single line, vision was recorded as 20/20--, meaning in this case that two letters were missed.

2. Distance Vision Under Varying Levels of Illumination with Different Color Targets.

Under Neodymium lighting, colors appear more vivid, in particular the colors red, green, and blue (Neodymlite Report). Therefore, it might be possible to perceive these colors at lower levels of illumination.

Especially critical at night is the ability of a motorist to see traffic signs at very low levels of illumination. Samples of standard traffic sign materials were obtained from the Traffic Control Materials Division of 3M Corporation. These materials are sold under the trade names "3M™ Scotchlite™ Electrocut™ Film Series 1170". The following colors were obtained from 3M.

Color	Product Code
Yellow	1171
Red	1172
Orange	1174
Blue	1175
Standard Green (Worboy)	1176 (dark green)
Green	1177 (lighter green)
Brown	1179

These materials were mounted over samples of 3M 3990 VIP Reflective Sheeting attached to 11" x 11" sheets of 1/4 inch thick masonite. A 1 1/2" x 1 1/2" square was cut out of the center of the bottom of each piece for the photometer head. A head for the photometer was mounted on the wall of the room, and the sheets were hung on rungs so they could be changed quickly during the research. The mounting position for the photometer head was the same for each sample of reflective material.

A Gigahertz-Optik P-9710-1 Optometer with a VL-3702-2 Photometric Detector was purchased to measure illuminance. This photometer can measure light levels in 1 millilux increments, down to a minimum level of 1 millilux. A 5 meter detector cable was set up between the photometric detector and the photometer.

Subjects sat 14 feet away from the colored sign materials. Light was projected onto the sign materials through the optometric projector. The illumination was varied using an iris diaphragm placed in front of the projected light source. The optometric projector was adjusted to uniformly light the colored sign materials and to not project light outside of the perimeter of the colored sign materials. The overhead room lighting was turned off.

Light was projected through the Neodymium Oxide doped windshield material (70 percent total light transmittance) and through the standard windshield material (78.6 percent total light transmittance).

Light silver colored reflective lettering used for road signs, 1" high and 4" high, was purchased from Letterco, Inc., Sounderton, Pennsylvania. The following lettering was applied to the various colored sign materials as shown in the table below:

Color	4" Letters	1" Letters
Yellow	1C	730
Orange	4A	4395
Red	G2	846
Blue	F0	164
Standard Green	D7	9852
Green	B6	130
Brown	5E	752

The diaphragm was opened very slowly from almost total darkness (some stray light is necessary in order to see the control on the diaphragm). Lighting measurements were taken at the point where the subject could properly identify the 4 inch high lettering, the 1 inch high lettering, and at the point where the subject could properly identify the sign color.

The test started with the standard windshield and proceeded through the 7 sign color materials. Then the Neodymium Oxide doped windshield was used for the 7 sign color materials. For every other subject, the order of presentation of the Neodymium Oxide doped glass and the standard windshield glass was alternated in the test. Thus, the second subject started with the Neodymium Oxide doped glass.

Prior to the start of the testing of the 7 colored sign materials, the examination room was darkened for three minutes to produce adaptation.

3. Vision at a Distance - Glare Interference

This test models the ability of a motorist to read a license plate of an oncoming vehicle at night.

Two tungsten halogen lamps were placed 12 inches apart facing the subject from a distance of 14 feet. The two lamps were 75 Watt MR-16 tungsten halogen line voltage (120 Volt) lamps. The lamp model was JX1015, made by Iwasaki Electric Co., LTD, and are of Japanese manufacture. The lamps have a 1500 axis candlepower rating.

The apparent angle subtended by the lamps mounted 12 inches apart at a distance of 14 feet models the headlights of an oncoming vehicle at a distance of about 90 feet. At that distance, the vehicle in low beam projects 26 Lux of light on a target, and in high beam projects 34 Lux of light at the maximum intensity of the beam.

The two tungsten halogen lamps were dimmed using a Powerstat variable autotransformer, Type 116B, as manufactured by The Superior Electric Co., Bristol, Connecticut. The variable autotransformer is rated at 10 KVA, input voltage 120 Volts, output voltage 0 to 140 Volts. The two lamps were dimmed with the variable autotransformer to provide approximately 34 Lux of light at the plane of the subject's eyes. The manual control dial was taped at 98 Volts.

Subjects were asked to read letters projected on an aluminum painted screen which was mounted between the two lamps. Letter sizes are 20/40, 20/30, 20/25, and 20/20. The amount of light on the screen with the optometric projector was 70 Lux. Subjects were given 10 seconds to read the letters. Data was recorded as in Test 1.

Subjects were first asked to read the letters through a piece of standard windshield glass having a total light transmission of 78.6 percent. In the second part of the test, subjects were asked to read the letters through a piece of Neodymium Oxide doped glass with a total transmission of 70 percent. For every other subject, the order of presentation was reversed in this test.

4. Rear Mirror Comparison

Three different rear view mirror technologies were compared in this test. These were standard single reflectance mirrors, Neodymium Oxide doped mirrors, and electrochromic mirrors

A standard side view truck mirror was provided by Beach Manufacturing, Inc, Donnelsville, Ohio. The mirror was 7 inches by 16 inches. Standard mirror glass, chromed on the front surface, is 62 percent reflective. Beach also provided a piece of Neodymium Oxide doped glass with a total reflectivity of 37 percent (supplied to them by Schott). The standard glass was cut in half, and was set horizontally in the mirror frame on the right side.

An electrochromic (self-dimming) inside rear view mirror, manufactured by Gentex Corporation (Zeeland, Michigan), was purchased from an aftermarket automotive supplier. The model of the mirror was the NVS Auto Dimming Rearview Mirror. Power to the mirror was supplied by a 12 Volt DC battery. The self-dimming mirror automatically reduces the total reflected light back to the driver in the presence of a glare source. When there is very little light in the rear view mirror, the total reflectance is 75 percent. When there is a glare source, the total reflectance is 6 percent. The electrochromic mirror was centered two inches below the bottom of the mirrors in the above paragraph.

The total viewing distance from the subject to the mirrors back to the screen of projected letters is 20 feet. A vision chart with reverse lettering was projected onto the aluminum screen at the front of the room. The subjects were seated with their backs to the vision chart which is at the front of the examination room. The subjects sat 3 feet from the mirrors and the distance from the mirrors to the projected reverse vision chart is 17 feet. The three mirrors are arranged so that all of them are aligned so that the reverse lettering can be seen without the subject having to change position.

A black cloth was placed over the two mirrors not being read so the subject is reading only one mirror at a time. Subjects were given ten seconds to read each line of lettering. The subject's left eye was blacked out. The geometry of the apparatus, with the mirrors very close to each other, makes it impossible to perform this test with both eyes, and to see only one mirror with both eyes.

Subjects were asked to read the vision chart in the standard mirror, the Neodymium Oxide doped mirror, and in the electrochromic mirror. The order of presentation was randomized between the 3 mirrors from subject to subject. There was approximately 60 Lux of light projected on the aluminum printed screen.

Initially, the two tungsten halogen lights were turned off. Subject's ability to read the lettering was recorded as in Test 1. In the second phase of the test, the two tungsten halogen lamps were turned on to produce a glare source, and the subjects were asked to read the reverse lettering in the three mirrors. The two tungsten halogen lamps were at the front of the examination room as in Test 1, on either side of the projected vision chart.

5. Will Yellow Turn Signals be Visible in the Rear View Mirrors and Through the Windshield?

Neodymium Oxide doped glass is an efficient filter for yellow light. A yellow turn signal must be visible in the rear view mirror and through a windshield.

For a windshield to meet present Federal safety standards, it must have a minimum total light transmission of 70 percent. A piece of Neodymium Oxide doped glass satisfying Federal safety standards will transmit a minimum of 15 percent of the yellow light at 586 nanometers, and somewhat more of the higher and lower frequency yellow light to either side of the maximum absorption point. Thus, on a theoretical basis, a yellow turn signal should be visible in a Neodymium Oxide doped rear view mirror or be able to be seen through a Neodymium Oxide doped windshield.

The human eye is sensitive to yellow light, and many sources of yellow light are not pure, and depending upon the source of the filtering media used to produce them, these sources may contain some green light along with some orange and red light in the side bands.

A Ford turn signal, part number F.L.20.85, E6EB-13215-AD, was purchased from a local auto parts recycler. It was mounted inside a wooden box with the wires leading out of the back to a 12 Volt power supply and a standard automotive flasher.

The box has a slot so that 3" x 6" pieces of neutral density filters, purchased from Schott Glass Technologies, may be mounted in front of the turn signal. Five neutral density filters with transmittances of 70%, 60%, 50%, 25%, and 10% were obtained for use in the experimentation.

a. <u>Visibility in the rear view mirror</u>

The turn signal was mounted so that the sight distance from the subject to the rear view mirror was 20 feet as described in the previous test. The turn signal was visible through a hole 1.75 inches in diameter, to model a turn signal at a distance of 90 feet to the rear. The turn signal was turned on and off with a standard automotive flasher. Visibility of the turn signal was tested with the tungsten halogen lamps turned on and with the tungsten halogen lamps turned off.

All five of the neutral density filters were placed in front of the turn signal. They were arranged with the least dense (70% transmission) in front to the most dense (10% transmission) to the back. The total transmittance of the five filters of the five filters is the product of the transmittance of each filter, for a total light transmittance of 0.525 percent.

When the turn signal is flashed on and off, subjects were asked if they can see it in front of the three mirrors, the standard mirror, the Neodymium Oxide doped mirror, and the electrochromic mirror. Subjects viewed the rear view mirrors through their right eye.

If the subject cannot see the turn signal in any one mirror, the 70 percent transmission neutral density filter was removed to increase the light transmittance to 0.75 percent. If the subject could not see the turn signal with that filter removed from the jet of filters, then the 60 percent transmission filter was removed to increase the light transmittance to 1.25 percent. This process of removing filters was continued, if necessary, until the subject was able to see the turn signal in the rear view mirror.

b. Visibility through windshields

This subtest checks the visibility of turn signals through a standard windshield and through a Neodymium Oxide doped windshield.

Subjects viewed the turn signal with the headlights on and off through the Neodymium Oxide doped windshield and through the standard windshield.

If the turn signal could not be seen through the windshield with the 5 neutral density filters in front of it, then the process of removing filters as described above was performed until the turn signal was visible.

For this test, each subject viewed the turn signal with both eyes.

6. Illumination and Subjective Fatigue

Neodymium Oxide doped lighting may be less fatiguing than standard incandescent illumination. Subjects were tested for their response to the illumination.

The testing proceeds as follows: The lights are turned off in the examination room. Then the two incandescent lamps are turned on, being mounted in a fixed position. The lamps are turned on for 30 seconds. The subject would be asked on a 1 to 9 scale as to the degree of fatigue. There would be a 30 second rest period, and the two Neodymium Oxide doped lamps would be turned on for 30 seconds. The subject would be asked again on a 1 to 9 scale with 1 being no fatigue and 9 being extremely fatigued.

The subject would be challenged for a second time with the Neodymium Oxide doped lamps, and for the fourth time, with the standard incandescent lamps. This ABBA pattern would be reversed for every other subject. To match photopic illuminance, it was necessary to use 75 watt soft white incandescent lamps and 100 watt Neodymium Oxide "A" type lamps.

7. Stereoscopic Depth Perception Comparison Between Neodymium Oxide Doped Windshields and Standard Windshields.

Depth perception measurements were made viewing targets through the Neodymium Oxide doped windshield glass and through the standard windshield glass. The Neodymium Oxide doped windshield glass is the same as used in the above tests; it has a total light transmittance of 70 percent, and the standard windshield glass has a total light transmittance of 78.6 percent.

In a Howard Dolman apparatus, subjects view two pins: one fixed and one movable. Subjects were able to manipulate the movable pin by pulling strings to line up the two pins. Six measurements were made with the Neodymium Oxide doped windshield and six measurements were made with the standard windshield.

Subjects were seated 13 feet away from the zero point of the fixed pin. The movable pin was set 6 inches in front or 6 inches behind the fixed pin. The subject would then move the pin to line it up with the fixed pin. The ABABAB presentation would be made for the standard windshield and BABABA for the Neodymium Oxide doped windshield. The presentation order would be reversed for every other subject. Measurements would be made with an accuracy of 1/8 inches.

Standard incandescent lamps were used to illuminate the examination room at the time of the testing. There was a white painted vertical surface at the back of the apparatus which provides contrast for the pins, which were painted black.

8. Equality of Distant Glare Comparison

This test compared subjective glare through a standard windshield, a Neodymium Oxide doped windshield, and a neutral density filter. The Neodymium Oxide doped windshield and the standard windshield were the same as used in the earlier tests. The neutral density filter had a total light transmission of 70 percent.

To model oncoming headlights, a pair of tungsten halogen lamps were mounted 12 inches apart on center 14 feet in front of the subjects. Two line voltage 75 watt MR-16 lamps with a rating of 1500 axis candela and a beam spread of 28 degrees, as manufactured by Iwasaki Electric Co., LTD, were used for this test. The test set-up was the same as Test 3.

The two lamps were turned on for 10 seconds to mimic an oncoming driver. The subject was asked to rate the glare through the 3 different glass media according to the De Boer scale (De Boer);

Rating	Meaning
1	Unbearable
2	
3	Disturbing
4	
5	Just Acceptable
6	
7	Satisfactory
8	
9	Just Noticeable

The order of presentation was randomized between subjects. Between each challenge, there was a rest period of 1.5 minutes. There were three replications for each of the three glass types.

9. After Image Decay Time

This test measured the decay time for the after image formed in the eyes after exposure to a glare source. Measurements were made through a piece of Neodymium Oxide doped glass and through a neutral density filter having a total light transmittance of 70 percent.

The after image decay time test was performed after seven minutes in order to produce adaptation. The overhead incandescent lighting in the examination room was turned off for one minute following this adaptation period.

The 70 percent neutral density filter was placed in front of the optometric examination eyepiece. Two tungsten halogen lamps, as described in the above test, were turned on for five seconds to model headlights coming from the opposite direction.

The subjects were asked to blink every 5 seconds until the after image of the lamps was not discernible. The total time was recorded as the time necessary for the after image to decay to the point it was not noticeable.

At that point, the subjects rested for 30 seconds, and were challenged with the piece of Neodymium Oxide doped glass with a total light transmittance of 70 percent. As before, the subjects were asked to blink every 5 seconds until the after image was not discernible. There was another rest period of 30 seconds, and the test with the Neodymium Oxide doped glass was repeated, and then tile test with the 70 percent neutral density filter was repeated as in the start of the test. This ABBA presentation was changed to a BAAB presentation for every other subject. A total of 4 timed trials were taken for each of the two types of glass.

The lamps used for this test were the same as in the earlier tests, a pair of JX1015 MR-16 tungsten halogen line voltage lamps made by Iwasaki Electric Co., LTD. The lamps are rated at 1500 axis candela, and were mounted 14 feet in front of the subjects.

10. Road Test

After completion of the optometric examination and clinical testing, and after receiving a new prescription where necessary, subjects were asked to obtain a new set of headlights for their vehicle at Centre Service, a motor vehicle repair shop in Syosset, New York. They were then asked to drive at night north and south along the Seaford-Oyster Bay Expressway. This road was chosen for the road test because it has no highway lights which might interfere with the vision provided by the headlights, and it has a straightaway where the viewing distance is .8 miles. It has three lanes in each direction, and it is divided in part by a concrete divider and in parts by a heavily wooded or a grassy meridian. The total length of the road test was 23.6 miles.

The subjects were divided into two groups randomly by Centre Service. The "A" group received new "TruView" Neodymium Oxide doped headlights, supplied by Wagner Lighting Products, a division of the Federal-Mogul Corporation. The "B" group received new tungsten halogen headlights as manufactured by Osram Sylvania.

After completion of test drive, subjects were asked to fill out a questionnaire with 12 questions and to rate the performance of the headlights on a scale of 1 (strongly agree) to 9 (strongly disagree). These questions were on the quality of the light and the ability to see at night. Subjects were asked to clock in tenths of a mile the maximum distances at which they could see the large green highway signs along the expressway, both in high beam and in low beam. Subjects were asked to check off weather conditions at the time of the drive.

Subjects were not aware that the panel was divided into two groups, and were only told that they were getting new headlights. They were also asked for any comments about the headlights. A copy of the instructions to the subjects and the questionnaire is included in the report on the next page.

ROAD TEST NEW HEADLIGHTS

As part of the research on glare and visibility, two new headlights will be provided for your use. Please make an appointment with Centre Service, 30 Underhill Boulevard, Syosset, at 516 921-1300 to obtain a new set of headlights for your vehicle.

Drive south at night on the Seaford Oyster Bay Expressway from Jericho Turnpike to Sunrise Highway. Get off at Sunrise Highway going east, go under the underpass, and head back north on Seaford Oyster Bay Expressway back to Jericho Turnpike.

After the test drive, please fill out this form and mail it back in the return envelope. As soon as Dr. Gordon Harris receives the filled out questionnaire, you will be promptly mailed a check in the amount of $100.00 for participation in this study. PLEASE COMPLETE WITHIN TWO WEEKS

			Strongly Agree				Strongly disagree			
1.	Is the light close to daylight?	1	2	3	4	5	6	7	8	9
2.	Is the light free of glare?	1	2	3	4	5	6	7	8	9
3.	Is the light easy on your eyes?	1	2	3	4	5	6	7	8	9
4.	Green signs are brighter?	1	2	3	4	5	6	7	8	9
5.	Red color is much redder?	1	2	3	4	5	6	7	8	9
6.	Blue color is much bluer?	1	2	3	4	5	6	7	8	9
7.	Good contrast of black and white road markings	1	2	3	4	5	6	7	8	9
8.	I can see the shoulders of the road better at night?	1	2	3	4	5	6	7	8	9
9.	Yellow signs easy to read?	1	2	3	4	5	6	7	8	9
10.	I can see better at night?	1	2	3	4	5	6	7	8	9
11.	I can perceive distances better?	1	2	3	4	5	6	7	8	9
12.	The light is whitish in color?	1	2	3	4	5	6	7	8	9

With your odometer, clock in tenths of a mile the maximum distance which you can see the large green highway signs?

High Beam (circle highest distance)	.1	.2	.3	.4	.5	.6	.7	.8
Low Beam (circle highest distance)	.1	.2	.3	.4	.5	.6	.7	.8

Weather conditions at time of test drive: Clear _____ Rain _____ Fog _____ Snow _____

Please provide us with any other comments below about these headlight lamps.
You may continue on the back of this form.

III RESULTS

OPTOMETRIC EXAMINATIONS

Of the 30 subjects, a surprisingly high number, 29, needed new prescriptions. All subjects were tested with the new prescriptions, both in the optometric exam room and in the road test.

Of the 30 subjects, 14 subjects had significant eye pathologies. The age of the subject, and the nature of the pathology is listed below:

Age	Eye Pathology
29	No depth perception, estrope, alternates vision from eye to eye.
35	Vacuole in right eye, possible early sign of cataract.
40	Eye infection.
41	Mild conjunctivitis.
45	Dry eyes.
45	Vacuoles in both eyes, possible precursors to cataracts.
49	Mild conjunctivitis.
52	Glaucoma, macular edema.
55	Corneal dystrophy.
65	Floaters.
69	Pterygiums in both eyes, suspected glaucoma.
70	Significant cataracts in both eyes, cataract surgery necessary.
71	Post surgical cataracts, diabetic, glaucoma.
72	Cataract in left eye.

The authors of this report believe that a large proportion of the subjects have not been seen by a qualified professional in a long time.

It is generally recommended that all drivers should have a routine professional eye examination by a qualified optometrist or ophthalmologist once a year. Anyone who senses vision problems should be seen by an optometrist or ophthalmologist immediately.

RESULTS

ANALYSIS OF DATA

General: Each of the tests was analyzed using the following procedure:

The statistics was performed using SPSS Version 9.0. A univariate analysis of variance (ANOVA), general linear model was conducted to determine the significant factors wherever tests were not appropriate by themselves. A type III sum of squares model was used for tests with no missing data and a type IV mode was used for those tests with some missing data. The subject is always used as a factor, so there are always two or more factors.

A "t" test was conducted for the test dependent variable (acuity, time, error, etc.) for the various types of glass or headlights. These statistics would augment the ANOVA statistics to distinguish the effects when the factor had more than two values. Independent sample "t" tests were performed when the panel of subjects was broken up into two groups. Paired sample "t" tests were performed when the subjects were challenged with different types of glass, mirrors, or headlights.

For a number of tests, there were only two means that needed comparison. When there were more than two means the "t" tests were used between the Neodymium case and the other cases only if the ANOVA showed that the null hypothesis was rejected, and if there were no repetitions of the measurements over the subjects. When there were multiple measurements per subject, Tukey's multiple comparison test was used in place of the "t" test.

The general hypothesis for all tests was that the variations in the dependent variable results because of the glare or mirror used were due to chance. This hypothesis was rejected if the F value or t value exceeded the F(.05) or t(.05) value. If the hypothesis was rejected, the result was deemed significant.

TEST 1 - Distance Vision Under Varying Illumination Levels

In this test, there were 30 subjects, 3 brightness levels, and vision was tested through the standard windshield glass (78.6% total light transmission) and through the Neodymium Oxide doped glass (70% total light transmission). The three brightness levels were 200 millilux, 2 Lux, and 20 Lux. The dependent variable was best acuity.

The data for Test 1 was not in a form for direct statistical analysis when recorded in the optometric examination room. For example, when there were two missed values on the 20/20 line, the data was recorded as 20/20--. There is a method for evaluating visual acuity when not all of the values or, a line are read correctly. What is done is to convert acuity to its logmar value (logl0 of the minimum angle of resolution). For 20/20 vision, the logmar is 0. For 20/30 it is log10 (30/20) = .176, and so on.

If a person reads only some of the letters on a line, then linear interpolation of the logmar values of the previous line and the partially read line is used to get an estimated logmar. The statistical analysis was performed on the logmar values and converted back to an acuity value after completion of the statistics.

An example should make the procedure clearer. Assume that the subject reads all of the letters on the 20/25 line, and 5 of the 8 letters on the 20/20 line. The difference in the logmar values between the two lines is 0.097. Since the subject missed 3 out of 8 letters, the estimated logmar is increased above the 20/20 value by 3/8 times 0.097, which is 0 + .375 x 0.097 = 0.0306.

Acuity is known to vary with light level, so there was no need to run an ANOVA to test for differences in acuity with light level. The question of interest was whether there were differences in acuity between the Neodymium Oxide doped windshield and the standard windshield glass at any of the light levels. Three paired sample "t" tests were run on the three illumination levels. For each of the "t" tests, there were 29 degrees of freedom. As seen in the table on the next page, no significant differences were found between the two glass types. The logmar means and standard deviations for this test are provided in Appendix C.

Lighting Level	Mean Neo	Mean Normal	“t” Value	“t” Probability
200 millilux	20/53.12	20/51.98	- .655	.518
2 Lux	20/27.54	20/26.90	-1.399	.172
20 Lux	20/21.71	20/22.45	1.036	.309

TEST 2 - Distance Vision Under Varying Levels of Illumination With Different Colored Targets

In this test, there were 30 subjects, 7 colored sign materials, 3 types of targets (ability to read 4" high lettering, ability to read 1" high lettering, and ability to correctly identify the color of the sign material), and vision was tested through the standard windshield glass (78.6% total light transmission) and through the Neodymium Oxide doped glass (70% total light transmission). The dependent variable was the light meter reading.

All of the light meter readings on the target were multiplied by .786 for the standard glass and .7 for the Neodymium Oxide doped glass to normalize the transmission of the light through the glass to the subject’s eyes. In this way, the spectral effect is the same at the slightly reduced illuminance (.7/.786) of the target illuminated to the same level and seen through the Neodymium Oxide doped glass versus being seen through the standard glass.

In the review of the data, it was noticed that in a number if cases the subjects were only able to identify the color of the light at the same light level as being able to discertain the 1" high lettering. In every case, the subjects were able to read the 4" high lettering before being able to read the 1" high lettering.

For the statistical analysis, light levels were averaged over all of the data points for being able to identify the color of the target material, and being able to read the different size lettering. ANOVAs were run for each of the 7 sign materials as a function of subject, target size, and glass type. For all 7 of the ANOVAs, the subject and target were significant, while the glass type was not significant. The mean light levels over the three target types are shown below, along with the probabilities for a glass effect. The complete ANOVAs are provided in Appendix C.

Color	Neodymium Glass	Standard Glass	Probability
Yellow	486.6	448.2	0.409
Red	295.7	302.7	0.779
Orange	457.7	401.1	0.224
Green (Worboy)	277.3	284.8	0.726
Green (Lighter)	201.6	240.0	0.067
Brown	305.6	350.5	0.270
Blue	264.1	254.9	0.847

TEST 3 - Vision at a Distance - Glare Interference

In this test, there were 30 subjects, and testing was done between the standard windshield glass (78.6% total light transmission), and the Neodymium Oxide doped glass (70% total light transmission). Subjects attempted to read lettering projected between two tungsten halogen lamps. As in Test 1, the logmar method was used to perform the data reduction and the subsequent statistical analysis.

A paired samples "t" test was run. There was a slight but statistically significant ($p = .013$) improvement in mean acuity with the Neodymium Oxide doped glass (20/36.6 vs. 20/38.8).

TEST 4 - Rear View Mirror Comparison

In this test there were 30 subjects, 4 mirror types, and subjects were tested with the headlights off and the headlights on. The 4 mirror types were the standard mirrors, Neodymium Oxide doped mirrors, the electrochromic mirrors in a dimmed state, and the electrochromic mirrors in an undimmed state. The dependent variable was the best visual acuity. As in Test 1, the logmar method was used to perform the data reduction and the subsequent statistical analysis.

In the case where the headlights were on, there were 5 subjects out of 30 where the visual acuity values for some or all of the 4 mirror types were recorded as 20/200 or worse. Three of these five subjects were the same subjects who had visual acuities of 20/200 for both glass types in Test 3.

An ANOVA was run with the subject, mirror type and headlight status (on or off). All three variables were statistically significant. The mirror type was a significant factor with a probability of 0.025.

Multiple paired sample "t" tests were run between the Neodymium Oxide doped mirrors and the other 3 mirror types, both with the headlights on and the headlights off. Results are shown in the table below: For each paired samples "t" test, there were 29 degrees of freedom.

Headlights Off

Mirror Type	Mean Visual Acuity	"t" Value	"t" Probability
Neodymium Oxide	20/26.02		
Standard Glass	20/25.38	1.436	0.162
Electrochromic, undimmed	20/25.43	2.027	0.052
Electrochromic, dimmed	20/30.48	-4.575	<0.0001

Headlights On

Mirror Type	Mean Visual Acuity	"t" Value	"t" Probability
Neodymium Oxide	20/53.85		
Standard Glass	20/50.00	1.681	0.103
Electrochromic, undimmed	20/56.88	-1.236	0.226
Electrochromic, dimmed	20/60.28	-2.210	0.035

TEST 5 - Will Yellow Turn Signals be Visible in the Rear View Mirror and in the Windshield?

In the rear view mirror portion of this test, there were 30 subjects, 4 mirror types, and the headlights were turned on and off. For the windshield portion of this test, there were 30 subjects, 2 windshield types, and the headlights were turned on and off.

Recorded values were the minimum percentage transmission of light through the set of neutral density filters placed in front of the turn signal.

The ANOVA showed that the headlight and subject variables were statistically significant. The mirror type was not significant. With the headlights off, all of the subjects could see the turn signal in all four mirrors at the lowest level of light transmission through the filter stack (0.00525). With the headlights on, the mean transmittances are provided below:

Mirror Type	Mean Transmittance
Neodymium Oxide	0.145
Standard Glass	0.097
Electrochromic, undimmed	0.128
Electrochromic, dimmed	0.172

The ANOVA for the windshield showed that the headlights being on or off was a significant factor. There were no significant differences between the subjects or the windshields. The probability for the windshield was 0.613, and the probability for the headlight was 0.016. The mean transmittance for the normal windshield was 0.022, and the mean transmittance for the Neodymium Oxide doped windshield was 0.031.

TEST 6 - Illumination and Subjective Fatigue

This test did not give any useful results. None of the subjects could determine that one light source, the standard incandescent bulbs or the Neodymium Oxide doped incandescent bulbs, was better than the other in reducing fatigue.

TEST 7 - Stereoscopic Depth Perception Comparison Between Neodymium Oxide Doped Windshields and Standard Windshields

Of the 30 subjects in the panel, two had no depth perception, and one subject did three trials through the standard windshield and the Neodymium Oxide doped windshield of the 6 trials planned for each subject in the research protocol. Of the 360 possible data points (30 subjects x 6 trials x 2 windshield types), there were a total of 330 data points. The dependent variable was the error in distance assessment which was measured in inches.

The ANOVA showed there were differences between subjects, but there was no significant difference between windshields with a probability of 0.881. The mean error for the Neodymium Oxide doped glass, which had a total light transmission of 70 percent, was 0.389 inches and the mean error for the standard windshield glass, which had a total light transmission of 78.6 percent, was 0.396 inches.

TEST 8 - Equality of Distant Glare Comparison

In this test there were 30 subjects, 3 types of glass, and three replications for each glass type. The dependent variable was the glare rating from 1 to 9 on the De Boer scale. A rating of 1 is unbearable and a rating of 9 is just noticeable. There were 270 data points.

The ANOVA showed that the significant factor) were the subject and the glass type. The probability was 0.026. Means are provided below:

Glass Type	Mean De Boer Rating
Neodymium Oxide	5.81
Neutral Density Filter	6.27
Standard Windshield Glass	6.08

Each subject made more than one glare rating, so the Tukey multiple comparison test was used to evaluate which differences were significant (Jerrold). The mean De Boer ratings between the Neodymium Oxide doped glass and the neutral density filter were significant at the .05 level. The critical value of the Tukey multiple comparison test with 266 error degrees of freedom and 3 classifications is 3.31 at the .05 significance level. The critical value between the Neodymium Oxide doped glass and the neutral density filter was 3.78, so there was significance. However, the differences for the other two classifications were not significant with critical values of 2.3 and 1.5.

TEST 9 - After Image Decay Time

Of the 30 subjects in the panel, only 23 were able to perform this test to obtain usable data. Subjects either had no response or had no after image. The analysis in this test was done only on subjects where it was possible to determine and record an after image decay time.

In this test, there were two types of glass tested, the neutral density filter and the Neodymium Oxide doped windshield glass. Both types of glass had a 70 percent total light transmission. Subjects were asked to provide the after image decay time for 4 replications of each type of glass. The dependent variable was the after image decay time in seconds.

The ANOVA showed the significant factors were the subject and the filter type. The mean decay time for the Neodymium Oxide doped windshield glass was 21.90 seconds and the mean decay time for the neutral density filter was 26.29 seconds. The mean decay time for the after image decay of the Neodymium Oxide doped windshield glass was 17 percent lower than the neutral density filter. The probability as provided by the ANOVA was .002.

TEST 10 - Road Test of New Headlights

Of the 30 subjects, 28 completed the road test. Each subject who completed the road test was paid $100.00 upon submission of the questionnaire, which asked the subject various questions about the quality of the light. Of the 28 subjects who completed the road test, 13 received the new "TruView" headlights, and 15 were in the group with the standard tungsten halogen headlights. Of the 15 subjects with the standard tungsten halogen headlights, 13 had fresh headlights put in their vehicle, and two subjects did not have their headlights changed out. They performed the road test with the existing headlights on their vehicle. These two subjects were subsequently dropped from the statistical analysis.

Both sealed beam and capsule type headlights were used in the study. Vehicle types included both foreign and domestic vehicles, with a mixture of passenger sedans, sport utility vehicles, and vans. None of the subject vehicles had high intensity discharge type headlights. All subjects in the "B" group, which was the group with the "TruView" headlights, received new capsule type lamps. In the "A" group, 8 subjects received new capsule type lamps, and 5 subjects received new sealed beam type lamps.

Subjects were asked about the weather conditions at the time of the test drive. Of the 26 subjects included in the statistical analysis, one of the "B" group reported slight fog at the time of the test drive. A review of the submitted questionnaire noted a similar pattern of responses compared with those subjects who drove in clear weather.

As the "B" group did not receive any sealed beam lamps, an ANOVA was run in the "A" group to determine if there was a significant difference in responses between the subjects who received sealed beam lamps, and those subjects who received capsule type lamps. There was no significance. The ANOVA is included in Appendix C.

Each of the 12 statements in the questionnaire, and the two questions relating to seeing distances in low beam and high beam, were analyzed statistically using an independent samples "t" test. There were 24 degrees of freedom for each of the 14 independent samples "t" tests. The "t" values and "t" probabilities are provided in the table on the next page. A negative "t" value indicates that the Neodymium doped headlight is favored over the standard headlights.

"t" Test Comparison Between Neodymium and Standard Headlights

Road Test

Question Number	Statement	"t" Value	"t" Probability
1	Is the light close to daylight?	-1.316	.200
2	Is the light free of glare?	-1.136	.270
3	Is the light easy on your eyes?	-2.225	.040
4	Green signs are brighter?	-1.277	.220
5	Red color is much redder?	-2.248	.035
6	Blue color is much bluer?	-2.008	.045
7	Good contrast of black and white road markings?	-1.023	.310
8	I can see the shoulders of the road better at night?	0.209	.850
9	Yellow signs easy to read?	-2.097	.045
10	I can see better at night?	-0.542	.590
11	I can perceive distances better?	-0.310	.750
12	The light is whitish in color?	0.684	.500

In high beam, the mean seeing distance was .531 miles with the Neodymium Oxide doped headlights and .550 miles with the standard headlights. In low beam, the mean seeing distance was .408 miles with the Neodymium Oxide doped headlights and .408 miles with the standard headlights.

13	High beam seeing distance	-0.223	.820
14	Low beam seeing distance	0.000	1.000

TEST 10 - Road Test Comments From Subjects

The following comments were provided by the subjects in the group which received the Neodymium Oxide doped headlights:

"These headlights were AMAZING. I would recommend them to anyone."

"I tried this with my car to see if the lighting would be the same but it was not. The lights in the (unreadable word) was better."

"There may be slight difference, but overall there was no major change. I can't say that there was any major improvement using these headlights."

"Having maintained cars & trucks for years I have noticed that the all the glass headlights stay clear longer. The lens on my 97 Contour (one side only) have turned yellow. I think the heat affects the plastic. How can 1 tell if the light is free of glare if I am NOT looking at it?"

The following comments were provided by the subjects in the group which received new standard headlights:

"I really didn't notice all that much difference from my original bulbs. Important question would be, if the oncoming driver was blinded or received any glare or starlight burst? (from my headlights)"

"I am not sure if it was just me but everything was about the same. I did see better to the sides and the green highway signs seemed to be brighter. There was no glare but colors were about the same except yellow on the back of school buses seemed to be brighter and some the black & white signs were lighter than others."

"On the last question you should clarify if I'm seeing the signs or reading them. If the question is about sight I'd say it was a greater distance."

"The sides of the shoulders appear brighter. Wording on signs stand out more. You can see AHEAD clearer when you are alone. When there are other vehicles pass or there are brights you lose the effect. Especially then they are behind you. But overall I'm satisfied with these bulbs. If you have any more tests like this one that helps vision it will reduce accidents, collisions, perhaps even fatalities. Thank you for letting me be part of this experiment, Dr. Harris."

Summary: There was one positive and one very positive remark for the Neodymium Oxide doped headlights, two positive remarks for the standard headlights, and two neutral remarks each for both headlights.

IV DISCUSSION

The purpose of the research was to quantify the possible reduction in glare and improvement in vision resulting from the use of Neodymium Oxide doped headlights, rear view mirrors, and windshields.

The research found some unexpected results. In general, the Neodymium Oxide doped headlights, rear view mirrors, and windshields performed as well as, standard glass for the same applications.

Test 1 showed that one could see visually as well through the Neodymium Oxide doped glass (70. total light transmission) as the standard windshield glass (76.8. total light transmission). The three independent samples "t" tests provided significances of .518, .172, and .305 for the 200 millilux, 2 Lux, and 20 Lux light levels, showing no statistical significance at the .05 level. Despite the lower transmittance of the Neodymium Oxide doped glass there was no statistically significant difference in acuity, and no consistent trend favoring the higher transmittance glass.

Test 2 looked at whether one could see colors better through the Neodymium Oxide doped glass compared with a standard windshield glass of equal transmittance. ANOVA tests on the 7 sign color materials provided a very wide range of probabilities ranging from 0.067 for the lighter green to 0.847 for the blue.

Test 3 tested glare interference when reading lettering projected between two glare sources. As described in the investigation section of the report, this test models the ability of a motorist to read a license plate on an oncoming vehicle at night. The mean visual acuity for the Neodymium Oxide doped glass was 20/36.6 compared with 20/38.76 for the standard windshield glass. The paired samples "t" test provided a probability of 0.013, indicating significance. Note that this visual task is far more difficult than simply reading a Snellen chart without glare sources as in Test 1. Also note that the Neodymium Oxide doped glass had a lower total light transmittance (70%) compared with the sample of standard windshield glass (78.6.). This result is a highly important finding.

Test 4 compared the visual acuity in 4 rear view mirrors, with the headlights on and with the headlights off. Multiple paired sample "t" tests were run between the Neodymium Oxide doped mirrors and the other mirror types. Despite having approximately half of the reflectance of the standard mirror and the undimmed electrochromic mirror, there was no significant loss of visual acuity with the Neodymium Oxide doped mirror. The Neodymium Oxide doped mirror provided significant better visual acuity than the dimmed electrochromic mirror, both with and without headlight glare. With the headlights off, the dimmed electrochromic mirror, when compared with the Neodymium Oxide doped mirror, had a probability $< .0001$, which is highly significant.

Test 5 showed that yellow turn signals will be visible in the Neodymium Oxide doped rear view mirror and in the Neodymium Oxide doped windshield. As discussed in the results Section, with the headlights off, all of the subjects could see the turn signal in all 4 mirrors at the lowest level of light transmission through the filter stack. The ANOVA showed no significant differences between mirror types. For the windshield, the type of windshield was not significant. This finding is very important, as concern has been raised that the use of Neodymium Oxide doped glass for these applications would make yellow turn signals difficult to see.

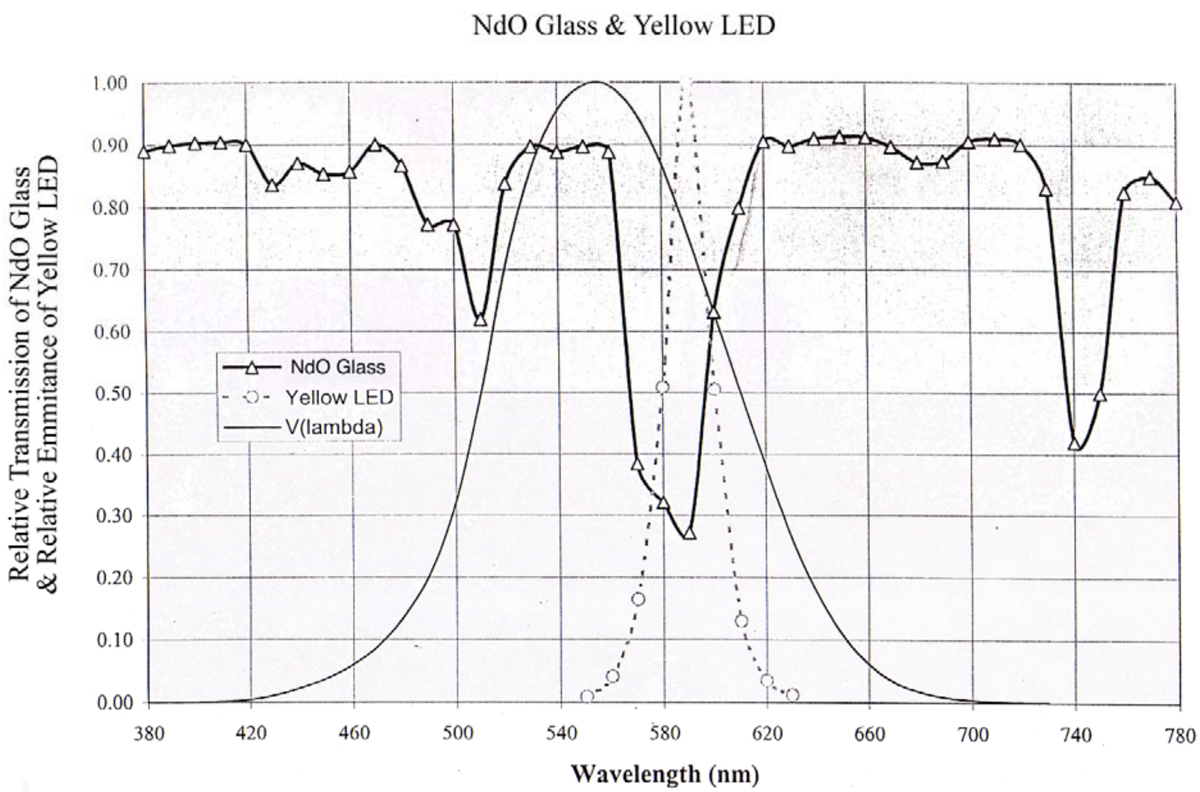
Concern has also been raised that the use of light emitting diodes, as compared with the present broadband yellow filters over an incandescent light source, for turn signals might make it harder to see them through a Neodymium Oxide doped glass. The spectrum for certain amber LEDs is quite narrow. As shown in Figure 2 on the next page, a Neodymium doped filter glass would filter out 60% of the light emitted by this certain yellow LED. In order to make up for the loss of light filtered by the Neodymium Oxide doped glass, it would be necessary to increase the amount of light emitted by a yellow turn signal, if available from the manufacturers of the LEDs.

Fortunately, LEDs are far more efficient in converting electrical energy to say, yellow light, than an incandescent lamp being filtered by a yellow plastic filter material. Advances in solid state electronics in the last 15 years have dramatically reduced the cost of the LEDs and these advances have also dramatically increased their light output as well. To properly compensate for the 60 percent loss of light being filtered by the Neodymium Oxide doped glass, the light output of a yellow turn signal would have to be increased about 150 percent greater than a standard yellow turn signal. Also, it might be necessary to modify 49 CFR 571.108, the Federal Motor Vehicle Safety Standard for lamps, reflective devices, and associated equipment.

Test 6, testing the differences in illumination and fatigue, between Neodymium Oxide doped lamps and standard lamps, did not give any results.

Test 7 compared stereoscopic depth perception through the Neodymium Oxide doped glass and through the standard windshield glass. The mean errors in judgment for both types of glass were almost identical, with 0.389 inches for the Neodymium Oxide doped glass and 0.396 inches for the standard windshield glass, even though the Neodymium Oxide doped glass had a lower total light transmission than the standard windshield glass (70.0% vs 78.6 %, respectively). The ANOVA showed no significance in glass types with a probability of 0.881.

Figure 2



Test 8 showed a significant difference in glare between the Neodymium Oxide doped glass and a neutral density filter. There were no significant differences between the standard windshield glass and the other two glass types. Note that the finding of significance between the neutral density filter and the Neodymium Oxide doped glass is academic, because neutral density filter type glass is not used for motor vehicle windshields.

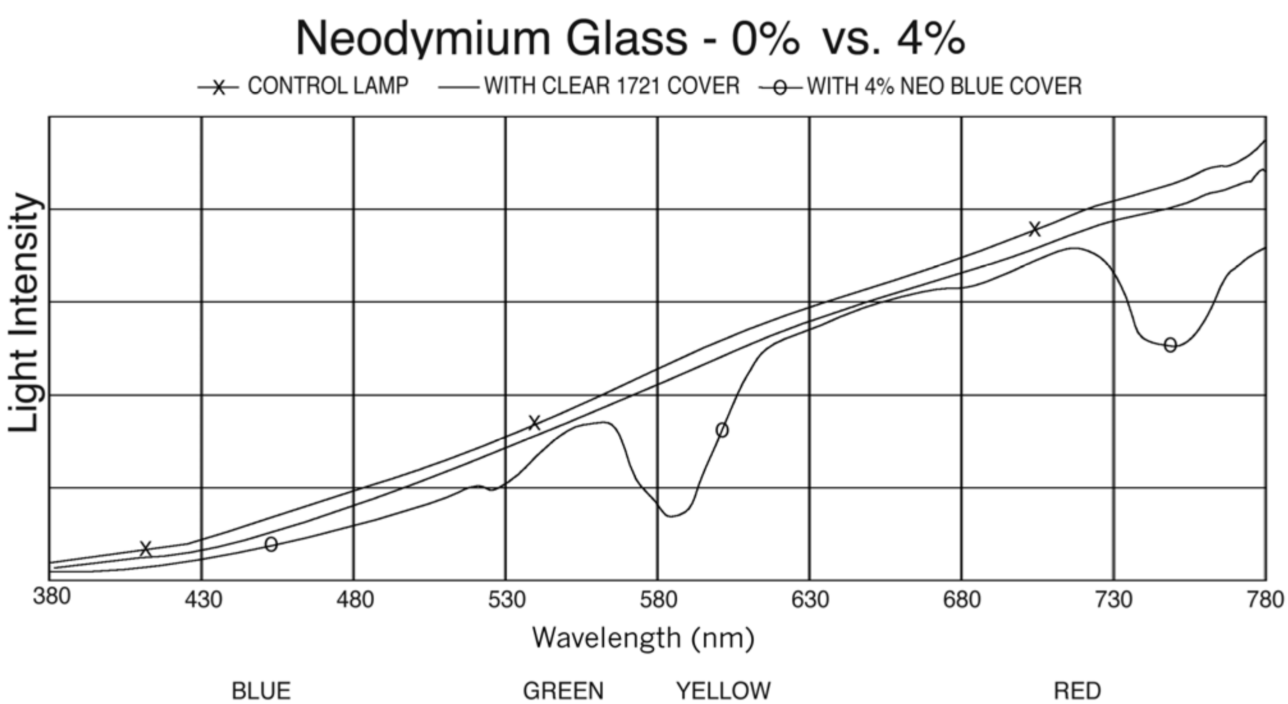
Test 9 showed a very significant difference in the decay time of after images in the eye. For the Neodymium Oxide doped glass, the mean decay time was 21.90 seconds compared with 26.29 seconds for the neutral density filter. Both types of glass had a total light transmission of 70%. The reduction in mean decay time was 17 percent. The ANOVA provided a probability of 0.002, giving a very significant difference in performance in favor of the Neodymium Oxide doped glass. While no comparison was made in the research in decay time between a standard windshield and a Neodymium Oxide doped glass, it should be expected that the mean decay time would rise with the standard windshield glass as it has a high total light transmittance of 78.6 percent.

Test 10 was the road test. There were 4 statements out of the 12 statements where the independent samples "t" probability was below .05, showing significance. Subjects found that the Neodymium Oxide doped headlights were easy on their eyes (.040), that the red color was redder (.035), that the blue color was much bluer (.045), and that the yellow road signs were easy to read (.045).

A surprise in the study was that the subjects found that yellow road signs were easy to read. It should be noted that yellow road signs usually have black lettering against a yellow background. In Test 2, for uniformity purposes, silver lettering was tested against colored backgrounds, as red, green, blue, and brown road signs use silver lettering. This finding may be a reflection of the wording of the statements, as the statement that the Neodymium Oxide doped headlights were easy on their eyes used the word "easy" as did the statement that yellow signs were "easy" to read.

The Neodymium Oxide doped headlights, as utilized in the road test, filter out a maximum of 70 percent of the yellow light at 586 nanometers, thus allowing a minimum of 30 percent of the light generated by the filament to be emitted from tile lamp to illuminate the roadway. See the graph in Figure 3. The 4 percent Neodymium Oxide doped glass, which is the lower spectral energy distribution curve, is utilized in the Neodymium Oxide doped headlights.

Figure 3

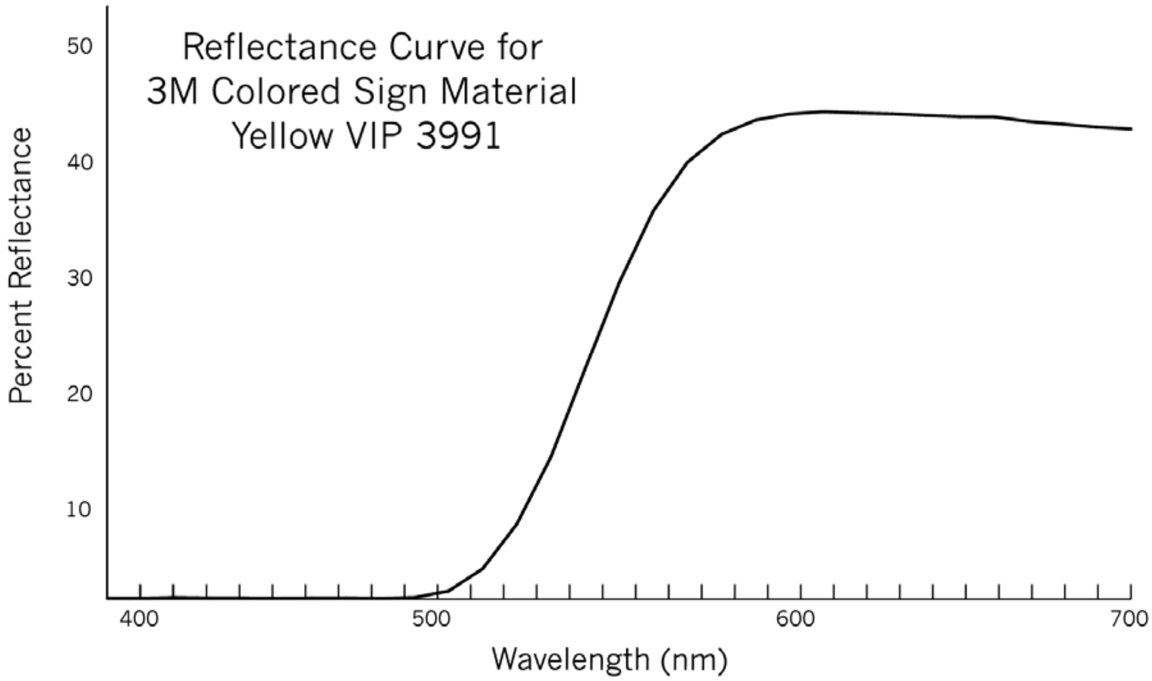


A reflectance curve for a yellow colored sign material is provided in Figure 4 on the next page. From 590 to 690 nanometers, the percent reflection is about 40 percent. Thus, while there is some reduction in the amount of yellow light being emitted from the Neodymium Oxide doped headlight to illuminate the yellow sign material, there is about the same reflectance in the orange and in the red, which tends to make the yellow signs appear to have a more saturated color hue.

There were no significant differences in the seeing distances between the Neodymium Oxide doped headlight lamps and the standard headlight lamps, and the mean seeing distances were very close.

The road test also confirms the work of McColgan et. al. in judging lamp preference. In that study, subjects used words such as "clearer", "more vivid", "brighter", and "more natural" in comparison to other headlight lamps. In side by side comparisons, for all of the times the Neodymium Oxide doped lamp was shown, it was chosen 92% and 95% of the time for the low and high luminance tests, respectively.

Figure 4



V PLANS FOR IMPLEMENTATION

Headlights

The concept of a Neodymium Oxide doped headlight lamp was first thought of in the summer of 1989. A United States Patent was filed in December, 1993. United States Patent Number 5,548,491, "Color Corrected Motor Vehicle Headlight" was issued in August, 1996. An effort was begun at that time to commercialize the patent. Research and development work was done by Corning Glass in 1999 to develop a new Neodymium Oxide doped Alumina Silica type glass for use in glass tubing to form tungsten halogen headlight lamps. A licensing agreement with Federal Mogul Corporation was signed in May, 2000, and limited sales of sealed beam Neodymium Oxide doped headlight lamps began soon afterwards under the trade name "LazerBlue". The licensing agreement was revised in February, 2003 to increase royalties to the inventor, Daniel Karpen. In August, 2003, Federal Mogul Corporation announced the "TruView" headlights, and began selling in the aftermarket 5 different sealed beam lamps and 4 halogen capsule type lamps, bulb models 9004, 9005, 9006, and 9007. Chains selling the lamps included Napa and Carquest stores, and several thousand stores carry the lamps as of the date of this report. The 9003 became available in the fall of 2004.

Federal Mogul has approached General Motors, Ford, and Daimler Chrysler among the domestic car manufacturers to install the lamps on new vehicles as original equipment. They have approached domestic truck manufacturers and foreign car makers, both in the Unites States and overseas.

Rear View Mirrors

The concept of a Neodymium Oxide rear view mirror was first thought of in December, 1993, just after the filing of the headlight patent. The "Motor Vehicle Rearview Mirror" patent was issued in December, 1998 as United States Patent Number 5,844,721. It took approximately one year for Schott Glass Technology to complete the research and development work to determine the amount of Neodymium Oxide to add to the glass to achieve a total reflectivity of just over 35 percent, the minimum reflectance required by the Federal Motor Vehicle Safety Standards. Marketing to the rear view mirror manufacturers began as soon as the patent was issued by the Patent Office. Approximately 40 manufacturers of rear view mirrors were identified in the United States as potential licensees.

In the summer of 2002, Schott Glass Technology started up a small glass float line to produce Neodymium Oxide doped glass for the rear view mirror industry. The line needs some changes to the equipment before large scale production can start. The cost of the alterations, plus the necessary start up costs for the glass furnaces, is estimated at several hundred thousand dollars. An order for glass would have to be several hundred thousand dollars in order to start production.

Daimler-Chrysler, Ford and General Motors have been approached on the invention, as well as a number of truck manufacturers as well as a number of foreign auto manufacturers operating manufacturing plants in the United States. In addition, several rear view manufacturers are marketing the Neodymium Oxide doped rear view mirror on their own directly to original equipment vehicle manufacturers.

Windshields

The concept of a Neodymium Oxide doped windshield was first conceived in May, 1999, and a United States Patent application was filed in May, 2001. The "Neodymium Oxide Doped Motor Vehicle Windshield And Safety Glazing Material" patent was issued by the United States Patent Office in September, 2002 as United States Patent Number 6,450,652.

Five major glass manufacturers have begun preliminary research and development work to fine tune the disclosures made in the patent specification. Federal Motor Vehicle Safety Standards require a minimum of 70 percent light transmittance for windshield materials. The patent was written around a solid piece of Neodymium Oxide doped glass with a total light transmittance of just over 70 percent. The plastic interlayer between the two panes of glass sandwiched together in a motor vehicle windshield lowers the total light transmittance by about .5 percent. What is needed is to make up small samples of Neodymium Oxide doped windshield glass with the plastic interlayer and to verify that these samples meet Federal safety standards. Once this research and development work is done, large scale manufacture of Neodymium Oxide doped windshield glass can begin at the glass manufacturers.

A typical float-line to manufacture flat glass can produce between 300 and 600 tons of glass per day. It is not enough for one vehicle marque to put Neodymium Oxide doped windshields on that one model as the amount of glass being produced by a major float-line is sufficient for several million vehicles per year. A typical windshield might weigh 30 pounds, thus a float line making 450 tons of glass per day would supply enough glass for 30,000 windshields per day. Full scale commercialization would require that several major motor vehicle manufacturers adopt the technology concurrently.

High Intensity Discharge Headlights

The concept of a Neodymium Oxide doped high intensity discharge headlight was developed in February, 1996. A United States Patent application was filed in February, 1998, and the "Color Corrected High Intensity Discharge Motor Vehicle Headlight" patent was issued by the United States Patent Office in October, 1999 as United States Patent Number 5,961,208.

The four major headlight manufacturers have been approached to license the patent. The Neodymium Oxide doped glass necessary for the implementation of this patent has been developed for the Neodymium Oxide doped tungsten halogen headlight, and it can be used for the Neodymium Oxide doped high intensity discharge headlight.

There are no insurmountable research obstacles, or "unknown unknowns" that would hamper development of the Neodymium Oxide doped high intensity discharge headlights. Decisions must be made by the major headlight manufacturers to make prototypes and to go forward to market the products.

VI CONCLUSIONS

This Safety IDEA research project expanded the knowledge base of experimental vision science related to Neodymium Oxide doped glass and illumination. The research was aimed at applications to transportation; however, the results of this project may be applicable as well to exterior illumination.

The research project looked at a number of vision tasks related to those that might be experienced by a motorist or truck driver. In the presence of a glare source, Neodymium Oxide glass improves the ability of a motorist to see detail, as exemplified by the test of reading lettering projected between two tungsten halogen lamps. Neodymium Oxide doped rear view mirrors, in the presence or a glare source, allow for better vision than an electrochromic mirror, which automatically dims; however, the amount of dimming is so great as to reduce the ability to discertain detail. Neodymium Oxide doped lighting appears to substantially reduce the duration of after images in the eye after exposure to a glare source; this problem occurs continuously in night driving.

The road test of this research project showed that Neodymium Oxide doped headlights are easier on the driver's eyes of his or her vehicle. Neodymium Oxide makes colors more vivid, in particular subjects reported that the reds were redder, the blue color was bluer, and that yellow signs were easy to read. This result is surprising since Neodymium Oxide, as a component of glass, will selectively filter yellow light. This result may have been an artifact of the questionnaire given to subjects.

As described in the section on plans for implementation, Neodymium Oxide doped headlights are being sold in the aftermarket, and there are no technological hurdles that would prevent the introduction of Neodymium Oxide doped glass rear view mirrors and windshields into the marketplace.

VII INVESTIGATOR PROFILE

Dr. Gordon Harris is a Doctor of Optometry, and he is a Fellow of the American Academy of Optometry. He is a practicing and research optometrist with over 45 years experience in clinical and research optometry. He was a Senior Research Associate at the Optometric Center of New York, and for 22 years was an Assistant Clinical Professor of Optometry at the State University of New York, College of Optometry. He is licensed in New York State, and he is certified in diagnostic drugs in New York State. His private practice includes the areas of general optometry, contact lenses, the treatment and management of ocular disease, treatment using ocular drugs, visual training, and developmental perceptual training. His mailing address is 441 Pulaski Road, Greenlawn, New York, tel: 631 421-2020, fax: 631 421-2055, e-mail: har441@optonline.net

Mr. Daniel Karpen is a professional engineer and an inventor with over 20 years experience in lighting and energy conservation consulting. He holds 7 United States patents, 2 Canadian patents, and has other patents pending. He holds 4 patents relating to the incorporation of Neodymium Oxide into the glass of the tungsten halogen headlight lamp, the high intensity discharge headlight lamp, the rear view mirror, and the windshield of a motor vehicle. His mailing address is 3 Harbor Hill Drive, Huntington, New York 11743, tel: 631 427-0723, fax: 631 427-0723.

Mr. Herbert Jaffe is a statistical and computer consultant, and performed the statistical analysis for this report. He was formerly a vice president at Shearson Lehman Corp, New York City where he directed special projects involving mathematical and statistical analysis. He was a director of engineering for Fairchild Republic, in Farmingdale, New York. His mailing address is 5 Pleasant View Drive, Huntington, New York 11743, tel: 631 421-4306.

VIII EXPERT REVIEW PANEL

The expert review panel reviewed the research protocol and performed peer review on this report prior to its release.

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NEODYMLITE REPORT . Oy Airam Ab Finland. Lampputtie 4, Box 6 SF-00751. Helsinki. Undated 9p

X APPENDICES

APPENDIX A - Schott Glass Color Calculation Software

	Date: 12/9/2000	Time: 12:13:11
Identification: NDF-1-2		Filename: \SC\NDF12.spc
Tank Identification: ND	Sampling Date, Time: 12/9/00	
Refractive Index: 1.523	Measured Thickness: 2.88	Desired Thickness: 2.9
Illuminant CIE D65	Observer Angle 2 degrees	
Tristimulus: x=67.25	Y=70.08	Z=95.06
Chromaticity: %=.2893	Y=.3015	Z=.409
Hunter L,a,b: L=83.71	A=1.43	B=13.84

Wavelength	%T Measured	%T Calculated
770	84.9	84.9
760	73.4	73.2
750	46.4	46.2
740	41.8	41.6
730	83.1	83.1
720	90.1	90.1
710	91.0	90.9
700	90.6	90.6
690	87.4	87.3
680	87.2	87.1
670	89.7	89.7
660	91.2	91.2
650	91.3	91.3
640	91.0	90.9
630	89.8	89.8
620	90.5	90.5
610	79.9	79.8
600	63.2	63.0
590	27.2	27.0
580	32.1	32.8
570	38.5	38.3
560	88.8	88.8
550	89.7	89.7
540	83.8	83.7
530	62.0	61.9
520	77.2	77.1
510	77.2	77.1
500	86.6	86.5
490	90.0	90.0
480	85.7	85.6
470	85.3	85.3
460	87.0	87.0
450	89.8	89.8
440	90.0	90.0
430	83.6	83.6
420	90.0	90.0
410	90.4	90.4
400	90.3	90.3
390	89.9	89.8
380	89.0	89.0

APPENDIX B - Reflectance Values of 3M Colored Sign Materials

Wavelength	Green VIP 3997	Blue VIP 3995	Red VIP 3992	Yellow VIP 3991	White VIP 3990	Orange HIS 9824	Brown HIS 3879	Green HIS 3877
400	0.29	3.32	0.62	0.10	16.97	2.29	1.03	0.64
410	0.45	7.51	1.11	0.08	31.83	3.71	1.06	0.67
420	0.67	12.56	1.12	0.14	41.56	3.69	1.01	0.75
430	0.81	14.11	0.67	0.10	43.64	2.77	0.93	0.89
440	1.07	12.80	0.36	0.10	43.87	2.09	0.96	1.12
450	1.88	11.03	0.21	0.08	43.95	1.67	0.96	1.92
460	4.22	9.55	0.17	0.10	43.85	1.46	1.05	4.58
470	9.22	8.38	0.15	0.11	43.77	1.45	1.13	9.66
480	15.76	7.41	0.09	0.07	43.61	1.57	1.23	15.27
490	20.54	6.57	0.12	0.14	43.49	1.81	1.30	18.89
500	20.86	5.87	0.10	0.69	43.28	2.16	1.39	19.57
510	18.33	5.21	0.10	2.57	43.10	2.89	1.54	18.36
520	14.60	4.20	0.13	6.33	42.83	3.90	1.77	16.19
530	10.69	3.15	0.09	11.99	42.47	4.94	2.07	13.20
540	7.13	2.22	0.16	19.40	42.10	6.46	2.53	9.40
550	4.44	1.45	0.18	26.70	41.78	9.28	2.99	5.76
560	2.52	0.86	0.22	32.75	41.44	13.59	3.89	2.93
570	1.35	0.51	0.55	36.85	41.11	19.19	4.97	1.26
580	0.64	0.30	1.98	39.20	40.71	25.16	6.34	0.57
590	0.46	0.20	6.95	40.41	40.51	30.53	7.37	0.32
600	0.36	0.08	16.33	40.93	40.31	34.41	7.61	0.23
610	0.34	0.08	26.81	41.11	40.09	36.49	7.75	0.26
620	0.30	0.06	34.31	41.01	39.67	37.50	8.12	0.20
630	0.35	0.06	38.06	40.94	39.55	37.73	8.67	0.23
640	0.27	0.02	39.82	40.80	39.41	37.56	9.14	0.21
650	0.33	0.04	40.56	40.69	39.27	37.18	10.13	0.23
660	0.35	0.05	40.80	40.68	39.32	36.75	11.49	0.29
670	0.36	0.08	40.67	40.29	39.06	36.30	13.43	0.24
680	0.41	0.05	40.54	40.07	38.85	35.82	16.08	0.27
690	0.37	0.12	40.44	39.81	38.46	35.49	18.40	0.28
700	0.39	0.25	40.52	39.66	38.27	35.19	19.34	0.24

APPENDIX C - Statistics

TEST 1: Logmar values as a function of incident illuminance & windshield type

		Standard Windshield		NdO glass	
Illuminance (Lux)	# points	Mean	Std. Dev.	Mean	Std. Dev.
0.2	30	0.41488	0.11058	0.42416	0.15809
2	30	0.12836	0.08286	0.13884	0.08601
20	30	0.05017	0.07952	0.03557	0.04807

TEST 1: Paired Comparison between NdO glass & Standard Windshield (Std. - NdO)

Illuminance (Lux)	Difference	Std. Deviation	d f	t	Probability
0.2	-0.00928	0.07758	29	-0.655	0.518
2	-0.01048	0.04105	29	-1.398	0.173
20	0.01460	0.07723	29	1.035	0.309

TEST 2 Brown ANOVA

Source Of Variation	Sum of Squares	Degrees of Freedom	Mean Sum of Squares	F	Probability
Windshield	90822.94	1	90822.940	1.227	0.27
Subject	9587012.60	29	330586.640	4.465	0.00
Symbols	8513377.50	2	4256688.700	57.486	0.00
Error	10884905.00	147	74046.975		
Total	29076118.00	179			

Windshield	Estimated Mean
Neo	305.604
Normal	350.530

TEST 2 Yellow ANOVA

Source Of Variation	Sum of Squares	Degrees of Freedom	Mean Sum of Squares	F	Probability
Windshield	66176.223	1	66176.223	0.685	0.409
Subject	15683449.000	29	540808.580	5.601	0.000
Symbols	9387072.200	2	4693536.100	48.610	0.000
Error	14193649.000	147	96555.438		
Total	39330347.000	179			

Windshield	Estimated Mean
Neo	486.578
Normal	448.230

TEST 2 Red ANOVA

Source Of Variation	Sum of Squares	Degrees of Freedom	Mean Sum of Squares	F	Probability
Windshield	2199.334	1	2199.334	0.079	0.779
Subject	8301483.800	29	286258.060	10.324	0.000
Symbols	4236934.100	2	2118467.000	76.401	0.000
Error	4076078.200	147	27728.423		
Total	16616695.000	179			

Windshield	Estimated Mean
Neo	295.750
Normal	302.741

TEST 2 Orange ANOVA

Source Of Variation	Sum of Squares	Degrees of Freedom	Mean Sum of Squares	F	Probability
Windshield	144467.7	1	144467.100	1.489	0.224
Subject	19096095.0	29	658486.040	6.786	0.000
Symbols	9560786.5	2	4780393.300	49.262	0.000
Error	14264923	147	97040.294		
Total	43066273	179			

Windshield	Estimated Mean
Neo	457.695
Normal	401.035

TEST 2 Green (Worboy) ANOVA

Source Of Variation	Sum of Squares	Degrees of Freedom	Mean Sum of Squares	F	Probability
Windshield	5249.902	1	5249.902	0.123	0.726
Subject	7305341.100	29	251908.310	5.908	0.000
Symbols	3547927.900	2	1773964.000	41.608	0.000
Error	6267417.200	147	42635.491		
Total	1712593600	179			

Windshield	Estimated Mean
Neo	273.975
Normal	284.777

TEST 2 Green (Lighter) ANOVA

Source Of Variation	Sum of Squares	Degrees of Freedom	Mean Sum of Squares	F	Probability
Windshield	66169.704	1	66169.704	3.412	0.067
Subject	4498797.700	29	155130.950	7.999	0.000
Symbols	2103653.400	2	1051826.700	54.236	0.000
Error	2850829.800	147	19393.400		
Total	9519450.600	179			

Windshield	Estimated Mean
Neo	201.654
Normal	240.001

TEST 2 Blue ANOVA

Source Of Variation	Sum of Squares	Degrees of Freedom	Mean Sum of Squares	F	Probability
Windshield	3878.837	1	3878.837	0.037	0.847
Subject	7122658.000	29	245608.900	2.300	0.000
Symbols	3010482.900	2	1505241.500	14.526	0.000
Error	15232643.000	147	103623.420		
Total	25369662.000	179			

Windshield	Estimated Mean
Neo	264.140
Normal	254.856

TEST 3 t-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	LOGNORM	.286820	30	.318185	5.809E-02
	LOGNEO	.261617	30	.316686	5.782E-02

	Paired Differences					
				95% Confidence Interval		
	Mean	Std Deviation	Std. Error Mean	Lower	Upper	t
Pair 1 LOGNORM-LOGNEO	2.520E-02	5.246E-02	9.578E-03	5.615E-03	4.479E-02	2.632

		Df	Sig. (2-tailed)
Pair 1	LOGNORM - LOGENO	29	.013

TEST 4 ANOVA

Source Of Variation	Sum of Squares	Degrees of Freedom	Mean Sum of Squares	F	Probability
Mirror	0.270	3	0.09002	3.192	0.025
Subject	7.561	29	0.26100	9.246	0.000
Headlight	6.108	1	6.10800	216.588	0.000
Error	5.809	206	0.02820		
Total	19.748	239			

Mirror	Estimated Mean
Elecdim	0.340
Elecnorm	0.279
Neo	0.272
Standard	0.249

TEST 4 - Headlights Off t-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	LMNEO	.114513	30	7.248E-02	1.323E-02
	LMELECNO	.104447	30	7.550E-02	1.378E-02
Pair 2	LMSTAND	.103490	30	7.960E-02	1.453E-02
	LMNEO	.114513	30	7.248E-02	1.323E-02
Pair 3	LMNEO	.114513	30	7.248E-02	1.323E-02
	LMELECDM	.183027	30	9.107E-02	1.663E-02

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Mean	Lower	Upper	T	Df	Sig (2-tailed)
Pair 1	LMNEO - LMELECNO	1.007E-02	2.720E-02	4.965E-03	-8.89E-05	2.022E-02	2.027	29	.052
Pair 2	LMSTAND - LMNEO	-1.10E-02	4.206E-02	7.679E-03	-2.67E-02	4.681E-03	-1.436	29	.162
Pair 3	LMNEO - LMELECDM	-6.85E-02	8.202E-02	1.497E-02	-9.91 E-02	-3.79E-02	-4.575	29	.000

TEST 4 = Headlights On t-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	LMNEO	.430170	30	.329746	6.020E-02
	LMELECNO	.453500	30	.357182	6.521E-02
Pair 2	LMSTAND	.397963	30	.312066	5.698E-02
	LMNEO	.430170	30	.329746	6.020E-02
Pair 3	LMNEO	.430170	30	.329746	6.020E-02
	LMELECDM	.496820	30	.317292	5.793E-02

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	T	df	Sig. (2-tailed)
Pair 1	LMNEO - LMELECNO	-2.33E-02	.103391	1.888E-02	-6.19E-02	1.528E-02	-1.236	29	.226
Pair 2	LMSTAND - LMNEO	-3.22E-02	.104933	1.916E-02	-7.14E-02	6.976E-03	-1.681	29	.103
Pair 3	LMNEO - LMELECDM	-6.66E-02	.165193	3.016E-02	-.128334	-4.97E-03	-2.210	29	.035

TEST 5A ANOVA

Source Of Variation	Sum of Squares	Degrees of Freedom	Mean Sum of Squares	F	Probability
Mirror	0.03951	3	0.01617	0.496	0.685
Subject	2.10000	29	0.07242	2.728	0.000
Headlight	1.00300	1	1.00300	37.792	0.000
Error	5.41500	204	0.02655		
Total	8.56200	237			

Mirror	Estimated Mean
Elecdim	0.0867
Elecnorm	0.06649
Neo	0.07510
Standard	0.05119

TEST 5B ANOVA

Source Of Variation	Sum of Squares	Degrees of Freedom	Mean Sum of Squares	F	Probability
Windshield	0.00246	1	0.002460	0.258	0.613
Headlight	0.05673	1	0.056730	5.948	0.016
Error	1.11600	117	0.009538		
Total	1.17500	119			

Windshield	Estimated Mean
Neo	0.03151
Normal	0.02246

TEST 7 ANOVA

Source Of Variation	Sum of Squares	Degrees of Freedom	Mean Sum of Squares	F	Probability
Glass	0.004187	1	0.004187	0.022	0.881
Subjects	43.095000	27	1.596000	8.525	0.000
Error	56.353000	301	0.187000		
Total	99.452000	329			

Glass	Estimated Mean
Neo	0.396
Normal	0.389

TEST 8 ANOVA

Source Of Variation	Sum of Squares	Degrees of Freedom	Mean Sum of Squares	F	Probability
Glass	9.919	2	4.959	3.702	0.026
Subject	764.194	29	26.352	19.669	0.000
Error	318.859	238	1.340		
Total	1092.971	269			

Glass	Estimated Mean
Neo	5.806
Normal	6.083
Neutral Density	6.272

TEST 9 ANOVA

Source Of Variation	Sum of Squares	Degrees of Freedom	Mean Sum of Squares	F	Probability
Filter	879.343	1	879.343	9.554	0.002
Subject	75934.308	22	3451.559	37.502	0.000
Error	14633.807	159	92.037		
Total	91466.249	182			

Filter	Estimated Mean
N D	26.288
Neo	21.902

TEST 10 Capsule vs. Sealed Beam Univariate Analysis of Variance

Between-Subjects Factors

		N
TYPE		7
	C	77
	SB	72
SUBJECT	1	12
	15	12
	16	12
	18	12
	19	12
	2	12
	20	12
	23	12
	28	12
	29	12
	4	12
	5	12
	6	12

Tests of Between-Subjects Effects

Dependent Variable: SCORE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	473.098[a]	14	33.793	17.780	.000
Intercept	1129.004	1	1129.004	594.038	.000
TYPE	2.432	1	2.432	1.280	.260
SUBJECT	408.724	11	37.157	19.550	.000
TYPE * SUBJECT	.832	1	.832	.438	.509
Error	267.979	141	1.901		
Total	3334.000	156			
Corrected Total	741.077	155			

[a]. R Squared = .638 (Adjusted R Squared = .602)

TEST 10 Independent Samples t-Test

Question		Mean	Std Err Of Mean	t	Mean Diff	Std Err Of Diff	95% UB	Con Int LB	t Prob
1	Neo	4.31	0.654	-1.316	-1.154	0.877	0.658	-2.965	.200
	Normal	5.46	0.584						
2	Neo	2.77	0.426	-1.136	-0.769	0.677	0.632	-2.167	.270
	Normal	3.54	0.526						
3	Neo	2.23	0.361	-2.225	-1.538	0.692	-0.111	-2.966	.040
	Normal	3.77	0.590						
4	Neo	2.92	0.445	-1.277	-1.077	0.843	0.682	-2.835	.220
	Normal	4.00	0.716						
5	Neo	3.15	0.390	-2.248	-1.769	0.787	-0.145	-3.393	.035
	Normal	4.92	0.684						
6	Neo	3.08	0.329	-2.008	-1.385	0.689	0.038	-2.809	.045
	Normal	4.46	0.606						
7	Neo	3.15	0.373	-1.023	-0.692	0.676	0.704	-2.088	.310
	Normal	3.85	0.564						
8	Neo	3.61	0.401	0.209	0.154	0.735	1.684	-1.377	.850
	Normal	3.462	0.616						
9	Neo	2.77	0.303	-2.097	-1.385	0.660	-0.022	-2.747	.045
	Normal	4.154	0.587						
10	Neo	3.31	0.644	-0.542	-0.462	0.851	1.298	-2.221	.590
	Normal	3.77	0.556						
11	Neo	3.85	0.436	-0.310	-0.231	0.745	1.315	-1.777	.750
	Normal	4.08	0.604						
12	Neo	4.39	0.797	0.684	0.692	1.012	2.788	-1.403	.600
	Normal	3.69	0.624						
13	Neo	0.5308	0.067	-0.223	-0.019	0.086	0.159	-0.1975	.820
	Normal	0.5500	0.054						
14	Neo	0.408	0.038	0.000	0.000	0.058	0.1191	-0.1191	1.00
	Normal	0.408	0.038						