

TRAFFIC SIGNAL GREEN LED STUDY

**Traffic Signal Unit
Office of Traffic, Security and Operations
Minnesota Department of Transportation**

June, 2003

Acknowledgement

We extend our thanks to people who supported the study, especially the following groups for their assistance:

- Washington County Transportation Division
- Mn/DOT Human Resource Office
- Mn/DOT market research group
- Mn/DOT Central Office Signal group
- Mn/DOT Central Office Lighting group
- Mn/DOT volunteers

For further information regarding the project, please contact:

- Ray Starr, Mn/DOT at (651) 284-3434 or ray.starr@dot.state.mn.us
- Rachel Guan, Mn/DOT at (651) 284-3436 or rachel.guan@dot.state.mn.us
- Wayne Sandberg, Washington County at (651)430-4339 or wayne.sandberg@co.washington.mn.us

TRAFFIC SIGNAL GREEN LED STUDY

I. BACKGROUND	1
II. LITERATURE REVIEW	2
III. FIELD TEST	3
A. GOALS AND OBJECTIVES.....	3
B. TEST SITE	3
C. TEST SUBJECTS	4
D. TESTED TRAFFIC SIGNAL TYPES	5
E. TEST QUESTIONS	6
F. TEST CONDITIONS.....	6
G. TEST PROCEDURES.....	6
IV. TEST RESULTS	7
V. DATA ANALYSIS.....	10
VI. SUMMARY OF RESULTS	11

Appendix

TRAFFIC SIGNAL GREEN LED STUDY

I. Background

Light Emitting Diode (LED) vehicle traffic signal indications have become popular in the last ten years in the US. The improved technology and significant energy saving made it an advantage over the traditional incandescent traffic signal indications. They are mainly used for red and green traffic signal indications. In recent years there have been more LED traffic signal heads installed in Minnesota.

Minnesota Department of Transportation (Mn/DOT) received a complaint from a color blind person about a change in the appearance of traffic signals over the last few years. The specific signals mentioned were green LED traffic signal indications located in Washington County. In the direct sunlight, the green indication appeared to be “ON”, even when it was not, especially near the spring and fall equinox. Washington County has been upgrading signal indications to LEDs since 1998. All new signal indications are LEDs. Mn/DOT contacted Washington County and discussed the issue. In 2002, Mn/DOT and Washington County conducted a preliminary investigation. Mn/DOT took photographs of different types of LED and incandescent signal heads in direct sunlight. See the appendix for some photographs from this preliminary investigation.

The preliminary investigation indicated that the most common type of green LED in the county has a clear lens. The light reflection of the unlit clear lens green LED could appear brighter than the lit red or amber indication under direct sunlight, although it is not green in color when unlit. For a person having a color vision deficiency the brightness, not the color, is the most important cue.

To further investigate the issue, Washington County installed several different designs of LED signal heads on Valley Creek Road. To understand the problems and serve the general traveling public better, the Mn/DOT Office of Traffic, Security, and Operations (OTSO) initiated an internal study on colorblind vision issues related to the LED traffic signal indication, utilizing the Valley Creek Road test site.

The research unit and market research group in Mn/DOT discussed the issue. At the same time OTSO personnel conducted a brief literature review on related issues. Once the issues and objectives were identified, OTSO launched a field test investigation. Since color blindness could be considered a sensitive privacy issue, the Mn/DOT Human Resource Office provided help on recruiting Mn/DOT volunteers. The Mn/DOT market research group provided help on field testing and data analysis. Details are documented in the following sections of this report.

II. Literature Review

There is literature regarding LED signal indications, but none of the literature directly addressed color blindness issues related to Green LED traffic signal indications. The following are brief summaries of literature reviewed:

In “Response To Simulated Traffic Signals Using Light-Emitting Diode and Incandescent Sources” (Transportation Research Record [1724]: 39-46), John Bullough used simulated 200mm (8”) LED and incandescent signals seen from 100m under daytime conditions. He measured the reaction time to signal onset; the number of missed signals; the number of signals correctly identified by color; and subjective ratings of brightness and conspicuity. For the reaction time test, he tested 10 subjects (5 males, 5 females) with 10 presentations in five sessions. For color testing, he tested 30 subjects (14 males, 16 females). None of the participants had color blindness. He found that: the red signals resulted in the shortest reaction times and green the longest; the percentage of missed signals increased as luminance decreases, especially for green signals; correct color identification rate was high; and the brightness of red was higher than yellow and green. In general the red signal appeared more saturated than the yellow and green signals, and the perceived brightness of a signal light increased for more saturated lights. LEDs have narrow spectral power distributions resulting in more highly saturated colors than incandescent signals.

In 2001, John Bullough reported a study performed under nighttime conditions to determine if signal luminance higher than the minimum might result in any discomfort (“Traffic Signal Luminance and Visual Discomfort at Night” Transportation Research Record [1754]: 42-47). He rated the discomfort looking directly at the simulated signal from two distances. He found that: color identification was very easy; the yellow signal had lower brightness and discomfort ratings than red and green signals; higher signal luminance resulted in higher discomfort ratings; a shorter viewing distance resulted in higher discomfort ratings; and red signals meeting ITE specifications were unlikely to cause discomfort whereas that was not the case for yellow and green signals.

Based on simulated research at the Lighting Research Center at Rensselaer Polytechnic Institute in 2002, John Bullough reported that for the same intensity, yellow and green signals resulted in longer than red reaction times and higher missed signals rate. (“Are Yellow Traffic Signals Brighter Than They Need To Be?” Research recap: Lighting Design and Application 32[12]: 18-21)

In 2003, John Bullough reported an investigation on the responses of Protans to red and yellow incandescent and LED traffic signals by simulated experiments measuring reaction time and color identification (“Detection and Identification of LED Traffic Signals by Protan Observers”. TRB 82nd Annual Meeting). Protans are people with color deficiency identifying long wavelengths of the visible spectrum. The red color

wavelength is longer in the spectrum than the yellow one. Protans often confuse the yellow as red traffic signals. The study conducted two experiments and observed 6 males (3 normal, 3 protan) in 10 trials. He found that: Missed signals for the protans were fewest with the yellow and greatest with the red LEDs; Direct view performed better than tracking tasks (simulated) for both groups.

New York State Department of Transportation (NYSDOT) evaluated LEDs installed at Troy-Green Island Bridge (“Evaluation of NYSDOT LED Traffic Installation” New York State Energy Research and Development Authority). After NYSDOT converted the red and green incandescent traffic signals to LEDs, the agency received calls indicating that the new signals looked different. The red and green LED signals seemed brighter than incandescent. The green LEDs caused momentary discomfort to drivers. NYSDOT considered the conversion to LEDs a success.

Current ITE standards were based on the studies in 1970’s and the studies did not use LED traffic signals. Gerhart King found that signal color was the most important factor affecting perceiving the signal indication and green signal indications resulted in the poorest response during a daytime test. [“Visibility of Circular Traffic-Signal Indications” Transportation Research Record 811 p7-13]. Measures of perception, defective color vision, visual acuity, visual performance, and sun-phantom effects were discussed for incandescent traffic signals in “Light Signals for Road Traffic Control”, CIE publication No 48 (TC-1.6) 1980 by the International Commission on Illumination.

III. Field Test

A. Goals and Objectives

The objectives of the field test were to answer the following questions:

- Is there really a problem with the LED green indication?
- Are any of the available designs better than the other designs?
- Is the best solution for people with color blindness acceptable for people not having color blindness?

The goal of the study is to help the OTSO signal unit to write the most appropriate specs for purchasing LED traffic signals.

B. Test Site

The field test site consisted of seven intersections on Valley Creek Road in Woodbury. The intersections are on the west bound direction from Interlachen Parkway to Valley Creek Plaza. It is a two-way four-lane divided highway. The road is orientated directly east and west except for the intersection at Bielenberg which is at an angle. At Bielenberg, both indications remained as the LED types that were in-place prior to the

test. At the valley Creek Plaza intersection, the right lane signal was partially shaded by a tree. See the site map in the Appendix.

C. Test Subjects

All test subjects were volunteers recruited from Mn/DOT. After sending out the recruiting letter via email, six color blind volunteers responded and 20 non color blind volunteers responded. Since the test could only take place under direct sunshine in the early morning, several of the volunteers dropped due to time constraints. In the end, four color blind volunteers and four non color blind volunteers participated in the test. Due to the small number of volunteers tested, the test results are not statistically significant but can provide insights on the issues of interest. See the recruiting letter, the data practices form, and the volunteer information form in the Appendix.

Volunteers were randomly assigned a test ID number and no personal information could be associated with any individuals after the data collection was complete. Both color blind and non color blind participants were represented on each test day.

Seven males and one female were tested during the study. The age of the volunteers ranged from 22 to 54 (two 20s, one 30s, three 40s, one 50s, one did not report). All four color blind participants were males, and three non color blind participants were males. The female participant was a non color blind volunteer. None of the color blind participants provide information regarding the specific type of degree of color blindness.

D. Tested Traffic Signal Types

Six different types of green LED indications and one green incandescent traffic signal indication were installed at the seven intersections. The signals were all mounted overhead directly over the center of the left lane or the right lane. The signals installed were as follows:

TABLE 1 Signal Types and Locations

Intersections / Locations	Signals
Interlachen Parkway - Left Lane	Clear-Old-Brand A
Interlachen Parkway - Right Lane	Clear-New-Brand B
Donegal Drive – Left Lane	Tinted-New-Brand B
Donegal Drive - Right Lane	Clear-Old-Brand B
Radio Drive (CSAH 13) - Left Lane	Clear-Old-Brand A
Radio Drive (CSAH 13) - Right Lane	Incandescent
Tower Drive - Left Lane	Tinted-New-Brand A
Tower Drive – Right Lane	Clear-Old-Brand A
Bielenberg Drive - Left Lane	Clear-Old-Brand A
Bielenberg Drive - Right Lane	Clear-Old-Brand A
Queens Drive - Left Lane	Clear-New-Brand A
Queens Drive - Right Lane	Clear-Old-Brand A
Valley Creek Plaza - Left Lane	Clear-Old-Brand B
Valley Creek Plaza - Right Lane	Clear-Old-Brand A

The differences among the green LED traffic indications tested can be categorized into the following:

- Green tinted lens versus clear lens
- High LED count (old technology) versus new lensed designs(new “incandescent look” technology – lower LED count)
- Two different brands

There was only one intersection with an incandescent traffic signal indication.

See the Appendix for photos of different types of LED signal indications individually and as installed.

E. Test Questions

The Mn/DOT Market research group assisted in developing the test questions for the green LED traffic signal study (Please see the study questionnaires in the Appendix). At each intersection, an assistant asked the volunteer the following three questions:

1. For the signal over the Left lane, does the green light on the bottom appear to be lit? (Yes, No, Can't Tell)
2. For the signal over the Right lane, does the green light on the bottom appear to be lit? (Yes, No, Can't Tell)
3. Do you have any comments about the appearance of these two green lights?

The questions were asked concerning the green light when the red light was lit, the green light was unlit, and the signal head was in direct sunlight.

F. Test Conditions

The test was performed shortly after the spring equinox early in the morning, so that the sun would be low in the sky directly behind the observer and shining directly on the signal in the westbound direction.

G. Test Procedures

Prior to test execution, the Mn/DOT market research group provided interview training to the test assistants. The OTSO signal unit and Washington County conducted a dry run at the test site to finalize the test procedures. The tests were performed over three days from April 8 through April 10, 2003.

Each morning before the test execution, all participants gathered near the site. The participants received pre-test instructions (See the Appendix for the instructions). Then each test vehicle headed to the test intersections.

There were three people for each test vehicle. The test participant sat in the passenger seat. A driver sat in front, and an interviewer sat in the back seat in each test vehicle. Two test vehicles traveled one behind the other as one fleet traveling in the right lane.

Washington County provided one shadow truck with an arrow board and traffic impact attenuator following each test vehicle. A maximum of two fleets were tested each day. (See the Appendix for a diagram of the fleet configuration.) The test vehicle stopped near the intersection where a good sun reflection could be seen. The test vehicles remained in place while the interviewer asked the questions and recorded the volunteer's responses. If the light changed before the volunteer finished answering, the vehicles remained in place until the next cycle.

IV. Test Results

Eight volunteers observed two signals at each of seven intersections, for a total of 112 observations. The following are the total summaries of the first two questions for each tested intersection for both right and left traffic signal indications:

TABLE 2. Total Observation Summary

	Number of Observations		
	All Participants	Color Blind	Non Color Blind
Appeared ON	16	14	2
Did Not Appear ON	89	36	53
Could not Tell	7	6	1
Total	112	56	56

For non color blind participants, less than four percent saw a green light ON when it was not. For color blind participants, twenty-five percent saw the green light ON when it was not.

The following table is the summary for perceptions from the participants:

TABLE 3 Perception Data Summary

Signals	Location	Appeared ON			Did Not Appear ON			Could not Tell		
		All	Color Blind	Non Color Blind	All	Color Blind	Non Color Blind	All	Color Blind	Non Color Blind
Tint-New-Brand B	Donegal Drive-Left Lane	2	0	2	6	4	2	0	0	0
Tint-New-Brand A	Tower Drive-Left Lane	0	0	0	8	4	4	0	0	0
Clear-New-Brand B	Interlachen Parkway- Right Lane	1	1	0	6	2	4	1	1	0
Clear-New-Brand A	Queens Drive-Left Lane	1	1	0	7	3	4	0	0	0
Clear-Old-Brand B	Donegal Drive- Right Lane	1	1	0	7	3	4	0	0	0
Clear-Old-Brand B	Valley Creek Plaza-Left Lane	0	0	0	8	4	4	0	0	0
Clear-Old-Brand A	Interlachen Parkway-Left Lane	1	1	0	7	3	4	0	0	0
Clear-Old-Brand A	Radio Drive-Left Lane	3	3	0	5	1	4	0	0	0
Clear-Old-Brand A	Tower Drive- Right Lane	2	2	0	5	1	4	1	1	0
Clear-Old-Brand A	Bielenberg Drive-Left Lane	1	1	0	6	2	4	1	1	0
Clear-Old-Brand A	Bielenberg Drive- Right Lane	1	1	0	6	2	4	1	1	0
Clear-Old-Brand A	Queens Drive- Right Lane	2	2	0	5	1	4	1	1	0
Clear-Old-Brand A	Valley Creek Plaza- Right Lane	1	1	0	6	2	4	1	1	0
Incandescent	Radio Drive- Right Lane	0	0	0	7	4	3	1	0	1

The following table is the summary of percentage of misperceived green signals (appeared ON) by signal type:

TABLE 4. Observations by Signal Type

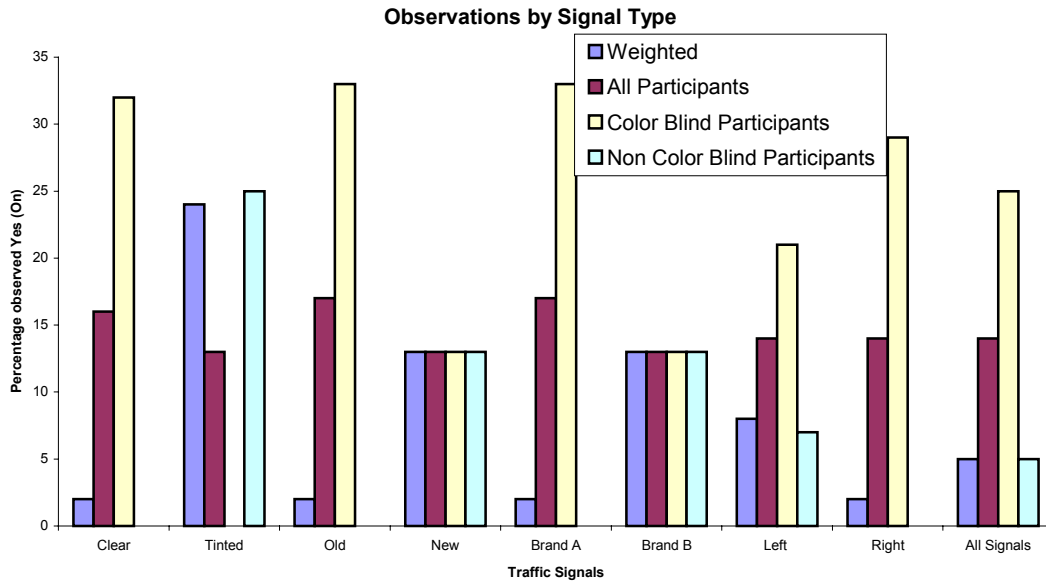
Numbers(%) Appeared ON	All	Color Blind	Non Color Blind	Weighted Total
Clear LED	14 of 88 (16%)	14 of 44 (32%)	0 of 44 (0%)	1.6%
Tinted LED	2 of 16 (12.5%)	0 of 8 (0%)	2 of 8 (25%)	24%
Old LED	12 of 72 (17%)	12 of 36 (33%)	0 of 36 (0%)	1.7%
New LED	4 of 32 (12.5%)	2 of 16 (12.5%)	2 of 16 (12.5%)	12.5%
Brand A LED	12 of 72 (17%)	12 of 36 (33%)	0 of 36 (0%)	1.7%
Brand B LED	4 of 32 (12.5%)	2 of 16 (12.5%)	2 of 16 (12.5%)	12.5%
Left	4 of 56 (14%)	6 of 28 (21%)	2 of 28 (7%)	7.7%
Right	7 of 56 (14%)	8 of 28 (29%)	0 of 28 (0%)	1.5%
Incandescent	0 of 8 (0%)	0 of 4 (0%)	0 of 4 (0%)	0%
All Signals	16 of 112 (14%)	14 of 56 (25%)	2 of 56 (4%)	5%

Due to the fact that about 10% of males have red-green color blindness, and assuming a 50-50 split between male and female in the population, about 5% of the total population has red-green color blindness. A very coarse approach to looking at the overall result is to provide a weighted total of which the color blind observations make up 5% contribution and the non color blind observations make up a 95% contribution. The weighted total is calculated as the following:

$$\left[\begin{array}{l} \text{Weighted\%} \\ \text{observed" ON"} \end{array} \right] = \frac{\left(95\% * \left[\begin{array}{l} \% \text{observed" ON"} \\ \text{for Non Color Blind} \end{array} \right] * \left[\begin{array}{l} \text{Total} \\ \text{Population} \end{array} \right] + 5\% * \left[\begin{array}{l} \% \text{observed" ON"} \\ \text{for Color Blind} \end{array} \right] * \left[\begin{array}{l} \text{Total} \\ \text{Population} \end{array} \right] \right)}{\left[\begin{array}{l} \text{Total} \\ \text{Population} \end{array} \right]} * 100\%$$

The left and right lane observations are shown in order to verify that observation angle differences in the two lanes did not influence the outcome.

The same data in bar graph form is shown below:



The participants also provided comments about the appearance of the two signals at each intersection (question 3). Basically they provided comments if they observed any differences between the signals. Some provided additional comments regarding the left signal, some on the right signal. The followings is the summary of the comments:

TABLE 5. Comments at Each Intersection

Intersections	Noticed Differences	Comments on Left	Comments on Right
InterLanchen Parkway	1/8	1/8	0/8
Donegal Drive	7/8	3/8	4/8
Radio Drive	6/8	5/8	3/8
Tower Drive	5/8	5/8	5/8
Bielenberg Drive	0/8	0/8	0/8
Queens Drive	5/8	3/8	4/8
Valley Creek Plaza	5/8	3/8	4/8

The following paragraphs are the summaries based on the comments the participants provided for each intersection.

At Interlanchen parkway, the green LED signals installed were clear lens old technology brand A and clear lens, new technology, brand B. One out of four said the green was

bright. Four of the participants noticed that something might not be right: glare, gray, or shimmer. Interesting enough that all these participants are non color blind.

At Donegal Drive, the signals were tinted lens, new technology, brand B and clear lens, old technology, brand B green LED signals. Seven out of eight participants commented on the differences between the two signals. One color blind participant indicated that the clear lens old technology signal washed out in the sunlight.

At Radio Drive, the clear lens, old technology, brand A green LED signal and a traditional incandescent green signal were installed. Six out of eight participants indicated a difference between the two signals.

At Tower Drive, tinted lens, new technology, brand A and clear lens, old technology, brand A green LED signals were installed. There were no relevant comments.

At Bielenberg Drive, clear lens, old technology, brand A green LED signals were installed over both lanes. Six out of eight participants indicated that the signals appeared the same.

At Queens Drive, new technology, clear lens, brand A and old technology, clear lens, brand A green LED signals were installed. Five out of eight participants indicated that they were different.

At Valley Creek Plaza, clear lens, old technology, brand A and clear lens, old technology, brand B green LED signals were installed. Five out of eight participants indicated a difference between the two signals.

V. Data Analysis

It is observed that there are differences between color blind and non color blind participants perceiving the green LED as “ON” when it is not lit. For each factor in the LED signal design, the type that had the highest percentage of wrong perception was opposite for the color blind as compared with the non color blind. For color blind participants, the clear lens, old technology, and brand A caused more misperceptions. However for non-color blind participants, the tinted lens, new technology, and brand B, caused more misperceptions. For color blind participants, about 25% participants perceived ON condition of the green LED signal under direct sunlight when it is not lit. For non color blind participants, it is about 4%. There were no misperceptions of the incandescent green signal, however there was only one incandescent signal of the fourteen tested signals. There were also one tinted new brand A and one clear old brand B that had no misperceptions. Also, every one of the clear old brand A’s were misperceived at least once.

Since the participants were told that the light would be red, and they could see the light turning red, their perceptions of the green being not lit may not reflect their real world experience.

VI. Summary of Results

The green LED traffic signal test was conducted under the direct sunlight in the field. There were four color blind and four non color blind participants. The misperception of the green LED was different between the color blind and non color blind participants. They were opposite in terms of how clear lens versus tinted lens; old technology versus new technology; and brand A versus brand B affected their perception of the green signal.

OTSO did not perform a statistical analysis based on the following considerations:

- The small sample size of participants.
- All volunteers were from Mn/DOT, not a random representation.
- The participants knew the light was not lit when asked if it appeared lit.
- The various signal configurations were not equally represented in the test site.

The study responded to the study objectives as follows:

1. Is there really a problem with the LED green indication?

The test did confirm that some common LED green signals can be perceived wrongly during direct sunlight conditions by people having red-green color blindness. Color blind and non color blind travelers perceived LED green indication differently.

2. Are any of the available designs better than the other designs?

The test indicated that the design and the technology also make a difference for the perceptions. There is a design that was better for color blind and another that was better for non color blind participants.

3. Is the best solution for people with color blindness acceptable for people not having color blindness?

The best solution for color blind is not the best solution for non color blind. More study would be required to determine conclusively whether any of the designs are acceptable or not.

This study will contribute to considerations of future use of Green LED traffic signal indications.

Appendix

A. PRELIMINARY INVESTIGATION FOR LED AND INCANDESCENT SIGNALS.....	1
B. INTERSECTIONS FOR GREEN LED TRAFFIC SIGNAL STUDY	2
C. GREEN LED TRAFFIC SIGNAL STUDY RECRUITING LETTER	3
D. DATA PRACTICES NOTICE	4
E. VOLUNTEER INFORMATION FORM	6
F. LED SIGNALS TESTED.....	7
G. LED SIGNALS AS INSTALLED	8
H. TRAFFIC SIGNAL GREEN LED STUDY QUESTIONNAIRES	10
I. PRE-TEST INSTRUCTION.....	12
J. TEST FLEET CONFIGURATION.....	13

A. Preliminary Investigation for LED and Incandescent Signals



Color



Black & White

Incandescent Traffic Signal: Which indication is lit?



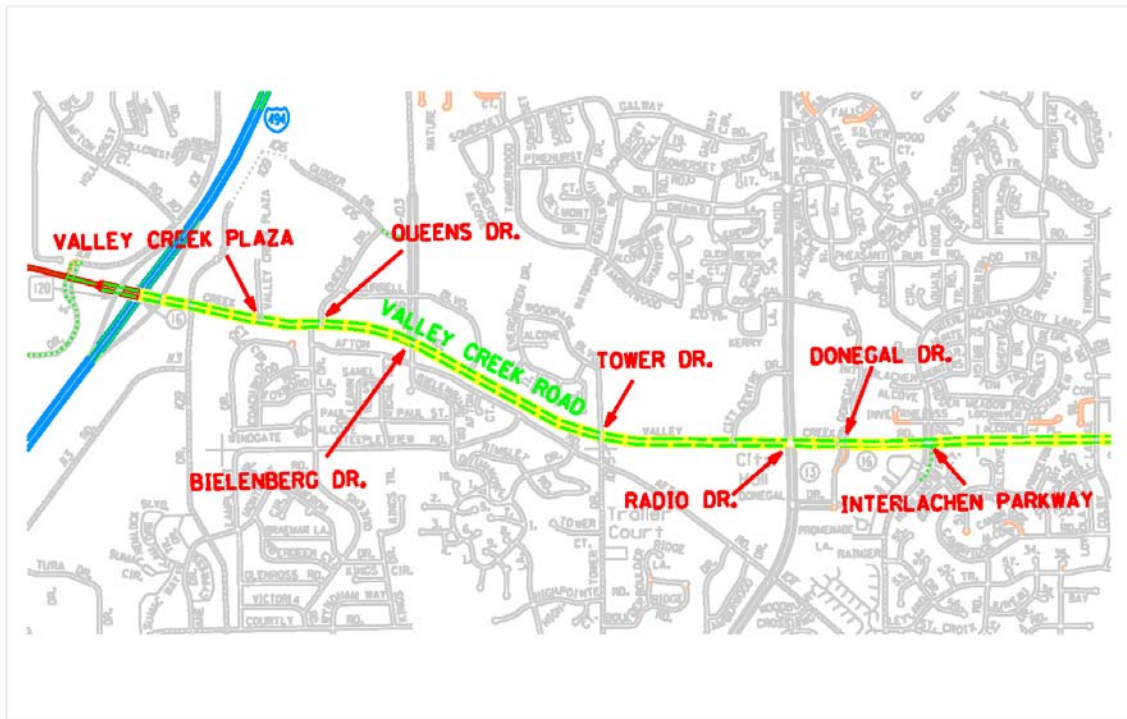
Color



Black & White

LED Traffic Signal: Which indication is lit?

B. Intersections for Green LED Traffic Signal Study



C. Green LED Traffic Signal Study Recruiting Letter

Mn/DOT Employees in the Metro Area:

Mn/DOT's Office of Traffic, Security and Operations is looking for volunteers to assist us with a Mn/DOT traffic signal study.

Input from the public has brought to our attention that a person with red-green color blindness can have special difficulty identifying red or green traffic signals when the sun is shining on them directly. We are looking for volunteers to assist us to evaluate several different designs of traffic signals.

We are looking for both non-colorblind and red-green colorblind volunteers who are not working in the traffic signal area. We plan to drive the volunteers through intersections with different traffic signal designs and request specific feedback regarding perception of the traffic signals. We are planning to do it between the dates of March 17, 2003 through March 28, 2003. Each volunteer would be needed for approximately two hours shortly after dawn on one day within this time frame. This is a great opportunity for you to contribute and help the traveling public.

All information collected will be maintained in accordance with the Minnesota Government Data Practices Act, Chapter 13 and will only be used for the purpose of the study. The study report will not identify any individual by name.

Participation in the study is voluntary. With prior written approval from your supervisor, you may use up to 2 hours of paid work time to participate. Your participation, however, must not result in overtime hours. For example, with prior supervisor approval, you can voluntarily flex your hours to participate, so long as it does not result in overtime.

If you are interested, please contact Rachel Guan at rachel.guan@dot.state.mn.us by March 12, 2003. Even if you are not interested in participating in the study, any general feedback from people with color-blindness is welcome.

D. DATA PRACTICES NOTICE

Pursuant to Minn. Stat. § 13.04 of the Government Data Practices Act, as amended, you are being notified that you are being asked to volunteer information, which includes private medical information as part of a Traffic Research Project. You are not required by law to supply the requested medical information, as providing such information is completely voluntary.

The purpose of the study is to identify the perception of traffic signals in red-green colorblind people and non-colorblind people. We will be asking whether you are color blind or not and, if you know, specific information about the type and degree of colorblindness. All information collected will be used only for purposes of this study.

Your participation in this study is completely voluntary. You may choose not to participate or to provide medical information at any time. If you do not tell us whether you are color blind or not, you will not be able to participate in the study. While information on type and degree of colorblindness is helpful, this specific information is not necessary.

Information that is gathered on you during the course of this research project may be classified as confidential, private or public. Any medical information gathered on you may be classified as confidential or private.

Individual names will not be used in this research project. Your name will not be linked to your medical information. The only place your name will be identified for the purposes of this study is during the scheduling process (e.g.: e-mail correspondence scheduling time and date for participation) and on this Data Practices Notice, where you will provide your signature. The Project Managers of this study will maintain this notice, including your signature, in a separate file. It will not be shared with the public or with others, except in compliance with the Minnesota Government Data Practices Act and /or other applicable law. Project managers will have access to all data.

Project results, including medical information, will be compiled into summary data. Summary data is data that has identifying information removed (e.g. your name). Anyone working on or concerned with this project will have access to summary data only.

Signature

Date

E. Volunteer Information Form

Could you please provide the following information? Thank You!

Gender: _____

Age: _____

Are you colorblind? _____

If Yes, what is the specific type and degree of the colorblindness? _____

Do you believe that
you are color weak?

Participant ID number: _____

F. LED Signals Tested



Clear Len – Old Technology – Brand A



Tinted Len – New Technology – Brand A



Clear Len – New Technology – Brand B

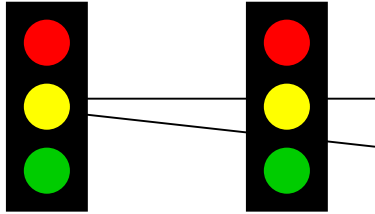


Tinted Len – New Technology – Brand B



Clear Len – Old Technology – Brand B

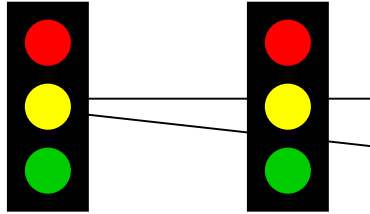
G LED Signals As Installed



Brand A
Clear
lens Old
Tech

Brand B
Clear lens
New Tech

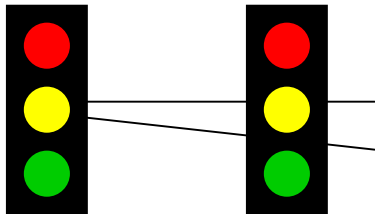
**WB CSAH 16 (Valley
Creek Rd) at Interlachen**



Brand B
Tinted lens
New Tech

Brand B
Clear lens
Old Tech

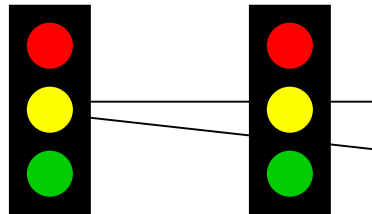
**WB CSAH 16 (Valley
Creek Rd) at Donegal Dr**



Brand A
Clear
lens Old
Tech

Incandesc
ent bulb –

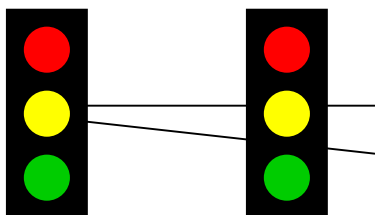
**WB CSAH 16 (Valley
Creek Rd) at CSAH 13**



Brand A
Tinted lens
New Tech

Brand A
Clear
Lens Old
Tech

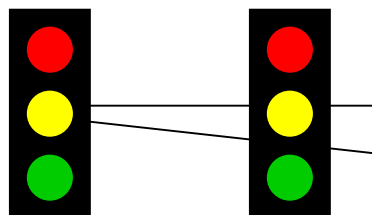
**WB CSAH 16 (Valley
Creek Rd) at Tower Dr**



Brand A
Clear lens
New Tech

Brand A
Clear lens
Old Tech

**WB CSAH 16 (Valley
Creek Rd) at Queens Dr**



Brand B
Clear lens
Old Tech

Brand A
Clear
lens Old
Tech

**WB CSAH 16 (Valley
Creek Rd) at Valley Creek**



Interlachen Parkway



Donegal Drive



Radio Drive



Tower Drive



Bielenberg Drive



Queens Drive



Valley Creek Plaza

H. Traffic Signal Green LED Study Questionnaires

Participant ID Number: _____

Survey Date: _____

Staff in Vehicle: _____

	QUESTION	ANSWERS
InterLachen Pkwy	1. For the signal over the <u>Left</u> lane, does the green light on the bottom appear to be lit? (Yes, No, Can't Tell)	
	2. For the signal over the <u>Right</u> lane, does the green light on the bottom appear to be lit? (Yes, No, Can't Tell)	
	3. Do you have any comments about the appearance of these two green lights?	
Donegal Dr.	1. For the signal over the <u>Left</u> lane, does the green light on the bottom appear to be lit? (Yes, No, Can't Tell)	
	2. For the signal over the <u>Right</u> lane, does the green light on the bottom appear to be lit? (Yes, No, Can't Tell)	
	3. Do you have any comments about the appearance of these two green lights?	
CSAH 13 (Radio Dr.)	1. For the signal over the <u>Left</u> lane, does the green light on the bottom appear to be lit? (Yes, No, Can't Tell)	
	2. For the signal over the <u>Right</u> lane, does the green light on the bottom appear to be lit? (Yes, No, Can't Tell)	
	3. Do you have any comments about the appearance of these two green lights?	

Tower Dr.	1. For the signal over the <u>Left</u> lane, does the green light on the bottom appear to be lit? (Yes, No, Can't Tell)	
	2. For the signal over the <u>Right</u> lane, does the green light on the bottom appear to be lit? (Yes, No, Can't Tell)	
	3. Do you have any comments about the appearance of these two green lights?	
Bielenberg Dr.	1. For the signal over the <u>Left</u> lane, does the green light on the bottom appear to be lit? (Yes, No, Can't Tell)	
	2. For the signal over the <u>Right</u> lane, does the green light on the bottom appear to be lit? (Yes, No, Can't Tell)	
	3. Do you have any comments about the appearance of these two green lights?	
Queens Dr.	1. For the signal over the <u>Left</u> lane, does the green light on the bottom appear to be lit? (Yes, No, Can't Tell)	
	2. For the signal over the <u>Right</u> lane, does the green light on the bottom appear to be lit? (Yes, No, Can't Tell)	
	3. Do you have any comments about the appearance of these two green lights?	
Valley Creek Plaza	1. For the signal over the <u>Left</u> lane, does the green light on the bottom appear to be lit? (Yes, No, Can't Tell)	
	2. For the signal over the <u>Right</u> lane, does the green light on the bottom appear to be lit? (Yes, No, Can't Tell)	
	3. Do you have any comments about the appearance of these two green lights?	

I. Pre-test Instruction

First fill out the data practices form and the vision information form.

1. As we indicated in our e-mail to you, Mn/DOT received a call from the public saying that a person with color blindness has special difficulty determining what color the traffic signal is when the sun is shining directly on it. The question is whether the Green light appears to be on when it really is not on. To follow up on this concern, Washington County has joined up with Mn/DOT and installed several different designs of traffic signals on Valley Creek Road. This morning we will be driving through these intersections to get your perceptions of the different designs. We have people both with and without color blindness participating.
2. The way the study will work is that you will be in a car in the passenger seat. There will be a driver and also an interviewer in the back seat. As we approach a signal, we will be stopping in the lane to ask 3 questions. There will be a truck behind us with an arrow board directing traffic around us. You will not need to be concerned about the traffic.
3. During the test we will be asking questions about what you see. Please respond according to what you actually see, not what you think you should be seeing. There are no wrong answers.
4. We are only interested in the traffic signals mounted directly over the left lane and directly over the right lane. Please ignore the left turn arrow signals for the left turn lane and ignore the signals mounted on the pole on the right side of the road. Just focus on the 2 signals mounted overhead directly over the lanes.
5. We will be asking you questions about the appearance of the Green light on the bottom of each signal at a point in time when the signal is not Green. In other words, when the Red light is lit we will ask you about the appearance of the unlit Green light in the direct sunlight. If the signal changes before you are done with the questions at that intersection, we will ask you to wait until the light changes again, and then we will ask you to continue with your answer. Here are the questions we will ask:

J. Test Fleet Configuration

