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Vision performance enhancement with ski goggle tints

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Abstract

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VISION AND PERFORMANCE ENHANCEMENT WITH SKI GOGGLE TINTS

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ABSTRACT

Three popular ski goggle lens tints; gold, vermilion and gray; were evaluated for their effect on vision and skiing performance. Subjects were tested for visual acuity and contrast sensitivity, timed in a Giant Slalom ski race course, and asked to complete subjective questionnaires on the effectiveness of the lens tints on their performance. A video of each run was observed by three ski professionals and ranked based on skier performance. No significant differences were found between the three tints for visual acuity, contrast sensitivity, run times or objective skier performance by video analysis. There was a subjective preference of the vermilion tint over the gold or gray tints.

KEY WORDS:

SKI PERFORMANCE
SKI ENHANCEMENT
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COLORED LENSES
TINTED LENSES
SKI GOGGLES
SUNGLASSES
VISUAL PERFORMANCE
GOLD LENSES
VERMILION LENSES
GRAY LENSES

INTRODUCTION

Many sunglass and ski goggle companies claim to have the top of the line, state of the art lenses that enhance vision in extreme weather conditions. This includes the use of different colored lens tints to achieve better all around vision. Recently there has been an emphasis on the use of colored lenses to enhance vision for sports purposes while protecting from ultraviolet radiation. Although many ski goggle companies have different tints that they claim work to enhance skier's vision in adverse weather conditions, there is a lack of published studies showing how these lenses affect vision, and ultimately performance, in these varied weather conditions.

The theory that certain lens colors are better for particular conditions is not new. In 1956, Wyszecki theoretically calculated which lens colors would be best to enhance vision in a snow field. He concluded that extreme purity red lenses would be the best, but low luminous transmission factors would be the same as neutral glass. Therefore, no specific colored goggle would improve vision (Wyszecki, 1956). Still, the concept of vision enhancement with tinted lenses remained popular and generated research attempting to determine the potential effects.

Clark (1969) surveyed nearly 100 studies on tinted lenses and their effect on vision. Although the majority of the studies show that there is no advantage of non-neutral lens tints over neutrally tinted lenses, many articles still supported specific lens tints for different activities and conditions. For example, amber and yellow tints were recommended for marksmen and shooting sports; brown-gray for mountain climbing; and yellow for fog, dim light or dull weather to enhance contrast of surroundings.

Clark's review (1969) along with the consensus of many other studies generally agree that lens color does not affect or enhance visual acuity. However, for many previous studies, visual acuity was the standard test for determining visual function and performance levels. Visual acuity tests a limited function of vision, namely the ability to resolve high contrast targets at high spatial frequencies. The normal person seldom encounters these conditions in daily human performance, with the exception of activities such as reading and road sign recognition.

It is now accepted that other procedures such as contrast sensitivity assessment at low contrast and mid spatial frequencies, and depth perception testing, may give more comprehensive and accurate information regarding visual status in the real world environment.

Research utilizing visual criteria other than acuity enhancement found varied results of the effect of tinted lenses on vision. Menard and MacKenzie (1969) found that tinted lenses had a gross overall improvement on stereopsis versus no lenses in place. They did not make comparisons of improvement between lens colors. However, Wynecoop (1987) found no significant difference in depth perception changes between clear, vermilion, and gold lens tints. Wilson (1991) showed that neither clear, plum, smoke, amber, nor orange-rose colored eye shields affected athlete's reaction time, anticipation timing, or depth perception. These studies were performed indoors in a lab setting and did not test performance in the sport's true environmental conditions. Wynecoop (1987) stated that the lighting conditions in her study were "less than one would find outdoors on a sunny or even an overcast day."

It is possible that testing lens tints and sunglasses that were designed for outdoor use are not achieving desired test results when tested indoors in a lab setting. However nearly all published material on the effect of tinted lenses on vision have been conducted in a lab setting. The exception to this rule has been a series of studies performed by Kinney et al. (1983a, 1983b). Kinney et al. tested lens tints outdoors in snow fields and found different results from the indoor tests. Depth perception and contrast sensitivity were improved by the use of yellow goggles over neutral goggles, particularly on overcast days. Yellow tinted lenses improved subject's reaction time to identify low contrasts of middle range spatial frequencies (1983b). It was also shown that skiers could better judge the depth of a snow depression on an overcast day with yellow goggles than with transmittance matched neutral goggles (1983a). Kinney et al. believed that they found an enhancing effect of the yellow lens by testing low contrasts of middle range spatial frequencies, those that humans are most sensitive to. They also attributed the perception of brightness with the yellow goggles to a physiological mechanism of activity in the chromatic and achromatic channels of color vision (1983b). These studies show that there may be a visual enhancing effect of tinted lenses, goggles or sunglasses, when tested in the environments for which they were designed.

The current study was designed to investigate the overall vision and subsequent performance enhancement effects for skiers using three popular commercially available ski goggle tints: Gold, Vermilion and Gray. Effects of the various tints on visual acuity, contrast sensitivity, and objective and subjective ski performance were tested.

METHODS

INSTRUMENTATION

Bailey-Lovey Logmar Acuity and contrast sensitivity charts were used to test subject's visual acuity and contrast sensitivity levels throughout the testing procedure both with and without the test lenses. Test distance was set at 13 feet, the calibration distance for our charts. The high contrast sensitivity chart offered optotypes at 83% contrast and the low contrast chart was 12% contrast for the weather and lighting conditions of the day. This was determined by taking an average of Tektronix J16 Photometer readings from the dark letter optotype and the white chart background every half hour of testing. Illuminance levels were also determined with this instrument. The levels varied due to changes in cloud cover and precipitation during testing from a maximum illuminance in full sunshine of 12500 lux to a minimum illuminance of 4700 lux with cloud cover and snow precipitation.

The timing device used to determine each subject's Giant Slalom course time was a Time Tech 2000 programmed for Alpine Club races.

Goggles and tint colors used were commercially available ski goggles at the time of the research testing. The gold lenses were Scott's Extreme V goggles with the T-35 Turbo Flow lens. The vermilion lenses used were from Bolle, model Chrono vermilion. The gray lenses were Carrera's Spider goggle and lens.

PROCEDURE

The testing was conducted April 13, 1995, between 9:00 am to 1:00 pm, at Mt. Hood Meadows Ski Resort, Mt. Hood, Oregon, on a southwest facing FIS homologated Slalom run known as Stadium. Testing took place in widely varying cloud cover, wind and precipitation conditions that directly affected lighting. During the testing period every imaginable combination of weather elements (except rain) was experienced. Conditions ranged from clear blue sky to limited visibility caused by snow, wind, clouds, and fog. Also experienced were lighting changes corresponding to the time of day and position of the sun relative to the slope orientation that was being used.

Ten subjects were recruited from a pool of expert skiers with significant ski racing experience to ensure consistent results and the subject's safety on skis. The subjects consisted of 4 women and 6 men ranging in age from 12 to 34 years.

Subjects were measured for baseline visual acuity and contrast sensitivity on the Logmar acuity charts without lenses in place. Subjects received test goggles in a counter balanced order and had their acuities and sensitivities measured through the test lenses prior to each prospective run. The subjects were then timed wearing the test lens in a Giant Slalom race course. After the run subjects completed questionnaires addressing the effect of the lens color on visual and skiing performance. The subject then received his/her next test lens and repeated the total sequence. Visual acuity, contrast sensitivities, and questionnaires were taken three times, once for each lens color. Six race course times were recorded and videotaped for each subject, two per test lens. Race times were discarded if the subject did not finish or fell in the race course. The videotape was reviewed by a panel of three ski professionals evaluating the quality of each of the subject's runs on a scale of one to five, one being the best and five as the worst. All results were then compiled and statistically analyzed for significance of effect.

RESULTS

Mean visual acuities varied by a maximum of one line of acuity on the high contrast chart (see Table 1).

LENS TINT	MEAN VA	STD. DEV.
No lens	0.07	0.079
Gold	-0.03	0.277
Vermilion	0.04	0.082
Gray	0.02	0.092

Mean low contrast visual acuity varied by a maximum of one and a half letters (see Table 2).

LENS TINT	MEAN VA	STD. DEV.
No lens	0.25	0.105
Gold	0.25	0.096
Vermilion	0.28	0.148
Gray	0.26	0.102

The difference between the values of the mean visual acuities above are statistically insignificant based on findings of ANOVA ($p>0.05$). The probability values are $p=0.3363$ for high contrast visual acuity and $p=0.5092$ for low contrast visual acuity.

Results showed that mean racer times between lens tints did not significantly differ (see Table 3).

LENS TINT	MEAN TIME	STD. DEV.
Gold	38.36 sec	3.265
Vermilion	38.24 sec	2.944
Gray	38.46 sec	3.188

Mean racer time comparisons between the first 3 runs and the last 3 runs revealed no significant difference (see Table 3).

LENS TINT	RUNS 1-3	RUNS 4-6
Gold	38.09	38.66
Vermilion	37.86	38.57
Gray	38.40	38.53

The probability values from ANOVA ($p>0.05$) is $p=0.9158$ for mean racer time by lens tint; and $p=0.3384$ for mean racer times of runs 1-3 vs. runs 4-6.

All of the subjective questions show that the racers chose vermilion as their preferred lens tint, with gold as their second choice and gray as the least preferred. Only five of the seven questions proved significant based on the Friedman test. Question numbers one, two, three, four and seven presented probability values of less than 0.05 based on our analysis. Questions five and six did not show a significant goggle preference ($p>0.05$) (see Table 4 and subjective questionaire in appendix).

Q#	GOLD	VERM	GRAY	P VALUE
1	2.40	1.50	3.50	0.0024
2	2.90	1.90	3.20	0.0353
3	3.00	1.70	3.20	0.0087
4	2.80	2.00	3.40	0.0224
5	2.60	2.00	3.00	0.1242
6	30%	70%	10%	0.4493
7	20%	50%	0%	0.0421

Video rankings of the skiers runs showed no significant variation between goggle colors. A Friedman test was run on the mean values which gave a probability value of $p=0.723$ (see Table 5).

LENS TINT	MEAN SCORE	STD. DEV.
Gold	2.60	0.966
Vermilion	2.65	0.833
Gray	2.70	1.16

DISCUSSION

The objective results obtained in this study did not differ greatly from earlier studies. Literature cited previously, although not related to skiing performance, supports the conclusion that different lens tints do not influence visual function, including static visual acuity. Most of the earlier studies were completed in clinical or laboratory environments, whereas this research was conducted in the natural setting

Decreased visual acuity on the low contrast chart was to be expected. According to Adler's Physiology of the Eye (1992) when contrast is reduced, there is a reduction in resolution, which accounts for the loss of acuity on the low contrast chart as compared to the high contrast chart. According to commercial ski goggle advertising, each company has a tint color that enhances vision in adverse weather and lighting conditions. In skiing, adverse weather or lighting leads to a situation of low to undistinguishable contrast in the snow surroundings.

There was not a significant difference between the mean values of the racer course times for each of the lens tints. This could be due to the lack of sensitivity of statistical analysis on small increments of time. Most ski races are won or lost by hundredths of a second. This study's parameters of the number of subjects and number of runs taken resulted in a small N value and therefore smaller total course times for the given lens tints. This limited the statistical value of this research. Other factors, including changing weather conditions with the use of different lens tints and brand names, did not produce a significant increase or decrease in skier performance as related to their course times.

Seven subjective questions about the various lens tints were included in this study which were lacking in previous studies. Racers in this study perceived that the vermilion lens significantly enhanced their performance over the gold or gray lenses. This may be due to the skier's previous experience with certain lens tints in certain weather and lighting conditions, which may have given the subjects a biased preference for the lens tint effectiveness. This bias can be developed by which name brand or tint is popular in the ski racing world at the time, or by personal experience of winning races with a particular lens tint in specific weather conditions. Another factor that may have influenced the tint preference is the perceived brightness of surroundings through the lenses. Environmental surroundings, particularly in low light and snow conditions, appear brighter through yellow lenses vs. clear or gray lenses.

Analysis of the video rankings supported the idea that none of the goggle colors tested had an objective effect on skier performance. Poor video quality and two skier falls prevented five of the sixty runs to be ranked. Although the video analysis was ranked using as objective criteria as possible, the analysis team still had subjective input within the team as to what affected the quality of a skier's run.

This project had certain design limitations that may have limited results in this case. Research design may have been improved with the following recommendations. Utilizing a larger sample size, both in subject numbers and runs taken may give more significantly relevant results to the study even though the data in this study remained consistent between subjects and test lenses.

Individual skier performance may have been enhanced by taking 6 runs on the same course within four hours. This may have produced a learning curve for each of the subjects on the race course and given the racers the opportunity to "learn" the course. Memorization of race courses is a technique taught to racers by their coaches in order to prepare for the strategy necessary to navigate each of the gates in the race course. This also allows for tactile motor feedback rather than relying on visual cues to navigate the course. Through our subject's repetitive runs, it may be possible that the only visual information the subject relied on was for snow and course conditions, for example ice or ruts, and not for the placement of the gates. In future studies, the number of runs taken by a single subject should be taken into account to decrease course memorization and the possibility of fatigue of the subject.

This study used commercially available ski goggle frames and lens tints. However, the same manufacturer for the goggles was not used. In future studies, the same goggle manufacturer should be used to decrease variability between companies in such areas as optical quality, comparable lens shapes and thickness, lens light transmission, frame interference, and comfort/fit of the goggle. Also, goggles should be matched for luminance transmittance to take one more variable out of the testing procedure. Within our study, several of the subjects disliked the gray lenses with complaints of vertigo, headaches, and distorted and double vision with wearing the lenses. These manifestations may have affected the subject's opinion of how the lenses affected their performance.

The one factor in our study that was completely out of our control was the weather. It would have been preferable to have an evenly overcast day to do the research testing. However, if that was what was desirable, the test site should have been moved to another location that had more consistent weather patterns throughout the day. Mt. Hood is notorious for unpredictable weather changes, and it proved itself on the day of testing, with sunshine, snow, fog, wind and every imaginable combination of these. Further research is needed for snowy, sunny or overcast weather conditions.

The weather changes secondarily affected the lighting conditions. In addition to variable environmental factors affecting the light, the lighting changed as the time of day progressed and the orientation of the ski run in relation to the sun. To reduce this variable, multiple test days could be utilized over the same hours of the day.

This study attempted to relate ski goggle tints to changes in ski performance. It was found that there is no objective benefit to wearing one lens tint versus others based on the research parameters of this study and uncontrollable weather variations encountered. There was a subjective preference choice of vermilion over gold and gray.

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	TABLE 1: High Contrast Visual Acuity			
subject	VA NL 95%	VA Gld 95%	VA Vm 95%	VA Gr 95%
1	0.02	0.00	0.00	0.00
2	0.12	0.10	0.12	0.10
3	0.10	0.02	0.12	0.02
4	-0.08	0.00	0.00	0.00
5	0.12	0.10	0.02	0.04
6	0.12	-0.80	-0.08	-0.08
7	0.02	0.00	0.00	0.00
8	0.02	0.02	0.02	-0.08
9	0.20	0.20	0.20	0.24
10	0.10	0.02	0.00	0.00
mean	**0.07**	**-0.03**	**0.04**	**0.02**

	TABLE 2: Low Contrast Visual Acuity			
subject	**VA NL 5%**	**VA Gld 5%**	**VA Vm 5%**	**VA Gr 5%**
1	0.18	0.20	0.20	0.14
2	0.22	0.22	0.22	0.22
3	0.20	0.30	0.42	0.30
4	0.14	0.20	0.10	0.20
5	0.36	0.36	0.36	0.32
6	0.20	0.22	0.30	0.32
7	0.14	0.06	0.20	0.20
8	0.22	0.24	0.14	0.20
9	0.42	0.40	0.60	0.50
10	0.40	0.30	0.30	0.24
mean	**0.25**	**0.25**	**0.28**	**0.26**

		TABLE 3: Racer Times						
subject	Gold time one	Gold time two	Gold Mn	Gold Diff	V time one	V time two	V Mn	V Diff
1	36.72	37.53	37.13	0.81	36.71	36.45	36.58	0.26
2	41.22	42.57	41.90	1.35	42.37	42.75	42.56	0.38
3	40.96	44.33	42.65	3.37		40.41	40.41	
4	34.27	35.33	34.80	1.06	36.59	35.35	35.97	1.24
5	33.80	35.12	34.46	1.32	34.67	35.06	34.87	0.39
6	37.32	36.82	37.07	0.50	36.96	36.78	36.87	0.18
7	40.70	39.81	40.26	0.89	39.58	42.32	40.95	2.74
8	34.51	34.25	34.38	0.26	33.87	34.65	34.26	0.78
9	40.19		40.19		39.57	40.74	40.16	1.17
10	41.25	42.17	41.71	0.92	40.44	41.23	40.84	0.79
	38.09	**38.66**			**37.86**	**38.57**		
	gold avg	**38.36**			V avg	**38.24**		
subject	Gr time one	Gr time two	Gr Mn	Gr Diff				
1	36.42	37.24	36.83	0.82				
2	42.26	43.33	42.80	1.07				
3	38.79	40.05	39.42	1.26				
4	33.77	35.78	34.78	2.01				
5	34.79	35.79	35.29	1.00				
6	38.00	36.47	37.24	1.53				
7	42.70	39.94	41.32	2.76				
8	33.98	34.41	34.20	0.43				
9	41.31	40.54	40.93	0.77				
10	42.02	41.70	41.86	0.32				
	38.40	**38.53**						
	gr avg	**38.46**						

TABLE 4: Subjective Questionaire Data

subject	Q 1 gr	Q 1 gld	Q 1 V	Q 2 gr	Q 2 gld	Q 2 V	Q 3 gr	Q 3 gld	Q 3 V	Q 4 gr	Q 4 gld	Q 4 V	Q 5 gr	Q 5 gld	Q 5 V
1	5	2	2	2	5	2	3	4	2	3	5	2	3	3	2
2	4	2	1	3	3	1	3	3	2	3	2	2	3	2	2
3	3	3	1	4	3	2	4	4	1	3	3	2	2	3	3
4	3	2	2	5	2	2	3	2	2	3	2	2	3	2	2
5	4	3	2	4	3	2	4	3	1	4	3	1	4	3	2
6	4	3	1	2	4	1	3	4	2	4	4	2	4	3	1
7	3	3	1	2	3	2	2	3	1	3	4	1	1	5	2
8	3	3	1	4	2	2	3	3	1	4	2	2	4	2	1
9	4	2	1	4	3	2	5	3	2	5	2	3	4	2	2
10	2	1	3	2	1	3	2	1	3	2	1	3	2	1	3
mean	**3.50**	**2.40**	**1.50**	**3.20**	**2.90**	**1.90**	**3.20**	**3.00**	**1.70**	**3.40**	**2.80**	**2.00**	**3.00**	**2.60**	**2.00**

subject	Q 6 gr	Q 6 gld	Q 6 V	Q 7 gr	Q 7 gld	Q 7 V
1	N	N	Y	N	N	N
2	N	Y	Y	N	Y	Y
3	N	N	Y	N	N	N
4	N	N	N	N	N	N
5	N	N	Y	N	N	Y
6	N	N	Y	N	N	Y
7	Y	N	Y	N	N	Y
8	N	N	Y	N	N	Y
9	N	Y	N	N	N	N
10	N	Y	N	N	Y	N
mean	**10**	**30**	**70**	**0**	**20**	**50**

TABLE 5: Video Analysis Data

subject	age	sex	lens order	racer #	gr-run 1	gr-run 2	gld-run 1	gld-run 2	verm-run 1	verm-run 2
1	23	F	123	**88**	3	3	4	4	4	4
2	12	F	231	**53**	2	2	3		4	3
3	15	M	312	**26**		2	3	2	2	4
4	34	M	213	**25**	3	2	3	3	2	
5	31	M	321	**30**	2	3	3	3	5	3
6	20	M	132	**56**	4	4	3	2	4	4
7	16	M	123	**93**	4	2	4	3	2	3
8	34	M	231	**71**	3	2	2	3	2	1
9	21	F	312	**35**	2	1	3	3	2	2
10	31	F	213	**52**	4	4	2			3
				mean	**3.00**	**2.50**	**3.00**	**2.88**	**3.00**	**3.00**
					gr avg	**2.74**	**gld avg**	**2.94**	**verm avg**	**3.00**

SKI GOGGLE RESEARCH PROJECT
RACER QUESTIONNAIRE

RACER # ____________________ COLOR # 1 2 3

Please rate the goggle lens that you just ran the course with for the following qualities. Rank each with 1 as the best, 2 as good, 3 as average, 4 as poor, and 5 as the worst. Please evaluate the LENS COLOR only, not other goggle factors like frame fit.

		best 1	good 2	ave 3	poor 4	worst 5
1.	Clarity of Vision	1	2	3	4	5
2.	Brightness of course and its surroundings	1	2	3	4	5
3.	Ability to judge snow contour or depth of ruts	1	2	3	4	5
4.	Depth perception judgement	1	2	3	4	5
5.	Ability to judge the distance to the next gate or length of transitions	1	2	3	4	5

6. Did this lens color improve your visual performance?

YES NO

If Yes, please explain how:

____

____

7. Did this lens color improve your racing performance?

YES NO

If Yes, please explain how:

____

____

Any additional comments on this lens and overall rating of lens color:

____

____