NIGHT VISION IMAGING SYSTEM
LIGHTING COMPATIBILITY ASSESSMENT METHODOLOGY: PART 2

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If night vision goggles (NVGs) are to be safely used by pilots, it is necessary that the cockpit lighting and displays be compatible with the operation of the NVGs. The current standard field practice for verifying that cockpit lighting and displays are compatible with the NVGs is to conduct a visual acuity degradation assessment. This method is subjective and, as the research described herein, relatively imprecise. An alternative method is to directly measure the amount of interfering light caused by the cockpit lighting and displays. This is referred to as the NVG light output method or NLO. The research reported here demonstrates the superiority of the NLO method compared to the visual acuity method with respect to objectivity and precision. Although the NLO method still needs some further refinement, it is recommended that this method be adopted as a standard field method for assessing cockpit lighting compatibility.

INTRODUCTION

The study and results described in this document are a follow-on effort to a study that was previously reported[10]. Much of the fundamental introductory material will not be repeated here. Therefore, it is recommended that this report be read in conjunction with reference 10 if the reader is unfamiliar with the basic issues being addressed in this study. Prior work[10] has established the viability of an inexpensive, alternative method of determining whether or not a cockpit lighting system is compatible with the operation of night vision imaging systems (NVIS) such as the night vision goggles (NVGs) shown in Figure 1.

Figure 1. F4949 night vision goggles

Unmodified aircraft cockpit lighting and displays can interfere with the proper operation of NVGs in several specific ways. For each interference mechanism, the effect on the image seen through the NVGs is a reduction of the light level or contrast of the view outside the aircraft. This reduction in light level or contrast can be manifested as a reduction in visual acuity and/or as an observed loss of contrast or brightness. Many techniques have been developed to produce cockpit lighting and displays that are reasonably compatible with the operation of NVGs[1]. *Reasonably compatible* means there is sufficient light for the pilot to view his/her instruments and displays (note: pilots look *under* the NVGs to directly view their instruments) but the lighting is such that it does not significantly interfere with the image of the exterior scene viewed through the NVGs.

Phase 1 of this joint research effort[10] between the Federal Aviation Administration (FAA) and the US Air Force Research Laboratory (AFRL/HECV) investigated the visual acuity assessment method using inexpensive equipment as well as an objective method based on NVG light output. The results from this first phase demonstrated that the visual acuity assessment method could be conducted just as well with inexpensive equipment and that the visual acuity method was relatively imprecise when compared to the inexpensive, objective method. The

objective method investigated was based on measuring the relative amount of light output increase that was encountered as the cockpit lighting and displays were turned "on" compared to the "off" condition. This extra light output is what would cause interference in the NVGs and thus should be related to the degradation in image quality of the NVG image. For simplicity, this objective method will be referred to as the NVG light output method or NLO method.

Although the results of the first phase of this joint effort were quite encouraging regarding the use of inexpensive equipment for assessing NVIS lighting compatibility for both the visual acuity (VA) and the NLO methods, there were three issues that needed to be resolved. The first issue related to the basic method of the study. In this first study, subjects viewed the visual acuity chart through the NVGs for six different NVIS radiance levels, plus lights off. These seven levels were presented randomly to make the study more objective. The current practice in the field is to look at the VA chart with lights "off" immediately followed by lights "on" to make it easier to compare the two conditions. Therefore the first study did not exactly duplicate what is currently done in the field, but rather used a procedure that was slightly more objective.

The second issue deals with the NLO method. This method uses an inexpensive illuminance meter taped to the eyepiece lens of the NVG so that a light reading is obtained that is proportional to the average scene luminance of the NVG image. Subjects were instructed to point the NVGs with the attached light meter through the simulated windscreen just as if they were looking through the NVGs at the visual acuity chart; only the illuminator for the VA chart was not on. Since there was no precision in pointing the NVGs through the simulated windscreen, it was possible that some of the field of view of the NVGs could contain the image of the cockpit lighting simulator, which could lead to a higher amount of variance in the NLO readings for the same NVIS radiance conditions.

The third issue has to do with selecting a "compatibility cut-off" level for the NLO method. Because of the relatively low light output level of the NVGs, the diffuser on the illuminance meter had to be removed to provide increased sensitivity. This means the light output is not calibrated to any specific, accepted photometric units. Since NVGs can vary in their maximum light output and in their gain values, some type of relative value (relative to the specific NVG used) must be established for acceptance/rejection criteria.

Resolving these three issues was the primary goal of the current research reported in this document. Issue one was addressed by presenting subjects with consecutive "off" then "on" conditions to accurately simulate the current field method. For issue two, subjects were instructed to look through the other ocular of the NVGs and make sure that no part of the cockpit lighting simulator that was emitting light was within the field of view of the NVGs. The third issue was resolved by determining the light meter reading when the NVGs were at their maximum output luminance. Then the criteria level would be a fixed fraction of this maximum light output level (e.g., 1% or ½%). This would insure that the amount of interfering light is a small fraction of the total NVG image light. This value was selected *ex post facto* to correspond to some other currently accepted criteria level dealing with visual acuity loss or NVIS radiance level. This is explained more fully in the analysis and discussion sections.

As in Phase 1, the primary results of this study are a collection of "probability of rejection" curves that graph the probability of rejecting the lighting system, because it is incompatible, against the NVIS radiance level.

APPROACH

The currently accepted visual acuity-based NVIS lighting evaluation method (henceforth called the "VA baseline method") was the baseline for this study. In order to determine if the NLO method was as good as the VA baseline method, some means needed to be devised to characterize the *goodness* of these methods so that they can be compared. Since the primary objective of doing an NVIS lighting evaluation is to make a pass/fail determination as to the compatibility of the NVIS lighting, it was possible to develop a probability of rejection (i.e., failure) of the lighting system as a function of the NVIS lighting radiance level, which is the basic criteria stated in the military specifications. For each NVIS radiance level, the

study provided repeated measures of "accept" or "reject" for each subject and the two evaluation methods. These repeated measures could be directly converted to a probability of pass or fail and graphed against the NVIS radiance level, thus producing the probability of rejection curve. Ideally, one would like this curve to be flat at 0% from an NVIS radiance level of zero out to some NVIS radiance level which marks the boundary between acceptable and unacceptable, and then the curve would shoot up to 100% just past that critical NVIS radiance level. If the curve gradually increases as a function of NVIS radiance then it indicates the method is relatively imprecise and prone to Type I and Type II errors (rejecting something that should have been accepted and accepting something that should have been rejected). Therefore the slope of the probability of rejection curve at the 50% probability point can be used as a measure of the precision of the evaluation method, one measure of the *goodness* of the method.

Two basic interference conditions were investigated: 1) light was reflected in the windscreen and 2) light was blocked from reflecting in the windscreen. The first condition causes a veiling luminance from the reflection and the second condition may cause a veiling luminance from light scatter within the objective lens of the NVGs. A total of six NVIS radiance levels were used for each of the two interference conditions (the levels were different for the two conditions because it required much more NVIS radiance to induce interference in the non-reflected mode versus the reflected mode). Each subject was presented with 10 trials for each NVIS radiance level, condition, and evaluation method. A trial consisted of a baseline measurement (either visual acuity or NVG light output) with the simulated cockpit lighting "off" and then a test measurement with the simulated cockpit lighting "on." This resulted in a total of 120 data points per subject (10 trials, six radiance levels, two interference conditions).

METHOD

Subjects: Three males and three females, ranging in age from 40-53, participated in this study. Prior to participation in the study, all observers underwent a visual examination to insure they had normal or corrected acuity of 20/20 or better.

Apparatus: A basic cockpit lighting simulator (NVIS lighting simulator or NLS) was used to recreate the lighting interference conditions and the aircraft windscreen and glare shield. The USAF 1951 Tri-bar chart was used to measure visual acuity, and was illuminated using a calibrated incandescent lamp. The NVIS radiance on the chart was monitored using a Photo Research 1530AR radiometer. Model F4949C NVGs were used in this study. An Extech Light ProbeMeter was attached to the NVGs to measure the luminance output of the goggles. The actual radiance and luminance of the lighting simulator was measured using an Instrument Systems Model 320 spectral scanning radiometer. For this study, the lighting simulator was configured in either a reflected or non-reflected mode.

Procedure: Subjects were seated behind the NLS and the armrest and seat height were adjusted. Since the NVGs were hand held, the armrest was positioned to allow proper alignment with the stimulus and to reduce fatigue. The room lights were turned off and the subject dark-adapted for 12 minutes. The subjects were then asked to focus the NVGs. For the reflected and non-reflected conditions, the following two tasks were counterbalanced. The NVIS radiance light levels were randomly presented for each task.

Task 1: With the NVIS lighting "off," subjects looked through a pair of F4949C NVGs at the Tri-bar chart and identified the group and element number of the smallest set of horizontal and vertical bars they could resolve. The lighting was then turn "on" and the subjects determined if there was a change in the group and element number they could resolve. Subjects closed their eyes between trials while the experimenter adjusted the NVIS radiance of the NLS.

Task 2: An Extech Light ProbeMeter was taped to the eyepiece of the right ocular of the NVGs using black masking tape. With the NVIS lighting in the "off" position, subjects viewed through the left ocular of the NVGs to aim the NVGs through the windscreen. The experimenter recorded this baseline reading then switched the NVIS lighting "on" and recorded the baseline plus interference reading. NVIS

radiance conditions were presented in a randomized order.

RESULTS

Although the individual subject data are of extreme interest due to some individual differences, there is insufficient space in this report to include those data. Figures 2 and 3 show the composite probability of rejection curves for all six subjects for the VA baseline method and the NLO method, respectively, for each of the two interference conditions (reflected mode and non-reflected mode). The graphs shown in Figures 2 and 3, depict the slopes of the curves at the 50% probability level and are summarized in Table 1.

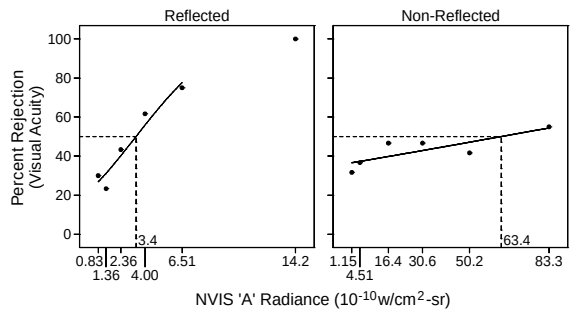

Figure 2. Probability of rejection curves for the VA baseline method for all six subjects combined. The dashed line corresponds to the 50% probability level. Each data point is the average over 60 samples (Six subjects, 10 trials each).

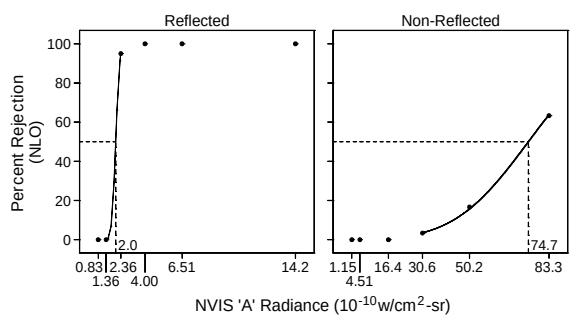

Figure 3. Probability of rejection curves for the NLO method for all six subjects combined. The dashed line corresponds to the 50% probability level. Each data point is the average over 60 samples (Six subjects, 10 trials each).

Table 1. Slopes of the probability of rejection curves at the 50% probability point. Values represent change in percent rejection for a 1 unit (10^{-10}w/cm^2-sr) increase in radiance. The higher the number the more precise the method (less chance of a Type I or Type II error).

Reflected	Visual Acuity	NLO
Yes	9.64	189
No	0.22	1.64

DISCUSSION AND CONCLUSIONS

The visual acuity results of this study, as depicted in Figure 2, are somewhat different than the previous study[10]. The slopes of the reflected mode rejection curves for the two studies are similar but the 50% rejection NVIS radiance point has been shifted by about 50 percent. The reflected mode shifted from a 50% rejection point NVIS radiance of 2.1 in the previous study (after NVIS radiance values of the previous study were corrected) to a 3.4 in the current study. However, the non-reflected mode visual acuity rejection curve did not change by much, shifting from 71.2 in the previous study to 63.4 in this study. The shift in the reflected mode 50% rejection point radiance may indicate that the first issue as discussed in the Introduction Section, regarding having an "off" condition always immediately preceding the "on" condition, did have an effect on the visual acuity "leniency" in allowing a lighting system to pass. From the results, using the 50% criteria point, the current field evaluation method is 50% more lenient (allowing lighting systems with higher NVIS radiance values to pass) as the more objective visual technique that was used in Phase 1.

The most striking results of this study, as in the first study, are apparent from Figures 2 and 3 and Table 1. The NLO method produces a much steeper probability of rejection curve, which means this method is much more precise than the visual acuity method. The technique of making sure the NVIS lighting was not in the field of view of the NVGs (for the non-reflected mode) had a substantial impact on the NLO method results in that it shifted the 50% probability point NVIS radiance from 5.9 in the previous study to 74.7 in this study, which is more in concert with the relatively aimless visual acuity results for the

non-reflected mode. This answers the question regarding issue two, described in the Introduction Section, where the NVIS lighting had an unintended affect on the NLO method if it was within the field of view.

The criteria value (what light level reading to use as the demarcation between acceptable and unacceptable lighting) was explored a little bit in this study. The curves shown in Figure 3 used a cut-off value of 0.148 (reading on the light meter), which corresponded to ½% of the maximum light output reading for that NVG. This is a very conservative value and should be investigated in future research.

The main conclusion from these studies is that the NLO method appears to be a very promising objective method of assessing the compatibility of cockpit lighting systems with NVGs. It can be used as a supplement to the visual acuity method or can easily be used to replace the visual acuity method. However, it should be required that a visual inspection of the lighting system, for reflections at particularly objectionable locations, and for light leaks, be performed using NVGs. Another fact that is evident from these studies is the considerable imprecision of the visual acuity method and its corresponding susceptibility to Type I and Type II errors (rejecting a lighting system that should have been accepted and accepting a lighting system that should have been rejected).

It is recommended that the NVG light output method be adopted as a standard, objective method of verifying that the cockpit lighting and displays are compatible with the operation of the NVGs.

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