

# Comparison of Three Night Vision Intensification Tube Technologies on Resolution Acuity: Results from Grating and Hoffman ANV-126 Tasks

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## ABSTRACT

Several methodologies have been used to determine resolution acuity through Night Vision Goggles.<sup>1, 2, 3</sup> The present study compared NVG acuity estimates derived from the Hoffman ANV-126 and a standard psychophysical grating acuity task. For the grating acuity task, observers were required to discriminate between horizontal and vertical gratings according to a method of constant stimuli. Psychometric functions were generated from the performance data, and acuity thresholds were interpolated at a performance level of 70% correct. Acuity estimates were established at three different illumination levels ( $0.06\text{-}5 \times 10^{-4}$  lux) for both procedures. These estimates were then converted to an equivalent Snellen value. The data indicate that grating acuity estimates were consistently better (i.e. lower scores) than acuity measures obtained from the Hoffman ANV-126. Furthermore significant differences in estimated acuity were observed using different tube technologies. In keeping with previous acuity investigations, although the Hoffman ANV-126 provides a rapid operational assessment of tube acuity, it is suggested that more rigorous psychophysical procedures such as the grating task described here be used to assess the real behavioural resolution of tube technologies.

**Keywords:** night vision goggles, visual perception, resolution, visual acuity, psychophysics, grating

## 1. INTRODUCTION

### 1.1 Background: Night Vision Goggles (NVGs) and Acuity.

Visual acuity during night vision goggle use is typically less than visual acuity at normal full light levels. Estimates of NVG visual acuity currently range from 20-30 to 20-60.<sup>1, 2, 3, 4, 5, 6, 7</sup> To assess goggle acuity, these studies have used a wide range of stimuli. The main thrust of these research efforts has been to establish rigorous assessments of goggle acuity that can be used to assess the behavioural visual acuity of night vision systems. For example, Pinkus and Task (1998) have used high contrast Landolt C's to evaluate the resolution of goggles and arrive at Snellen acuity estimates in the range of 20-20 to 20-30 for high light levels. Further, their results showed that lowering illumination levels degrades acuity (e.g. as it gets darker acuity will get worse). These earlier studies were conducted using older NVG technology than are examined in the current study.

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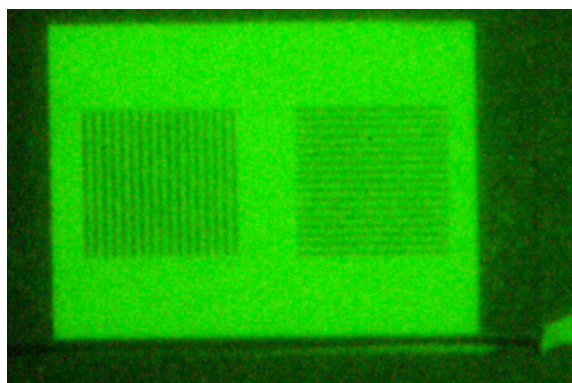
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## 1.2 Visual Acuity Defined

Visual acuity refers to the ability to see small details-where “small” refers to visual angle. Typically this is tested with standard targets with a gap between two small dots or two stripes (Figure 1). A person who can resolve gaps subtending a visual angle of 1 minute has “normal” visual acuity by definition, and it is expressed as “20-20”. If a person can only resolve a 2 minute gap, their acuity is said to be “20-40” since the smallest gap they can resolve at a viewing distance of 20 feet could be resolved by a person with normal acuity at a viewing distance of 40 feet. In general, if the smallest gap that can be resolved is N minutes of visual angle, visual acuity is “20-(NX20)”. (e.g., if N = 5 minutes, visual acuity is 20-100.). 20-20 is not the best possible acuity; people with very good acuity can do as well as 20-10 (the ability to resolve a gap subtending  $\frac{1}{2}$  minute of visual angle).

## 1.3 The NRC Grating Acuity Task (NGRAT)

High contrast (80 %) square wave gratings of light and dark bars (see Figure 1) were used to estimate visual acuity. These gratings were produced using a high-resolution photo-grade laser printer. The NGRAT requires that observers discriminate between horizontal or vertical lines spaced at several gap distances. Stimuli were presented to observers using a Two-Alternative Forced Choice procedure (2-AFC). For each trial a pair of gratings, one vertical and one horizontal, was presented side-by-side and the subject was required to verbally indicate the location of the vertical grating. The location of the vertical grating was randomly selected on each trial. Both gratings in each stimulus pair had the same gap separation. Five different gap distances were presented for each illumination and NVG condition. Using standard psychophysical analysis methods, the resolution acuity for each subject under each lighting and NVG condition was determined. These acuity threshold calculations are described in detail below. Figure 1 shows a view of the stimuli through NVGs. The NGRAT measurement procedure described here has been used extensively across several vision science domains to assess visual acuity.



**Figure 1** Horizontal and Vertical Gratings viewed through NVGs.

## 1.4 Assessing Acuity using the Hoffman Aviation Night Vision (ANV) 126

The Hoffman ANV-126 test set utilizes the USAF-1951 Tribar test to assess goggle visual acuity (Figure 2). This device can be set to a series of light levels simulating night lighting conditions in the goggles. The task involves an observer viewing the stimuli through the NVGs and stating the group and element he/she can resolve. The group and element selected can then be converted to a Snellen fraction. As Pinkus and Task (1998) have pointed out, one problem with the tribar chart test is that there are slight discrepancies in observer’s responses that are attributable to a shift in acuity criteria that can be as great as 60% (i.e. As the observers judge when they can see the object, the criteria that is used to assess for “seeing” can vary from observer to observer). These data suggest that to best assess goggle technologies a more objective measurement should be utilized.<sup>1</sup>

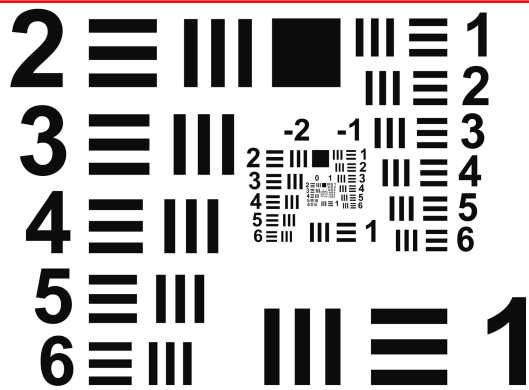


Figure 2 Example of USAF-1951 Bar Chart stimuli typically tested in Hoffman ANV-126 (Taken from Pinkus and Task, 1998).

1.5 Current Study: Assessment of three Night Vision Goggle Technologies using the NGRAT and the Hoffman ANV-126.

Acuity is a central visual process during night flight operations. It can also be used as a good starting point for assessing basic goggle performance. In the current study we measured visual acuity for three tube technologies using the NGRAT and the Hoffman ANV-126. Due to commercial and military sensitivity we have referred to the compared technologies as goggles A, B and C.

2. METHODS

2.1 Participants

Six NVG experienced observers (4 pilots, 2 flight engineers) with normal (20/20) or corrected-to-normal vision participated in the experiment. Participation in this study was wholly voluntary. Subjects were recruited from the Griffon fleet of the Canadian Department of National Defence. These observers had a minimum of 300 flight hours using NVGs. Subjects were familiar with the normal focusing and handling procedures of NVGs. All methodologies and test procedures were approved by the Research Ethics Board (REBs) of the National Research Council.

2.2 Apparatus

Subjects adjusted the goggles for the appropriate interpupillary distance (IPD) and focused them on a stimulus that was adapted from the USAF Tribar chart test (see Figure 3). Subjects had their head stabilized in a chin rest and goggles were mounted at the appropriate distance from their eyes. Observers were tested at a 3 m viewing distance from the stimuli under well controlled lighting conditions. The NGRAT was used to evaluate acuity. Stimuli were mounted in a small plexiglass holder aligned with the observers' line of sight. The experimenter was positioned to the left of this shelf. The experimenter wore non-reflective black clothing. For each observer, separate tests of acuity were conducted using the NGRAT and the Hoffman ANV-126.

Three adjustable 2856K color temperature Halogen lamps were used to create three different illumination levels that ranged from cloudy starlight to half moonlight (see Table 1).<sup>9</sup> An aperture was used to manipulate the illumination intensity without changing the colour temperature. Figure 3 shows a picture of the experimental set-up with light sources used to illuminate stimuli. This apparatus was adapted from an original design by Pinkus and colleagues at Wright Patterson Air Force Base.<sup>10</sup> Each of the light sources had its aperture set to produce one of the three requisite illumination levels as shown in Table 1 below.

Illumination levels NGRAT stimuli	Illumination levels Hoffman ANV-126	Nominal Illumination level
0.06= 5.57 X 10 <sup>-3</sup> fc	0.016 lux=1.5 X 10 <sup>-3</sup> fc	Quarter moon
0.00138= 1.28 X10 <sup>-4</sup> fc	0.0016 lux=1.5 X 10 <sup>-4</sup> fc	Starlight
0.00050= 4.65 X 10 <sup>-5</sup> fc	0.0005 lux=5 X 10 <sup>-5</sup> fc	Cloudy starlight

Table 1 The three illumination levels used in the current study for the NGRAT and the Hoffman ANV-126



Figure 3 Experimental Apparatus and light sources used to illuminate stimuli.

2.3 Procedure

Six subjects were tested on three goggle types at three different illumination levels. Subjects were run in sessions by light level. During a particular session subjects were tested with each of the three goggles. The order of goggle testing was randomized between subjects and sessions. One experimenter programmed the stimuli, while a second recorded the observer’s responses. At the beginning of testing, for each goggle type, subjects spent approximately 5-10 minutes adjusting and focusing their goggles. They were presented the focusing stimulus (described above) and instructed to focus the objective lens and then the eyepiece to establish a clear image of a range of bars (as in the Hoffman ANV-126). Two easily detectible gratings (20-60 and 20-80) were then presented to ensure that sharp focus was present for the grating stimuli. Once these steps were achieved, formal testing was initiated. During formal testing, subjects were required to make a choice as quickly as possible when the stimulus was revealed. Subjects responded according to the 2-AFC procedure described above.

2.4 Target selection and threshold estimates

The investigators conducted preliminary tests to select a range of stimulus values (i.e. grating gap sizes) that produced chance (50%) to high (100%) levels of detection performance. These values were used in formal testing. A method of constant stimuli was used to obtain the final threshold estimate. Based on the preliminary testing, the experimenter selected a set of 5 bar spacing values that could be converted to specific Snellen equivalents (20/xx) including 20-15, 20-25, 20-35, 20-50, and 20-60. These stimuli were presented ten times in random order for each session. The proportion of correct responses at each stimulus level are counted and plotted against the stimulus levels. Performance data were cumulated over sessions and threshold estimates were based on the minimum image size level that subjects could discriminate on an experimenter defined 70% of the trials. This performance level is typically selected in human psychophysics and can be considered an industry standard.

2.5 Calculation of Snellen Fractions

Threshold estimates were obtained by applying best fitting sigmoidal functions to the acuity data and interpolating the target value that corresponded to 70%. Panel A, of Figure 4 shows how a typical acuity estimate is computed. This threshold bar spacing ( $T_1$ ) is then converted to a Snellen Fraction using the calculation described above as  $20-(T_1 \times 20)$ . Figure 4B shows a hypothetical function of Snellen fraction values at several different light sources.

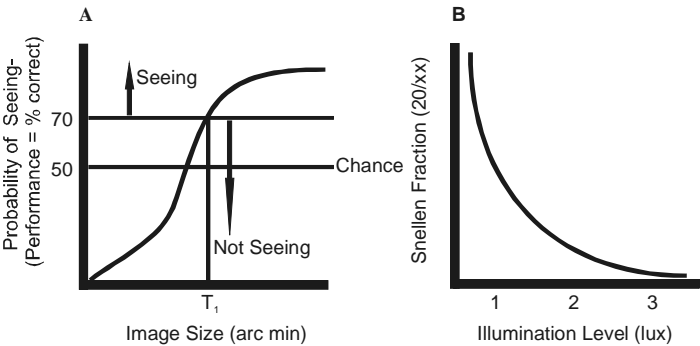


Figure 4 Hypothetical Psychometric functions illustrating how Acuity detection performance functions (Panel A) are used to derive Snellen Fractions (Panel B).

3. RESULTS AND DISCUSSION

3.1 Acuity Test Results

Figure 5A illustrates the Snellen Fractions for the NGRAT on goggles A, B, and C. This figure shows that goggle type B had consistently higher Snellen fractions than both Goggles A and C. This threshold data was analyzed using a 3 X 3 Two-factor repeated measures analysis of variance (ANOVA) (Goggle-Type X Illumination Level). The results showed significant effects for Goggle Type and Illumination level, while the interaction was not significant. Follow-up comparisons between mean Snellen fractions indicates that Snellen fractions are lowest at the brightest illumination levels (i.e. the best acuity was obtained). The comparisons between Goggle types showed that both Goggles A and C had lower Snellen fractions than Goggle type B. There was no significant difference between Goggle A and Goggle C. This trend held at each illumination level ( $p<0.05$ ).

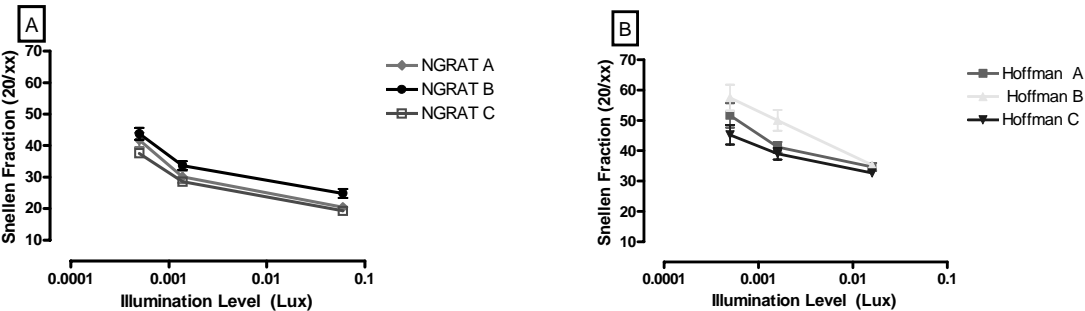
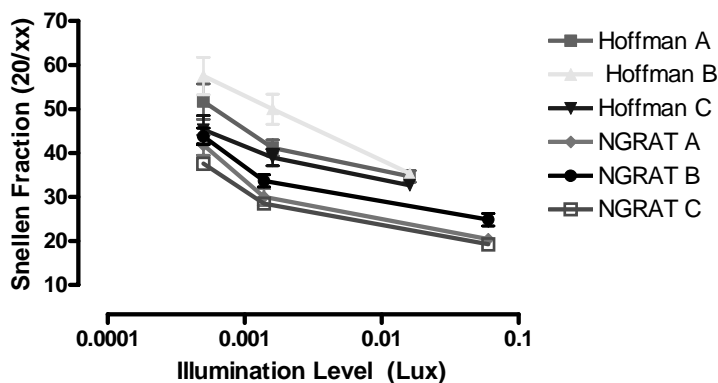


Figure 5 A. NGRAT (left panel) and (B) Hoffman (right panel) Snellen Fractions plotted as a function of increasing illumination level.



**Figure 6** NGRAT and Hoffman Snellen Fractions plotted on a single graph.

Figure 5B shows the Snellen Fractions derived from the Hoffman ANV-126. The Hoffman data was also analyzed using a two-way ANOVA. The results showed significant effects of Goggle Type and Illumination level. The interaction between these variables was also significant. Follow-up comparisons for the Hoffman ANV-126 were similar to the NGRAT. There was no significant difference between Goggle A and Goggle C. However, at the brightest level of illumination there were no differences in goggle resolution values. Figure 6 shows a summary of both acuity measures plotted on a single graph. Due to slightly different methods of setting illumination level these results cannot be compared statistically. However, the general trends in these functions are similar for both acuity measures. Overall the trends show that acuity scores using the NGRAT procedure were consistently better (i.e. lower scores) than acuity measures obtained from the Hoffman ANV-126. This may be attributable to physical differences between acuity test methodologies. For example, there were no intervening optics when testing acuity with the NGRAT. The Modulation Transfer Function (MTF) of the Hoffman ANV-126 may contribute to slightly reduced measures of acuity. It could also be attributable to discrepancies in estimating acuity using the USAF-1951 Bar chart in the Hoffman ANV-126 test set (see discussion above on observer criteria). The use of our 2-AFC method of constants procedure ensures that a shifting criterion is less likely. In the current task, subject's responses over many trials in conjunction with experimental controls (e.g. select the vertical grating) are used to estimate acuity levels rather than a single assigned value on one trial.

**3.2 Interpretation of Acuity Test Results**

These findings suggest that differences between the three Goggle types increase as the illumination level is decreased. For both the NGRAT and Hoffman ANV-126 acuity measures Snellen Fractions were consistently lower for both Goggles A and C than for Goggle B. These results suggest that Goggles A and C have consistently better resolution than Goggle B. As a consequence, subjects could see more detail through Goggles A and C than they could with system B. Goggle A and C had similar Snellen fractions indicating that resolution through these systems are almost equal. The current results suggest that overall goggle C performs well at all three light levels ranging from very bright (quarter moon) to very dim (cloudy starlight) (see Table 1). This demonstrated superior performance across this broad illumination range suggests that goggle C performs best under a wide variety of lighting conditions.

**3.3 Implications for Specifications and Assessment of Intensification Tube Technologies**

To date, several investigations have assessed the resolution of night vision intensification tube technologies using a series of psychophysical tests.<sup>1, 2, 3, 4, 5, 6, 7</sup> As mentioned above, these tests of acuity have been somewhat more

extensive than the Hoffman ANV-126 and may provide a more accurate estimate of the behavioural resolution provided by a specific tube technology. Although the Hoffman ANV-126 is a useful diagnostic tool, it may be necessary to move towards industry specifications that include behavioural estimates of the acuity of these technologies. This would allow NVG users to determine the impact of tube technologies on first principle visual functions such as acuity. Such an effort would prove valuable in enhancing current technology. This also ensures quality control for user and industrial provider alike.

**4. CONCLUSIONS**

In summary, Goggle A and C provided the best acuity values across a broad illumination range. Goggle B provided the poorest resolution values. Goggle C provides the best acuity across all light levels. These results indicate that goggle C may have the best dynamic range of all goggles tested since it provides superior performance in both high and low illumination conditions. Further, these behavioural estimates show impact of device characteristics on perception at the visual system rather than an external measure of the device itself. As such they provide a nominal estimate of the impact of various tube technologies on the perception of detail. Such nominal estimates of acuity are useful for establishing the range of performance of NVGs in terms of visual acuity and will provide helpful ranges for the operator.



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