

## Improving nighttime mobility in persons with night blindness caused by retinitis pigmentosa: A comparison of two low-vision mobility devices

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**Abstract**—This study compared the effectiveness of the ITT Night Vision Viewer with the Wide Angle Mobility Lamp (WAML) as low-vision mobility devices for people experiencing night blindness due to retinitis pigmentosa (RP). Both engineering bench testing and functional evaluations were used in the assessments. Engineering evaluations were conducted for (1) consistency of the manufacturer’s specifications, (2) ergonomic characteristics, (3) modifications of devices, and (4) pedestrian safety issues. Twenty-seven patients with RP conducted rehabilitation evaluations with each device that included both clinical and functional tests. Both devices improved nighttime travel for people with night blindness as compared with nighttime travel with no device. Overall, the WAML provided better travel efficiency—equivalent to that measured in daytime. Recommendations have been developed on ergonomic factors for both devices. Although some participants preferred the ITT Night Vision Viewer, overall most participants performed better with the WAML.

**Key words:** electronic night-vision aid, legal blindness, light-amplification devices, low vision, mobility, night blindness, night-vision devices, portable illumination sources, retinitis pigmentosa, visual fields.

### INTRODUCTION

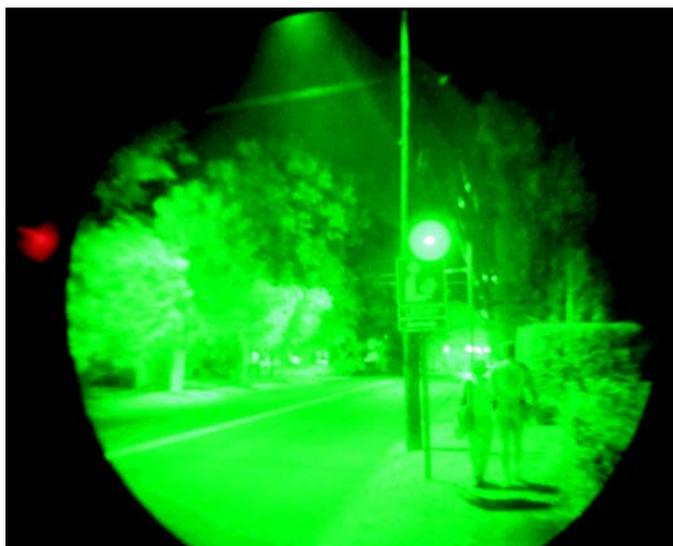
Night blindness primarily caused by retinitis pigmentosa (RP) limits functional independence at night and

affects individuals’ mobility—ability to travel safely—as compared with daytime travel function. Many individuals with this disease either travel using the sighted or human guide technique at night (**Figure 1**) or avoid nighttime travel altogether. A variety of other ocular disorders can

**Abbreviations:** AWS = Adapted Walking Speed, BRC = Blind Rehabilitation Center, COMS = Certified Orientation and Mobility Specialist, DEF = Device Evaluation Form, DOD = Department of Defense, FOV = field of view, IMQ = Independent Mobility Questionnaire, logMAR = logarithm of minimum angle of resolution, PEF = Participant Evaluation Form, PPWS = Percentage of Preferred Walking Speed, PWS = Preferred Walking Speed, RP = retinitis pigmentosa, SE = standard error, SKILL = Smith Kettlewell Institute Low Luminance, SST = Scotopic Sensitivity Tester, VA = Department of Veterans Affairs, VFQ-25 = 25-item Visual Function Questionnaire, VHA = Veterans Health Administration, WAML = Wide Angle Mobility Lamp.

**This material was based on work supported by the Department of Veteran Affairs, Veterans Health Administration, Rehabilitation Research and Development Service, grant C2244R.**

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DOI: 10.1682/JRRD.2004.08.0091



**Figure 1.**

Many individuals with night blindness caused by retinosa pigmentosa travel with sighted guide at night. *Photograph courtesy of John C. Lakey, The Salisbury Post, Salisbury, NC.*

be associated with impaired nighttime function such as age-related macular degeneration, diabetes, glaucoma, and cataracts [1]; even normal aging alone can contribute to increased visual problems at night [2]. In a study of problems in mobility among persons with low vision, lighting conditions and dim illumination were reported as the second-highest problem area [3]. Clark-Carter et al. reported that at least 30 percent of visually impaired people make no independent journeys outside their homes [4]. Severe or profound night blindness is a hallmark of RP from the earliest stages of the disease [5]. During winter months, some individuals with early RP, who remain gainfully employed, must travel to and from work in darkness.

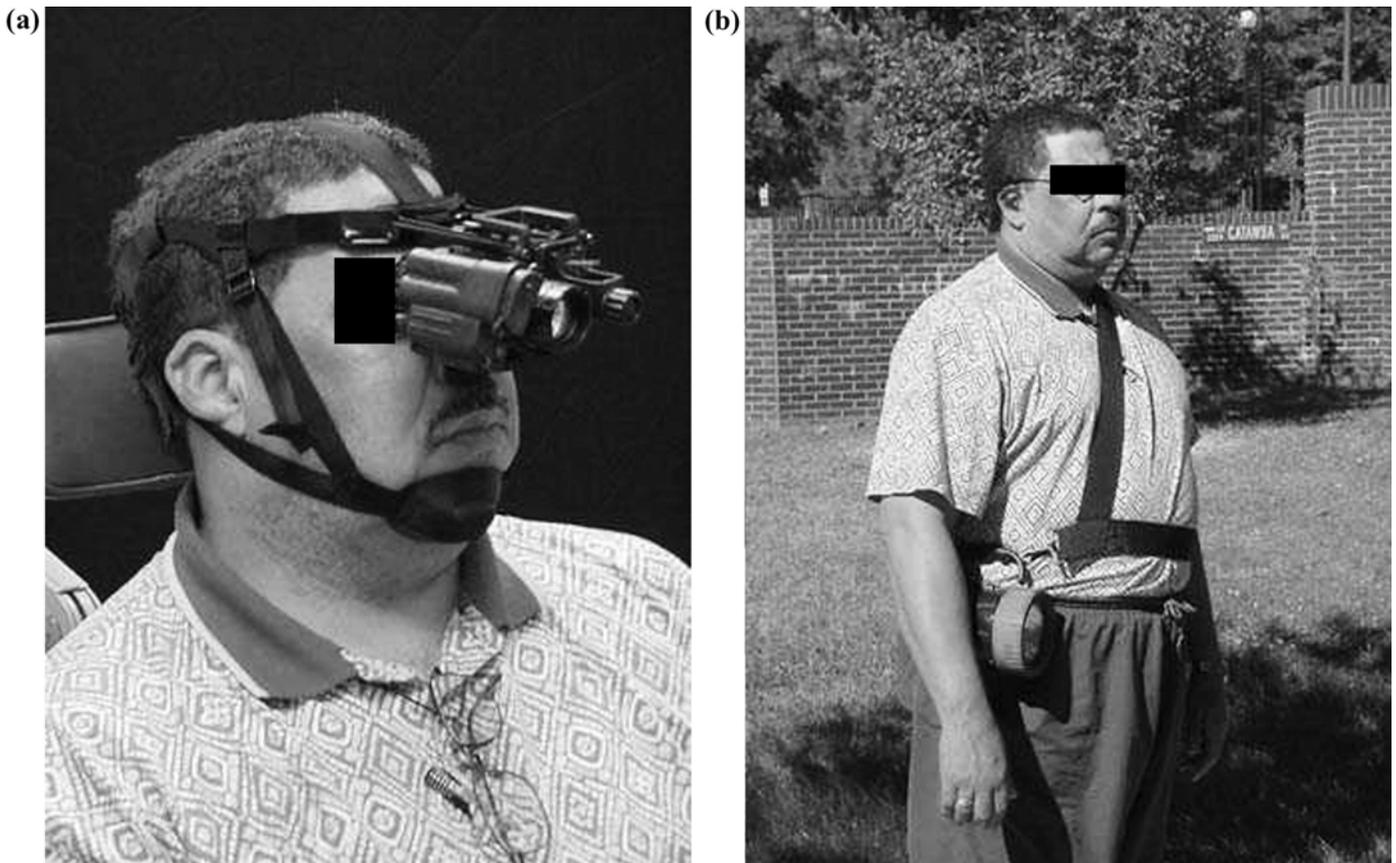
An estimated 100,000 people in the United States have inherited retinal degenerations similar to RP [6]. According to De l'Aune et al. [7], 5 percent of veterans admitted to Department of Veterans Affairs (VA) Blind Rehabilitation Centers (BRCs) were classified as legally blind because of RP and 22 percent were classified as legally blind because of glaucoma. The number of severely visually impaired persons continues to rise, and by the year 2008, it is estimated that over 150,000 veterans will meet the criteria for legal blindness and over 880,000 will have severe visual impairments [8]. In addition, the number of persons with functional night blindness continues to grow and can be estimated to be 53,400 veterans, a signifi-

cant number [9]. Many other veterans in the early stages of RP are not yet classified as legally blind but must deal with functional night blindness.

The most frequent rehabilitation approach recommended for persons with nighttime mobility limitations due to RP is the use of the long white cane [10]. Due to a natural tendency to use remaining vision—which is somewhat possible for the RP population during daylight but impossible at night—many individuals with RP reject use of the long white cane and tend instead to rely on visual clues. As their cane skills are not often practiced, these individuals may be unsafe when attempting to use the long cane during nighttime travel. They must give up their independence by avoiding nighttime travel, travel only with a sighted individual, or risk injury by traveling unsafely. Typically, individuals with early to moderate stages of RP do not use guide dogs because of a lack of need during daytime travel.

Currently, the standard nighttime low-vision mobility devices are designed to bring auxiliary lighting into the travel environment. Night mobility devices may be classified as (1) portable illumination sources that can be carried and used to provide auxiliary light in the travel environment (e.g., various flashlights, headlamps, etc.), and (2) light-amplification devices (e.g., the ITT Night Vision Viewer). Portable illumination devices have been issued to and used by visually impaired veterans for some time. Anecdotal reports from VA Visual Impairment Service Team coordinators and BRCs throughout the United States suggest that veterans with RP and other ocular disorders are increasingly requesting the new Generation 3 ITT Night Vision Viewer (model number NQ6015) (referred to in this paper as “ITT”) (**Figure 2(a)**).

A common version of an auxiliary lighting device is the Wide-Angle Mobility Lamp (WAML) that is essentially a high-intensity flashlight the size of a single automobile headlamp and is powered by a large battery (**Figure 2(b)**). The WAML is an example of a portable illumination device (i.e., flashlight) that has been purposefully outfitted for use as a low-vision device for night mobility. It is one of few night mobility devices in widespread use, and it is described as the most appropriate portable illumination device for persons with both night blindness and restricted visual fields [11]. This device is worn with a shoulder strap and carried at the hip. Unfortunately, disadvantages and limitations are reported by users of the WAML [12–13]. Its battery operates for only 1 hour after charging [14], and when the battery loses power the



**Figure 2.**

Night mobility devices may be classified as light-amplification devices like (a) Generation 3 ITT Night Vision Viewer and portable illumination sources that can be carried and used to provide auxiliary light in travel environment such as (b) Wide-Angle Mobility Lamp. *Photograph courtesy of Luke Thompson, Department of Veterans Affairs Medical Center, Salisbury, NC.*

light beam fades rapidly, without warning, sometimes stranding the night-blind user in a dangerous environment. In addition, through a survey of WAML users, Morrissette reported complaints about the WAML's weight and size [15]. Some users reported that pedestrians reacted negatively to the WAML's brightness.

While relatively few other rehabilitation techniques have been developed to increase the abilities of this population to travel independently and safely in poor illumination, or at night, the ITT has the potential to augment traditional rehabilitation techniques in meaningful ways. It functions as a light-amplification device and expands the range of nighttime illumination in which the eye can function. The original ITT Night Vision Aid was produced in cooperation with the Department of Defense (DOD). The Retinitis Pigmentosa Foundation realized the potential of the first light-amplification device for use by persons with

night blindness in the 1970s. Research reported by Berson demonstrated that the original ITT device improved light detection thresholds and visual acuity in nighttime illumination conditions [16–19].

More recently, ITT Industries, Inc. (Roanoke, VA), has marketed a third generation system that can be handheld and either mounted to a helmet or worn on the head for hands-free operation, the NQ6015. The NQ6015 model purportedly provides improved resolution and advanced light-level controls. The current third generation image-intensification technology represents a significant advance in night-vision devices and may have the potential to provide improved night vision and mobility to veterans with night blindness. There are reports that night-vision devices are being used by the DOD during night battles and by police during night work. Some consumers and researchers have concerns about the negative effect on depth perception

from monocular use of the ITT [20–21]. Previous research by Morrisette et al. [12] indicated that the electronic night-vision aid evaluated was not as effective at improving night vision as the WAML. The newer version of a previous model electronic night-vision aid, the ITT, has attracted the interest of veterans with night-vision problems, and they are requesting the Veterans Health Administration (VHA) issue it as a prosthetic device.

A nighttime mobility device that would allow veterans with night blindness to function at night in a fashion similar to daytime could have an important role in low-vision rehabilitation.

## METHODS

This project was designed to evaluate a high- and a low-technology nighttime mobility device and compare the function of people with RP who use the devices with their function in daytime and in nighttime with no device. Data collection was organized into two phases. Phase 1 evaluated the engineering components of the devices including: mechanical bench testing (experiment 1), ergonomic human factors (experiment 2), modifications of the devices (experiment 3), and pedestrian safety issues (experiment 4). Phase 2 of the study assessed rehabilitation and included clinical and functional evaluations of visually impaired individuals. Experiments and evaluations incorporated both quantitative and qualitative measures.

### Phase 1 Engineering Evaluation

The engineering evaluations determined the capabilities and characteristics of both the ITT and the WAML. It is not unusual for manufacturers' literature and published specifications to contain information that is incorrect, misleading, or incomplete. Performance claims may be based on laboratory tests, under ideal conditions, not operational field conditions. Instrument performance may also vary over time and between instruments.

#### *Experiment 1A Mechanical Bench Testing of the ITT*

**Methods.** Early first-generation scopes and goggles were adversely affected by exposure to bright light. When an intense light source, such as a vehicle headlight, entered the field of view (FOV) the photocathode became saturated and the viewer ceased to function for an extended period of time. The ITT incorporates a bright-source protection circuit to prevent this. The ITT collects

light that cannot be seen by the naked eye and focuses it on a photocathode that converts it into electrons. The electrons pass through a microchannel plate that multiplies them before they strike the phosphor screen that emits the light seen in the viewfinder. The manufacturer makes no claim with regard to the amount of light amplification and we intended to determine the amount of intensification through laboratory measurements.

Three ITTs were obtained from the manufacturer. A schematic drawing and parts list for the monocular were provided by the manufacturer. Tests were made, under both laboratory and field conditions, for researchers to determine the effect of high-intensity light sources on the viewer. Laboratory tests were conducted by placing high-intensity light sources in various positions in the FOV of the ITT and observing any effect on the image. The laboratory was kept in near-total darkness during the testing. The test light sources included a 12 V automobile headlight, a 6 V handheld lantern, and a flashlight operated by two C batteries. All tests were conducted with a distance of 10 ft between the viewer and the light source.

Engineering field tests were conducted by observing high-intensity light sources under existing field conditions. All tests were conducted after astronomical twilight ended. High-intensity light sources that included vehicle headlights, single and multiple street lights, and a 6 V handheld lantern were viewed at various distances from and positions within the FOV of the device. The various light sources were viewed through the monocular while the wearer was standing at the edge of a trafficked street and while walking on the adjacent sidewalk.

**Results.** Each of the three ITTs obtained from the manufacturer came complete with head mount, owner's manual, and belt pouch carrying case. Although the initial examination revealed the image to be distinctly clearer in two of the ITTs, all three met minimum gain and resolution standards. However, the exact gain could not be determined since the laboratory equipment has a range of 1 to 10,000, which the ITT exceeded. We can only state that the ITT can intensify light by a factor of 10,000 or more.

We verified the manufacturer's specifications for weight and physical dimensions of the ITT. Product literature describes this device with a 40° FOV, a 14 oz weight, focusable optics, and dimensions of 6 × 2.5 × 5.5 in. The device is purported to allow the user to see a 6 ft man at 500 yd under starlit conditions. The laboratory FOV, measured as 38°, was slightly less than the published specification

of 40°. This would not be noticeable when the device is used in a normal fashion, with the wearer turning his or her head from side to side. The battery life exceeded the published specification. Both laboratory and field tests showed that high-intensity light sources had little effect on the ITT. When light sources were viewed directly, a halo was visible around the source, but the image remained visible.

The test ITTs measured  $4.5 \times 2.25 \times 2.0$  in. We also confirmed the manufacturer's weight specification of 13.8 oz for each of the three ITTs. The test ITTs' length, height, width, and weight measurements were consistent with the manufacturer's published specifications.

Due to the degraded image in the third ITT, its FOV could not be determined. This ITT was not used for any additional tests. The two remaining ITTs could be focused from infinity to a near distance of approximately 10 in., which confirms the manufacturer's published specifications. The ITTs had an eyepiece diopter adjustment of +2 to -6 to facilitate individual user differences. Laboratory measurements confirmed the 60 h battery life claimed by the manufacturer with test results of 64 and 67 h of continuous burn time (two AA alkaline batteries required).

Each of the three light sources had a halo around them when viewed through the ITT. The halo became more distinct as the source was moved from the outside edge to the center of the FOV. The image brightness decreased as the source intensity increased, but at no time did the image disappear. The halo did tend to obscure features in the immediate vicinity of the light source.

The results in the real world were similar to the laboratory results. The high-intensity light sources had a halo around them. The halo became more noticeable as the source intensity increased and as the wearer looked more directly at the source. Although the brightness of the image in the ITT decreased, at no time did the image disappear. As in the laboratory test, the halo made features in the immediate vicinity of the light source less distinct.

#### *Experiment 1B Mechanical Bench Testing of the WAML*

**Methods.** The WAML consists of a 20 W, sealed-beam, halogen-cycle bulb and produces 1,400 cp in a  $30^\circ \times 20^\circ$  beam. Three WAMLs were purchased from the manufacturer (Oceanic, San Leandro, CA). Each Ocean Pro 101 rechargeable hand light came complete with shoulder/waist strap assembly, 120 V battery charger, and owner's manual. Each WAML was fitted with a 6 V bulb. The manufacturer also provided schematic drawings and parts lists. During the engineering evaluation,

numerous measurements were made on each device and the results compared with the manufacturer's published specifications.

**Results.** Of the three WAMLs, one was unsuitable for testing, which left two for use in this project. Each WAML was equipped with a shoulder/waist strap assembly that held the WAML in a position resting against the hip. The physical dimensions and weight of the WAML agreed with the published specifications while the beam pattern was slightly different.

In appearance and size, the WAML looks like many commercially available, handheld, rechargeable lanterns. However, the WAML has two metal rings for attaching the shoulder/waist strap assembly. It is equipped with a 6 V wide-angle bulb that is used in emergency lighting equipment.

The two test WAMLs measured 8.5 in. in length and 5 in. in diameter, without the handle. This agrees with the manufacturer's published specifications. We confirmed the manufacturer's specification weight of 5 lb, without the strap assembly, for the test units. The published specifications indicate a  $30^\circ$  horizontal by  $20^\circ$  vertical beam, while laboratory measurements determined the beam dimensions to be  $\sim 28^\circ$  horizontal by  $21^\circ$  vertical. The specified maximum beam intensity of 1,400 cp was verified by laboratory measurements.

While the published specifications claim a charge duration time of 1 h for the rechargeable gel-type battery, repeated tests of the two functioning units produced inconsistent charge durations with a maximum of  $\sim 45$  min for the first unit and  $\sim 50$  min for the second. The bulb output decreases with burn time so not all of this maximum time would be usable. For some tests, the light output for both WAMLs dropped off sharply after 40 min of burn time.

The WAML's owner's manual states that a spot-beam replacement bulb is available and provides 3.5 h of light per charge. By definition, this spot beam is a thinner beam and would not provide the same lighted walking path as the original beam. When contacted, Oceanic indicated that they did not stock the replacement bulb but that it was available from various vendors. We approached several local vendors and after considerable difficulty obtained a lamp. As received, the lamp would not fit into the WAML without modification to the base contacts. After installation, the lamp would not function with a fully charged battery. In view of these problems,

no further attempt was made to include the spot-beam replacement lamp in this study.

### *Experiment 2 Ergonomics of the Devices*

**Methods.** The human-factors evaluation was conducted to determine the suitability of the two devices for human use. While the intent of both the ITT and the WAML is to improve an individual's night mobility, the two devices are dissimilar in physical and operational characteristics. The human-factors evaluation focused on the user's assessment of ease of use, object identification, comfort, and other subjective parameters. A small group of nonvisually impaired participants was enrolled and asked to use the two devices while negotiating a test route and then to rate each device. The participant's use of each device was observed and rated by an accompanying observer. The observer noted participant activities relative to the device being evaluated and recorded additional notes following each walk.

Six participants were recruited from The University of North Carolina at Charlotte, including students, faculty, and faculty spouses. Two additional participants were recruited from the general population for a total of eight participants, all with unimpaired vision. The participants included two black females, two white females, and four white males. They ranged from 19 to 58 years of age. The participants signed informed consents and were compensated for their participation.

A test route was established on the campus of The University of North Carolina at Charlotte. The test route included a long inclined ramp, a reversed wheelchair ramp, up steps, down steps, street curbs, sidewalks, a marked pedestrian crossing, a large paved area, a grassy area, and an interior hallway. There was a low level of ambient light throughout the outdoor test route and the hallway was well lit.

Testing occurred after dark. Participants were given a verbal overview of the research project and participation was explained in detail. Both the ITT and the WAML were demonstrated. Each participant was allowed to become thoroughly familiar with the device before it was fitted to him or her with the aid of the researcher. Each participant was asked to walk around a darkened laboratory room until he or she felt comfortable with the device. The device was then removed, and the participants were given a set of written instructions and a description of the test route. The instructions informed the participants that they would walk the test route three times, once with no

device and then with each of the two devices. After each walk with a device, participants would complete a questionnaire evaluating the device. After reading the instructions, the participants were given an opportunity to ask questions before beginning the first walk.

A trained observer accompanied each participant until he or she completed the circular route and returned to the laboratory room. After walking the route with no device and returning to the laboratory room, the participants were given another opportunity to ask questions before refitting the first randomly selected device. After the device was refitted and adjusted, the participants exited the building and began the second walk with the observer following close behind. During this walk, the observer noted participants' use of the device, rated it on the Participant Evaluation Form (PEF), and took notes regarding the walk. After completing the walk with the first device and returning to the laboratory, the participants were asked to complete a Device Evaluation Form (DEF) that had 22 questions related to the participants' impressions of the device and its function. Participants were then given an opportunity to give verbal comments. After completing the DEF and commenting on the first device, the participants were introduced to the second device and the procedure was repeated.

**Results.** Table 1 shows the results of the nonvisually impaired participants' ratings of ergonomic features of the devices. In general, subjects found the ITT performed worse than the WAML for detecting and negotiating stairs or curbs, but rated the ITT's balance and weight better than the WAML's (Figure 3). The observers' ratings on the PEF are summarized and shown in Table 2. While observers found relatively few areas of difference between the two devices in general, they rated the WAML higher in ability to detect distant objects and the ITT higher in ability to identify and negotiate curbs and steps.

Based on the results of the human-factors evaluation, we explored a number of alternative designs for mounting both the WAML and the ITT. The alternative designs made no changes to the basic devices themselves and only included changes that could be retrofitted to existing devices. One participant objected to the weight of the ITT head mount and one indicated that it interfered with normal hearing.

**Table 1.**

Ergonomics of devices. Nonvisually impaired participants' mean ratings of Wide-Angle Mobility Lamp (WAML) and Generation 3 ITT Night Vision Viewer (ITT) ( $n = 8$ ) on Device Evaluation Form.

Parameter	WAML	ITT
Ability to Maintain Position Over Time	3.0	4.0
Adequacy of the Field of View	3.0	3.4
Balance of the Device	2.6	3.3
Weight of the Device	2.0	2.5
Ability to Detect Objects at Your Feet	3.6	1.9
Ability to Detect Distant Objects	3.0	3.5
Ability to Identify Up Stairs	3.5	3.0
Ability to Identify Down Stairs	2.8	2.4
Ability to Negotiate Up Stairs	3.4	2.5
Ability to Negotiate Down Stairs	3.0	2.0
Ability to Identify Up Curbs	3.5	2.8
Ability to Identify Down Curbs	3.0	2.6
Ability to Negotiate Up Curbs	3.4	2.5
Ability to Negotiate Down Curbs	3.3	2.0
Ability to Adapt to Oncoming Headlights	3.3	3.3
Feeling of Safety While Using the Device	3.4	3.3
Ability to Maintain Level of Illumination	3.5	3.6
Overall Comfort Wearing the Device	2.5	2.6
Overall Mean	3.1	2.8

1 = very poor, 2 = poor, 3 = average, 4 = good, 5 = very good.

### Experiment 3A Modification of the ITT

**Methods.** We contacted ITT Industries, Inc., to determine if other head mounts were available. They advised that the head mount supplied with the monocular was the only one available from them. They were aware that a "hair net" type head mount had been tested in the past, but it had not proved satisfactory.

In an attempt to improve the comfort of the existing head mount, we added padding to a variety of areas. Participants reported the padding to marginally improve the fit (at best) and to somewhat reduce the stability of the head mount.

**Figure 3.**

Ergonomics of devices: Study participant being fitted with Generation 3 ITT Night Vision Viewer. Photograph courtesy of John C. Lakey, *The Salisbury Post*, Salisbury, NC.

An attempt was next made to attach the monocular to a head mount that would not produce the sensation of "tightness" on the head. Three helmet-type head mounts were developed and tested. The alternative designs were fabricated by attaching the monocular to a bicycle helmet, a military helmet liner, and a football helmet. Large motorcycle helmets and helmets worn by racecar drivers were considered to be too bulky and restrictive for consideration.

**Results.** According to the small subset of subjects, none of these options improved comfort, fit, or stability to a meaningful degree.

### Experiment 3B Modification of the WAML

**Methods.** In an attempt to make the WAML more comfortable, we added padding to the shoulder strap. Padded seat belt covers are available from various automotive suppliers, and they readily fit the WAML shoulder strap. The padded cover fit completely around the neck strap and was held in place by Velcro fasteners.

**Results.** Three participants tested the modified padded assembly, and all agreed that it was more comfortable than the original padless assembly.

#### *Experiment 4 Pedestrian Safety*

Since the manufacturer's literature indicated that the ITT would flicker and potentially turn itself off if exposed to oncoming bright lights, the researchers believed evaluating the safety of the device for travel at night was prudent. This was not a factor with the WAML and it was not evaluated.

**Methods.** Pedestrian safety was evaluated with regard to the effect of oncoming headlights while participants were using the device. This was accomplished in two steps. First, the project engineers evaluated how well the device performed in their assessments. In addition, participants were exposed to illumination from oncoming vehicle headlights while engaged in the nighttime mobility assessments. Qualitative safety data were also obtained through a question on the DEF and an open discussion following each device evaluation session.

**Results.** The nonvisually impaired participants were observed while walking with the ITT. None of them appeared to experience any difficulties with walking, although they slowed down at curbs and steps to look down at their feet. The participants indicated that they felt the slowing down was necessary to negotiate the elevation change safely. The participants reported that when looking directly at an oncoming vehicle with the ITT, they observed a halo around the headlights. However, the viewer image remained and the halo faded when the participant looked away from the headlights. This halo phenomenon was also observed during controlled laboratory and field tests. The participants did not feel that it presented any safety hazard, a finding that confirms the engineering evaluation.

### **Phase 2 Clinical and Functional Rehabilitation Evaluations at Baseline and with each Device**

#### *Methods*

**Participants.** Twenty-seven participants diagnosed with RP and stating that they had severe nighttime mobility problems were recruited and enrolled. Participants provided medical records from an eye exam completed within the past year to document the presence of RP and to report on any other ocular diseases that might coexist (records were

**Table 2.**

Ergonomics of devices. Observers' mean ratings of nonvisually impaired participants use of Wide-Angle Mobility Lamp (WAML) and Generation 3 ITT Night Vision Viewer (ITT) ( $n = 8$ ) on Participant Evaluation Form.

Parameter	WAML	ITT
General Ease of Use	3.1	3.1
Battery Life/Duration	5.0	5.0
Ability to Detect Objects at Your Feet	1.6	3.3
Ability to Detect Distant Objects	3.4	2.9
Ability to Identify Up Stairs	2.6	3.3
Ability to Identify Down Stairs	3.1	4.1
Ability to Negotiate Up Stairs	1.9	3.3
Ability to Negotiate Down Stairs	2.6	2.8
Ability to Identify Up Curbs	2.5	3.4
Ability to Identify Down Curbs	3.5	3.4
Ability to Negotiate Up Curbs	2.1	3.3
Ability to Negotiate Down Curbs	3.0	2.8
Ability to Maintain Level of Illumination	5.0	5.0
Ability to Adapt to Oncoming Headlights	3.8	3.4
Appearance of Overall Comfort	3.0	3.1
Overall Mean	2.6	2.9

1 = very poor, 2 = poor, 3 = average, 4 = good, 5 = very good.

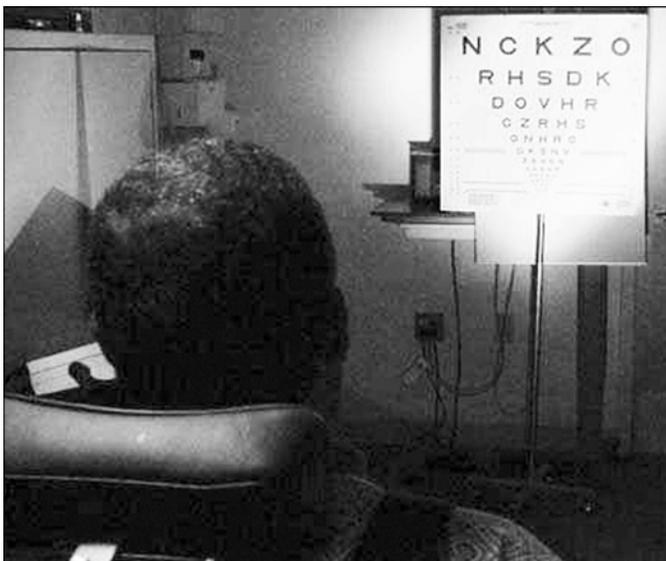
reviewed by an optometrist). Criteria for inclusion in the study were that participants be between the ages of 30 and 60, be able to see for daytime travel (long cane use was expected and encouraged), have profound night-vision problems that severely limit night mobility, have no other physical problem that could limit mobility, be able to pass the screening instrument for cognitive function, be willing to participate in a night mobility evaluation, and do not regularly use a night mobility device. We obtained informed consents and scheduled participants for evaluation.

**Clinical Baseline and Experimental Evaluations.** Participants were scheduled for clinical evaluation where researchers obtained data on their functional visual status without the devices in standard lighting and under nighttime conditions. Data were collected on extent of visual field, high-contrast visual acuity, low-luminance visual

acuity [22], peak contrast, glare, and dark adaptability. Devices were then presented in a randomized fashion, and data were collected on visual field, high-contrast visual acuity, and contrast under nighttime conditions (**Figure 4**).

**Outdoor Nighttime Baseline Functional Mobility Evaluations.** We evaluated participant baseline performance in an outdoor environment during nighttime without the devices under the supervision of a Certified Orientation and Mobility Specialist (COMS). A research assistant was trained to observe contacts with obstacles; score the research participant; position obstacles in appropriate, predetermined locations along the routes; and retrieve the obstacles when completed.

Four standardized mobility routes were developed for the nighttime mobility evaluations (**Figure 5**). Each of the four sections of the route was designed to be functionally equivalent with an overall length of ~200 m (including two blocks separated by one turn); one street crossing with a down curb and an up curb; 20 obstacles (either naturally occurring in the environment or artificially placed at the same locations for each session); one block of each two-block route located on a dark, minimally traveled residential route with small sidewalks and shrubs; and the other block of each two-block route located on a well-lit, main road with wide sidewalks.



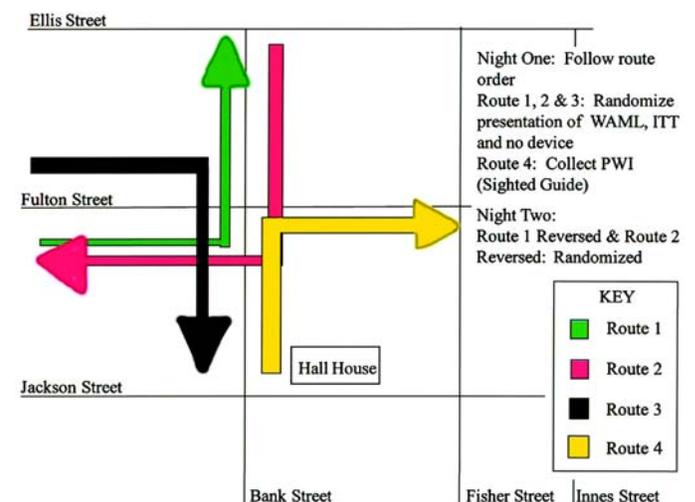
**Figure 4.** Clinical baseline and experimental evaluations. Participant viewing distance acuity sign with Wide-Angle Mobility Lamp. *Photograph courtesy of Luke Thompson, Department of Veterans Affairs Medical Center, Salisbury, NC.*

Natural lighting measures were taken at specified locations during participant testing. The evaluations began 30 min after dusk according to National Oceanic and Atmospheric Administration published timetables.

The participants were presented with three experimental conditions (i.e., walking with the ITT, the WAML, and no device) in a randomized fashion on three of the routes, and we collected data related to their walking speed on the fourth route. In addition, we recorded and tabulated overall travel time, missed curbs, and unintended contacts with the environment as additional measures of mobility performance under each condition.

Preferred Walking Speed (PWS) [4] was measured in a sighted guide mode on the fourth route. An Adapted Walking Speed (AWS) was also measured under the three experimental conditions. We calculated Percentage of Preferred Walking Speed (PPWS) [23], the primary measure of walking efficiency used in this study, for each experimental condition with the percentage score,  $AWS/PWS \times 100$ .

Per Geruschat, Turano, and Stahl [24], unintended contacts with obstacles were recorded for each participant. Each route was evaluated for the number of obstacles available (20). First, we conducted a thorough evaluation of naturally occurring obstacles such as tree limbs, trip hazards, etc. If obstacles were moved during



**Figure 5.** Outdoor nighttime functional mobility evaluations. Four standardized mobility routes were developed for nighttime mobility evaluations with visually impaired participants. Data were collected for Generation 3 ITT Night Vision Viewer (ITT), Wide-Angle Mobility Lamp (WAML), habitual travel mode (i.e., no device), and Preferred Walking Index (PWI).

the duration of the study, another similar obstacle was placed in the same location. Second, additional artificial obstacles were placed on each route at specified locations to equal the 20 obstacles needed for the standardized route. These included a 1 ft high fluorescent soccer cone, a plant container, a trash can, a piece of carpet cut in a circle to simulate a mud puddle, etc. Participants were scored on the number of stumbles, bumps, neglected stairs, and problems with orientation under each of the three randomized conditions.

**Standardized Surveys.** Twenty-seven participants completed survey questionnaires for researchers to capture participant-perceived mobility performance, including the Independent Mobility Questionnaire (IMQ) [25] and the National Eye Institute's 25-Item Visual Function Questionnaire (VFQ-25).

### Results

Twenty-seven qualified, visually impaired participants enrolled in this phase of the project, gave their informed consent, and completed the testing. One participant enrolled, completed the first day and night of testing, and then withdrew from participation. Participants ranged in age from 30 to 59. Twenty-two of the twenty-six participants were Caucasian, three were African-American, and one Hispanic. Fifty percent were female. Ten had a high school degree or less, five had some college, nine had a college degree, and two had a master's-level degree. Eleven participants had an annual income of \$50,000 or more. Twenty-one participants were living with someone, ten were disabled, ten were employed, five were retired, and one was a homemaker. Twenty used no device to

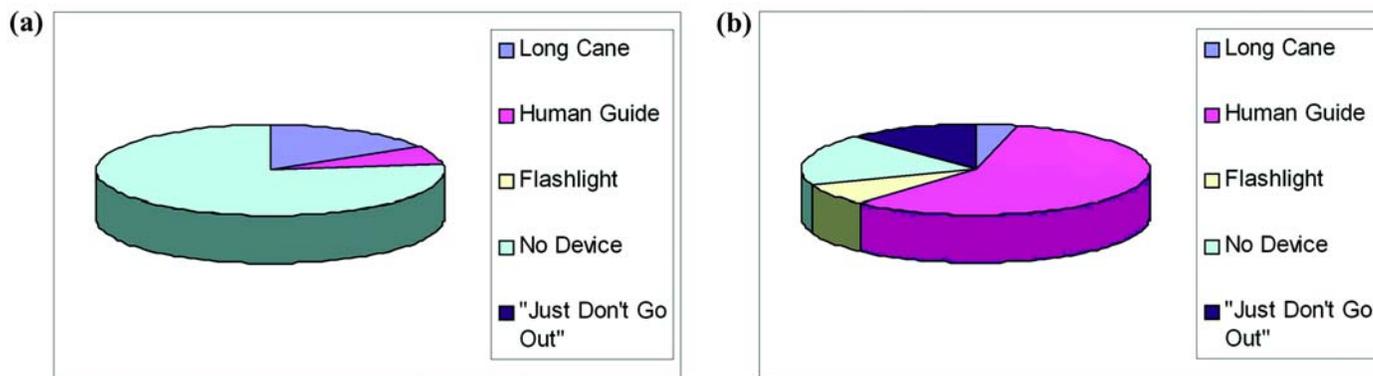
walk independently during the day, four used a long cane, two used a sighted guide, and fifteen used a sighted guide only at night. **Figure 6** compares participants' daytime and nighttime reported travel habits. This self-report shows a significant difference between the habitual daytime and nighttime travel patterns of the participants.

**Functional Results PPWS.** Significant differences in PPWS ( $p = 0.0001$ ) were observed between devices. Estimated means and standard errors (SEs) for each device, adjusted for routes traveled, are  $62.4 \pm 3.2$ ,  $69.6 \pm 3.2$ , and  $76.9 \pm 3.2$  for no device, the ITT, and the WAML, respectively. The largest difference was between the WAML and no device at night.

**Functional Results Unintended Contacts.** The number of unintended contacts per person varied from 1 to 31. The mean numbers of unintended contacts were significantly different between the three conditions ( $p = 0.0001$ ) with the highest number encountered using no device ( $17.5 \pm 1.1$ ) and the lowest number when walking with the WAML ( $7.8 \pm 1.1$ ). The mean and SE for the ITT was  $10.7 \pm 1.1$ .

**Functional Results Comparing PPWS and Unintended Contacts.** For participants with a higher number of unintended contacts (16–31) while using a device, a lower PPWS was also found (**Table 3**). This was true for both the WAML ( $51.0 \pm 7.0$ ) and the ITT ( $47.0 \pm 5.8$ ) ( $p = 0.0004$ ). Participants with less than 16 unintended contacts maintained relatively high PPWS scores while using the devices ( $80.0 \pm 2.9$  for the WAML and  $72.7 \pm 3.0$  for the ITT).

**Associations between Functional Performance and Clinical Measures.** Secondary analyses explored differences in the logarithm of the minimum angle of resolution



**Figure 6.**

Self-reported (a) daytime vs. (b) nighttime travel habits for visually impaired participants ( $n = 27$ ).

(logMAR) of visual acuity, visual fields, and contrast sensitivity. All three varied significantly for each device ( $p = 0.0001$  for each comparison). Mean and SE are reported in **Table 4**. LogMAR visual acuity with the WAML did not differ from no device during the day ( $p = 0.53$ ), but the results with the ITT were significantly different from those in daylight, nightlight, or with the WAML ( $p = 0.0001$ ). The same results were observed for visual fields and contrast sensitivity. We observed decreases in visual acuity, visual field, and contrast sensitivity in nighttime versus daytime trials with the ITT that indicate there may be functional implications. We found further evidence of this when comparing the clinical findings with the PPWS functional rating (**Tables 5–7**). Decreases in visual acuity may be demonstrated by a decreased ability to judge distances. Decreases in contrast sensitivity may result in difficulty identifying objects, and increased tripping at curbs or bumping shoulders on doorways may demonstrate decreases in visual field.

Higher PPWS was associated with higher contrast sensitivity ( $p = 0.01$ ), better logMAR visual acuity ( $p = 0.02$ ), and larger visual fields ( $p = 0.01$ ) for all three test conditions. A larger range in values was measured for the WAML and the ITT experimental condition than for the habitual condition (i.e., walking at night with no device).

Higher PPWS was also associated with better low-luminance visual acuity scores, and differences in PPWS between high (poorer performance) and low (better performance) scores were larger for the WAML and the ITT than the habitual test condition (**Table 8**).

Dark adaptation was measured using the Scotopi Sensitivity Tester (SST) [26]. The SST data for 13 of the 27 participants (including one pilot participant) are shown in **Figure 7** and illustrate differing levels of dark adaptation (i.e., some degree of retinal recovery after a bright-light stimulus over varying time intervals). Of the 27 participants, 14 showed no retinal recovery after a full 30 min from presentation of the bright-light stimulus (i.e., indicating more impaired retinal functioning). A delayed dark adaptation interval was associated with lower PPWS ( $p = 0.04$ ), higher numbers of unintended contacts ( $p = 0.0002$ ), lower visual acuity ( $p = 0.01$ ), lower contrast sensitivity ( $p = 0.02$ ), and smaller visual fields ( $p = 0.003$ ).

## SURVEY RESULTS

### Survey Data

As a group, participants reported problems with vision, well-being, distance vision, peripheral vision,

**Table 3.**

Relationship between Percentage of Preferred Walking Speed (PPWS) and number of unintended contacts with obstacles for Generation 3 ITT Night Vision Viewer (ITT), Wide-Angle Mobility Lamp (WAML), and habitual travel mode (i.e., no device) for visually impaired participants (mean  $\pm$  standard error,  $p = 0.0004$ ,  $n = 27$ ).

Device	No. Participants	No. Obstacles	PPWS
Habitual	8	1 to 15	$57.8 \pm 4.0$
	18	16 to 31	$64.5 \pm 3.1$
WAML	24	1 to 15	$80.0 \pm 2.9$
	2	16 to 31	$51.0 \pm 7.0$
ITT	23	1 to 15	$72.7 \pm 3.0$
	3	16 to 31	$47.0 \pm 5.8$

**Table 4.**

Secondary analyses of relationship between logarithm of minimum angle of resolution (logMAR) visual acuity, visual fields, and contrast sensitivity in daytime with no device, nighttime with no device, nighttime with Generation 3 ITT Night Vision Viewer (ITT), and nighttime with Wide-Angle Mobility Lamp (WAML) for visually impaired participants (mean  $\pm$  standard error,  $n = 27$ ).

Device	LogMAR	Visual Fields	Contrast Sensitivity
No Device Daytime	$0.51 \pm 0.1$	$2.8 \pm 0.2$	$1.3 \pm 0.1$
No Device Nighttime	$-1.55 \pm 0.1$	$0.6 \pm 0.2$	$0.5 \pm 0.1$
ITT	$-0.87 \pm 0.1$	$2.0 \pm 0.2$	$1.0 \pm 0.1$
WAML	$-0.55 \pm 0.1$	$2.8 \pm 0.2$	$1.3 \pm 0.1$

**Table 5.**

Secondary analyses of relationship between Percentage of Preferred Walking Speed (PPWS) and contrast sensitivity under nighttime conditions with Generation 3 ITT Night Vision Viewer (ITT), Wide-Angle Mobility Lamp (WAML), and habitual travel mode (i.e., no device) for visually impaired participants (mean  $\pm$  standard error,  $p = 0.01$ ,  $n = 27$ ).

Device	Contrast Sensitivity	PPWS
Habitual	0 to 0.7	60.1 $\pm$ 3.7
	> 0.7 to 1.35	66.2 $\pm$ 4.7
WAML	0 to 0.7	69.8 $\pm$ 3.7
	> 0.7 to 1.35	88.1 $\pm$ 4.7
ITT	0 to 0.7	63.3 $\pm$ 3.7
	> 0.7 to 1.35	80.0 $\pm$ 4.7

**Table 6.**

Secondary analyses of relationship between Percentage of Preferred Walking Speed (PPWS) and logarithm of minimum angle of resolution (logMAR) visual acuities under nighttime conditions with Generation 3 ITT Night Vision Viewer (ITT), Wide-Angle Mobility Lamp (WAML), and habitual travel mode (i.e., no device) for visually impaired participants (mean  $\pm$  standard error,  $p = 0.02$ ,  $n = 27$ ).

Device	logMAR Acuity	PPWS
Habitual	<2	66.0 $\pm$ 4.2
	=2	59.8 $\pm$ 3.6
WAML	<2	89.1 $\pm$ 4.2
	=2	67.8 $\pm$ 3.6
ITT	<2	81.7 $\pm$ 4.2
	=2	61.0 $\pm$ 3.6

social functioning, driving, role limitation, and dependency (with the greatest difficulty in the areas of driving and peripheral vision) on the VFQ-25 survey instrument

### Associations Between Survey Data and Functional/Clinical Abilities

In habitual nightlight with no device, no significant associations were found between PPWS, the number of unintended contacts, the Hopkins mobility survey, and the VFQ-25. A lower overall score on the VFQ-25 was associated with poor visual acuity ( $p = 0.002$ ) and reduced contrast sensitivity ( $p = 0.002$ ). We observed subitem associations between acuity and well-being ( $p = 0.01$ ), social function ( $p = 0.02$ ), color vision ( $p = 0.001$ ), driving ( $p = 0.03$ ), and dependency ( $p = 0.02$ ). We also observed subitem associations between contrast sensitivity and near vision ( $p = 0.001$ ), social function ( $p = 0.02$ ),

**Table 7.**

Secondary analyses of relationship between Percentage of Preferred Walking Speed (PPWS) and degrees of visual field under nighttime conditions with Generation 3 ITT Night Vision Viewer (ITT), Wide-Angle Mobility Lamp (WAML), and habitual travel mode (i.e., no device) for visually impaired participants (mean  $\pm$  standard error,  $p = 0.01$ ,  $n = 27$ ).

Device	Visual Field ( $^{\circ}$ )	PPWS
Habitual	0,1,2	61.5 $\pm$ 3.0
	3,4	73.2 $\pm$ 10.5
WAML	0,1,2	74.7 $\pm$ 3.0
	3,4	102.0 $\pm$ 10.5
ITT	0,1,2	67.2 $\pm$ 3.0
	3,4	99.8 $\pm$ 10.5

Note: Only two individuals have visual fields  $>2^{\circ}$  with habitual light.

**Table 8.**

Secondary analyses of relationship between Percentage of Preferred Walking Speed (PPWS) and Smith Kettlewell Institute Low Luminance (SKILL) acuity scores under nighttime conditions with Generation 3 ITT Night Vision Viewer (ITT), Wide-Angle Mobility Lamp (WAML), and habitual travel mode (i.e., no device) for visually impaired participants (mean  $\pm$  standard error,  $p = 0.01$ ,  $n = 27$ ).

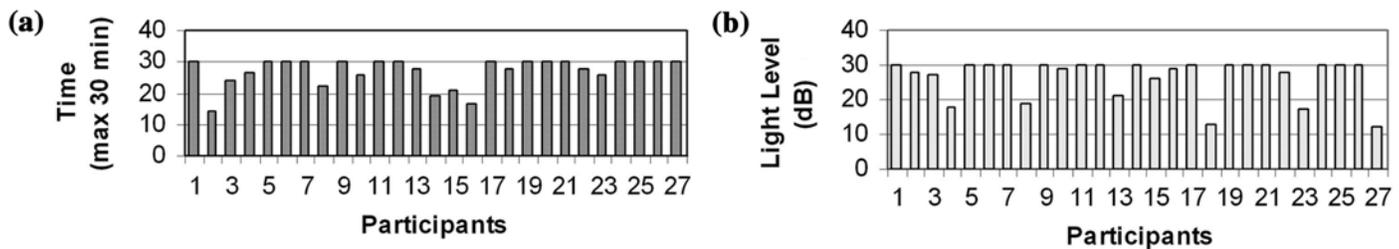
Device	SKILL Score	PPWS
Habitual	15 to 40	65.6 $\pm$ 3.1
	41 to 87	55.1 $\pm$ 4.6
WAML	15 to 40	84.3 $\pm$ 3.1
	41 to 87	60.1 $\pm$ 4.6
ITT	15 to 40	77.9 $\pm$ 3.1
	41 to 87	51.3 $\pm$ 4.6

color vision ( $p = 0.0003$ ), driving ( $p = 0.03$ ), and dependency ( $p = 0.02$ ). The "Walking into Dimly Lit Areas" subitem of the IMQ and the well-being subitem of the VFQ-25 were both associated with decreased PPWS ( $p = 0.01$ ).

## DISCUSSION

### Engineering

As reported, the manufacturer's specifications for the ITT and the WAML were relatively accurate. One exception was that the manufacturer stated the WAML's battery duration was 1 h and actual testing indicated the light to drop off sharply after 40 min. One of the three WAMLs tested did not hold a battery charge. Two other exceptions are that the ITT had a  $38^{\circ}$  visual field compared



**Figure 7.**

Dark adaptation as measured by the Scotopic Sensitivity Tester ( $n = 27$ ). Data include time to adapt to (a) dimmest light level for each participant and (b) dimmest light level participants were able to adapt to within 30 min. Light level was measured in decibels. Participants unable to dark adapt within the 30 min are indicated by a score of 30 dB.

with the manufacturer's claim of a  $40^\circ$  visual field and that one of the three ITTs tested did not provide an acceptable clarity level.

#### *Generation 3 ITT Night Vision Viewer*

Questionnaire results, comments, and suggestions regarding the ITT related to the discomfort caused by the head mount, the weight of the device, the lack of an automatic focusing device, and the monochromatic viewing image. The ITT is a relatively heavy device, weighing 13.8 oz, that must be held in a secure position  $\sim 3$  in. in front of one eye. This position must be maintained while the user is moving about in a normal fashion. The head mount supplied with the monocular accomplishes this with a semirigid plastic headband and a series of straps that go over, around, and behind the head. This arrangement includes a neck pad at the base of the skull, a forehead pad, and a chin pad in front. The monocular is attached to the front of the plastic headband in a cantilevered fashion that magnifies the effect of its weight. In order to ensure that the monocular maintains a constant position, the head mount must be tightly fitted to the user's head, which unavoidably results in some degree of discomfort. The head straps can be adjusted but it should be noted that the range of adjustment would not accommodate either our smallest or largest participant.

Automatic distance focusing is available on many cameras and could in theory be applied to the ITT. However, this would add additional cantilevered weight and compound existing problems associated with the head mount. The manufacturer advises that the monochromatic image in the viewer is an inherent characteristic of the device and cannot be changed.

#### *Wide-Angle Mobility Lamp*

The questionnaires, major comments, and suggestions regarding the WAML related to its stability, weight, and shoulder/waist strap assembly. The WAML moved about while the user was walking, if not restrained by hand, and the weight of the WAML could be felt where the supporting strap crossed the shoulder and where the WAML rested against the hip.

While a user is walking, the WAML moves as it rests on the hip, which is a result of the movement of the whole body as well as that of the hip. The movement may be somewhat reduced by adjusting the shoulder strap to raise the WAML to waist level. However, in this position the reduction in movement was hardly noticeable and the participants reported that this was an awkward position for the WAML because it interfered with arm movement. The cinema industry has developed an equipment platform that stabilizes handheld cameras while the cameraman walks about, but it is too large and too costly for use with the WAML.

## **Rehabilitation**

### *Surveys*

Although all visually impaired participants tested were physically capable of ambulation and all reported they moved about during the day, most with no assistance (i.e., devices or human guide), nighttime travel provided significant challenges to these individuals. Eighty-two percent reported that they either did not go out or they required assistance to go out at night; whereas, only 23 percent reported use of some type of assistance during the day. Of the 82 percent who reported difficulty traveling independently at night, 12 percent totally restricted their nighttime independence by choosing not to go out at

all. Survey results showed that these participants had some degree of difficulty that affected well-being, social function, color vision, driving dependency, and “walking into dimly lit areas.” The issue of independent travel at night is complicated by the fact that the United States has a shortage of COMS [27] that teach compensatory travel skills to this disability group.

### *Clinical Evaluations*

No significant differences in measures of daytime function existed between no device and the WAML at night. Therefore, when using the WAML in nighttime lighting levels, participants’ visual acuity, visual fields, and contrast sensitivity levels were similar to their daytime levels. Performance with the ITT improved performance on visual tests relative to nighttime performance with no device, but not to daytime levels. As is best practice in the field of low vision and blindness rehabilitation, we recommend that people with legal blindness acquire proper instruction in the use of a long cane by a COMS. If it is determined that the individual could also benefit from a low-vision mobility device, the long cane will assist with any depth perception problems caused by the device or will locate obstacles in the path that are obscured by a visual-field deficiency.

### *Functional Evaluations*

Statistically significant improvements in PPWS ( $p = 0.0001$ ) were found for both the WAML and the ITT, with the WAML providing the greatest improvement over night mobility with no device. Unintended contacts with the environment were also lower for both the WAML and the ITT ( $p = 0.0004$ ), with the WAML once again providing the best performance.

Another measure on functional-mobility tasks was developed for this project (not described here) for the purpose of exploring the potential role of a measure based on real-world tasks at night. Two of the functional-mobility tasks evaluated showed statistically significant performance differences between the two devices, with the WAML outperforming the ITT on both ( $p < 0.0001$ ). On the third functional mobility task (retrieving mail), no significant differences were found between the ITT and no device. This data should be considered preliminary and exploratory, but it does suggest that there could be benefit in developing and validating real-world measures of performance.

### *Associations Between Clinical Measures and Functional Performance*

Better contrast sensitivity, visual acuity, visual fields, low-luminance visual acuity, and dark adaptation scores were associated with higher PPWS. A better dark adaptation score was also associated with fewer numbers of unintended contacts.

## CONCLUSIONS

There is almost a four-fold increase in the number of participants with RP who require assistance at night as compared with their daytime travel needs. These results show that persons with severe night blindness associated with RP benefit from improved night mobility if they use low-vision night mobility devices. Both the WAML and the ITT provided improved night mobility (both on the clinical-visual measures and functional-mobility measures). Based on the results of this study, the WAML improved night mobility to a higher degree than the ITT. In fact, participant performance under nighttime conditions with the WAML was roughly equivalent to daytime performance.

The engineering evaluation showed that there were human-factors issues that related to the weight and battery of the WAML as well as to the comfort, fit, and cost of the ITT. Cosmetic appearance of both devices bothered some participants.

Further investigation should include other conditions associated with night-vision disability that are of higher incidence in the population (e.g., age-related macular degeneration, glaucoma, and cataracts) and evaluating other types of low-vision night mobility devices (e.g., Maglight, Stinger, miners’ lights, etc.) that are smaller in size and have a longer battery life than the WAML.

## RECOMMENDATIONS

It is vitally important for professionals to provide consumers with knowledge of the types of devices available for nighttime travel as well as their positive and negative attributes. As is always the case in providing rehabilitation care, devices need to be tailored to individual needs.

### Wide-Angle Mobility Lamp

A more convenient, longer-lasting battery and a dimmer switch for social situations were suggested.

### Generation 3 ITT Night Vision Viewer

Optical improvements include increasing the visual field and improving visual acuity and contrast sensitivity. Human-factors improvements include redesigning the head mount to provide additional comfort and better fit for varied sizes. ITT recommends using the head mount over one eye only (rather than binocularly) in an effort to minimize the effects of errors with depth perception. This does not improve depth perception for an individual with night blindness because these individuals are unable to see anything with the unaided eye. We recommend that individuals with night blindness routinely use a long cane for travel at night.

### ACKNOWLEDGMENTS

We would like to thank our two research assistants, Ms. Laura Fiaschetti and Mr. Rodney Hunt for their untiring efforts to assist with obstacle placement and retrieval on the route. Ms. Fiaschetti also helped with development of our data maintenance system. Many thanks also go to Kevin Scott Johnson, a third research assistant, who assisted with some of the engineering portions of the project. We gratefully acknowledge the VHA's Rehabilitation Research and Development Service for funding this research project, the administration and employees of the Hefner VA Medical Center for their support, the research participants for their time and effort in participating in the project, and the citizens of Salisbury, NC, who observed and encouraged us as we walked their neighborhoods at night.

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Submitted for publication August 4, 2004. Accepted in revised form February 22, 2005.