Establishing Mobility Measures to Assess the Effectiveness of Night Vision Devices: Results of a Pilot Study

Kim T. Zebehazy, George J. Zimmerman, Alex R. Bowers, Gang Luo, Eli Peli

University of Pittsburgh and Schepens Eye Research Institute

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Abstract

In preparation for an evaluation of night vision devices, an exploratory study was conducted to gain initial experience with the sensitivity of chosen mobility measures under night conditions. The measures included cane contacts and object recognition distances. Results provide preliminary evidence that these two measures may be sensitive to the effects of a night vision device.

Introduction

In addition to their restricted peripheral fields, persons with retinitis pigmentosa (RP) report significant problems with seeing in low levels of illumination, causing difficulty with night travel (Turano, Gersuchat, Stahl, & Massof, 1999). Several devices have been developed to support the visual needs of persons with night blindness. These devices include wide-angle flashlights (Morrissette, Marmor, & Goodrich, 1983), adapted military light intensifier devices (Berson, Mehaffey, & Rabin, 1974), and systems that use high sensitivity (also infrared sensitive) video cameras (Friedburg, Serey, Sharpe, Trauzettel-Klosinski, & Zrenner, 1999; Spandau, Wechsler, & Blankenagel, 2002; Hartong, Jorritsma, Neve, Melis-Dankers, & Kooijman, 2004). New devices are also in development, including the “Minified Augmented-View” device, which incorporates field expansion along with night vision enhancement to address both the field and night vision needs of persons with RP (Peli, 2001; Bowers, Luo, Rensing, & Peli, 2004).

In order to guide development of new night vision devices as well as provide accurate information to potential consumers of such devices, it is important to evaluate their usefulness in supporting efficient and safe mobility in areas of low illumination. Evaluation of night vision devices that provides sufficient details about mobility performance in real-world night situations would also benefit the orientation and mobility (O&M) specialist who might be involved in introducing and training clients to effectively use such devices for safe and independent travel.

Methods of evaluating mobility performance while using night vision devices have varied, ranging from subjective decisions by trained specialists about a person's travel abilities while performing functional tasks (Spandau et al., 2002), to designs that used a more objective set of measures including recorded occurrences of mobility behaviors, total time to walk a course, or preferred walking speed (Morrissette et al., 1983; Robinson, Story & Kuyk, 1990; Hartong et al., 2004).

This pilot study included mobility measures used in previous night vision device studies, as well as two new measures (cane contacts and object recognition distances) to gain an initial impression about these measures' sensitivity to changes in mobility with night vision devices. In addition, in preparation for future studies, this exploratory investigation was conducted to provide information about any difficulties of assessing outdoor night mobility in a real world environment. The pilot results are reported in order to open an avenue for discussion amongst professionals in the field.

Method and Participants

Course Design and Mobility Measures

The assessment included two main sections: a mobility course and an object recognition task (similar to the daylight object detection task used by Goodrich and Ludt (2003)). An earlier study (Bowers et al., 2004) reported differences in mobility performance and perceived visual difficulty without a night vision device at lighting levels equivalent to those found on well-lit and poorly-lit streets (about 16 lux and 2 lux, respectively). Based on this finding, the mobility course was divided into a high light section (median 15 lux) and a low light section (median 2.5 lux), each consisting of approximately 8-9 short city blocks and natural occurring obstacles. The object recognition section was situated in a low light area (median 1.5 lux). Mobility performance was scored by an O&M specialist (COMS). An additional O&M specialist was present to monitor participant safety and to give route instructions.

Along the high and low light sections of the course, participants were instructed to walk at a natural pace, attempting to avoid body contact with all obstacles. They were scored for the occurrence of mobility behaviors grouped into three main categories: cane contacts, body contacts and mobility errors (Table 1). Besides cane contacts, these measures were consistent with those used in other night vision studies. Time to complete each route was also recorded. Since many potential users of night vision devices are likely to use the device in conjunction with a long cane, the number of cane contacts was tallied. The inclusion of this additional measure was based on the premise that a change in the number of cane contacts between walking the routes with and without a device might provide an indication of the extent to which vision versus tactual information was used to navigate the environment in these two conditions.

Along the object recognition task section of the course, participants were asked to find five objects of varying sizes and contrast shown to them ahead of time indoors: a large black plastic garbage bin, a large orange traffic cone, a small orange pumpkin basket, a yellow "caution wet floor" clapboard, and a navy umbrella in open position. Objects were placed on the right or left side of the sidewalk from ground to hip level. Participants were asked to visually search for these objects and to stop each time they could first identify an object. An ultrasound measure or standard tape measure was used to measure the recognition distance. The location of the objects was varied between the participants. The inclusion of this task was considered important for two reasons. First, an increase in detection distance of obstacles at night, which may occur when using a night vision device, could improve safety and ease of movement. Second, night vision devices could be used for visual detection of specific landmarks for navigation; therefore, some measure of a person's ability to recognize objects using the device is important.

Participants

Two adults were recruited who had RP and self-reported difficulties in outdoor night travel due to reduced vision. Table 2 summarizes the participants' visual and mobility characteristics. Under dim illumination conditions, the device improved contrast sensitivity for both participants to the levels attained at normal (standard) room lighting without the device. However, visual acuity with the device was restricted by the limited resolutions of display and camera such that visual acuity at low light levels did not improve with the device; similar results were reported by Bowers et al. (2004).

Both participants completed the whole course with and without a night vision device. For the mobility course, order of the route sections (high and low light) and the starting direction of each section were reversed between the device and no-device conditions to reduce any learning effects. For the with device assessments, the device was used continuously.

The Device

Each participant used the MultiVision (Trivisio, Switzerland) night vision device and received 40 minutes of device training prior to the start of the mobility assessment. The MultiVision provides a video image of the environment, gathered through a high sensitivity camera mounted on the front of a pair of goggles. The image is displayed onto two small video screens enclosed within the goggles. The user wears the goggles, watching the video screens to see where s/he is going. The field of view of the system was 32 degrees horizontal by 24 degrees vertical.

Results

Mobility Measures

As indicated by the low number of body contacts and mobility errors made (Table 3), neither pilot participant had difficulty traveling with or without the device in the high light section of the course. The low light section, with lower illumination levels and increased concentration of obstacles was more challenging and both participants made more contacts and mobility errors than in the high light section (Table 3). Furthermore, Participant 2, who used a long cane, showed an increase in cane contacts at the low light level. For both participants, the most frequently recorded mobility errors were shuffling/hesitations, followed by sudden stops and loss of balance. High stepping and curb approach errors were rarely recorded, while veers and spotter interventions did not occur at all.

The impact of the night vision device on mobility performance was different for the two participants at the high light level: Participant 1 took longer to complete the section and made a few more mobility errors with the device, while Participant 2 took just 5 seconds less to complete the section and made fewer cane contacts (Table 3). For the low light section, there were clear differences in mobility performance with and without the night vision device. Participant 1 demonstrated worse mobility performance (made more body contacts and mobility errors) and took 45 seconds longer to walk the section with than without the device. By comparison, Participant 2 took about the same time to walk the section and made more body contacts, but fewer mobility errors and far fewer cane contacts when using the device.

For Participant 2, the increase in body contacts and reduction in cane contacts was partly a result of a change in cane technique adopted when using the device. Without the device, he used touch technique and changed to diagonal technique with the device. For comparison purposes, Participant 2 was asked to walk half (4 blocks) of the low light route section again with the device, using touch technique. Cane contacts using both techniques decreased when using the device, but less dramatically when maintaining touch technique (a decrease of 35 contacts compared to 45 for the 4-block section). Also, the same pattern of increased body contacts and decreased mobility errors was present along this portion of the route, but at different ratios depending on the cane technique used: less of an increase in body contacts (three compared to nine) and more of a decrease in mobility errors (four compared to one) with touch technique and the device. The potential confound of having the participant walk the same section twice should be noted.

Object Recognition Task

In general, object recognition performance was better with than without the night vision device for both participants, especially Participant 2 (Table 4). There was an overall increase in object recognition distance when using the device; Participant 2 missed two objects without the device, but saw them with the device.

Discussion

Mobility Errors

In the low light section of the course Participant 1 made more mobility errors with than without the device, while Participant 2 made fewer errors with the device (Table 3). The opposite effect for the two participants could be due to insufficient device training, but may also relate to differences in visual characteristics between the participants, a finding consistent with previous studies (Morrissette et al., 1983; Rohrschneider, Spandau, Wechsler & Blankenagel, 2000; Spandau et al., 2002). Participant 1, with a larger field and better contrast sensitivity at low light levels (Table 1), did not find the device useful, reported that it limited her natural eye scanning and blocked the view of her feet (similar comments have previously been reported for the Multi-Vision device (Spandau et al., 2002; Hartong et al., 2004)). By comparison, Participant 2 with a much narrower field and poorer contrast sensitivity at low light levels, found the device useful in the low light section of the course providing visual information about objects that otherwise would not have been seen, and made fewer mobility errors with the device.

Despite the overall low number of errors in the high light section, both participants did show similar behaviors with a slight increase in mobility errors when using the device. It is likely that the slightly poorer mobility performance with the device at this light level was due to insufficient device training and the limitation on natural eye scanning imposed by the restricted field of the device.

Body Contacts

The increase in body contacts with the use of a night vision device for both participants is inconsistent with previous night vision studies (Morrissette et al., 1983; Hartong et al., 2004). This might be due to a combination of reasons. First, the definition used for counting body contacts in this study was strict and even included brushing against plants in window boxes (which were a common feature in the neighborhood used). The majority of the increase in body contacts for both participants with the device occurred at the middle/vertical level, which was either due to brushing against street lamps with the arm or shoulder, or brushing against plants in window boxes. Second, for both participants, most of these harmless “to the side” contacts occurred in one extremely cluttered part of the low light route where the sidewalk was very narrow. Since the night vision goggles limit the extent of the field that can be scanned with eye movements alone, it appears the need to switch to full head scanning affected the participants, particularly in cluttered areas. More training, including head scanning techniques, may help alleviate this problem (Hartong et al, 2004).

Cane Contacts and Cane Use in Night Vision Studies

For the cane user (Participant 2) the total time to walk the course was similar in both conditions. However, the reduction of cane contacts by this participant when wearing the night vision device shows promise as a measure of the increase in the use of vision to navigate the environment. A similar pattern was also shown by a pre-pilot cane-user (not reported here) with RP and 7 degree fields: in the low light section, total time to walk the course was similar with and without the device, but a 50% reduction of cane contacts was observed when using the device. Since the implication of the utility of the cane contacts measure is based on patterns observed in only one participant (and a pre-pilot participant), further investigation is warranted. Also, refinement of the measure and recording procedures to make counting cane contacts less cumbersome is necessary.

The approach taken in this study (and Robinson et al., 1990) was to allow the use of a cane during all mobility assessments. Although this does not allow direct assessment of the extent to which the night vision device alone might improve mobility, it is nevertheless a valid approach that measures how much the device improves mobility in the habitual with-cane situation. We suggest that cane users might use night vision devices as a supplementary aid, not as a replacement for the cane. In particular for the MultiVision device used in this study, the limited field of view of the device (32 degrees horizontal field) and the challenges it thus poses for eye scanning (especially when a person is not fully adapted to the device) suggest that a cane should be used.

Object Recognition Task

The object recognition task could only be accomplished using visual information and provided a direct measurement of the visual benefits of the night vision device in a real world environment. As expected, overall object recognition distances increased when using the night vision device, especially for Participant 2 who had more impaired vision at low light levels than Participant 1. However, this real world task presented some difficulties, which have to be overcome, including variation of lighting conditions at different object locations, items being stolen, and items on the sidewalk that could be mistaken for an intended target. The task could also be improved by the inclusion of more functional natural-environment objects (which most likely will be low contrast) to better simulate real landmarks the person may be trying to recognize.

Conclusions

The ultimate goal of night vision device evaluation studies in real-world settings is to gain as much functional information about the device’s benefits and limitations to users with night blindness. In order to provide specific details that will assist O&M specialists in creating training protocols for their clients on the devices, reporting on a wide variety of measures may be useful. Preliminary results of this exploratory study suggest that both cane contacts and object recognition distances, measures not previously used in night vision device evaluation studies, may be sensitive to changes in mobility behavior resulting from increased visual information when using the device; our findings invite discussion from the field.

Tables

Table 1: Definitions of the mobility measures for the high and low light routes.

1. Cane contacts: Anytime the cane strikes an obstacle anywhere along the path, including catches on sidewalk cracks.
2. Body contacts: Contacts with an obstacle with any part of the body. Includes contacts when stepping up curbs (under stepping), but not stumbles over elevation changes or sidewalk cracks. • **Low Level Obstacles:** Obstacles from knee height down (e.g. curbs, stairs) • **Middle Level/Vertical Obstacles:** Obstacles occurring between knee height and chest level (e.g., clapboard store signs on the sidewalk), or obstacles that extend vertically (e.g., street lamp poles, parking meters). • **High Level Obstacles:** Obstacles at face and head level (e.g., low hanging tree branches, awnings).
3. Mobility errors: • **Sudden stops:** Stops to avoid contacting obstacles. The traveler sees the obstacle in time not to contact it, but not with enough time to go around it naturally. • **Spotter Intervention:** The O&M Specialist intervenes during travel to ensure safety for whatever reason. • **Shuffling/Hesitations:** Sliding the foot forward or reaching the hand out to investigate the path tactually, or the excessive slowing of pace (does not include slowing to adjust controls of the device). • **Loss of Balance:** Includes tripping, stumbling or other mild unsteadiness caused by subtle low level changes (texture changes, sidewalk cracks, elevation changes) • **Errors in Curb Approach:** Stopping too far from the curb (before the start of the curb ramp) or stepping past the end of the curb into the street before stopping. • **High Stepping:** Stepping over something that does not exist (false stepping) or excessively high for the height of the object being stepped over (stair, curb, obstacle in path). • **Veer off of Path:** Walking off of the sidewalk, stepping off the parallel curb, or, in wide open areas, veering way off the desired line of travel without recovery.

Table 2: Visual acuity (VA), visual field (VF), and contrast sensitivity (CS) of the pilot participants without and with the night vision device using the protocol described in Bowers et al. (2004)

		Without Device			With Device	
Light Level		**Standard**	**16 lux**	**2 lux**	**16 lux**	**2 lux**
Participant 1: No cane Female 44 years old	**VA**[1] (Snellen)	20/42	20/55	20/87	20/73	20/69
	VF[2] (degrees)	> 37[4]	> 37[4]	30	29	29
	CS[3] (log units)	1.35	1.30	1.00	1.35	1.55
Participant 2: Long cane Male 35 years old	**VA**[1] (Snellen)	20/23	20/42	20/69	20/58	20/58
	VF[2] (degrees)	13	9	6	9	10
	CS[3] (log units)	1.40	0.80	0.75	1.30	1.30

1. Visual acuity measured on Early Treatment for Diabetic Retinopathy Study chart.
2. Visual field horizontal diameter measured on tangent screen
3. Letter contrast sensitivity measured at 1m on Peli-Robson chart; the higher the score the better the contrast sensitivity (i.e. the better the ability to see letters of lower contrast)
4. Field extent was greater than the width (37 degrees) of the tangent screen at the test distance used.

Table 3: Scores on mobility measures for the high and low light routes

		High Light Route		Low Light Route	
		Without Device	**With Device**	**Without Device**	**With Device**
Participant 1	**Cane Contacts**	NA	NA	NA	NA
	Errors				
	Body contacts	0	1	5	11
	Mobility Errors	1	3	5	14
	Total	**1**	**4**	**10**	**25**
	Time to complete (minutes:seconds)	3:05	3:27	5:43	6:28
Participant 2	**Cane Contacts**	**13**	**5**	**62**	**3**
	Errors				
	Body contacts	0	0	4	12
	Mobility Errors	2	4	13	9
	Total	**2**	**4**	**17**	**21**
	Time to complete (minutes:seconds)	3:38	3:33	5:54	5:50

Table 4: Recognition distances at which objects were identified.

Object	**Recognition distances (feet)**					
	Participant 1			Participant 2		
	Without device	With device	Increase with device	Without device	With device	Increase with device
Garbage bin	4.3	7.7	3.4	Missed	14.0	14.0
Traffic cone	5.3	16.3	11.0	Missed	20.6	20.6
Clapboard	37.5	27.8	-9.7	11.4	21.9	10.5
Umbrella	11.0	14.0	3.0	6.0	Stolen[2]	NA
Pumpkin	Incorrect[1]	19.4	NA	15.8	12.8	-3.0

1. Participant identified the wrong target (a Halloween pumpkin rather than our pumpkin basket)
2. Umbrella was stolen before participant reached that section of the route

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