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Assessing visual detection ability for mobility in individuals with low vision

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Abstract We investigated the mobility performance of legally blind patients with age-related **maculopathy** (ARM) as assessed by their ability to visually detect hazards in their travel path. The three types of hazards were: drop-offs (a curb), obstacle on the travel surface (a small wastebasket), and a **head-height** obstacle (a piece of foam insulation projecting across the travel path at head height). We also recorded the patient's logMAR visual acuity and Pelli-Robson contrast sensitivity. Three distinct daylight assessments were made in a naturalistic outdoor environment: an initial assessment of distance to visually detect each of the three types of hazards; an assessment designed to assess the subject's maximum potential visual detection distance; and a final assessment following training and fitting with filters to reduce glare to determine the increase, if any, in visual detection distance for the three types of hazards. The inter-rater and test/retest reliabilities of the assessment procedure were studied. The results indicated that many ARM patients are unable to visually detect some hazards at a safe distance, that their ability to improve can be predicted from the assessment, and that most subjects can improve their ability to visually detect obstacles if provided **appropriate** training and filters. The limitations of this study and their implications are discussed.

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Introduction Studies of mobility performance of low vision patients have utilized both artificial courses, often consisting of laboratory or office spaces with strategically placed obstacles,¹ and real-world settings, typically consisting of residential areas utilizing naturally occurring obstacles.^{5, 8} Other studies have chosen to increase the complexity of the real-world environments by utilizing complex pedestrian-heavy routes such as those found in shopping malls.^{8,9}

While most studies have focused upon the relationship between clinical variables (i.e., visual acuity, contrast sensitivity, and visual field) and the ability to avoid obstacles in the travel path and to navigate the prescribed route,³⁶ others have added the scoring dimension of percent preferred walking speed (PPWS),⁶⁸ which was first advocated by Clarke-Carter and colleagues as a method of comparing mobility performance of blind pedestrians using different mobility techniques.⁹ PPWS is primarily an efficiency measure since it is based upon the individual's walking speed, although it may also be considered an indirect measure of travel confidence on the assumption that a less confident walker (i.e., one who fears tripping or falling) will walk slower than one who is more confident. This is a plausible assumption since it has been shown that for elderly individuals, self-reported limitations in visual abilities correspond to objectively measured visual abilities."

To date, the consensus of the literature appears to be that visual factors (primarily visual field and contrast sensitivity) may account for some intersubject variability in low vision mobility."⁶⁸ The literature also suggests that changes in the travel environment (i.e., illumination) can facilitate or inhibit travel ability, although this may be dependent upon the specific visual loss of the subjects studied. Hassan and colleagues, for example, found that there was no significant difference in PPWS between ARM and age-matched individuals not having ARM in daylight, although the ARM subjects had slower PPWS in dim illumination.' Retinitis pigmentosa (RP) subjects, studied by Haymes and colleagues, showed no difference in PPWS between indoor and outdoor mobility, suggesting that these variations in illumination did not result in changed mobility performance.' Kuyk and colleagues also studied mobility under photopic and mesopic conditions and found that subjects with an acuity loss took less time to complete an artificial route than did subjects with either a peripheral field loss or a combination of acuity loss and peripheral field loss.¹² These investigators also reported that for all subjects floor level walk-around objects were contacted significantly less often than either step-over or head level objects'.

Both Haymes et al.' and Hassan et al.⁶ have advocated the use of PPWS as a measure of mobility and Hassan et al.' noted that the number of contacts made with objects in the environment was a relatively poor measure, because such contacts are relatively rare occurrences. Hassan et al.⁶ also noted that route familiarity could decrease the number of errors made, indicating that familiarity with the travel route enhanced performance. Haymes et al.' found that some RP patients, particularly those with little residual vision, limit their travel to simple routes – a finding consistent with our clinical impressions of elderly visually impaired subjects seen at the Western Blind Rehabilitation Center. The limitation of traveling only simple familiar routes may serve the same purpose as noted by Hassan et al.' in that route familiarity reduces errors by limiting the chance the person will make an error. The limitation of travel to familiar environments may ease the mental effort required for travel, a supposition supported in a recent study by Turano and her colleagues indicating that for subjects with RP mental effort is increased and reaction times slowed during walking."

In real-world settings, travel errors are not confined to infrequent contacts with laboratory obstacles. Visual impairment is a documented risk factor for hip fracture in the elderly.^{4,5} The risk of falls also does not appear to be related to unfamiliar or complex environments as vision-related accidents have been documented in the **individual's** home,¹⁶ nursing homes,¹⁷ and the community.¹⁸ The personal cost of a fall, whether in the home or community and whether caused by tripping hazards, undetected curbs, or protruding objects, ranges from a 'nasty bump' to severe injury.¹⁸ An additional cost may be that elderly visually impaired individuals self-limit their travel, which prevents them from obtaining adequate exercise and/or otherwise limits their ability to lead a healthy independent life-style which may put them at risk of other diseases.¹⁹ This risk is significant since, for the elderly, being visually impaired may double the risk of a fall resulting in a hip fracture.²⁰

Clearly, vision-related variables have been shown to be important determinants of travel, and efficiency measures such as **PPWS** are useful research tools in studying the travel behavior of visually impaired individuals. It also appears that differences in pathology or type of loss (e.g., loss of acuity or peripheral field loss) may also be an important consideration. Little attention, however, has been paid to many of the factors that may affect the travel safety of **individuals**. In addition, while vision variables have been shown to predict travel disability, they have not been assessed as measures of rehabilitation potential. That is, given that the low vision individual has a travel deficit, can the individual's travel efficiency or safety be improved through the utilization of low vision devices and/or through rehabilitation training? In short, there is little scientific literature related to the safety and rehabilitation potential of low vision travelers even though it has been over 20 years since **Genensky's group highlighted the problem.**²¹

One relatively untried but promising approach to vision rehabilitation strategies for low vision mobility is the study of the perceptual factors influencing mobility performance. Harold **Richterman**,²² in a paper published over 35 years ago, advocated the use of perceptual information in training the low vision traveler. Dodds and Davis' were perhaps the first investigators to formally study visual perception and mobility skills. They found that performance on such perceptual tasks as textural shearing, degraded figure, and embedded figures was a better predictor of mobility performance (as measured by PPWS) than were visual acuity and visual field.²³ **Although the Dodds and Davis study has not been systematically replicated and perceptual factors in mobility have been largely ignored in the intervening decade, other researchers are beginning to advocate the study of perceptual factors in low vision.**²⁴⁻²⁶

In this paper, we report on a study of ARM patients' untrained ability to detect three types of travel hazards (a curb, an obstacle on the travel surface, and an overhanging object), a method of assessing the patients' ability to improve upon their untrained visual detection ability, and the improvement patients attained after training and the provision of appropriate filters. Our primary measure is the distance at which patients reported being able to **visually** detect each of the hazards. Our

intent is to initiate additional studies of the perceptual factors involved in low vision mobility, particularly as they appear to relate to travel safety.

Method and subjects Subjects were patients admitted to the Western Blind Rehabilitation Center (WBRC) for vision rehabilitation therapy, including orientation and mobility (O&M). The WBRC is an inpatient facility providing comprehensive vision rehabilitation services, including low vision, O&M, living skills, and computer-access training, as well as psychological and social services support. The average age of the 60 subjects (56 male, 4 female) was 78.6 years (range: 49-93). All were diagnosed with ARM and patients having additional significant visual pathologies were excluded from the study. The average logMAR visual acuity was 1.06 (fo.285) and the average Pelli-Robson contrast sensitivity was $0.895(\pm 0.37)$. Most subjects (68.3%) reported using no mobility device prior to admission. Only six (10%) reported using a long cane. An additional 21.7% reported using either a wheelchair (n = 1), support cane (n = 7), walker (n = 2), or scooter (n = 3). Sunglasses (filters) were reported as being used in travel by just under half the subjects (n = 29, 48.3%) at the time of their admission.

The initial distance visual recognition assessment (DVRA) occurred soon after admission and prior to any formal mobility training other than the initial familiarization with the WBRC necessary for patients to find their way from their rooms to the dining room, nursing office, TV room, and other common areas. The initial DVRA consisted of two parts: an assessment of the patient's ability to visually detect the three types of hazards prior to training (initial assessment, IA) and an assessment in which the O&M instructor provided the subject with instructions on how to visually identify each obstacle (potential assessment, PA). The PA was so named because it represented an explicit attempt to quantify the subject's potential to improve his ability to visually detect hazards. The PA instructions included using environmental contextual cues, appropriate scanning patterns, and perceptual cues. Contextual cues may include the presence of automobiles, street signs, fire hydrants, and other familiar features. Perceptual cues included noting color or contrast differences (i.e., between a gray sidewalk curb and a black asphalt roadway), relative motion changes, figure ground changes, textural changes, etc. As the subjects were observed during the IA, instructors noted that subject's scanning patterns seemed to be inefficient or limited and did not allow the subject to 'see' all relevant areas of their travel environment. Some would fixate a point in space directly in front of themselves without scanning. Others would look downwards at a point just in front of their feet and 'shuffle' forwards. Still others showed other variations, but few demonstrated scanning patterns their instructors considered safe or efficient.

The IA and PA were accomplished during a single session, usually requiring between 30 and 90 minutes. The IA and PA as well as the final assessment (FA) were conducted between mid-morning and mid-afternoon on sunny days. The FA was conducted in a separate session after all DVRA and mobility training had been completed (usually 25-35 hours). The 25-35-hour DVRA and mobility training was pri-

marily mobility training in the use of a long cane, optical devices if prescribed, and the development of mobility skills in a variety of residential and business environments. The DVRA training consisted of utilizing opportunities that occurred during the normal mobility lesson to reinforce the visual perceptual concerns identified in the IA and PA. In this manner, the DVRA training was integrated into the existing mobility program and did not constitute a separate training activity. Prior to DVRA training, the patients were prescribed an appropriate filter (usually a UV shield or a NoIR filter), which was worn during the FA. NoIR and UV shield filters accounted for 80% of those prescribed, and three filter tints (amber, gray, and yellow) were used most often, accounting for over 70%.

The procedure and subject instructions for the IA and FA measurements were identical. Subjects were told that there were three types of hazards they were to verbally identify as soon as they were seen. Subjects were told that there were multiple occurrences of each type of hazard and that they occurred in no particular order. The subject was to stop and visually state when they first saw the hazard; at that time, the instructor marked the spot and then measured the distance from that point to the obstacle. Incorrect identifications were ignored, although the subjects were told that they made an incorrect identification. For example, if a subject identified a curb cut as a curb, the instructor told the subject the type of error and they continued walking. In reality, only the first occurrence of each type of hazard was recorded for data analysis. Distances measured were recorded to the nearest foot.

The three types of hazards used in the DRVA were: a drop-off that was a naturally occurring gray curb (next to a black asphalt driveway) measuring five inches high (12.7 CM); a surface obstacle (represented by a gray-colored wastebasket) measuring 16 (40.7cm) inches high, 13 (33 cm) inches wide, and 11 (28 cm) **inches deep**; and an **overhang** represented by a **three** foot (99 CM) long **black** foam **cylinder (pipe insulation)**, **1.25** inch (6.3 cm) **in** diameter, **projecting** at head **height** into **the travel path**. The **head-height** obstacle was **attached** to one of **numerous** small trees bordering the travel path and placed so that it was at head height (i.e., approximately eye level) of the subject being tested. The curb used in the study was one of several naturally occurring curbs and curb cuts in the test route. The surface obstacle and **overhanging** hazard were placed before the subject entered the test route. 'Iivo routes were used for testing. These were two identical' routes in a large parking lot at our facility. We assume that they were equally difficult since each was the mirror image of the other. That is, one had trees/shrubs on the right and cars on the left, while the mirror-image route had trees/shrubs on the left and cars on the right. Two 'I-shaped mirror-image sections of sidewalk were chosen. Each was about 250 feet in length, and neither was in areas likely to have been traveled by the subjects in this study. Shrubs and small (i.e., 15-20 ft.) trees bordered the sidewalks. One of the two routes was used for the IA and the other for the FA. The PA was conducted on the same route as the IA. The routes were located in areas with low pedestrian traffic, and instructors ensured that pedestrians were not present during testing

sessions. Subjects used their habitual corrections during the IA. The subject was instructed to stop and point to the obstacle when it first became visible and instructors measured from that point to the hazard (to the nearest foot).

INTER-RATER RELIABILITY To estimate the inter-rater reliability, two instructors were paired in 32 separate observations of subjects. One instructor indicated the point from which the measurement was to be made, while the second instructor either confirmed that point or indicated a different point. There was agreement in most cases, and an insignificant disagreement (i.e., less than 6in. or 15.2cm) in a few cases. Since measurements were recorded to the nearest foot, we judged these differences to be insignificant and concluded that our inter-rater reliability appeared to be very high.

TEST/RETEST RELIABILITY Test/retest reliability was established using 21 subjects with whom an IA was administered on one day and a second IA on the following day. The data from the test/retest reliability study were used only for that purpose and are not included in the data reported elsewhere in this paper. Considerable effort was made to ensure that the two assessments were conducted at the same time of day and under the same weather conditions. Subjects were dropped from this test/retest study if there was a change in weather conditions (i.e., sunny on the first day and cloudy on the second). The subjects for the test/retest reliability study were all patients at the Western Blind Rehabilitation Center, with an average age of 71.5 years (range: 46-88); 18 were male and three were female. Chronbach's alpha computed for the three assessments was 0.805, indicating good test/retest reliability.

Results There were significant differences between the IA and both PA and FA for all types of hazards. Table 1 presents the average distance, standard deviation, and range in both feet and meters for the three hazards and three assessments. The average IA visual detection distance prior to training was 5.5 feet for the drop-off, 29.5 feet for the surface obstacle, and 10.4 feet for the overhang. Visual detection distances measured during the PA and FA were significantly greater than those measured during the IA, but were not significantly different from each other. Table 2 provides the t-tests for these relationships. Figures 1 and 2 are scatter plots of the IA and FA and PA and FA data, respectively, for all subjects. Figure 1 shows both the high number of subjects who, on the IA, could not visually detect the curb at even close distances and the amount of increase the subjects were able to attain with training and filters. Figure 1 also shows that some subjects were able to visually detect the drop-off at quite substantial distances. Figure 2 is a scatter plot of the PA and FA for the drop-off and graphically shows the high correlation between the predicted distances and those actually measured after the intervention.

In examining the data for all types of hazards, it was noted that the standard deviations were very high in relation to the means. This led us to examine the frequencies of the visual detection distances for each of the three hazards. This examination showed that there is a great

Assessment condition	Hazard		
	Drop-off	Surface obstacle	Overhang
Initial assessment (IA)			
Feet	5.5 (7.7)	29.5 (26.0)	10.4 (8.3)
Range (ft)	0-32	2-107	0-42
Metric equivalent	1.7 (2.4)	9.0 (7.9)	3.2 (2.5)
Range (m)	0-9.8	0.6-32.6	0-12.8
Potential assessment (PA)			
Feet	19.6 (13.9)	62.8 (44.7)	26.6
Range (ft)	0-74	7-198	2-140
Metric equivalent	5.6 (4.2)	19.8 (13.6)	8. (7.7)
Range (m)	0-22.6	2.1-60.4	8.1-42.7
Final assessment (FA)			
Feet	20.4 (11.8)	71.2 (48.3)	25.7
Range (ft)	0-49	8-282	4-116
Metric equivalent	6.2 (3.6)	21.7 (14.7)	7.8 (6.7)
Range (m)	0-14.9	2.4-85.6	1.2-35.4

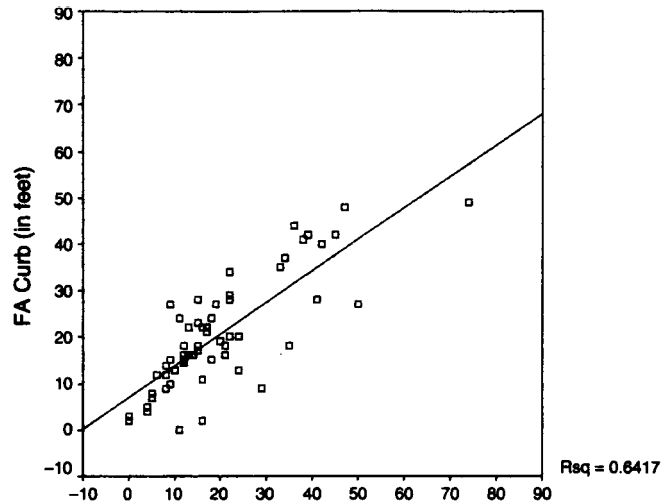
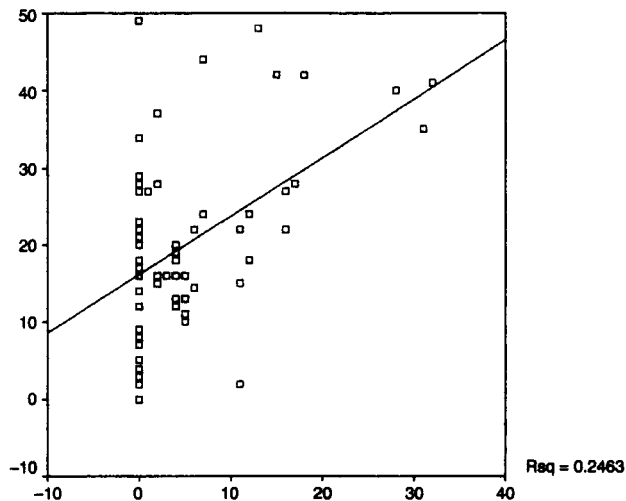
TABLE 1. Average visual detection distances for each of the three types of mobility hazards in each of the three testing conditions. The three hazards were a drop-off, a surface obstacle, and an overhanging object. The three testing conditions were initial assessment (IA), potential assessment (PA), and final assessment (FA). Distances are given in both feet and meters with standard deviations shown in parentheses. The *range* of scores for each hazard and each assessment condition are shown in both feet and the metric equivalent.

	<i>t</i>	<i>Significance (2-tailed)</i>
Drop-off pair		
IA & PA	-8.749	0.000
IA & FA	-11.077	0.000
PA & FA	1.383	NS
Surface obstacle pair		
IA & PA	-9.934	0.000
IA & FA	-8.977	0.000
PA & FA	-1.960	NS
Overhang pair		
IA & PA	-5.778	0.000
IA & FA	-6.576	0.000
PA&FA	-0.372	NS

TABLE 2. t-tests of means for each hazard in the initial assessment (IA), potential assessment (PA), and final assessment (FA) conditions.

diversity of distances at which each hazard is detected, that different hazards are detected at different distances, and that each hazard may place a greater or smaller percentage of travelers at risk of failing to detect the hazard. It was also apparent from the FA data that most subjects markedly increased the distance at which they were able to visually detect each type of hazard.

Prior to the intervention, over half of all subjects could not visually detect the drop-off at three feet or less and 75% could not do so at six feet or less. Forty-four percent could not visually identify the curb at a distance of one foot or less. Only slightly more than 23% could visually detect the curb at 10 feet or further. The percentages of subjects having difficulty visually identifying the surface obstacle and the overhang were smaller than that for the drop-off: 10% were unable to detect the surface obstacle at six feet or less, while about 40% were



1 IA Curb (in feet) PA Curb (in feet) 2

Fig. 1. Scatterplot comparing visual detection distances for the drop-off assessed in the IA and in the FA. The r-square value indicates that 25% of the variance in the FA is accounted for by the IA.

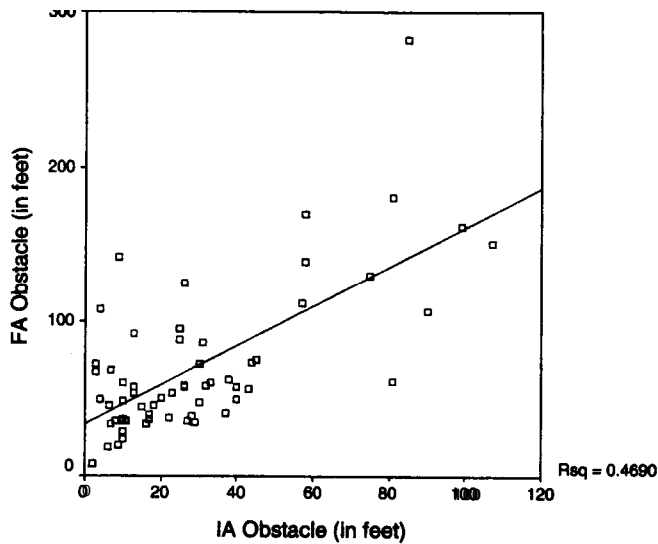
Fig. 2. Scatterplot comparing visual detection distances for the drop-off assessed in the PA and in the FA. The r-square value indicates that 64% of the variance in the FA is accounted for by the PA.

	<i>Distance</i>			
	<i>3ft. (5119 m)</i>	<i>3. z-6ft. (0.9-2.8m)</i>	<i>6.z-20 ft (1.8-3.r m)</i>	<i>?soft. C3.1 m)</i>
IA drop-off	53.3%	20.0%	3.3%	23.4%
FA drop-off	6.7%	3.4%	8.4%	81.5%
IA surface obstacle	5.0%	5.0%	18.3%	71.7%
FA surface obstacle	0%	0%	1.7%	98.3%
IA overhang	16.7%	23.4%	21.7%	38.3%
FA overhang	0%	3.3%	10.0%	86.7%

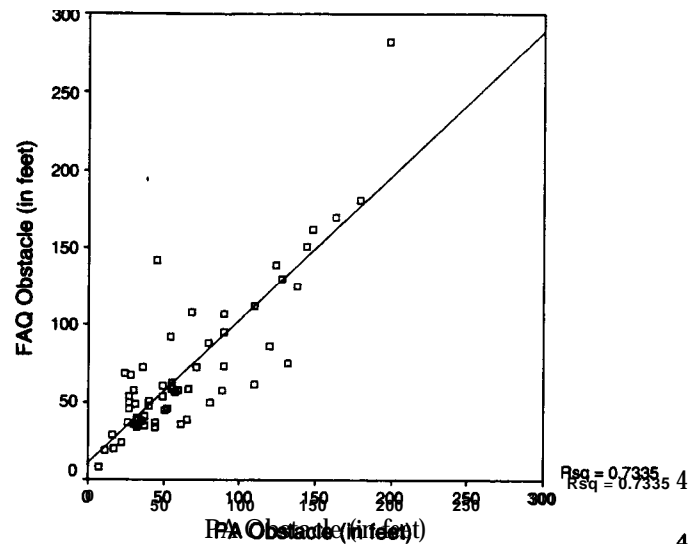
TABLE 3. Percentage of subjects unable to visually detect a hazard by distance to the hazard in the initial assessment (IA) and final assessment (FA) conditions.

unable to detect the overhang at to feet or less. The surface obstacle was the most easily detected of the three hazards studied, with over 70% of subjects doing so **during** the IA. **Slightly** less than 40% of the subjects were able to **detect** the **overhang during the IA** (Table 3).

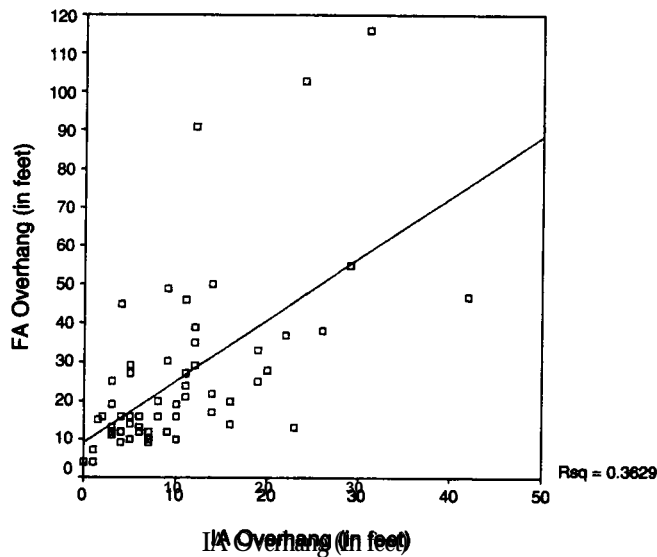
Visual detection distances changed dramatically following training and fitting with appropriate filters. The percentage of patients unable to visually detect the curb declined markedly after training. Post training, only 6.7% could not identify the curb at three feet or less and an additional 3.4% could not identify it between three and six feet. In all, even after training, some 10% of the subjects could not visually detect the curb at a distance of six feet or less. All subjects were able to visually detect the surface obstacle at six feet or more, and almost all (98.3%) could do so at to feet or more (see Figures 3, 4). All subjects could also visually detect the **overhang**, post training, at a distance of at least three feet and the majority (86.7%) could do so at to feet or more (see Figures 5, 6).



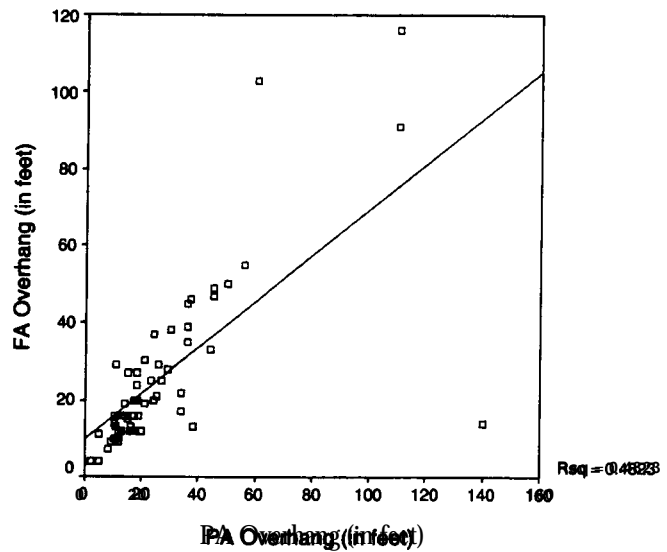
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4



5



6

Fig. 3. Scatterplot comparing visual detection distances for the surface obstacle assessed in the IA and in the FA. The r-square value indicates that 50% of the variance in the FA is accounted for by the IA.

Fig. 4. Scatterplot comparing visual detection distances for the surface obstacle assessed in the PA and in the FA. The r-square value indicates that 73% of the variance in the FA is accounted for by the PA.

Fig. 5. Scatterplot comparing visual detection distances for the overhang assessed in the IA and in the FA. The r-square value indicates that 36% of the variance in the FA is accounted for by the IA.

Fig. 6. Scatterplot comparing visual detection distances for the overhang assessed in the PA and in the FA. The r-square value indicates that 48% of the variance in the FA is accounted for by the PA.

Pearson correlations between the PA and FA measures showed high degrees of correlations. For the drop-off measure, PA and FA were correlated $r = 0.801$ ($p < 0.000$). The surface obstacle PA and FA were also correlated $r = 0.856$ ($p < 0.000$) as were the overhang PA and FA $r = 0.694$ ($p < 0.00$). These correlations indicate that the PA measures account for between 48% and 73% of the variability.

Stepwise regressions using SPSS 11.0 were computed for each of the three types of hazards with age, visual acuity, contrast sensitivity, and PA as independent variables and FA as the dependent variable. A stepwise regression tests the contribution of each independent variable to the dependent variable. In the regression analysis of the FA for the drop-off, age, visual acuity, and contrast sensitivity dropped out of the tested model, leaving only the PA variable ($R = 0.801$; $R^2 = 0.642$). Similarly, the variables age, visual acuity, and contrast sensitivity also dropped out in the stepwise regression of the FA for the surface obstacle, leaving only the PA variable ($R = 0.856$, $R^2 = 0.733$). With regard to the overhang, the only significant contribution was for the PA variable ($R = 0.694$, $R^2 = 0.482$). This is not surprising in view of the nonexistent or low correlations between age, visual acuity, contrast sensitivity, and FA for each of the three obstacles. Of the nine possible correlations, seven were not significant; only the correlations between contrast sensitivity and visual detection distance for the drop-off ($r = 0.279$, $p < 0.031$) and head-height obstacle ($r = 0.240$, $p < 0.064$) were significant. Although significant, these two correlations accounted for little variance (i.e., 8% and 6%, respectively). In contrast, the correlations between PA and FA were $r = 0.801$ ($p < 0.000$) for the drop-off, $r = 0.856$ ($p < 0.000$) for the surface obstacle, and $r = 0.694$ ($p < 0.000$) for the head-height obstacle. The amount of variance accounted for was 64%, 73%, and 48%, respectively.

Discussion Previous studies of low vision mobility have utilized both laboratory and naturalistic routes in which to assess mobility performance. The measures of performance have primarily examined contacts with environmental obstacles and time to complete the route, often expressed as the percent preferred walking speed or PPWS. PPWS is, as previously noted, primarily a measure of the individual's efficiency of travel. Contacts with environmental obstacles, whether in the laboratory or in the naturalistic environment, have not proven to be a clinically useful measure, in large part, because such contacts rarely occur. Prior studies have also sought to determine the relationship between clinical variables, typically age and measures of visual acuity and contrast sensitivity, although visual field characteristics resulting from various eye pathologies have also been assessed. Additional studies have sought to better understand the effects of varying illumination or the familiarity of the traveler with the route.

In this study, we sought to extend the range of studies of low vision mobility by investigating whether the clinical variables measured (age, visual acuity, contrast sensitivity) were related to the distance at which subjects with ARM could visually detect three distinct types of mobility hazards: a curb, a surface obstacle, or an overhanging object. The extent to which a guided assessment, conducted immediately after the initial assessment of visual detection distance, could predict the individual's performance after appropriate training (in visual detection of these hazards) and fitting with a filter to reduce glare effects was also explored.

Age was not significantly related to the subject's ability to visually detect any of the three types of obstacles, even though our subjects

covered a wide age range (49-93 years). Of **the clinical variables (visual acuity and contrast sensitivity)**, only **visual acuity** was related to the final visual **detection distance** of a **hazard and then only for the surface** obstacle. Correlations between visual acuity and contrast sensitivity and the three types of hazards, as measured in the initial assessment (IA) or final assessment (FA), were low or **nonsignificant**. For the method employed here, it seems fair to conclude that visual acuity and contrast sensitivity did not accurately reflect the **individual's** potential for improved performance.

The potential assessments did accurately predict the post-intervention potential for all three types of hazards, accounting for between 48% and 73% of the intersubject variability. Stepwise linear regression for each of the three types of hazards found that the potential assessments (PA), but not age, visual acuity, or contrast sensitivity, were significantly related to post-intervention visual detection distances. The rehabilitation intervention significantly increased visual detection distances for most subjects for all three types of hazards. The regression analysis finding that visual acuity and contrast sensitivity did not significantly contribute to the regression deserves more thought since prior research has shown these variables to be correlated with mobility performance. A possible reason they did not for this study was that part of an individual's ability to visually detect hazards relates to their visual acuity and contrast sensitivity and are therefore implicitly incorporated into the assessment used in this study. Of perhaps greater influence in the visual detection of hazards is the individual's ability to perceive the hazards and utilize this information in guiding their mobility. The later is likely a learned skill. If this is the case and if visual acuity and contrast sensitivity are inherent in the measures we used, then their inclusion as separate factors in the regression equation was redundant and/or overshadowed by the measure used. Alternatively, visual acuity and contrast sensitivity may have, for the subjects studied, little to contribute to the measures as evidenced by their low correlation with any of the assessments. More study is clearly warranted.

Another question raised by this study is the extent to which training is necessary to result in the increased visual detection distances from the IA to the FA. Since the PA correlated highly with the FA, it can be argued that in administering the PA the subject learns all that is necessary and further training is not needed. While this is a possible explanation, our clinical experience did not support this conclusion. During training, the subjects were not consistently able to identify and respond to (i.e., independently stop before contacting) hazards. Their ability to respond did improve throughout the course of training. The current study, however, was not designed to assess training effects, and thus the question of the dosage (amount) of training necessary remains unanswered.

Of considerable interest was the finding that the potential assessments appear to accurately predict those subjects who will improve as a result of the intervention and those subjects who will not improve. It may also differentiate those whose visual detection distances are already sufficient for the types of hazards measured in this study. This suggests that the potential assessment provides a good deal of speci-

ficity (i.e., differentiating those who will and will not benefit from the intervention).

We were unable to find any literature that discussed visual detection distances in terms of safety or efficiency of travel. In other words, what distance is the minimum distance a traveler should be able to visually detect a particular hazard in order to safely avoid it? Alternatively, at what minimum distance should a traveler be able to visually detect a particular hazard in order to efficiently respond to it? This lack of information makes it difficult to determine the efficacy of an intervention since the criteria to define efficacy are not known, and its absence in the literature suggests that more discussion of safety in the context of visually guided travel for individuals with low vision is needed.

To begin a preliminary discussion of minimum safe or efficient visual detection distances, we surveyed 16 very experienced O&M instructors from around the United States asking each: what is the minimum safe visual detection distance for a curb and what is the minimum efficient visual detection distance for a curb? The consensus minimum safe distance was considered to be 3–6 feet or 0.9–1.8 meters (i.e., 1–3 steps) away from the curb. The consensus minimum efficient distance ranged from 6 to 15 feet or 1.8 to 4.6 meters away from the curb. The responses were quite consistent, with only two suggesting significantly greater distances: 8–10 feet (or about 3–4 steps) for safety and 15–16 feet (or about 6–7 steps) for efficiency. If these safety and efficiency distances are valid, it would appear that our intervention is indeed efficacious since the majority of subjects did not conform to these prior to the intervention, but did attain distances greater than those judged necessary for safe and efficient travel. It should also be pointed out that many of the experts we polled were more comfortable discussing minimum safe and efficient distances in terms of the individual's step length, rather than in distances, as this took into consideration stride length which they considered to be an important factor, particularly in assessing safety.

The data are also of considerable interest in that they suggest that severely visually impaired ARM patients are at greater risk of mobility-related accidents than earlier studies have suggested. This is consistent with the literature on fall risk for older visually impaired individuals. While visual detection distances for the three types of hazards varied by the type of hazard, the majority of patients (73%) appeared to be at risk due to an inability to visually detect the drop-off; only 10% to 25% of the subjects appeared to be at risk due to an inability to visually detect a surface hazard and/or a head-height obstacle.

Certainly, the limited distances at which many subjects could detect the tested mobility hazards would place them at risk for unsafe travel as rated by the expert O&M instructors we surveyed. The fact that only 10% used a long cane (prior to training) further underlines the implied risk. As noted earlier, visual impairments are a risk factor for hip fracture-related falls and for a general decrease in independent travel. While it is tempting to link the results of the present study directly to such severe injury or curtailment of independent activities, the current study provides only circumstantial information. Additional work is

needed both to confirm our results and to establish such linkages should they exist. Nevertheless, it is important to note that the current study suggests that ARM patients may be at greater risk of injury **than** prior research has suggested. In particular, ARM patients appear to be at greatest risk of injury due to their inability to detect drop-offs, and drop-offs have not been extensively studied in prior research. This study presents evidence that the level of risk can be quantified and that appropriate **interventions** may reduce it by increasing the distance at which patients can visually detect mobility hazards.

There are limitations to the present study and many unanswered questions. The use of only three 'target' hazards limits the study in that other target sizes and/or types (i.e., larger curb heights or larger or smaller obstacles) would likely yield different visual detection distances. And, as noted, only one measurement was made for each obstacle in each assessment. Multiple measures may improve the precision of the assessments, but would also increase the time required to complete the assessment. Similarly, lighting conditions can influence mobility performance; thus, it would be reasonable to conclude that different results would be obtained under other lighting conditions.

The amount of training necessary to allow ARM patients to maximize their visual detection distances is a question for future research. Similarly, we did not parcel out the effect of adding filters in the FA. Although filters are useful, it has been our clinical experience that they do not result in improved visual detection distances to the extent measured in the current study for the increase from IA to FA. The relative contribution of training and filters does warrant additional study to parcel out their relative benefit to ARM patients.

The following conclusions seem warranted within the limitations of this study.

- ARM patients may be at greater risk of fall-related injury than prior research has indicated.
- The distance at which ARM patients are able to visually detect environmental hazards can be quantified and used as a mobility indicator.
- There appears to be substantial differences between the types of hazards in the degree of risk they pose to ARM travelers. Drop-offs may present the most serious risk, followed by head-height obstacles and surface obstacles.
- It appears possible to predict whether training and fitting of filters will improve the patient's performance and, if so, how much improvement is possible.
- Further research may find it profitable to explore alternative measures of mobility performance and their interactions (i.e., **PPWS** and **DVRA**) and **the** interaction of **these measures** with different **types** of objects commonly found in the environment.

If further research confirms the results of this study, it will have substantial implications for clinical practice patterns. For example, if the DVRA does correlate with fall risk and is amenable to quantification and change, as suggested by the current study, one could argue that all severely visually impaired ARM patients should be assessed as to their

relative risk. And, if they are found to be at risk, it will be possible to further argue that an appropriate efficacious intervention should be made.

It is interesting to also note that the current study uses a very straightforward, easily administered assessment of visual ability. Current clinical tests of visual acuity and contrast sensitivity were found to be largely unrelated to the subject's 'real-world' performance. This is not a unique finding – numerous investigators studying mobility have reached similar conclusions, as have others researching different functional tasks (i.e., low vision reading behavior and clinical measures). During Dr. Gordon Legge's acceptance of the Glen A. Fry Award from the American Academy of Optometry, in the context of measuring low vision reading, he commented 'The conclusion is an obvious one: the best way to assess low vision reading performance is to measure it.' (Legge,²⁷ P.768). Our findings suggest a similar obvious conclusion: the best way to assess low vision mobility is to measure it.

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