Definition of Low Vision and Its Impact on Accessibility and Performance

Robert W. Massof, Ph.D.

Lions Vision Research and Rehabilitation Center
Wilmer Eye Institute
Johns Hopkins University School of Medicine
Definition of Low vision
Low vision

Chronic visual impairments that cause functional limitations or disability

Chronic: cannot be corrected with medical or surgical intervention or refractive error correction

Visual impairment: loss of visual acuity, loss of contrast sensitivity, loss of peripheral vision, central blind spots

Functional limitations: Increased difficulty with reading, mobility, visual motor activities, interpreting visual information

Disabilities: Unable to perform usual or customary daily activities
Low Vision and Blindness
(usually defined in terms of impairments)

World Health Organization

Blindness

• Corrected visual acuity <20/400 in the better seeing eye
  or
  • Maximum visual field diameter <10°

Low vision

• Corrected visual acuity <20/60 and ≥20/200 in the better seeing eye
  or
  • Maximum visual field diameter ≥ 10° and <20°
Low Vision and Blindness
(usually defined in terms of impairments)

United States

Blindness (Social Security)
- Corrected visual acuity <20/100 in the better seeing eye (previously was ≤20/200)
- Maximum visual field diameter <20°

Low vision (Medicare)

*Better seeing eye with best correction*
- Mild: visual acuity <20/40 and ≥20/60
- Moderate: visual acuity <20/60 and >20/200 or visual acuity ≥20/60 and central scotomas
- Severe*: visual acuity ≤20/200

*ICD-9-CM expands Severe into Severe, Profound, Near total blindness, Total blindness
Definition of visual acuity
Visual acuity

- Visual acuity is a measure of the limit of visual resolution.
Visual acuity

• Visual acuity is the limit of visual resolution.

• What is important to vision is the size of the image on the retina.
20/20 visual acuity means that the smallest letter that a person can identify is 5 arcmin of visual angle in size and has critical detail that is 1 arcmin.
Conventionally, visual acuity is specified as the minimum angle of resolution (MAR) or as a ratio of the test distance to the object size (d/h)
For Snellen notation, the test distance \((d)\) is standardized at 20 feet and the object height \((h)\) is specified as the distance in feet that the letter subtends a visual angle of 5 arcmin.
20/20 visual acuity means that the test distance is 20 feet and the letter subtends 5 arcmin at 20 feet. 20/200 visual acuity means that the test distance is 20 feet and the letter subtends 5 arcmin at 200 feet.
Prevalence and incidence of low vision
Prevalence and incidence of low vision and blindness in the U.S.

Five low vision prevalence studies (corrected visual acuity <20/60 in the better seeing eye)

BES: Baltimore Eye Study
BDES: Beaver Dam Eye Study
FES: Framingham Eye Study
SEE: Salisbury Eye Evaluation
MCVS: Mud Creek Valley Study

Prevalence and incidence of low vision and blindness in the U.S.

- Incidence rate estimated from derivative of prevalence rate vs age functions fit to eye study data.
- Incidence and prevalence rate vs age differs between races because of different causes of visual impairments

Annual incidence of low vision and blindness

Growth in prevalence of low vision and blindness

Estimates for 2010

• Mild low vision (<20/40 to ≥20/60 in the better eye with best correction) has a prevalence of about 2.5 million

• Moderate low vision (<20/60 to >20/200 in the better eye with best correction) has a prevalence of about 750,000

• Severe low vision (≤20/200 in the better eye with best correction) has a prevalence of about 1.25 million

• Only 10% of people with severe low vision are functionally blind (no useful vision)
Characteristics of the low vision population
LOVRNET Clinical Centers
The low vision population

• Most people with low vision are old (median age is 75 years)
Distribution of patient ages

Mean 72
Median 76
SD 16
The low vision population

• Most people with low vision are old (median age is 75 years)
• Most people with low vision are women (68%)
Distribution of patient gender

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th>Females</th>
<th>Total</th>
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<tbody>
<tr>
<td>Mean</td>
<td>71</td>
<td>72</td>
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<td>SD</td>
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<td>16</td>
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<tr>
<td>Max</td>
<td>96</td>
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<td>98</td>
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<tr>
<td>Min</td>
<td>20</td>
<td>18</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>228</td>
<td>34%</td>
</tr>
<tr>
<td>Females</td>
<td>435</td>
<td>66%</td>
</tr>
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</table>
The low vision population

• Most people with low vision are old (median age is 75 years)
• Most people with low vision are women (68%)
• Most people with low vision have central vision loss
• Major causes of functional limitations from low vision
  – Reduced visual acuity
  – Reduced contrast sensitivity
  – Glare and other adverse consequences of environmental illumination
Visual system disorders

- Exudative AMD: 29%
- Atrophic AMD: 10%
- Other macular: 2%
- Inherited macular degeneration: 3%
- Inherited retinal degeneration: 5%
- Diabetic retinopathy: 10%
- Other retinal vascular: 3%
- Other retina: 6%
- Glaucoma: 9%
- Optic atrophy: 9%
- Other optic neuropathy: 3%
- Stroke: 2%
- Anterior segment: 2%
- Other: 5%
The low vision population

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  - Reduced visual acuity
Visual acuity

Visual acuity in better eye

Percent of patients

20/20 to 20/60

<20/60 to >20/200

20/200 to >20/500

20/500 or worse
Self-reported vision status vs visual acuity

Quality of vision rating

- Excellent
- Very good
- Good
- Fair
- Poor

Visual acuity in better eye

- 20/20 to 20/60
- <20/60 to >20/200
- 20/200 to >20/500
- 20/500 or worse
The low vision population

• Most people with low vision are old (median age is 75 years)
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  – Reduced visual acuity
  – Reduced contrast sensitivity
Loss of contrast sensitivity

- Blur is only half the story
- Information in the image is defined by contrast (light:dark ratio that defines the border of an object or feature)
- Many low vision patients experience a loss of contrast sensitivity (which they describe as “glare”)
Contrast Sensitivity

- Pelli-Robson chart is used to measure contrast sensitivity.
- Large letters, well above the visual acuity limit, decrease in contrast as you move across and down the chart.
Contrast Sensitivity

- Pelli-Robson chart is used to measure contrast sensitivity.
- Contrast varies in 0.1 log unit steps for each triplet of letters.
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Contrast

• Contrast is the ratio of light to dark in the image:
  - Contrast ratio: \( \text{Contrast} = \frac{L}{D} \)
  - Weber contrast: \( \text{Contrast} = \frac{L-D}{L} \)
  - Michelson contrast: \( \text{Contrast} = \frac{L-D}{L+D} \)

• Contrast does not depend on the amount of light – only the ratio.
Contrast sensitivity

Bivariate Fit of Log CS By Log MAR

Orthogonal Regression

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Ratio</th>
<th>Correlation</th>
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<tbody>
<tr>
<td>Log MAR</td>
<td>0.613885</td>
<td>0.39061</td>
<td>1.178596</td>
<td>-0.5984</td>
</tr>
<tr>
<td>Log CS</td>
<td>0.968945</td>
<td>0.424059</td>
<td></td>
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<table>
<thead>
<tr>
<th>Intercept</th>
<th>Slope</th>
<th>LowerCL</th>
<th>UpperCL</th>
<th>Alpha</th>
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<tbody>
<tr>
<td>1.635398</td>
<td>-1.08563</td>
<td>-1.2829</td>
<td>-0.9187</td>
<td>0.05000</td>
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Contrast sensitivity

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum-of-Squares</th>
<th>df</th>
<th>Mean-Square</th>
<th>F-ratio</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>VA</td>
<td>13.32</td>
<td>3</td>
<td>4.44</td>
<td>34.39</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Error</td>
<td>32.54</td>
<td>252</td>
<td>0.13</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Compare CS to VA

Contrast Sensitivity

- >1.3
- 0.8-1.3
- <0.8

Visual acuity

- 20/20 to 20/60
- <20/60 to >20/200
- 20/200 to >20/500
- 20/500 or worse

Percent of patients in acuity category
Self-reported vision status vs contrast sensitivity

- Excellent
- Very good
- Good
- Fair
- Poor
The low vision population

• Most people with low vision are old (median age is 75 years)
• Most people with low vision are women (68%)
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• Major causes of functional limitations from low vision
  – Reduced visual acuity
  – Reduced contrast sensitivity
  – Glare and other adverse consequences of environmental illumination
Self-reported vision status

**Self-reported vision quality**

- **Excellent**: 0%
- **Very good**: 0%
- **Good**: 10%
- **Fair**: 30%
- **Poor**: 60%

**Effect of lighting on performance of activities**

- **Major effect**: 80%
- **Moderate effect**: 20%
- **No effect**: 0%
People with low vision have other health problems
Distribution of health state (by age on right)
Distribution of health problems

Self-reported health problems
Distributions of cognitive and emotional states

Self-reported memory problems

Self-reported emotions
Physical limitations on motor function
Physical limitations on mobility

Self-reported physical assistance with mobility

Self-reported history of falls
Physical limitations on daily activities

Self-reported physical limitations on daily activities (severity)

Percent of patients

Physical disabilities

Moderately difficult

Very difficult

Impossible to do
Sensory impairments

- Hearing impairment: 40.0%
- Hearing aid: 18.7%
- Numbness in fingers: 19.3%

Onset age of visual impairment:

- 0 - 5 yrs
- 6 - 18 yrs
- 19 - 40 yrs
- 41 - 60 yrs
- > 60 yrs

Change in vision over the past year:

- Worse
- Same
- Improved
- Vision fluctuates
Psychosocial characteristics of the low vision population
Sources of support

Percent of patients

Source of support

no-support
family-support
friends-support
community-support
church-support
vocational-support
home-health-support
support-groups
Living arrangements

<table>
<thead>
<tr>
<th>Living Arrangements</th>
<th>Percent of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>live-alone</td>
<td>0%</td>
</tr>
<tr>
<td>with-spouse</td>
<td>30%</td>
</tr>
<tr>
<td>with-adult-children</td>
<td>50%</td>
</tr>
<tr>
<td>with-young-children</td>
<td>40%</td>
</tr>
<tr>
<td>with-sibling</td>
<td>10%</td>
</tr>
<tr>
<td>with-guardian</td>
<td>5%</td>
</tr>
<tr>
<td>nursing home</td>
<td>0.3%</td>
</tr>
<tr>
<td>assisted living</td>
<td>0%</td>
</tr>
</tbody>
</table>
Occupational status

Percent of patients

- Receiving disability
- Currently employed
- Seeking employment
- Student
- Volunteer
Transportation

Source of transportation

Percent of patients

- drive-self
- public-transportation
- taxi-cabs
- ride-with-family
- chauffeur-service
- special-service
- can-walk-to-transit
- do-walk-to-transit

0% 10% 20% 30% 40% 50% 60% 70% 80% 90%
People with low vision have a higher risk of falls and injuries
Falls in the older population

• 1/3 of people over age 65 have fallen at least once in the preceding year.
• About 1/3 of people over age 65 have a fear of falling.
• The risk of falls and the prevalence of fear of falling increases with age.
Hip fractures in the older population

- 90% of hip fractures in seniors are caused by falls
- Visual acuity loss is a major independent risk factor for hip fractures
- Relative to people with 20/20 visual acuity, the risk of hip fracture:
  - Doubles for visual acuity in the range of 20/30 to 20/40
  - Triples for visual acuity in the range of 20/50 to 20/70
  - Quadruples for visual acuity worse than 20/70
Accidental death

• Accidents are a leading cause of death in seniors
• Falls account for 50% of accident-related deaths (car accidents account for most of the other 50%)
Death rate in low vision

• Visual acuity loss predicts increased mortality in people over age 65

<table>
<thead>
<tr>
<th>Visual acuity</th>
<th>All causes of death</th>
<th>Death from trauma</th>
</tr>
</thead>
<tbody>
<tr>
<td>20/25</td>
<td>20%</td>
<td>30%</td>
</tr>
<tr>
<td>20/32</td>
<td>35%</td>
<td>45%</td>
</tr>
<tr>
<td>&lt;20/32</td>
<td>60%</td>
<td>120%</td>
</tr>
</tbody>
</table>

Compared to people with 20/20 visual acuity
Low vision and falls

• Studies agree that the relative risk of falls for older people increases by a factor of 2 when visual acuity is worse than 20/30 (1998 Australian study, 2003 UK study, 2003 US study)

• Studies also agree that physical activity limitations range from 30% more prevalent in older people with mild visual impairment (using walking tests, balance tests, stair climbing tests) to twice as prevalent in older people with severe visual impairment
Balance

• Three systems are required to maintain balance:
  – Proprioceptive (sensory feedback from joints, muscles, and pressure on skin)
  – Vestibular (sensation of body movement from acceleration forces on the inner ear)
  – Visual (sensation of body movement from “optic flow”)

• You need two out of these three sources of sensory information to maintain your balance
Age-related neurodegeneration in joints, muscles, and skin

• There is an increased prevalence of arthritis, peripheral neuropathy (e.g. from PAD), and other musculoskeletal and neurodegenerative diseases with age

• Also, there is an age-related neurodegeneration that occurs in everyone, which slows reaction time and interferes with muscle control and coordination
Age-related neurodegeneration of vestibular hair cells

- Vestibular organ in the inner ear controls balance and eye movements that compensate for head movements.
- The nerve cells in the vestibular system degenerate with age in everyone, which leads to a loss of balance information and a loss of reflexive eye movement control.
Mobility problems in low vision

Studies of people with low vision, even moderate low vision, show that they

- Walk more slowly than do people of the same age who have no vision problems
- Have interrupted gaits or stumble with changes in surface hardness and/or texture (e.g. transitioning from tile to carpet or sidewalk to grass)
- Have difficulty detecting curbs or other abrupt changes in level (e.g., cracked and pitched sidewalk)
- Have difficulty with mobility under conditions of changing illumination (e.g., shadows and glare)
- Have difficulty with stairs (especially in poor light)
Possible reason for high risk of falls in people with low vision

• Typical age-related neurodegenerative changes in proprioceptive (muscle/joint/skin sensations) and vestibular (balance/dizziness) systems force older people to rely more on vision to control mobility and maintain balance.

• Even small amounts of visual impairment push the older person very close to or past the “tipping point” (pun intended) for recovering from missteps and preventing falls
Functional consequences of low vision
Effect of visual acuity on functional ability
Effect of contrast sensitivity on functional ability
Effect of central blind spots on functional ability (independent of visual acuity)
Focus on mobility

- Increase contrast
- Reduce camouflage and clutter
- Increase light
- Reduce glare
- Increase safety
  - steps, stairs, drop-offs
  - changes in surface elevation
  - transitions in surface texture