Human Factors for Safety

Human Factors

• Physical
• Sensory and perception
• Cognitive (decision making)
Importance of Human Factors

- Human factors are involved in 85% of crashes
- Human factors are impeded by aging processes - diseases

Elderly Involvement in Crashes

- Elderly drivers over-involved in fatal accidents for mileage driven
- More elderly pedestrians per 100,000 population killed
- Older driver fatalities increased by 27% from 1991 to 2001
Physical

- Reaction Time
  - Movement Time after initiation of movement
    - Changes in muscle mass and elasticity
    - Joint strength- arthritis
- Strength
- Flexibility and ROM
- Head and Neck mobility
- Agility (new concept)

Strength

- Decrease in muscle tone
- But no research to show direct impact on driving
  - braking
Movement

- Older people often suffer from muscle and joint stiffness
- Makes it difficult to turn head and body
- Consequently, motor component of reaction time slows with increasing age

Agility

(World Health Organization classification)
- Dexterity in the use of limbs
- Impact on use of controls
- Size of controls
Flexibility and ROM

- Decline in overall flexibility with age
- Increase in osteoarthritis-joint problems
- Can impact:
  - Entering and exiting vehicle
  - Backing up, parking, turning-etc
  - Lane Changing
- Decrease in Physical Fitness

Head and Neck Mobility

- Vehicle Operations
  - Scanning, mirror use
  - Problems with merging
  - Problems with Blind Spots
  - Skewed Intersections particularly a problem
Driver Fragility

- Fragility increases beginning at 60-64 yrs.
- By age 80, elderly more likely than 20 yr. To die from injuries sustained in a crash:
  - 4 times – male
  - 3.1 times - female

Vision

- Primary external stimuli
- 90% of driver information is visual
- Required visual acuity
  - Static and dynamic
- Major problem for elderly drivers
Vision

- Visual acuity standards must be met for licensing
  - 20:60 in Oregon
- Quality of vision deteriorates away from focal point
  - 3-5° cone, excellent vision
  - 10° cone, clear vision
  - 20° cone, satisfactory vision
    - MUTCD standard for important control devices
  - Beyond, increasingly blurred
Sensory Perceptual

- Changing Eye Physiology
  - Requirements for increased lighting
  - Due to decrease in pupillary diameter
  - Optic media – more scattering of light
  - Changes in lenses
Foveal Vision

- Most acute vision central angle of 30°
- Cones: color vision center of retina
- Rods: motion detection outer part of retina
  (Peripheral vision up to about 170°)

(Actually 3-5°)
Terminology-Vision

- Acuity
  - Static
  - Dynamic
- Light Sensitivity
  - Glare recovery

Age Related Changes in Lenses

- Increase absorption of “blue” light
- Increase in thickness of lens
- Problems of muscles that adjust shape of lens
  - Difficulty in accommodation
  - Loss of visual acuity
  - Increased use of bi-focals
Age Related Changes in Lenses

• Dynamic Visual Acuity
  – Ability to see moving objects
  – Scanning
  – Most relevant to driving, but not measured

Visual Acuity

• Fewer receptor cells on retina with age results in:
  – Resolution of fine details is coarser
  – Solved by greater size and contrast of important details, and increased illumination
    • Use of large print media
Visual Acuity

• Younger drivers – average 20 / 20
• Older drivers – average 20 / 60

Visual Acuity

• Near age 70, progressive loss in ability to focus on near objects
  – Due to loss in lens elasticity
• Speed eye changes focus at various distances decreases
  – Problem: viewing dashboard to road scene
• Drivers typically become more long-sighted with age

Elderly Static Visual Acuity

• Visual Acuity
  – Relatively constant to 50 yrs.
  – Declines progressively faster with age


Elderly Static Visual Acuity

• Normal physiological changes causes:
  – Greater sensitivity to glare
  – Reduction in contrast sensitivity

• Diseases that reduce acuity:
  – Cataracts
  – Macular Degeneration
  – Glaucoma
Eye Movement

- Drivers shift their eyes to see full visual field
- Eye movement time
  - Eye shift, 0.15 – 0.33 sec
  - Eye fix/focus, 0.1 – 0.3 sec
- Elderly takes longer to
  - Shift eyes and focus
  - Recover from glare

Dynamic Visual Acuity

- Acuteness of vision for an object with angular movement or ability to see a moving target detail
- Performance improves with illumination
- Unrelated to static acuity
Dynamic Visual Acuity

- Acuity of moving target:
  - Decreases with increasing target velocity
  - Improves with increased exposure time
  - Is better when target is “foveal” on central rather than peripheral
  - Varies for drivers with the same static acuity


Dynamic Visual Acuity

- Of visual factors, dynamic acuity relates strongest to driving record
- Regular deterioration in dynamic visual acuity with advancing age
- Dynamic visual acuity is strongly related to accident involvement regardless of age

Glare

- Brightness in the field of vision that is substantially greater than luminance eyes are adapted
- Glare recovery
  - 15 year old person – 2 sec
  - 65 year old person – 9 sec

Light Sensitivity

- Contrast sensitivity function
  - Better predictor than visual acuity of ability to see
  - Problems with small objects
  - Need high levels of contrast
- Increased time to adjust to dark
  - Problems with tunnels and shadows
- Ability to see contrast begins to diminish in 40s
Glare Sensitivity and Recovery

- Light to dark: ~6 sec to full visual acuity
- Dark to Light: ~3 sec to full visual acuity
  - Due to increased lens opacity
  - Problem for people with cataracts
  - Problem with on-coming headlights
  - Glare recovery time increases with age
**Contrast Sensitivity**

- Ability of an individual to process contrast information
- Provides driver’s ability to see patterns in the environment
- In general, older adults have decreased contrast sensitivity

**Visual Acuity in Poor Light**

- Minimum amount of light needed to see, increases with age
- For every decade over 25, twice as much brightness at night is needed
- By age 75, drivers need 32 times the brightness of 25 yrs.
Dark Adapted Vision

- Minimum energy needed to elicit a sensory response after a period in dark
- Threshold for dark adapted vision increases with age (i.e., light sensitivity decreases)
- Increases over 4% per year between 22 and 43 yrs

Night Time Myopia

- Perhaps most important problem
- Affects large proportion of drivers over 40 years
- Also especially a problem for short sighted drivers of all ages
Night Time Myopia

- Many drivers with this problem avoid driving at night
- Elderly drivers most reported difficulty at night is:
  1) Seeing the road
  2) Glare
- Possible improvements:
  - Fog stripes and more street lighting

Source: AA Foundation for Road Safety

Vision in Poor Light

- Viewing a target 20/200 in poor light of 0.20 cd/m² resulted in:

<table>
<thead>
<tr>
<th>Age group</th>
<th>18-25</th>
<th>60-64</th>
<th>65-69</th>
<th>70-74</th>
<th>75-79</th>
<th>80-87</th>
</tr>
</thead>
<tbody>
<tr>
<td>% failing to see 20/200 target</td>
<td>1.7</td>
<td>23.1</td>
<td>48.3</td>
<td>57.1</td>
<td>70</td>
<td>75</td>
</tr>
</tbody>
</table>

Source: Sturr, et al., Human Factors, 32
Depth Perception

- Primarily provided by environmental cues for driving
- Ability to judge depth decreases with age
- Requires two eyes
- Impact of dark environments

Peripheral Vision

- Useful field of View (UFOV)
  - Measure of spatial area and usually much smaller than visual field size
  - Involves binocular vision
    - Detection, localization and identification of targets
Peripheral Vision

- Visual field shrinks as people age
- Little decrease in visual field before 55
- Shrinkage is dramatic after 65-70

Peripheral Vision

- Shape and movement detected outside 65-90° (from line of sight)
- Less peripheral vision as speed increases
  - 37° at 40 mph
  - 29° at 50 mph
  - 20° at 60 mph
Aging Characteristics in UFOV (Usable Field of Vision)

- Reduced speed of visual processing
- Reduced ability to divide attention
- Reduced ability to discriminate against a background

Visual Localization

- Older drivers have difficulty in identifying a target among distractions
- Changes of vision and cognition make it difficult for elderly drivers to detect moving or stationary objects in the periphery
Detection and Tracking of Moving Objects

- Driver in 60's and 70's lag farther behind targets
- Elderly less able to detect movement and changes of vehicles in visual field
- Also difficulties of understanding behavior of vehicles in front: stopping, slowing, speeding up and reversing

Eye Movements Slow

- Eye muscles commonly atrophy with increasing age
- Elderly less able to raise their eyes
- Much slower to make eye movement to fixate object
Diseases

- Cataracts: Opacity of eye
- Glaucoma: high pressure within eyeball
  - Prevents cataract surgery
- Macular degeneration
  - Impaired central vision

Perception-Reaction Time

PIEV Process – Reaction to external stimuli

- Perception – time to see
- Intellection – time to understand
- Emotion – time to decide
- Volition – time to execute
Perception-Reaction Time

- Range from 0.5 – 5.0 sec for a simple event
- Minimum 0.5 PRT for emergency event
- Added conflicts and complexity increase PRT, depending on amount of data

Control Perception-Reaction Time

- PRT for traffic signal control is assumed = 1.0 sec
- Recent research shows
  - Alerted PRT for control ~ 0.9 sec
  - Unalerted PRT for control ~ 1.3 sec
Design Perception-Reaction Time

- Assumed to be 2.5 sec
- Based on 85% PRT
- Recent research shows
  - 95% of PRT = 2.5 sec
  - 85% of PRT = 2.0 sec

Decision Perception-Reaction Time

- PRT for complex conditions with numerous conflicts
  - AASHTO decision PRTs range from 3 – 14.5 sec
  - Each additional conflict adds increment of time, ~ 1.5 sec
Elderly Driver’s PRT

PRT times for elderly drivers are slower

<table>
<thead>
<tr>
<th>Activity</th>
<th>Average</th>
<th>Elderly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stopping Sight Distance (Design = 2.5s)</td>
<td>2.5s</td>
<td>4.95-5.95s</td>
</tr>
<tr>
<td>Traffic Control (Control = 1.0s)</td>
<td>0.82</td>
<td>0.98-1.61s</td>
</tr>
<tr>
<td>Crossing Road from Stopped Position</td>
<td>2.99s</td>
<td>3.31-4.56s</td>
</tr>
<tr>
<td>Left-Turn thru Traffic (Design = 2.0s)</td>
<td>2.24s</td>
<td>2.56-3.81s</td>
</tr>
</tbody>
</table>

Attention

- Problems with attention switching abilities problems
- Dementia
  - Problems getting lost
  - Following directions
  - Stopping for directions
  - Failure to yield
Complex Situations

• Elderly drivers take about 1.5 sec to scan each item

Prescribed Drug Effect

• Reliable evidence that prescribed drugs increase risk of crashes, especially for elderly drivers
• For elderly, many drugs have higher active level of drugs for longer
• Central nervous system effects increase with age
Cognitive Functions

• Important factors in aging cognition
  – Variability of performance increases with age
  – Speed of processing information decreases with age
  – Therefore, amount of processing is reduced

Difficulty Judging Gaps

• Older drivers tend to accept a gap to cross based on spacing distances, regardless of speed
• Older drivers’ poor distance/speed perception and judgment may account for right-of-way accidents, such as improper left-turns
Stability Sensations

• Drivers react to
  – Curves
    • Limited by tangential accelerations or friction
  – Rough roads
    • Rough surface texture, RPMs for rumble strips
  – Cross slope / superelevation
    • Reduced or negative superelevation increases side friction and accelerations

Modifying Factors

• Fatigue
  – Reduces alertness and slows reactions
• Alcohol and Drugs, affects
  – Alertness
  – Judgment
  – Self control
  – Physical coordination
• Weather
  – Gives unexpected vehicle/pavement response
  – Limits visibility
Conditional Response

- Driver responses are dictated by habit, standardized design, and control
- Drivers attempt to maintain speeds
Drivers Scan and Sift Data

- Driver scans, samples and selects from available information to guide driving
- Complex situations and numerous conflicts;
  - Increase the workload
  - May not give adequate time to select and judge conditions
  - Are difficult for elderly drivers

Divided Attention

- Brake reaction time slowed 0.5 sec. for young drivers, for using cell phone
- Older drivers not tested. Likely elderly are already using their compensatory capacity to cope with other declines
ITS

- In vehicle devices:
  - Navigation
  - Audio
  - Cell phones
- European Trends
- Japan

Primary Concept

- Driver must sift through all information and determine relative importance
  - Control – driver/vehicle interaction most important
  - Guidance – path selection, next in importance
  - Navigation – route selection, least important
- Elderly drivers have difficulty assessing and shifting importance
Expectancy

- A driver is led to expect a given design/control condition due to the information presented
  - Formal information – roadway alignment, centerline stripes, regulatory signs, etc.
  - Informal information – brushlines, tree lines, fences, roadside barriers, etc.

Example of Expectancy

Curvature in one direction

Next curve, opposite direction; NOT
Example: Intersection Lanes
Should Line Up
Example: Driver Assumes Two Lanes are Presented

Future Implications

- Presently, 85% crashes involve human factors
- Elderly drivers are over-involved in fatal crashes and pedestrian fatalities
- Older segment of population is growing twice the rate of the rest of the population
- Traffic volumes and travel are increasing, adding complexity and conflicts to present day conditions
Road Signs

- Difference between Text and Symbols
  - Better performance for distance
  - Interpretation of symbols may be a problem
    - Cultural Context