Outline

• Essential Human Factors of Drivers
  – Sensory
  – Physical
  – Cognitive
  – Information Processing
  – Context: Older Drivers
• Concepts of: Primacy and Expectancy
Context

Population demographics
US population is ageing, becoming more obese
• Adults with physical difficulties: 35.6 million
• Adults unable to walk a quarter mile: 15.9 million
• Adults with hearing trouble: 34.5 million
• Adults with vision trouble: 19.4 million
• People who are obese in 2030: 42% of population

Who are we talking about

• Drivers
• Pedestrians (ADA) and Bicyclists (Day 2)
• Transportation Professionals
• Other Stakeholders
• Elected officials?
• ____________________
• ____________________
Learning about aging and disabilities...

- There are many types

- They often are combined

- They are rarely “black and white”
  - “If we design for people with disabilities it is easier for everyone to use!”

Sensory Perceptual

- VISION most important in driving
  - Provides 90-95% of driver-related information
- Eye Physiology – how aging impacts eyes and driving
  - Requirements for increased lighting
  - Due to decrease in pupillary diameter
  - Optic media – more scattering of light
  - Changes in lenses
- Driving Impacts: Traffic Control Devices, Signage and Lighting
Eye Physiology

Key Words

- Lens
- Retina
  - Rods and Cones
- Macula
- Fovea
- Vitreous Body

Age Related Changes in Lenses

- Increase absorption of “blue” light
- Increase in thickness of lens-stiffer
- Problems with muscles that adjust shape of lens
  - Difficulty in accommodation
  - Loss of visual acuity
  - Increased use of bifocals

Impacts night driving, signage
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

Driving Impacts: Signage and Lighting

Visual Acuity

**Ability to See**
- 3° - 5° cone – excellent vision
- 10° cone – clear vision, can see texture, shape, size, color, shading, etc.
- 20° cone – satisfactory vision, regulatory and warning traffic control devices
- ~70°- 90° cone – peripheral vision, primarily see movement

**Time to See**
- 0.15 - 0.33s to shift eye
- 0.1 - 0.3s to focus or fix on object
- ~0.5 -1s to move head
**Visual Acuity**

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

- Need to follow MUTCD
- Quality and condition of TCD and Signs
- Importance of Retroreflectivity

**Static Visual Acuity**

- Age related normal physiological changes causes:
  - Myopic and older drivers [What is myopia?]
  - Greater sensitivity to glare [Why should I be concerned?]
    - Reduction in contrast sensitivity
      - ?Are my socks black or blue?
  - Diseases that reduce acuity:
    - Cataracts & Glaucoma
    - Macular Degeneration
Many “blind” people are not completely blind.

Cataracts
Glaucoma

Age-related Macular Degeneration
Diabetic Retinopathy

Retinitis Pigmentosa
Dynamic Visual Acuity

- Ability to see **moving** objects
- Scanning
- Most relevant to driving, but not routinely measured
- Not related always related to age

Glare and Light Sensitivity

- Contrast Sensitivity Function (CSF)
  - Better predictor than visual acuity
  - Problems with small objects [Impacts Stopping Sight Distance]
  - Need high levels of contrast [Ambient illumination, retroreflectivity]
- Increased time to adjust to the dark [Impacts speed]
  - Problem with tunnels and shadows, and dawn and dusk
  - Interior controls and exterior lights and signs [Driver distractions]
Glare Sensitivity and Recovery

- Glare recovery time increases with age
- Older driver impacts due to increase opacity of lens
- Problem for people with cataracts
- Problems with oncoming headlights
- Myopia and lasik surgery
- Headlights (European)

Visual Acuity in Poor Light

- Minimum amount of light needed to see, increases with age
- Affects large proportion of drivers over 40 years
- Also especially a problem for short sighted (myopic) drivers of all ages

- Driving Impacts: SSD, roadway design, TCD, illumination
**Visual Cues**

Daytime
- Many cues available
- Driver task relatively easy

Nighttime
- Few cues remain
- Task more difficult

*Retroreflectivity provides nighttime guidance*

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**Night Safety Problem**

- Glare from opposing traffic
- Adverse weather conditions
- Aging driving population
- Visible traffic signs
- Driver expectancy
- Fatigue
- Increased alcohol use
- Crashes
Key Nighttime Visibility Issues

- Signs
  - Location
  - Sheeting materials
- Headlamps
  - Amount of light for signs
- Vehicle
  - Height of head lights
- Driver
  - Visual capabilities
  - Comfort level

Driver Luminance Needs

Starting at age 20, the amount of light needed to see doubles every 13 years

![Graph showing driver luminance needs](image-url)
Illumination by Modern Headlamps

• AAA tentative results show ability to see reduced by 60% from day to night with most advanced headlights

<table>
<thead>
<tr>
<th></th>
<th>LOW BEAM Lighted Distance</th>
<th>Max. Vehicle Speed*</th>
<th>HIGH BEAM Lighted Distance</th>
<th>Max. Vehicle Speed*</th>
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</thead>
<tbody>
<tr>
<td>Halogen Reflector</td>
<td>300 feet</td>
<td>39 mph</td>
<td>400 feet</td>
<td>48 mph</td>
</tr>
<tr>
<td>Halogen Projector</td>
<td>400 feet</td>
<td>45 mph</td>
<td>500 feet</td>
<td>55 mph</td>
</tr>
<tr>
<td>High-Intensity Discharge (HID)</td>
<td>400 feet</td>
<td>45 mph</td>
<td>500 feet</td>
<td>55 mph</td>
</tr>
<tr>
<td>Light-Emitting Diode (LED)</td>
<td>450 feet</td>
<td>52 mph</td>
<td>500 feet</td>
<td>55 mph</td>
</tr>
</tbody>
</table>

*To ensure a fully-lit stopping sight distance. Calculations based on American Association of State Highway and Transportation Officials (AASHTO) guidelines.

Source: AAA

Can we decide to replace signs based on daytime inspections?
Degraded Stop Sign

Contrast Sensitivity

- The ability of an individual to process contrast information
- It underlies a driver’s ability to see patterns in the environment
- What color are my socks?
- [Condition of road side signs, roadway conditions]
Depth Perception

- Requires **two** eyes [binocular vision not evaluated by DMV]
- Primarily provided by environmental cues for driving
- Impact of dark environments
  - Pot holes
- Impacts ability to judge speed and gaps
- [Intersection design and operations, new TCD – flashing yellow]

Peripheral Vision

- Useful field of view (UFOV)
  - Measure of spatial area and usually much smaller than visual field size
  - Involves binocular (two eye) vision
- Visual field shrinks as people age
- Little decrease in visual field before 55 years
- Shrinkage is dramatic after 65-75
- [Driving impacts: situational awareness & skewed intersections]
Eye Movements

• Eye muscles commonly atrophy with increasing age
• Older drivers less able to raise their eyes
• Much slower to make eye movement to fixate object
• [Roadway Design, Decision Sight Distance]

Vestibular and other sensory factors

• Geometric design
  – Vertical and horizontal curves
• Tactile
  – Rumble strips, speed humps and bumps
• Flat light
  – Impact on driving-perception
What about hearing and smell

Hearing
Not required for driving and not tested
Important for environmental cues and clues
Detecting sirens
[Driving impacts-distracted driving]

Smell?
Vehicle condition-brakes or over heating
External – smoke, skunk
[Driving Impacts-situational awareness]

Physical Characteristics

• Reaction Time
  – Movement time after initiation of movement
• Strength
• Flexibility and ROM
• Head and neck mobility
• Agility (new concept)
**Strength**

Changes in muscle mass and elasticity
- Decrease in muscle tone
  - Joint strength – arthritis
  - Decrease in bone mass
- But no research to show direct impact on driving – Braking
- [Adapted vehicles can compensate for physical limitations]

**Movement**

- Makes it difficult to turn head and body
  - Turning, weaving and backing
  [Back up cameras and other driving assists compensate]
- Older people often suffer from muscle and joint stiffness
  - Getting in and out of cars
  [Small SUV’s are higher and a choice of the over 60 crowd]
- [Driving impacts: motor component of reaction time increases, Braking distance increases]
Flexibility and ROM of Older Drivers

- 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
  - Ability to drive long distances, mental alertness

Head and Neck Mobility

- Vehicle operations - how much can you really see!
  - Scanning, mirror use
  - Problems with merging
  - Problems with blind spots
  - Vehicle type (small car vs SUV)
  - Skewed intersections particularly a problem
    {peripheral vision impacts as well}

Driving assist technology impacts - Good or Bad
Agility

(World Health Organization classification)
• Dexterity in the use of limbs
• Impact on use of controls
  – Ventilation/heat
  – Radio
  – Navigation devices
  – Driver assist technology
  – {let’s talk about these!}

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
**Cognitive Function**

Important factors in Aging Cognition:
- Variability of performance increases with age
- Speed of processing information decreases with age
- Therefore, amount of processing is reduced, and time required increases
- [Driving Impacts: think about higher speed limits, congested driving, weaving]

**Processing Information**

- Functional cognitive processing
- Impact on Changeable Message Signs (CMS)
  - Bits and bytes
    - Control the amount of information presented
    - Use few key words {How many lines of text?}
  - Scroll rates
    - Speed of presenting information
  - Spreading
    - Placement and frequency of signs
- [Driving Impact: WORKZONES]
Attention

• Problems with attention switching abilities problems
• Dementia
  – Problems getting lost
  – Following directions
  – Stopping for directions
    • ‘Not just a gender issue!’
  – Failure to yield

Driver Cognitive Workload

• Traffic conditions and roadway design constantly change
• High volume and high speed conditions add complexity
• Heavier driver cognitive workloads require longer decision times and compound problems arising from driver expectancy
• Think about this in the context of older drivers!
Distraction

Definition: a thing that prevents someone from giving full attention to something else

Distracted Driving: -the practice of driving a motor vehicle while engaged in another activity, typically one that involves the use of a cellular phone or other electronic device.

"AAA now says that distracted driving accounts for 25 to 50 percent of all accidents"

Alcohol

Alcohol is a depressant drug. It slows down the activity of the central nervous system, including the brain.

Alcohol could affect your driving by causing:

• Impaired vision
• Reduced reaction times
• Reduced concentration and vigilance
• Feeling more relaxed and drowsy, which may cause a driver to fall asleep at the wheel
• Difficulty in understanding sensory information
• Difficulty doing several tasks at once (e.g. keep in the lane and in the right direction, while concentrating on other traffic)
• Failure to obey road rules
• Over confidence, which may lead to risk taking

{http://www.druginfo.adf.org.au/topics/how-does-alcohol-affect-driving}
Drugs

• After alcohol, marijuana is the drug most often found in the blood of drivers involved in crashes.
• Stimulant drugs, such as caffeine, amphetamines and cocaine, may increase alertness, but this does not mean they improve driving skills.
• Amphetamines do not seem to affect driving skills when taken at medical doses, but make some people overconfident, and can lead to risky driving.
• Higher doses of amphetamines often make people hostile and aggressive.

Stimulants - Cocaine

Cocaine
• Feel confident about their driving ability
• Affects vision, causing blurring, glare and hallucinations.
• “Snow lights”—weak flashes or movements of light in the peripheral field of vision—tend to make drivers swerve toward or away from the lights
• May also hear sounds that aren’t there, such as bells ringing, or smell scents that aren’t there, such as smoke or gas, which distract them from their driving
Cannabis and other hallucinogens

Cannabis
- Impairs depth perception, attention span and concentration, slows reaction time, and decreases muscle strength and hand steadiness
- All of which can affect a person’s ability to drive safely.

Hallucinogenic drugs, such as LSD, ecstasy, mescaline and psilocybin, distort perception and mood
- Driving while under the influence of any of these drugs is extremely dangerous

Prescribed Drug Effect

- Reliable evidence that prescribed drugs increase risk of crashes, especially for elderly drivers
- For seniors (slower metabolism), many drugs have higher active levels and last longer
- Central nervous system effects increase with age
- Increased potency of over the counter (OTC) drugs
Other Key Concepts - Human Factors

- Expectancy
- Primacy
- Sight distance
- Retro-reflectivity
- Geometric design

Expectancy and Primacy

**Expectancy**
- Drivers readiness to respond to events and information in predictable ways
- Impacts speed and accuracy of information processing
  
  [Driving impacts: all aspects of roadway design and operations]

**Primacy**
- Most important information first
  
  [Driving impacts: all aspects of roadway design and operations]
Driving Task Depends Upon

- Information received
  - Prior to the trip or previous knowledge
  - While enroute
- Information used

Errors result from

- Insufficient information
- Too much information at one time
  - Overloads the sensory system
  - Creates confusion
- Inattentiveness - even to simple situations
  - Cell phones - four times as likely to cause crashes

Driving Consists of

- Control
  - physical steering and speed control
- Guidance
  - road-following and traffic safety
- Navigation
  - trip planning and route following

Guidance Task Most Demanding

- Requires extensive enroute information
- Is a dynamic process
  - Car following
  - Passing
  - Lane changing, merging
  - Pedestrian avoidance
  - Response to traffic control devices
  - Maneuvering within roadway alignment

[What will be the impact of driver assist technology?]
**Sight Distance**

*Sight distance (SD)* is the distance that a vehicle travels before completing a maneuver in response to some roadway element, hazard, or condition that necessitates a change of speed and/or path. Sight distance is based on two key components:

i. The perception-reaction time (PRT) required to initiate a maneuver (pre-maneuver phase)

ii. The time required to safely complete a maneuver (MT)

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**Schematic showing the Perception Reaction and Maneuver Time Components of SIGHT Distance**

*Diagram A:* The hazard is visible to the driver for enough away that there is sufficient distance for the driver to recognize and react to the hazard and to complete the maneuver necessary to avoid it.

*Diagram B:* Because of the steep vertical drop, the driver’s sight distance is shorter than in Diagram A making it possible for a hazard to be hidden from sight until there is insufficient distance to avoid it.

*Note: distance not to scale*

Source: NCHRP Report 600, p: 5-2
Design Perception Reaction Times

design 2.5 sec
operations/control 1.0 sec

- Perception reaction times were based on the 85th percentile driver
- [Older drivers PRT due to vision and reaction time changes]

Figure 1 – Median driver reaction time to expected and unexpected information.
Source: 1994 Green book – Based on Figure II-18

Figure 2 – 85th-percentile driver reaction time to expected and unexpected information.
Source: 1994 Green book – Based on Figure II-19
Current Research on Perception Reaction Time

Table 1 - Brake Reaction Times Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>85th</th>
<th>95th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gazis et al.</td>
<td>1.48</td>
<td>1.75</td>
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<tr>
<td>Wortman et al.</td>
<td>1.80</td>
<td>2.35</td>
</tr>
<tr>
<td>Chang et al.</td>
<td>1.90</td>
<td>2.50</td>
</tr>
<tr>
<td>Sivak et al.</td>
<td>1.78</td>
<td>2.40</td>
</tr>
</tbody>
</table>

Perception-Reaction Times Considering Complexity and Driver State

<table>
<thead>
<tr>
<th>Route</th>
<th>Driver State</th>
<th>Complexity</th>
<th>Perception-Reaction Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Volume Road</td>
<td>Alert</td>
<td>Low</td>
<td>1.5 s</td>
</tr>
<tr>
<td>Two-Lane Primary Rural Road</td>
<td>Fatigued</td>
<td>Moderate</td>
<td>3.0 s</td>
</tr>
<tr>
<td>Urban Arterial</td>
<td>Alert</td>
<td>High</td>
<td>2.5 s</td>
</tr>
<tr>
<td>Rural Freeway</td>
<td>Fatigued</td>
<td>Low</td>
<td>2.5 s</td>
</tr>
<tr>
<td>Urban Freeway</td>
<td>Fatigued</td>
<td>High</td>
<td>3.0 s</td>
</tr>
</tbody>
</table>
Design for Human Factors

- Important information sources should be **separated**
- Decision points should be **separated**
- Complex situations increase
  - Decision time
  - Likelihood of a wrong decision
- Critical design and traffic-control devices should have high priority visibility

Driver Expectancy

- Drivers rely on training, experience and habit
  - Formal information
    - Traffic-control devices and primary geometric design features of the roadway
  - Informal information
    - Roadside features, land use features, and information signing
Driver Expectancy

• What about new Traffic Control Devices?
  – Flashing yellow arrow
  – HAWK or Pedestrian Hybrid Beacon
  – Roundabouts
  – Colored Pavements
  – Bike Boxes

Expectancy Problems

At times expectations are in error because
  – Use inappropriate informal information
  – The formal information provided is not proper
  – The information at a location is conflicting
Expectancy Problems

- Reconstruction and realignment of a roadway section
  - **Problem:** Driver’s mistake joint as roadway centerline pavement

- Confusing or contradiction traffic controls
  - **Problem:** Roadway speed limit sign on curve gives drivers indication of unsafe speed on curve
Expectancy Problems

- **Unexpected curve**
  - **Problem:** Gap in trees implies the roadway goes straight ahead

**Cross Section**

Expectancy Problems

- **Informal information mistaken for roadway alignment**

**Problem:** Delineator posts imply that roadway goes straight ahead
Expectancy Problems

• Driver expectancy violated by abrupt reverse curve at construction site
  – Problem: Driver could not see abrupt alignment due to splash / spray and drove into triple trailer

Van collides with triple trailer in rain due to splash and spray

Warning Sign: Divided Highway Ahead
Beginning of New Pavement
Area of head-on collisions
Striped for no passing

Expectancy Problems

• Sequence of mixed information is misunderstood by some drivers
  – Problem: Drivers mistake new pavement and newly reconstructed intersection as beginning of divided highway section
**Expectancy Problem**

- Conflicting formal information
- Roadway curves left, but warning sign shows curve to right

**Geometric Cues or (Mis)cues**

- Alignment of arterial and parkway ramp is not self-explaining
- First route marker shows Route 6 going to the right
- First word sign, on glance, suggests Route 6 is going to the left
- First line on the first word sign indicates the sign is for trucks and trailers, but that is not immediately clear to unfamiliar, approaching drivers
- Car drivers also visually key on the sign. Confusion is created as to which road is Route 6, Route 293, and Route 9W
Mis Cues - continued

- Due to sign location and spacing, drivers don’t have enough time to identify the important information.
- Word signs have too many lines of information
  [What is the maximum number of lines?]
- Sign font size too small
- Confusing information for trucks
- Access to intersecting routes or ramps also confusing

Erratic Curb Alignment

- Confuses drivers expected path
• Opening between barn and trees on the right implies to driver the roadway alignment goes through that opening

Summary

• Vision-Key to driving
• Physical requirements – many compensated
• Cognitive Processing - driver assist technologies
• Autonomous Vehicles
• [Driving Impacts: Roadway Design, Signage, illumination]
What can you do to make the driving task easier for everyone?

• ______________________________

• ______________________________

• ______________________________

• ______________________________

• ______________________________