CONTRAST SENSITIVITY MEASUREMENTS, INTERPRETATION AND MODIFICATIONS
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Goals

- Review types of contrast sensitivity tests and their measurements
- Discuss how contrast sensitivity tests should be interpreted
- Discuss environmental and patient centered modifications

Vision

- Ability to see details, objects and their environment
- Typically measured with high contrast charts
  - Snellen most common test in primary care
  - Test is typically given at 20 foot distance
- Using visual acuity charts measures ability of patient to see details
  - Good measurement of spectacle blur
  - Does not give functional or descriptive picture of how well patient sees

Vision

- Despite good visual acuity patients may still have complaints that far outweigh their performance on acuity testing
  - Poor mobility
  - Difficulty with facial recognition
  - Problems with glare

Visual acuity

- Functionally, does not assess patients performance in real life situations

Contrast Sensitivity

- Contrast is the difference in luminance between an object and its background
Contrast Sensitivity

- Contrast sensitivity is the measurement of the ability to discern and detect an object against its background.

- Descriptive measurement of visual ability
- Identifies additional layers of visual performance
- Ginsberg et al. stated “Contrast sensitivity is the best predictor of visual function.”

Indications for Contrast Sensitivity Assessment

- Case history
  - First indicator whether patient has difficulties with contrast
  - Chief complaint may directly indicate need for contrast testing
  - Careful questioning of patients' difficulties in home environment, school or vocational setting, etc

- Glare questioning
  - Environmental lighting
    - What is primary lighting source?
      - Pros and cons
    - Response to sun light
  - Are there activities you avoid because of lighting?

- Mobility questioning
  - Do you bump into things?
  - Do you have difficulty stepping off curbs?
  - Do you feel safe when traveling independently?
Indications for Contrast Sensitivity Assessment

- Entrance testing does not match patient complaints
  - Reasonable visual acuity
  - Reasonable visual field
  - Patient reports poor performance in multiple activities

Indications for Contrast Sensitivity

- Whittaker and Elliot found in a study of 116 patients with ocular dysfunction, 16 presented with normal visual acuity but had reduced contrast sensitivity
  - Those 16 patients had ocular disease ranging from glaucoma and multiple sclerosis
  - Optometry and Visual Science, 1992

Indication for Contrast Sensitivity Assessment

- Ocular diagnosis
  - Certain diagnoses are more likely to give contrast sensitivity measurements than others
    - Optic nerve conditions
    - Corneal disease or treatments
    - Cataracts
    - Diabetic retinopathy
    - Retinitis pigmentosa

Optic Nerve Conditions

- Optic nerve conditions
  - Glaucoma
  - Optic atrophy
  - Optic neuritis/multiple sclerosis
  - Hereditary Optic nerve disease
    - Contrast Sensitivity can measure progression in these conditions before visual acuity
    - Important to test CS in these patients for mobility

Corneal Conditions
Corneal disease and treatment

- Corneal Scarring
- Dry Eye
- Keratoconus
- Corneal Transplant
- Contact lenses
- Refractive Surgery
  - Lasik
  - PRK

Cataract

- Congenital
- Nuclear Sclerosis
- Cortical Cataracts
- Posterior Subcapsular Cataract
  - Scatters light toward retina: reduces image quality
  - Scatters light toward cornea: causes reduction in light
  - Scatter of light increases 16 times between 40 and 80

Cataracts

Diabetic Retinopathy

- Vitreous Hemorrhage can scatter light and reduce illumination
- Laser treatments reduce ability for light to be absorbed by retinal cells
- Macular edema causes reduction in high frequency contrast loss

Diabetic Retinopathy

Retinitis Pigmentosa
Retinitis Pigmentosa

- Retinal degeneration
  - Reduced light absorption
  - Reduced acuity/visual field
  - Cataract could further reduce contrast
  - Macular pathology can further reduce higher frequency contrast loss

Weber’s Contrast

- \( \frac{(I-I_b)}{I_b} \)
- \( I \) = Luminance of Object
- \( I_b \) = Luminance of background

Michelson’s Contrast

- \( \frac{(I_{max}-I_{min})}{(I_{max}+I_{min})} \)
- \( I_{max} \) = maximum Luminance
- \( I_{min} \) = minimum Luminance

Contrast Confounders

- Glare: Poor lighting, sunlight
  - Can be related to quality of light or ocular health
    - Poor light position
    - Warmth of light source (fluorescent vs halogen)
    - Reflection off of image source
  - Age

Inclement weather

- Fog and rain cause scatter of light
  - Adds general depression to illumination
  - Important to consider with driver or independent traveler
Patterns
- Background patterns reduce luminance of background
- Cause figure ground effect where object can get lost compared to background
- Confuses visual interest

Poor image quality
- Washes out darkness of tint
- Less difference between object and background
- Poor edge quality, not well defined
- Induces blur that cannot be improved on with magnification or spectacle prescription

Age
- Contrast loss across all frequencies
- Decrease of 4.6 letters per decade (Hägerstrom-Portnoy et al)
- Due to reduced optical quality and neural integrity

Age
- Physical changes to the cornea and lens cause increased light scatter
- Decreased quality of tear film causes poor image quality
- Increased incidence of dry eye

Age
- Recovery from bright lights takes 8 times longer over the age of 58
- Greater than 3 minutes to recover from 1 minute of light exposure.
- Poses increased difficulty adjusting from light to dark and potentially decreased safety

Safety
- Contrast sensitivity associated with injuries and falls
  - Wood et al (2011) found that ‘visual acuity and reduced contrast sensitivity’ were consistent visual predictors of falls
  - Surprisingly, visual field was not as significant a factor
Safety

- Falls were correlated to poor visual acuity and reduced contrast sensitivity
  - 54% fell more than once, 30% fell more than twice
  - More likely to happen on level surface
  - Outdoor falls more common than indoors

- Referral for Orientation and Mobility is imperative to reduce falls and injuries
- Need to incorporate home evaluation into rehabilitation plan
- Need to educate patients and family members on contrast enhancement and demonstrate in office

Contrast sensitivity—Measurements

- Useful measurements in vision rehabilitation and disease management
- Gives descriptive measurement of vision
- Can show disease progression, i.e., glaucoma, optic atrophy (Wilensky and Hawkins, 2001)
- Can be used to predict performance

History of Contrast Sensitivity Testing

- Computer generated stimulus
  - Grated acuity
  - Used initially for research purposes
  - Time consuming
  - Expensive
    - Consider cost of computer and maintenance
    - Cost of program

- The Arden Chart
  - First contrast chart used in clinic
  - Seven cards with variable grates
  - Presented at 57 cm

  a

  b

  c

Arden Test

- Hand held test of grated acuity
- Originally used as screening test for glaucoma
- First noted clinical test for assessing contrast sensitivity
  - First commercially available test
  - Gives information of spatial frequency and quality of vision loss
Contrast Sensitivity

- Measurements are taken using standardized tests
  - Requires consistent illumination
  - Proper test distance
  - Proper spectacle correction
- Several tests available
- Can be used for clinical or research purposes
  - Purpose of test sometimes dictates chart used

Measurements

- Can be taken binocularly or monocularly
- Charts available for distance or near
  - Requires good, uniform illumination
  - Requires proper spectacle correction

Vistech

- Grated Measurements
  - Requires uniform illumination
  - Test distance 3 meters
    - Near chart is available
  - Directly measures types of spatial contrast loss
    - High, medium and low

Binocular vs. Monocular Testing

- Binocular Testing
  - More efficient
  - Gives overall, general picture of summation of vision
- Monocular Testing
  - Gives information of binocularity
  - More useful for disease progression
  - Can confirm binocular rivalry

Vistech

- 5 levels of spatial Frequency
  - 1.5 cpd, 3 cpd, 6 cpd, 12 cpd, 18 cpd
  - Measurements for Medium and low spatial frequency
  - Forced Choice
    - Only 4 possible answers
Vistech

- Wide range of applications possible
- Disease progression
- Research purposes
- Indicates more specifically level of contrast sensitivity loss
- Unfortunately, has not been shown to be extremely repeatable
- Multiple variants are available

Letter Charts

- More recognizable to patients
- More common clinically
- Available in single letter or continuous text
- Requires visual acuity that allows for recognition of letters

Pelli-Robson Contrast Sensitivity

- Common chart used for clinical and research purposes
- Test distance is typically 1 meter but can vary
- Highly repeatable
  - Maintain proper testing conditions
  - Plots one point on contrast curve
- Highly researched
  - Newer contrast charts are compared to Pelli-Robson

Pelli-Robson

- Each line has two triplets, of letters with descending contrast
  - 100% is highest contrast
  - .6% is lowest contrast
- Scored based on last triplet with 2 correct letters
- Letters are 4.9cm X 4.9 cm
- Testing is completed at 1m
  - Equates to 1 cycle per degree

Pelli-Robson

- Quick and efficient to administer
- Has expiration date to ensure maximal contrast
- In order to measure different types of spatial contrast, use different test distances
  - 3 meter, 1 meter, .5m
Near Charts

- Less cumbersome
- Easier to ensure uniform illumination
- Requires proper spectacle correction
- Variability in recording measurements
- With exception of MARS chart, not as reliable and repeatable

MARS Chart

- Test distance is 40-50 cm,
- Letters are 16mm by 16mm
- Easier to fully illuminate
- 3 different test cards to reduce patient memorization
- Can test monocularly or binocularly
- Shown to be useful for clinical and research purposes

MARS Chart

- Each letter has descending contrast
  - Pelli-Robson descends in triplets
- Stored in dark envelope to deter fading and yellowing of background
- Requires proper spectacle correction
- Good repeatability

Colenbrander Continuous Text

- 10% contrast
- Test distance is 40 centimeters
- Acuity range is .2 M to 8M
- Can use acuity measurements for predicting magnification
- Presentation of text is familiar to patients
  - More consistent with goal print
  - Similar to near acuity charts

Hiding Heidi

- Good for children or non verbal patients
- Forced choice
- Requires good cooperation
- Difficult to ensure proper illumination
  - Still gives useful information, but may have variability from exam to exam
Lea Reduced Contrast Chart

- Useful for children, patients with poor cognition or aphasia
- Can use with key from Lea acuity chart to assist non-verbal or shy patients
- Available in multiple forms
  - Some tests give percentage loss
  - Other tests give Log Mar

Test Selection

- Large variety of tests available
- Research is ongoing
  - Determines which tests are most reliable
  - How each testing method compares to each other
  - Development of new, more efficient tests
  - Which tests predict disease progression

Interpretations

- Contrast testing results in a better picture of how a patient sees
- Findings help determine interventions and rehabilitation
- Dictates additional referrals to improve rehabilitation potential

Interpretation

- Administering test identifies a contrast problem
  - Is that enough information?
    - Not really. Need to know how much contrast loss is present to provide efficient rehabilitation
  - Is the information consistent with disease diagnosis?
    - Hopefully. May require further investigation of ocular health
  - What do those numbers mean?
    - They quantify contrast loss and help drive and direct rehabilitation strategies.
Spatial Frequency

- Spatial frequency is a scientific and statistical method of calculating visual detail
  - Measured in sinusoidal waves
  - Different sizes and level of detail of stimuli have different sized waves

Interpretation

- Types of contrast sensitivity loss
  - High Spatial Frequency Loss
  - Medium Spatial Frequency Loss
  - Low Spatial Frequency Loss

High Spatial Frequency

- Over 10 cycles per degree
- Related to 'detail vision'
  - Features of an object
  - Correlates closely with visual acuity
  - Spatial frequency most affected by spectacle blur

Medium Spatial Frequency

- 2-6 cycles per degree
- Relates to object recognition
- Compounded by bad lighting, weather, etc
- Reduction in MSF warrants referral for ADL evaluation and O&M

Low Spatial Frequency

- Less than .5 cycles per degree
- Gross recognition detection of objects
- Effect compounded by poor lighting, poor weather conditions
- Warrants referral for O&M, ADL assessment
**Interpretation**

- Level of contrast loss
  - Profound
  - Severe (less than 1.5 log Mar)
  - Moderate
  - Near Normal
  - Normal

**Interpretation and Modifications**

- Goal for rehabilitation increase threshold
- Increase contrast detection and increase patient sensitivity
- Severe contrast loss is when <1.5 or 70%
  - Need multidisciplinary approach
  - Rehabilitation teachers, OT, O&M

**Thresholds**

- Determine contrast of object of interest
- Need to improve ability for visual system to appreciate object of interest
- Interventions and modifications are designed to improve ability to function
  - Improve possibility of detection by visual system

**Thresholds**

- Consider reading a newspaper
  - Someone with mild CS loss
  - Someone with severe to profound CS loss
  - How much modification will be necessary to achieve goal?

**Thresholds**

- Contrast reserves of 3:1 typically yield the most successful rehabilitation
- Goal is to have patient's contrast detection 3 times more sensitive than contrast of object
  - Newspaper contrast is 75%, patient threshold is 15%, reserves = 75/15 = 5
  - Newspaper contrast is 75%, patient threshold is 60%, reserves = 75/60 = 1.25

**Thresholds**

- Depending on contrast of object of interest and contrast sensitivity of patient success may vary
  - Need to evaluate contrast of object of interest and compare to contrast sensitivity of patient
  - Contrast enhancement strategies may improve appreciation of an object, but not to a functional level
  - Dictates whether modifications can be simple to complex
Modification
- Improve contrast reserves
- Improve function of visual system
- Improve patient mobility
- Improve safety in the home, school and work place

Modifications
- Patient centered
  - Reduce contrast confounders at or adjacent to ocular surface
  - Modify sensitivity of the visual system
    - Improve ocular health
    - Filters
    - Patient centered

Modifications
- Improve ocular health
  - Remove cataract
    - Reduce scatter of light
    - Improve resolution
  - Vitrectomy
  - Treat corneal pathology
    - Dry eye treatment
    - Corneal transplant

Modification
- Glare is excessive light that instead of improving object detection, reduces image quality
  - Goal is to reduce extraneous light but still allow useful light through
    - Useful light is typically filtered by different color tints
    - When considering glare need to assess disability

Modification
- Need to consider type of glare complaint to determine darkness and color
  - Discomfort glare vs Disability glare
  - Is light ‘painful’ or ‘uncomfortable’?
  - Is light causing inability to see?

Modification
- Glare reduction requires knowledge of pathology and environmental lighting
  - Need to know what cells in the eye are working to be able to absorb certain wavelengths
  - Need to know what wavelength of light entering eye that need to be blocked
Modification

- Need to assess patient in environment of complaint
  - Best to test in classroom, work station, home to properly assess current lighting effects

- Test outdoors when possible to determine proper sun filter
  - May need to test in different weather situations
  - May need to suggest more than one filter

Modifications

- Filters
  - Reduce glare
  - Transmit useful light
  - Block light that causes scatter
    - Improve image quality
    - Improve discomfort

- Filter evaluation is directed by patient preference
  - Start with lighter filter and then progress to darker tints
  - No studies have definitively shown one tint or transmission over another
  - Companies make recommendations
  - Clinical consensus
  - Patient rules

Suggested Tints for ocular conditions

- NOIR makes several suggestions
  - Macular Degeneration: Yellow, Amber, Plum
  - Glaucoma: Yellows, Ambers and Grays
  - Achromatopsia: Dark Orange-Red, Red
  - Retinitis Pigmentosa: Amber, Gray, Gray-Green
  - Diabetic Retinopathy: Amber, Gray, Green
  - Corneal Pathology: Yellow, Amber, Red

- www.noir-medical.com

Modification

- Glare control
  - Fit-over option
  - Tint spectacle lenses
  - Transition lenses
  - Tinted contact lenses
  - Spectacle treatments
    - Polarization
    - Mirror coat
    - Anti-reflective coating

Modifications

- Glare reduction
  - Recommend a wide brimmed hat/visor
  - Use hand while indoors to block light
  - Position self away from direct glare
Modification

- **Environmental Changes**
  - Used to enhance contrast away from visual system
  - Designed to make objects of interest appear to have greater contrast
    - Use opposite colors on color wheel
    - Use shades of differing luminance
  - Reduce causes of glare before it affects visual system
    - Use matte surfaces rather than glossy
    - Adjust lighting/light source

- **Lighting**
  - Proper lighting is essential
  - Task light vs Over head light
  - Positioning of light source
    - Below eye level
    - Directed toward paper or object of interest

- **Light Bulbs**
  - Warmth of light is crucial
    - Halogen
    - Fluorescent
    - Day light

  - May need to re-evaluate filter based on light bulb preference

- **Placement of light in environment**
  - Illumination of dark hallway
    - Consider placement of lights to guide patient
    - Position light sconces toward wall to reduce potential of light scatter
    - Use of lights outdoors to illuminate pathway

- **Lighting can improve mobility**
  - When traveling in poorly lit or poor contrast pathways, patients can use a flash light or a head borne light to improve detection
  - Can modify specific items in environment to illuminate or enhance contrast pathways
Modification

- Lighting source
  - Depends on patient goals
  - Need to evaluate area of use
  - Consider portability
  - Look at range of use
    - Task lamp that can travel from room to room
    - A Brandt Floor Lamp that can be moved on wheels at different areas of the house

- Reading can be frustrating for patients with poor contrast sensitivity
  - Reading speed may be slow due to poor letter recognition
  - Recognition of letters may be reduced causing poor efficiency while reading
  - Modifications may range from simple to complex strategies to improve contrast

Modification

- Typoscopes
  - Reduce background glare
  - Increase contrast at border
  - Reduce Figure-ground
    - Signature guide
    - Check Writing guide
    - Envelope guide

- Straight edge: contrast from background
  - Post-it notes
  - Bright Line
    - Yellow
    - Rose
  - Typoscope with acetate filter
    - Create any color filter

Modification

- Use higher contrast or opposite colors to improve detection of objects
- Doorways, windows and baseboards can be painted or highlighted with paint or tape to improve detection
- Stairs and railings can be marked with opposite colors to improve safety and detection of depth

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Modifications

- Speaking of Pets…
  - Consider High contrast collar and leash
  - LED illuminated collar and leash
  - Use sight substitution, i.e. bell on collar

- Electronic magnification
  - Closed circuit television
    - Reverse polarity
    - Flat screen
  - Portable vs Desk top application
  - Computer based application
    - Zoom Text/Zoom Text Express
    - Windows accessibility/Apple Accessibility

- Modifications
  - Electronic magnifiers can increase contrast to 100%
  - Maximize environmental presentation of material
  - Great strides in development of electronic magnification have made devices more accessible
  - Portability and range of use should be considered when performing assessment

- Modifications
  - Electronic Magnification
    - Distance and Near devices are available
    - Reading devices are small and more affordable
    - Improvements in resolution has improved function
    - Variable use of cameras
    - Acrobat, Multiview, and Onyx have increased access to distance viewing points not previously available with optical devices of same magnification

Modifications
Modifications

- Got an app for that?
- When purchasing cell phone, consider contrast options
  - Smart phone accessibility options
  - Apps available for increased contrast and magnification
    - Magnification
    - Contrast
    - Screen Readers

- Changing spatial frequency of object of interest also improves contrast
- Using relative size magnification, a larger version of an everyday object may improve visual ability
  - Large button phone
  - Large print checkbook
  - Large print crossword puzzles

- What happens when contrast can’t be improved to functional levels?
  - Sight substitution
  - Tactile
    - Bump dots
    - Puffy paint
  - Auditory
    - Books on Tape
    - Text to speech programs on a computer

Conclusions

- Contrast sensitivity is a useful and important part of functional vision assessment
  - Gives useful information for improving rehabilitation outcomes
  - Beneficial for determining appropriate referrals
  - Identifies areas of poor visual performance

Questions?