welcomes you to
A Brighter U Panel
"Coming to our Senses: How Advances in Neuroscience are Restoring our Sight and Hearing"

An interdisciplinary enterprise
—focused on enhancing the capability & well-being of persons with sensory loss
—by translating fundamental scientific research to functional and accessible devices and therapies
—that can maximize potential and quality of life for those with sensory loss.
The Center’s **primary goals** are:

- to provide national leadership in doctoral and postdoctoral training in translational sensory science,
- to facilitate interdisciplinary research and
- to enhance collaboration and connection to the medical-device industry and the general public.

We have a unique educational opportunity to provide **interdisciplinary research experiences** for

- undergraduate,
- graduate,
- postdoctoral students

We are **ideally positioned** in the Twin Cities with outstanding connections to industry and community.

- We have ongoing active collaborations with five area industries in our first year

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**Faculty**

- Vision, hearing, balance, tinnitus, proprioception, and neuroscience scholars in sensory science
- 40+ faculty researchers from five University of Minnesota colleges and the Mayo Clinic:
  - Engineering
  - Medicine
  - Liberal arts
  - Biological Sciences
  - Education & Human development
  - Mayo Clinic Rochester
- Generous support from the Office of the Vice President for Research, CLA, AHC, and CSE
Leaders

- Peggy Nelson, Gordon Legge, Andrew Oxenham serve as executive and scientific directors

- Meredith Adams, Hubert Lim, Linda McLoon and Sandra Montezuma are scientific advisors, representing vision, hearing, balance, tinnitus

Elliott Hall S39

Hearing
Vision
Balance
Tinnitus

Physiology:
EEG
Eye-tracking
GSR

Behavior:
Hearing simulations
Visual navigation and tracking
• See our website for updates
• Symposium May 19, here in McNamara
• We all know individuals with sensory loss
  During this time of high technology
  and advances in brain sciences:

  we are excited about new
developments in sensory
  sciences

The Impact of Impaired Vision on Reading and Mobility

Gordon E. Legge, Ph. D.
legge@umn.edu

Minnesota Laboratory for Low-Vision Research
Department of Psychology
University of Minnesota, Twin Cities
Lighthouse letter acuity chart

Four points on the Snellen scale

- 20/20 – Conventional standard for normal vision
- Less than 20/60 – One criterion for low vision
- 20/200 or less – Legal blindness
- 20/2,000 – Bottom of the acuity scale
AGE-RELATED MACULAR DEGENERATION (AMD) AND READING DIFFICULTY
Schematic visual span

A

Normal vision

B

Low vision with scotoma

MOBILITY AND VISUAL ACCESSIBILITY
Visual accessibility is the use of vision...

...to travel efficiently & safely through an environment.
...to perceive the spatial layout of key features in the environment.
...to keep track of one’s location & orientation in the environment.

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### Benches In Shade & Sunlight

<table>
<thead>
<tr>
<th>Normal Vision</th>
<th>Mild Blur</th>
<th>Severe Blur</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Normal Vision" /></td>
<td><img src="image2" alt="Mild Blur" /></td>
<td><img src="image3" alt="Severe Blur" /></td>
</tr>
<tr>
<td><img src="image4" alt="Normal Vision" /></td>
<td><img src="image5" alt="Mild Blur" /></td>
<td><img src="image6" alt="Severe Blur" /></td>
</tr>
</tbody>
</table>
Image Variations Due to Sunlight

Image Variations Due to Sunlight & Blur
Conclusions

• Low vision afflicts millions of Americans, but research findings can enhance the functional value of impaired vision.

• Macular degeneration causes reading problems, due in part to a reduced visual span for letter recognition.

• The visual accessibility of indoor spaces can be enhanced by developing software tools for architects and designers to identify features posing visibility problems for people with low vision.

Better Hearing
Advances in Auditory Science

Andrew J. Oxenham, PhD

Distinguished McKnight University Professor
Departments of Psychology and Otolaryngology
### Hearing and Hearing Loss

<table>
<thead>
<tr>
<th>Age Frequency region</th>
<th>18-80 0.5-4 kHz</th>
<th>61-71 0.5-4 kHz</th>
<th>71-80 0.5-4 kHz</th>
<th>71-80 4, 6, 8 kHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 20 dB HL</td>
<td>22.6%</td>
<td>50.8%</td>
<td>74.0%</td>
<td>98.1%</td>
</tr>
<tr>
<td>&gt; 30 dB HL</td>
<td>11.2%</td>
<td>25.3%</td>
<td>47.0%</td>
<td>91.1%</td>
</tr>
<tr>
<td>&gt; 40 dB HL</td>
<td>5.8%</td>
<td>10.7%</td>
<td>29.7%</td>
<td>81.3%</td>
</tr>
<tr>
<td>&gt; 50 dB HL</td>
<td>2.9%</td>
<td>5.7%</td>
<td>12.4%</td>
<td>68.7%</td>
</tr>
</tbody>
</table>

Hearing loss is very common!

(Davis, 1995)
Effects of hearing loss

- Loss of sensitivity to quiet sounds.
  - Might miss important information
- Difficulty understanding speech in noisy backgrounds.
  - Can affect lifestyle
  - Untreated could potentially lead to social isolation and cognitive decline

Current hearing aids help, but do not restore "normal" hearing.

The Ear
Bach in the Cochlea

© 1997 Howard Hughes Medical Institute
(A.J. Hudspeth, Rockefeller University)

Electron Microscope Images

- Inner Hair Cells
- Outer Hair Cells
- Stereocilia
Sources of hearing loss

• Loss of outer hair cells:
  – Poorer tuning (harder to “hear out” different sounds)
  – Loss of sensitivity (can’t hear quiet sounds)
  – “Loudness recruitment”

• Loss of inner hair cells and synapses:
  – Loss of sensitivity?
  – Poorer representation of high-level sounds

• Different types of loss may require different treatment, but how do we tell?

Windows into the human cochlea

• Otoacoustic emissions (Kemp, 1978)
  – Can tell us about tuning (Shera, Guinan, Oxenham, 2010)
  – Can provide a window into the function of outer hair cells

• Behavioral masking tasks
  – May help differentiate between different types of loss.

• EEG
  – Electrical signals from the cochlea and brainstem can help with diagnoses.

*CATSS research is paving the way to better individual diagnosis and treatment of hearing loss.*
Restoring Hearing via Cochlear Implants

Challenges:
• Recreating ‘normal’ temporal activity in the auditory nerve

Providing good electrical separation between neighboring electrodes

Perceptual roles of envelope and fine structure

Hilbert transform: breaks down a waveform into its envelope (modulation) and fine structure (carrier).
Only envelope is provided to cochlear implants.
Auditory chimeras

- Principle: take the fine structure of one sound and combine it with the envelope of another. What do you hear?
- Does envelope or fine structure dominate perception?

Speech chimeras

- S1: “The clown has a funny face”
- S2: “The car is going too fast”

16-channel chimera:
- Fine structure – S1
- Envelope – S2

Which sentence do you hear?

Speech taken from HINT sentence corpus (Nilsson et al., 1994)
Melody chimeras

- Frere Jacques
- Twinkle twinkle

16-channel chimera:
- Fine-structure – Twinkle twinkle
- Envelope – Frere Jacques

Which melody do you hear?

(Tunes altered to eliminate any rhythmic cues.)

Envelope vs. Fine Structure

Dominance of each code depends on the material:
1. Envelope is dominant for speech.
2. Fine structure is dominant for melodies (pitch), and localization.

For speech:
- Results support most current cochlear implant coding schemes.

For music:
- Results explain why cochlear implant users have difficulty with music.

CATSS Researchers are working to improve the stimulation strategies in cochlear implants to enable music perception and speech perception in complex backgrounds.
New Directions in Brain Technologies to Treat Hearing Disorders

Lab Director: Hubert Lim
Institute for Translational Neuroscience
Department of Biomedical Engineering
Department of Otolaryngology–Head & Neck Surgery
University of Minnesota–Twin Cities, U.S.A.

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A new era of brain machine interfacing and neural prosthetics
Main Research/Clinical Thrusts

1. Deep brain stimulation (DBS) for hearing restoration and treating tinnitus

2. Ultrasound neuromodulation (noninvasive brain stimulation) for treating tinnitus

Some Statistics on Deafness & Tinnitus

- >5% of population (>360 million people) has disabling hearing loss and needs treatment (WHO)
- Tinnitus is a phantom sound percept that is annoying or debilitating for 1-5% of the population
- Tinnitus is highest service-connected disability for veterans and top war-related health cost in the U.S. (American Tinnitus Association)
- Tinnitus is linked to hearing loss and is abnormal activity patterns within the auditory brain
- Deafness & tinnitus population is increasing rapidly!
Main Research/Clinical Thrusts

1. Deep brain stimulation (DBS) for hearing restoration and treating tinnitus

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1. DBS for hearing

>200,000 patients with cochlear implants and many understand speech in quiet

>1,500 adults and children (<2 years old) with brainstem implants but limited performance

Need new solution for central auditory implants and to further improve above cochlear implants
1. DBS for hearing & tinnitus

- Bi-shank electrode array
- In 2016-2019 will implant and evaluate 5 patients with deafness and tinnitus
- Funding from the National Institutes of Health (NIH) (jointly with Minnesota, Germany, Cochlear Limited)

1. DBS for hearing & tinnitus

- Success with the AMI can open up its use in Minnesota and worldwide for deafness, tinnitus, and other brain disorders using leading brain technology
- Potentially reaching millions of patients
Main Research/Clinical Thrusts

1. Deep brain stimulation (DBS) for hearing restoration and treating tinnitus

2. Ultrasound neuromodulation (noninvasive brain stimulation) for treating tinnitus
2. Ultrasound neuromodulation for tinnitus

- Animal experiments to figure out optimal stimulation parameters for brain activation
- Then move into human clinical trials, initially for tinnitus and then other brain disorders
- Ongoing collaboration with Medtronic Neuromodulation
- Could treat >15 million Americans and >200,000 Minnesotans with tinnitus
- Can expand to other brain disorders, such as pain, depression, and stroke recovery