NDSU CENTER FOR VISUAL AND COGNITIVE NEUROSCIENCE: CORE LABORATORY FACILITIES

McCourt, Mark E., Dan Gu, Enrique Alvarez, Ganesh Padmanabhan, Alyson Saville, and Jesse Wiesenborn

Center for Visual and Cognitive Neuroscience, Department of Psychology, College of Science and Mathematics, North Dakota State University

NDSU CENTER FOR VISUAL AND COGNITIVE NEUROSCIENCE

NIGMS

1. Technical Services Core Facility

The Technical Services Core Facility provides advanced programming, electronics design, EEG recording and analysis, and web development and maintenance support to the NDSU CVCN. It is currently comprised of five key personnel.

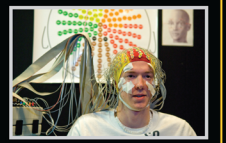
Dan Gu (Senior Software Engineer)
Ganesh Padmanabhan (Software Engineer)
Enrique Alvarez (Electonics and Software Engineer)
Alyson Saville (EEG Technician)
Jesse Wiesenborn (Web Developer)

2. High-Density Electroencephalography (HD-EEG) Core Facility

EEG Recording Instruments

The NDSU CVCN supports several laboratories for the conduct of high-density EEG neuroimaging experiments. The overarching enterprise of the CVCN is to facilitate the ability of our researchers to conduct experiments that shed light on the causal relationship between nervous system activity and human sensation, perception, cognition and action. The history of vision science has proven that indirect measures of neural function, such as sensory thresholds or perceptual matches, are a remarkably powerful tool for the "psychoanatomical" dissection of nervous system structure and function. Recent advances in neuroimaging technology have resulted in the development of non-invasive methods allowing the direct observation of ongoing brain activity during the execution of sensory, perceptual and cognitive tasks. Clearly, it is a major benefit when advances made through psychophysical experimentation and indirect inferences can be supplemented and augmented by parallel experiments which directly reveal neural activity. The HD-EEG Core Facility hosts three different EEG recording instruments:

(2) BioSemi recording suite
(1) Electrical Geodesics recording suite
(1) ANT recording suite



Ancillary Instruments

Polhemus electrode digitizer
TMS device

EEG Recording Chambers

EEG recording equipment is installed in (2) 8' x 10' x 8.75' radio frequency (RF) shielded enclosures. RF-shielding is required because scalp-recorded electrical signals generated by brain activity are measured in microvolts, and these tiny potentials must be highly amplified for recording and analysis. These fields arise from AC current in electrical wiring, and/or from the power supplies of laboratory equipment. The RF-shielded recording chambers (Lindgren, Inc.) installed during Phase I of the COBRE reduced magnetic field strength at 60 Hz by 30dB, and by 100dB at 14 kHz. The reduction of EM contaminants ensures that our electrophysiological experiments are conducted in an electromagnetically and acoustically quiet environment.

EEG Data Analysis Workstations

Several data analysis workstations are equipped with proprietary (Brain Electrical Source Analysis: BESA) as well as open-source (EEGLAB, ERPLAB, Cartool, Laura, Vareta, Loreta) and custom-coded EEG analysis software.

3. Driving Simulator Core Facility

The Driving Simulator Core Facility provides an important tool to CVCN researchers which enables them to study perceptual and cognitive processes within the context of a dynamic and interactive environment – an environment with high ecological validity which presents challenges that are analogous to those faced by the visual system in the real world, and in a task that has obvious real-world implications. This Core facility is staffed by members of the Technical Services Core Facility.

The Driving Simulator Core Facility is based on a DriveSafety DS-600c research driving simulator. The simulator includes a realistic vehicle cab consisting of driver and passenger seats, a center console, a fully-instrumented dashboard, a rearview mirror display, and controls for steering, braking, and acceleration. The cab is mounted on a motion platform in order to simulate a limited range of motion while driving. The simulated environment is projected onto three large screens that provide a 180˚ view of the simulation, and displayed on three mini-LCD screens mounted on the rear-view and side mirrors. A FaceLAB eyetracker (a component of the Eyetracking Core Facility) is mounted on the dashboard, and can be used to compute point-of-gaze, within and outside the cab, as participants drive the simulated vehicle. The simulation is computer controlled using DriveSafety's Vection software, which enables real-time data collection and updating of the displays. DriveSafety's HyperDrive Authoring Suite is used to model complex driving scenarios and to precisely control the presentation of stimuli within the simulated environment. CVCN researchers have full control over the environment, objects and events that might influence the driver's behavior.

4. Immersive Virtual Reality (IVR) Core Facility

The IVR Core Facility allows researchers at the CVCN to conduct cognitive, psychophysical and electrophysiological research in immersive virtual reality environments. The IVR Core Facility is comprised of several interfacable instruments: 1) Two head-mounted real-time updated virtual reality visual display systems (NVIS nVisor SX60 and NVIS nVisor SX111) with spatially co-registered auditory virtual reality capability (WorldViz, Inc.; AuSim, Inc.), and a 3D orientation- and position-tracked 18-sensor CyberGlove II); and 2) a 180o field of view immersive visual display system (VisionStation; eLumens, Inc.). This Core facility is staffed by members of the Technical Services Core Facility.

The VisionStation (Elumens, Inc.) large-format (1.5 m diameter) hemispherical projection system. To an appropriately positioned observer images projected by the eLumens display subtend 180o, encompassing the entire field of view. This wide field of view enables the study of visual interactions across the totality of visual space (including ganzfelds) and permits the study of visual processing at extreme visual eccentricities.

The IVR Core laboratory is a resource to numerous CVCN researchers studying cognitive and visual processing as well as audiovisual multisensory integration. Researchers interested in the potency of peripheral (exogenous) stimuli to capture spatial attention using variants of the Posner cueing paradigm are currently employing the eLumens portion of the IVR core facility to present truly "peripheral" (50o eccentricity or more), as opposed to merely perifoveal (15o) cues, to more precisely determine whether peripheral visual processing (and attentional resources at such large eccentricities) differs in quantity or quality from what has heretofore been studied. The head-mounted immersive VR system has already proved invaluable for conducting studies of brightness and lightness perception and cognitive control (task-switching study).

5. High Dynamic Range Imaging and Display (HDRID) Core Facility

The High Dynamic Range Imaging and Display Core Facility consists of image acquisition and display devices. This Core facility is staffed by members of the Technical Services Core Facility.

HDR Image Display

Display devices are a Brightside Technologies (Dolby Laboratories, Inc.) DR-37P 37" high dynamic range display monitor. As opposed to standard LCD or CRT displays, which possess mesopic peak intensities of about 300 cd/m2, and typical contrast ratios of 3,000:1, the DR-37P achieves high dynamic range by possessing a backlight consisting of an array of 1380 individually-controlled high-intensity light-emitting diodes, and a front panel consisting of a high-resolution (1920 x 1080 pixel) LCD display.

The second device is a 2nd generation high dynamic range display, the HDR47E High Dynamic Range Monitor (Sim2 Multimedia, S.p.A.), with a 47" LCD Display with 2202 High Power LEDs backlight; Resolution 1920 x 1080 pixels.

Possessing peak luminances in excess of 4,000 cd/m2 (fully photopic, viz. daylight, intensity) and contrast ratios exceeding 200,000:1, the HDRI Core laboratory allows CVCN researchers to study the behavior of the visual system using stimuli with a truly "natural" range of image intensity.

HDR Image Capture

Two calibrated high-resolution digital single lens reflex camera systems which allows these camera systems to serve as mega-pixel photometers/colorimeters.

The Canon EOS-1D Mark II is a high-resolution professional digital camera featuring a full-frame 24 x 36 mm CMOS sensor with 16.7 million effective pixels. The Nikon D3 is a high-resolution digital camera featuring a full-frame 24 x 36 mm CMOS sensor with 12.1 million effective pixels. It's extremely low noise, fast capture rate and ultra-high sensitivity qualify it as the sensing component of the HDR light probe capture system. Mounted in a high-precision, detent-stopped rotator, augmented with GPS, and equipped with a wide-angle lens, the Nikon D3 captures 360 x 180 degree light probes of natural environments. These light probes can be systematically analyzed in terms of spatial frequency, color, luminance, and spherical harmonics to better understand the properties of the natural environment that human vision evolved to interpret. These light probes can also be used to light virtual objects using modern 3D rendering packages such as Maya (Autodesk, Inc.).

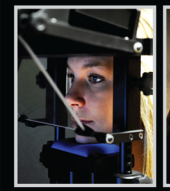
Both camera systems are used for calibrating and analyzing the performance of the DR-37P HDR and the HDR47E displays. These calibrated instruments can capture images of the natural environment, which are essential for the analysis of the spectral and spatial content of natural scenes. This Core Facility is staffed by members of the Technical Services Core Facility.

HDRID Core Facility is of significant value to those CVCN researchers studying visual processing. Evolutionary theory is arguably the most powerful unifying idea in all of biology, and a corollary is that visual systems, including human vision, can best be understood as biological devices optimized over geological time to extract behaviorally-relevant information from the natural environment. While visual neuroscience has made impressive progress in the past half century toward understanding the anatomical and neurophysiological bases of normal and disordered visual perception by taking an engineering approach, using "unnatural" stimuli such as sinewave gratings and noise textures, a paradigmatic shift has recently emerged which emphasizes the crucial importance of using "natural images" as a research tool. Until the advent of high dynamic range displays, however, truly "natural" images were unavailable to researchers in laboratory settings. The DR-37P and HDR47E displays are experimental prototypes, but the development of HDR displays holds enormous promise for both basic research and as an assistive technology for persons with low vision.

6. Eyetracking Core Facility

This collection of instruments facilitates the conduct of cognitive, psychophysical and electrophysiological research using eyetracking and pupilometric methods. The Eyetracking Core Facility is a distributed collection of research instruments available for general use rather than a centralized common-use instrument. This Core facility is staffed by members of the Technical Services Core Facility. The eyetrackers for use within this research facility include:

- Two Eyelink 1000 video-based eyetrackers with a sampling rate up to 1000 Hz. These are cutting-edge instruments that perform real-time eyetracking with exceptional spatial resolution. The Eyelink 1000 Tower mount incorporates the camera and illuminator housing within a combined chin and forehead rest with the use of an infrared reflective mirror. A display computer is equipped with applications for stimulus display, data file viewing and the creation of experimental paradigms; a host computer runs controls the operation of the eyetrackers itself. The Eyelink 1000 has a resolution of 0.01° and an average error of less than 0.5°.



- A FaceLAB (Seeing Machines, Inc.) eyetracker is installed in the DS-600c driving simulator. This device tracks head and eye movements at a rate of 60 Hz, enabling the collection of point-of-regard data while also allowing considerable freedom of movement (head rotation up to 90° is permissible, as is translation up to 13" horizontally and 9" vertically). The FaceLAB eyetracker has an average gaze position error of less than 1°.

- A Tobii X120 stand-alone eye tracking units that allows for large head movements (12" x 9" x 12"), providing a distraction-free test environment that ensures natural behavior, and therefore valid results. It has a sampling rate of 120 HZ and provides spatial resolution of 0.3° and an average error of 0.5°. The binocular eye tracking capability allows for studies of individual eyes' movements.
- A EyeFollower (LC Technologies, Inc.) provides subjects with the largest amount of free head movement (30" x 20" x 24") of any remote eye tracker. It automatically locates, focuses, and tracks the users with no time consuming adjustments or recalibrations. It is highly accurate (0.4°) and tolerant to many variations, such as pupil drift and head range movement.

Eyetracking is an essential technology for visual and cognitive neuroscience. Three types of eye movements are of interest include: high-velocity (saccadic) eye movements which abruptly change point of regard; slow-velocity (pursuit) eye movements that maintain stable fixation with movements of the observer or object of regard; and stable fixation itself, with no movement of the eyes, the observer, or the point of regard. Specific research questions dictate the appropriate type of eye monitoring. Studies requiring observers to make particular eye movements must ensure that observers comply with experimental demands, and studies requiring precise stimulus location require knowledge of where the fovea is directed with respect to stimuli. A large proportion of projects by CVCN researchers require the sophisticated eyetracking technology provided by this Core Facility.

7. ElectroOptical/Mechanical Instrumentation Core Facility

Research in visual and cognitive neuroscience demands precise calibration of stimulus delivery devices and response collection systems. Because our research is often on the cutting edge of technology we must often design and fabricate custom stimulus delivery and response collection hardware/software to accomplish our experimental objectives. Meeting this crucial need, the CVCN supports an ElectroOptical Instrumentation Core Facility to provide all our researchers, as well as other members of the department and campus community, access to essential calibration and fabrication instrumentation to support their research programs. The ElectroOptical Instrumentation Core Facility is a collection of research instruments available for general use rather than a centralized common-use instrument. This Core facility is staffed by members of the Technical Services Core Facility. Instruments available are:

- Konica-Minolta luminance meter (LS-110). High sensitivity spot photometer used for measuring the luminance of emissive or reflective sources.

- PR-650 SpectraColorimeter (PhotoResearch, Inc.). This instrument, calibrated to NIST standards, enables spectroradiometric and colorimetric calibration of emissive and reflective displays.

- Two high-end digital cameras (Canon EOS-1D Mark II; Nikon D3) calibrated to perform megapixel photometry/colorimetry.

- Casio High Speed Exilim Ex-zr100 digital camera. Capable of taking video at a frame rate of 1000 Hz. Facilitates measurement and calibration of the temporal characteristics of stimuli presented on visual displays.

- Minolta VIVID 9i high precision 3D laser rangefinder. Because the process of visual perception involves constructing internal models of 3D scenes from 2D retinal images, this laser rangefinder (and associated software) measures depth relationships in 3D scenes, enabling the acquisition of "ground truth" in studies of depth and distance perception.

- VariSpec Liquid Crystal Tunable Spectral Filter. Computer-controlled tunable interference filter providing selection of monochromatic light (10 nm passband) in the visible and near-infrared wavelengths. In combination with a high-intensity xenon light source the VariSpec serves as a monochromator; mounted in the optics of calibrated digital cameras it allows the acquisition of hyperspectral HDR images.

- Extech 407764 Datalogging Sound Level Meter. This device is a type 2 SPL meter with an RS232 interface for computer control and datalogging.

- Protek B803 Sweep Function Generator. This is a 2 MHz bandwidth function generator with less than 2% total harmonic distortion.

- Instek GDS-820S 150 Mhz Digital Storage Oscilloscope. A 150 MHz bandwidth storage oscilloscope with a 2SGsa/s sampling rate and FFT analysis capabilities.

- B+K Precision model 2120B dual trace oscilloscope (30 MHz bandwidth).

- CircuitSpecialists CSI 825A SMD Rework station. Microprocessor controlled assembly and rework station for surface-mount electronics.

- CircuitSpecialists CSI474 thermostatically controlled desoldering station. Permits repair and rework of custom-built through-hole electronics.

- CircuitSpecialists CSI 3005X5. A high-stability regulated DC benchtop power supply for powering and testing electronic circuits.

- FireBall V90 CNC Router. A high performance computer controlled shaping machine capable of making custom hardware as well as in-house printed circuit boards.

Supported by
NIH/NIGMS/IDeA/COBRE
grant P20 GM103505