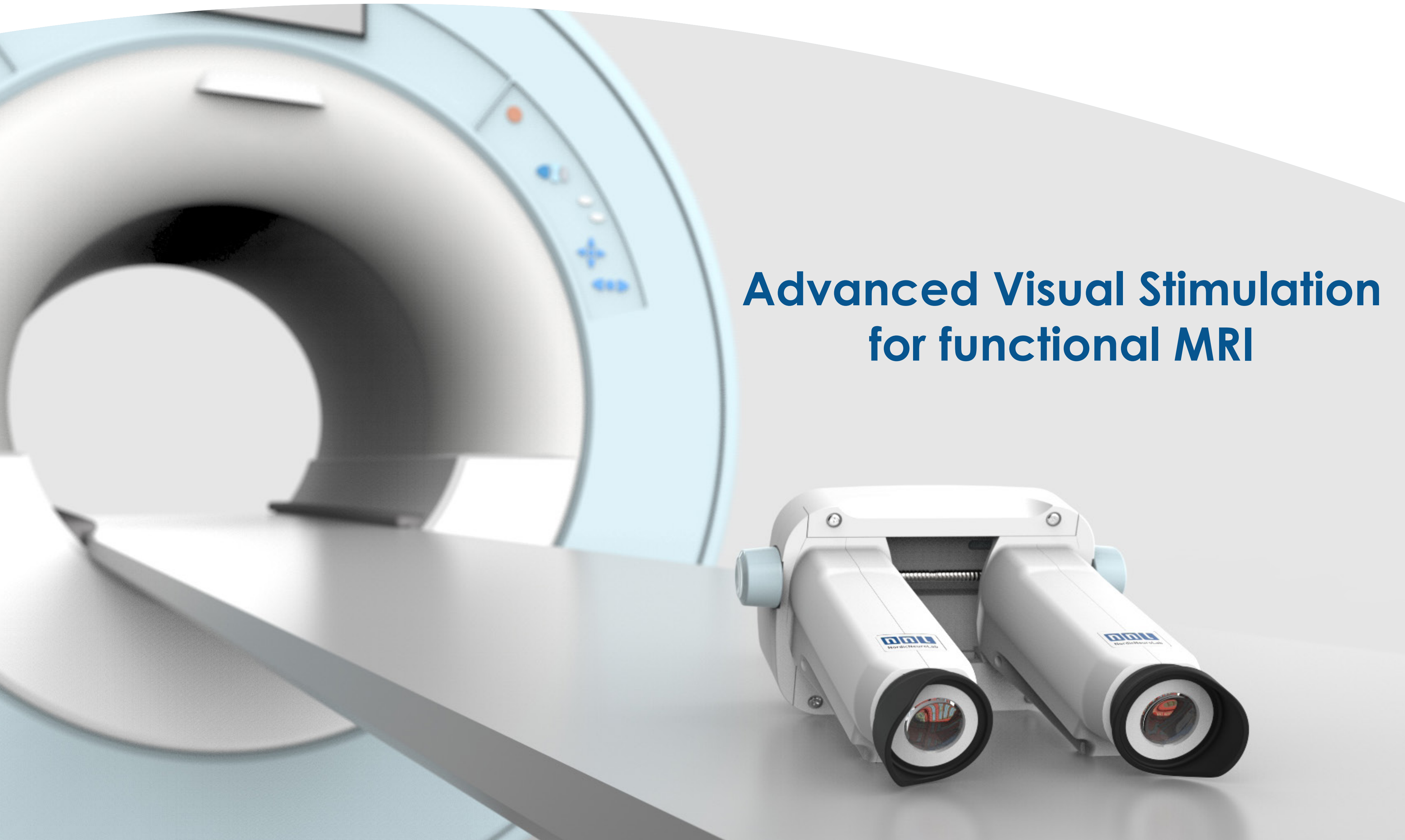
VisualSystem HD

NordicNeuroLab



Advanced Visual Stimulation for functional MRI

Making functional MRI easy

The VisualSystem HD (VSHD) is NordicNeuroLab's latest generation of MR compatible goggles. The VisualSystem (VS) is a binocular head mounted display (HMD) designed to provide high resolution images to patients positioned in an MRI scanner for both patient comfort and functional imaging applications.

From 2006 to 2019, NordicNeuroLab sold more than 400 VS goggles to clinicians and researchers throughout the world, who have used them for a range of task-based studies with 2D and 3D stimuli and eye-tracking applications.

The original VisualSystem has been successfully used in clinical fMRI studies for pre-surgical mapping purposes, by researchers studying cognitive processes, neuro-degenerative disorders, traumatic brain injury and concussion (i.e. Department of Defense studies, VA Medical Centers), and neuro-developmental studies, just to name a few.

NNL strives to meet the needs of our users as applications and technical requirements advance. One of the greatest advancements of the VSHD is that it is now entirely constructed using in-house components, providing NNL the ability to continue to improve the system based on the needs of our customers.

With the new VisualSystem HD introduced to the market in November 2018, the device has been entirely re-designed with improved reliability, ease of use, and performance capabilities. The development team at NordicNeuroLab has taken full control of the technical design and is working continuously on incremental product updates, benefiting new and existing users of the device.

First Generation NNL VisualSystem

Second Generation NNL VisualSystem

VisualSystem HD new features comparison

After obtaining user feedback, our team at NordicNeuroLab redesigned the VS, incorporating the advancements in technology and the technical specifications that many of our current customers had suggested. With larger built-in OLED displays and fully redesigned custom optics, the VSHD has significant improvement in image quality and color balance, as well as an increased field of view (FOV) for the subject. The integrated eye tracking cameras allow for quicker calibration and sharper eye-tracking image quality.

With the head coil specific adapters and the increase in diopter range and focus adjustment, the VSHD enables easier attachment and quicker set up times at the preferred viewing angle. NordicNeuroLab has also upgraded the RF noise shielding and mechanical stability of the VSHD, resulting in better signal-to-noise ratio and an improvement in overall safety of the device.

Feature	First generation VS	VSHD	Improvement
Display	Dual SVGA OLED (800x600@85Hz)	Dual Full HD OLED, one for each eye 1920x1200@60Hz, 71Hz (16:10 WUXGA) 1920x1080@60Hz, 80Hz (16:9 FHD) 1600x1200@60Hz, 85Hz (4:3 UXGA)	Significant improvements to image quality and color balance (380% increase in pixels)
Field of view	28.6° horizontal x 20.3° vertical	52.1° horizontal x 34.0° vertical (60° diagonal)	80% increase FOV (horizontal) Pixel density increased from 28.0 to 36.8 pixels per degree (horizontal)
Signal Path	Analog signal chain over copper	Fully digital signal chain over fiber	No video signal degradation from source to OLED
3D/Stereo-scopic	Not supported	Independent HDMI input for each eye 3D Fully Integrated	Capable of showing real 3D
Eye Tracking	3rd party ET camera module 640x480@60 Hz interlaced	Integrated ET and IR Illumination 640x480@60Hz progressive	Improved usability, significantly less time on calibration and set up. Shaper eye tracking image quality due to progressive video format
Mechanical	Diopter range: -5 to +2	Diopter range: -8 to +5 Improved stability and focus adjustment	Increase number of potential users Easier to obtain stereopsis
Other		Improved RF noise shielding Improved mechanical stability New power supply unit (significantly less magnetic)	Improved product robustness in MR environment Perceived product quality and ease of use Improved safety

VSHD Features

Wide field of view

The VisualSystem HD comes with dual OLED screens allowing for presentation of stimuli within a large area of the participant's visual field while inside the MRI scanner.

By rendering sharp images and brilliant colors through its 1920x1200 resolution, high quality graphics and text can be presented to the subject. An individual's field of view (FOV) is the extent of observable area one can see through the eyes at any given moment in time, for instance, viewing through an optical device such as a telescope, binoculars, or virtual reality (VR) headset.

In VR and other computer-generated simulations, a large FOV is essential to experiencing an immersive, life-like stimulus environment.

With a calculated horizontal and vertical FOV of 52.1° and 34°, respectively, the VSHD is a significant improvement for MR studies when comparing the FOV of current LCD or projector based systems, which usually rely on the usage of a mirror. The VSHD's expanded FOV increases the immersive experience for the subject and provides better mapping possibilities for functional imaging studies examining visual field deficits or functional field mapping.

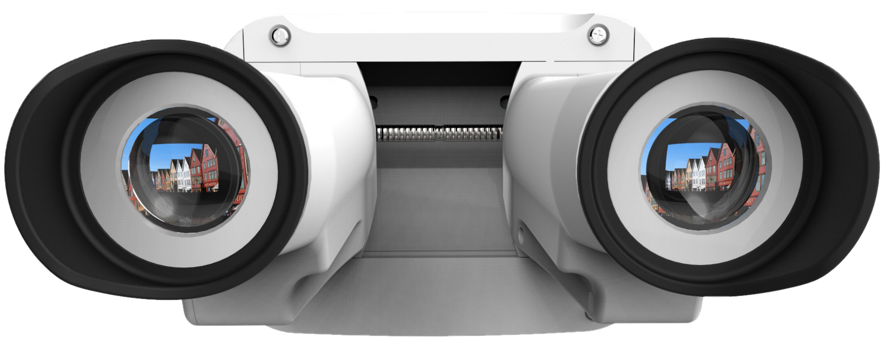
3D Stereoscopic View

The brain receives two slightly different images of the world due to the horizontal separation of the eyes. The cerebral cortex integrates these subtle differences with additional perceptual cues and cognitive factors which enables us to perceive stereoscopic depth and to experience three-dimensional space.

With the addition of 3D stimuli and environments to create the perception of stereoscopic depth, the VSHD can simulate everyday-life visual perception by increasing the realism of the presented stimuli.

By reducing the sensory differences between artificial stimuli and the real-world environment, it leads to a more engaging viewing experience known as "immersion"(Gaebler, 2014).

The VSHD allows the user to take advantage of stereoscopic display to create VR stimulus presentations inside an MRI environment, providing more 'real world' stimuli and strong ecological validity (Parsons, 2017). This unique technology allows researchers to experiment and measure human cognition and behavior with dynamic and interactive naturalistic task-based paradigms.



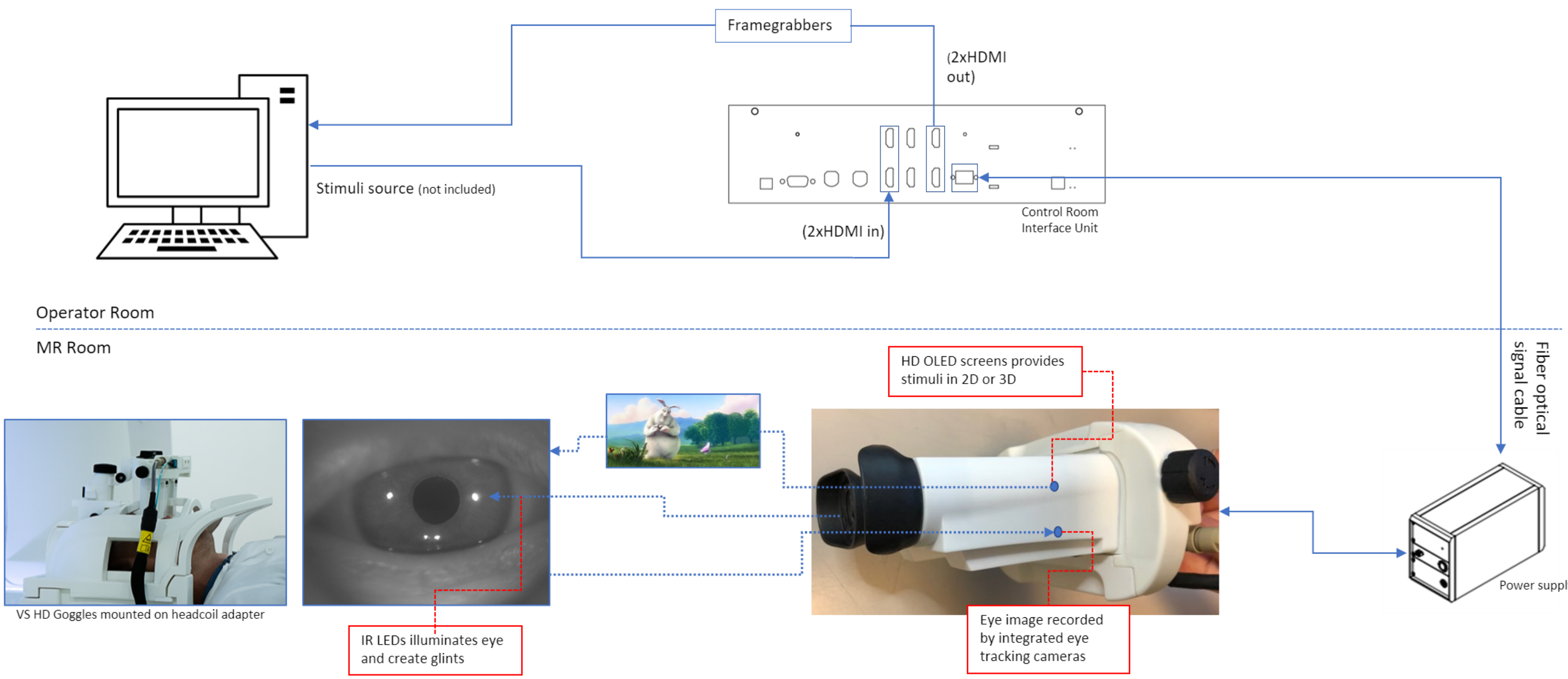
VSHD Features

Digital and open signal chain

The VisualSystem HD has a fully digitalized signal chain, from the output of the computer to the VSHD. There is no signal degradation or compression from repeaters or from the powerful magnetic field and gradients, which helps prevent any reduction in picture quality and loss of color in the image. In addition, the system is open, and all inputs and outputs are standard off-the-shelf solutions.

When connected to a PC, the VSHD shows up as two separate monitors, so the desktop can either be extended or duplicated upon, which allows the user to utilize standard software solutions for paradigm generation.

For eye tracking, the cameras operate independently of one another with their own dedicated HDMI input and USB frame grabber which offers flexibility in connecting to multiple eye tracking software solutions. To support additional frame grabbers, converters to composite video can be provided by NordicNeuroLab.



VSHD Features

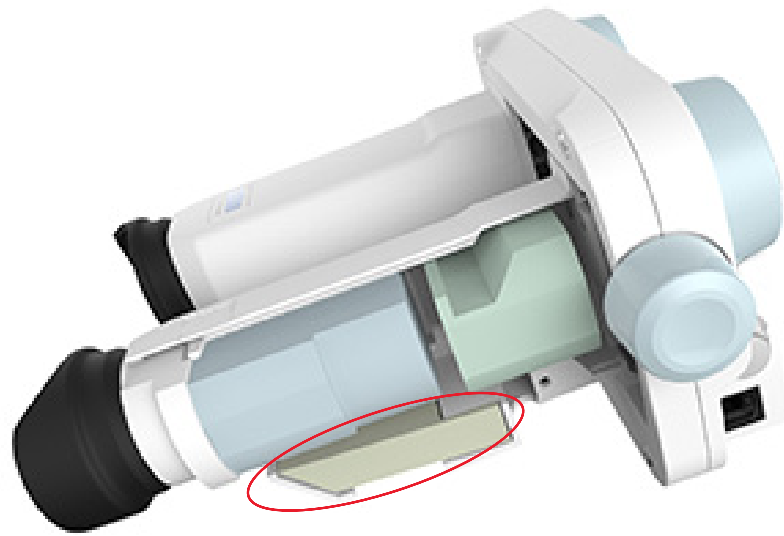
Eye tracking cameras

NordicNeuroLab's VisualSystem HD offers integrated eye tracking cameras.

One challenge in functional MRI (fMRI) is identifying fluctuations in the subject's attention and compliance during a task. For studies requiring active task performance, these concerns can be addressed in part by analyzing performance measures (e.g. accuracy, reaction, etc.).

However, for passive state studies (e.g. resting state fMRI, naturalistic view fMRI, etc.), there are no such responses to monitor. Passive state studies have struggled with changes in participants' attention and compliance due to the increased likelihood of individuals growing disinterested. As a response, researchers require participants to remain with their eyes open during the scans which can be tracked via video recording (Son et al, 2019).

For both active and passive studies, being able to monitor the participant's alertness via an eye tracking camera is critical. The VSHD comes with 2 frame grabbers that convert the camera signal from HDMI to USB. This allows the PC to capture the signal as 2 separate USB cameras. On most PC's, these can be viewed in the built-in camera application that can appear on the desktop for the technician or researcher to view. An alternative is installing the free IP Camera Viewer which allows for monitoring both eyes simultaneously.



The eye-tracking camera is located within the marked area.

Eye Tracking and Analysis

The NordicNeuroLab VSHD is the only MR-compatible goggle system with integrated binocular eye tracking cameras. Eye tracking is a powerful tool that can also be used for studying eye position and movement (gaze), and pupil size and reactivity (pupillometry).

Non-invasive and easy to set up eye trackers are increasingly being applied in a wide range of brain science disciplines - both clinical and research - as well as technology development in virtual reality, marketing, and product design.

The integrated eye tracking cameras of the VSHD provide users with a reliable and easy to set up eye tracking and stimulus display system. When paired with eye tracking software, it enables users to study features such as gaze position (x-y coordinate pupil position), pupil size, and fixation time, among other metrics. Data can also be used in real time to allow selection or navigation using the eye, or other real time feedback used to modify the stimulus itself.

Eye-tracking is an additional physiological measure that, along with imaging data, is beneficial to researchers and clinicians. By using eye-tracking technology, one can determine the subject's involvement in a given task by monitoring eye movements and collecting measurements in relation to a visual stimulus (Blascheck et al., 2017). Simultaneous collection of fMRI with physiological recordings (e.g. sweat response, heart rate, respiratory, eye movements) is commonly used in neuroscience, neuropsychology, and many applications involving human factors, behavior and the ocular system (Bonhage et al., 2015; Tylen et al., 2012; Hausler et al., 2016).

Eye tracking metrics such as 'scan paths' (which incorporate measures of saccades and fixations), in combination with fMRI activity, provide more information about the relationship between eye movement patterns and neural activity and can assist in diagnosis of schizophrenia, autism, attention, learning and language disorders (Ciaramidaro et al., 2018; Prasad et al., 2020), traumatic brain injury, concussion (Johnson et al., 2014) and addiction (Kim et al., 2015). The combination of using this data to map neural correlates associated with ocular motor function has revealed the existence of what has been more recently termed as the eye movement network (Coiner et al., 2019).

Eye Tracking and Analysis

How does it work?

The VisualSystem HD eye tracking cameras use infrared light sources to illuminate the eye. The same infrared sources create coronal reflection dots which enable more robust tracking.

Binocular eye tracking cameras allow for independent and simultaneous monitoring of each eye. The two integrated cameras transfer a video stream to a connected computer or monitor. In addition to eye monitoring, users may want to record and analyze eye tracking parameters. To accomplish this, outputs are transferred via HDMI signal, allowing the VSHD to be used with a range of monitoring and analysis software (e.g. Arrington Research), including systems supporting composite video.

Acquired images can be analyzed using the Pupil Center Corneal Reflections (PCCR) method.

Eye-Tracking Cameras	
Type	Video-based Pupil Centre Corneal Reflection (PCCR). One independent output video stream for each eye (binocular)
Image Resolution	640x480 (progressive)
Frame Rate	60 fps
Field of View	25mm ocular plane horizontal
Video Output	HDMI (can be externally converted to composite video)
Supported Software	Arrington ViewPoint, MRC, software supporting HDMI/composite frame grabbers

Eye Tracking Software

Arrington ViewPoint

NordicNeuroLab has formally tested the compatibility with the ViewPoint EyeTracker software by Arrington Research, Inc.

The ViewPoint EyeTracker provides a complete eye movement evaluation environment, including fixation, saccade, and drift classification, region of interest events, integrated stimulus presentation, simultaneous eye movement and pupil diameter monitoring (ocular torsion option also avaliable) and a software development kit (SDK) for communicating with other applications, all in real time. It incorporates several user selectable methods to optimize the system for a particular application.

There are many ways to interface to the ViewPoint EyeTracker for data synchronization,communication and control:

- Graphical User Interface (GUI)
- Command Line Interface (CLI)
- Software Development Kit (SDK)
- Ethernet (data, control, and remote viewing of eye video, in real time)
- Digital I/O (e.g. for: triggering, synchronization, event marking)
- AnalogOut

ViewPointClient Interfaces to third party products

- Integrity Suite
- MATLAB
- E-Prime
- LabView
- Python (including: VisionEgg, PsychoPy)
- Presentation
- Gazetracker

ArringtonResearch

VSHD Compatibility and Integration

The VSHD is designed to fit most head coils and is easy to mount with coil-specific adapters. The adjustable arm allows for fast and precise positioning at the preferred viewing angle. The built-in diopter correction and fine-tuning of pupil distance are easy to regulate and customize to each patient, both adults and children.

The head coil adapter connects directly to the VSHD and the head coil, allowing movement of the VSHD in the x, y, and z directions inside the head coil.

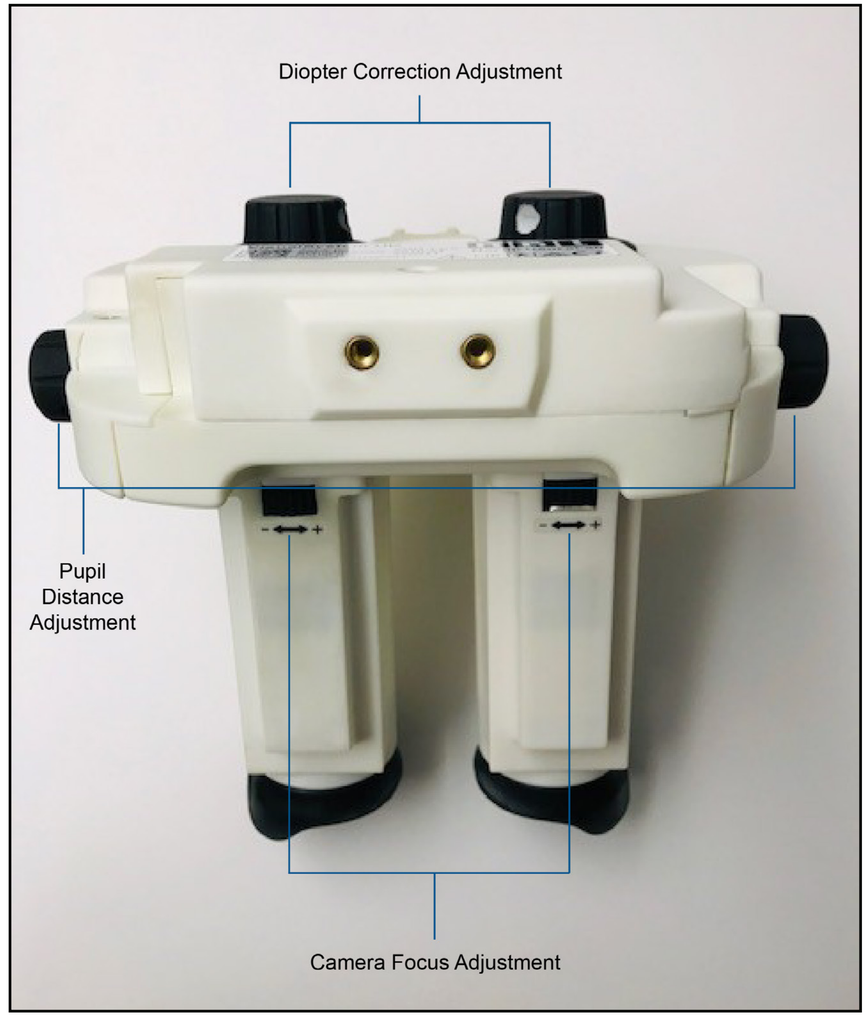
The VSHD has been tested and is compatible with the following head coils.

- Siemens Head/Neck 20 channel
- Siemens Head/Neck 64 channel
- TDI 48 channel
- MRI Instruments 32 channel
- Nova Medical 32 channel*
- Invivo 8 channel

The adapters have been manufactured to fit and mount the VSHD on these head coils.

Coil adapters are under continuous development. Please contact your NNL representative if your specific head coil is not listed.

* Pupil distance adjustment is limited due to narrow coil fit



2D Stimulus Presentation Software

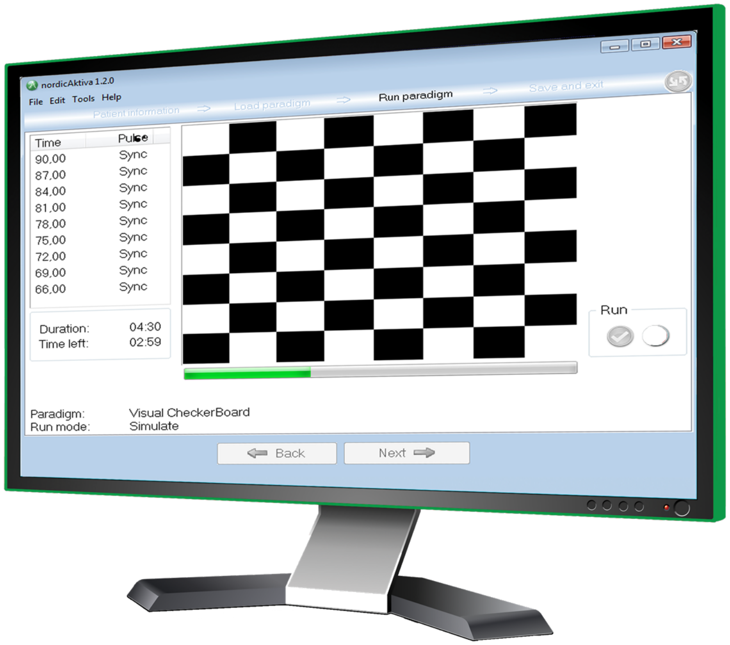
nordicAktiva is NordicNeuroLab's clinical stimulus presentation and work-flow software. By using nordicAktiva, a single technician can handle stimulus presentation and image acquisition at the same time.

With an intuitive interface and detailed easy to understand instructions available in multiple languages, the user is guided step-by-step through the process of presenting stimuli during image acquisition.

Block design paradigms include common language, cognitive and sensory motor tasks which can be presented visual and aurally.

nordicAktiva runs seamlessly with the NNL fMRI hardware, displaying the paradigm to the patient during the MR imaging exam. An integrated hardware test assures that the fMRI hardware is connected and communicating properly prior to the exam.

The VSHD is also compatible with third party stimulus presentation software solutions (e.g. Presentation, E-Prime, PsychoPy, MATLAB, etc.) which provide more advanced research paradigm design capabilities such as event related design.



For more information regarding compatibility of 2D software, please contact a NordicNeuroLab representative.

3D Stimulus Presentation Software

Display technology is used in various fields, from entertainment to medicine, and conveys more than 80% of information being displayed in 2D and 3D forms, with 3D implementations expected to increase with the desire for more realistic images (Heo et al., 2017).

Tasks using conventional 3D stimuli do not realistically reflect what is seen by the human eyes in real-life, and having the extra dimension of depth to incorporate in stimuli with 3D objects particularly benefits those investigating learning and task performance (Kozhevnikov et al., 2008).

When the influence of stereoscopic depth was introduced in neurophysiology and subjective experiments, reports indicated that 3D movies were more strongly experienced than 2D movies. At the neural level, 3D movies produced high inter-subject correlations of cortical networks when compared to the same 2D movies.

One of the prominent uses of fMRI has been to study the effects of virtual reality (VR) environments on brain activity. 3D stimuli can be created on various software platforms, allowing the user to experience the simulation as if they are present in the environment. Depending on the goals of the study, the computer-generated environment can be designed to test behavior while maintaining experimental control (Kalpouzos et al., 2010; Weiderhold et al., 2008).

With the use of the VSHD and additional feedback devices, one can create interactive scenarios inside the MR scanner. Some of the first applications of these simulations focused on investigating and controlling pain in burn patients using a snow world (Hoffman et al., 2006).

After observing modulations in brain regions associated with pain, the investigators realized the value of these immersive environments on sensory brain networks. This unique technology allows one to experiment with paradigm designs that are dynamic and interactive, creating a more engaging experience for the subjects with a high degree of ecological validity and therefore gathering data that may be more generalizable to the real world.

There are a wide variety of off-the-shelf tools on the market to create 3D environments, from gaming platforms such as Unity and Unreal, to research tools such as PsychToolbox from MATLAB and PsychXR for PsychoPy. NordicNeuroLab is currently developing sample code/paradigms for the most common 3D/VR software platforms to aid our users in getting started.

(Hoffman et al., 2006)

PC Hardware Configurations

For Stimulus Delivery

The following recommendations assume that the user will run paradigms and eye tracking software as well as other applications that require medium performance of the computer hardware. For applications where high performance is required such as real-time rendering of complex 3D environments, one must additionally consult the system requirements of the specific software application.

Processor:
Intel i5/i7/i9/Xeon AMD Ryzen or better

Memory:
16 GB or better

Disk:
SSD 256 GB or better

Graphics Card
All medium range and high range from nVidia, AMD and Intel such as:

- nVidia Series GTX 1060/1070/1080, RTX 2080, Quadro, Titan
- AMD Radeon RX Series 400, 500, Vega
- Intel HD Graphics Series 620/630, Iris Plus Graphics Series 640/650

Graphics card should have a minimum of 3 digital outputs of type HDMI, DVI, or DisplayPort Dual-Mode. For laptops, 2 outputs are sufficient for 3D. Adapters are needed for DVI and DisplayPort Dual-Mode to convert to HDMI.

For 2D use only, 2 outputs are sufficient (1 for laptop).

Inputs/Outputs/Slots

- 3x HDMI, DVI, DisplayPort Dual-Mode (Laptop 2x HDMI, DVI, DisplayPort Dual-Mode)
- 2x available USB 3.0 ports (for eye tracking where a USB frame grabber is required)
- 1x USB 2.0 or better

Corporate information

About Us

With nearly 20 years of experience, NordicNeuroLab provides products and solutions that define the field of functional MR imaging. Being a spin-off from the fMRI research environment in Bergen, Norway, we understand the growing need for reliable and innovative tools in this emerging field. This is why we make it a priority to collaborate with research and clinical teams from both academic and medical centers, MRI system manufacturers and third party vendors.

From advanced post-processing and visualisation software for BOLD, Diffusion/DTI and Perfusion/DCE imaging to fMRI hardware for audio and visual stimulation, eye tracking and patient response collection, NordicNeuroLab products are used around the world by researchers and clinicians alike. We are dedicated to bringing the most advanced neuroimaging tools to market while making functional MRI programs easy to implement.

Our Mission Statement

NordicNeuroLab will apply world leading competence and experience to provide professional solutions for functional imaging, enabling improved patient care and clinical efficiency.

Our Corporate Values

- We push for innovation
- We listen to our customers
- We focus on ease of use
- We deliver high quality
- We value safety

Service and Support

NordicNeuroLab takes pride in providing excellent service and support to our customers. Whether you are working with our team directly or through local partners and distributors, we are ready to support you in any way we can. We offer warranty, software maintenance solutions and professional installation and training packages based on your individual needs. We also offer online and on-site workshops in order to further improve product understanding and customer satisfaction.

Regulatory Compliances and Certificates

NordicNeuroLab has always emphasized quality and safety in the development and production of our devices. NordicNeuroLab fMRI hardware system is designed, developed and manufactured under certified ISO 13485 Quality Management system. As our product portfolio grows, we continue to ensure that all of our products intended for clinical use meet regulatory and safety requirements, have respective market clearances, and are tested for international UL and IEC consensus standards for Device Safety and Electromagnetic Compatibility (EMC) for medical equipment.

The VSHD has been market cleared in the EU and the US.

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