g.tec

Brain-Computer Interface & Neurotechnology

Research Product Catalog for Current & Future BCI Applications

UTE

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Editorial

Current and future BCI applications

g.tec started developing brain-computer interfaces (BCI) about 20 years ago, after presenting the first portable BCI system in 1999 at the BCI Meeting in Rensselaerville, New York. This device had an EEG amplifier within the floppy drive housing of an HP laptop system. From there on, BCI technology evolved rapidly:

In 1999, we demonstrated the first BCI session with 100 % accuracy using a motor imagery BCI system with Common Spatial Patterns. In 2007, we released the first commercial BCI for home use, called intendiX. This P300 speller could achieve 100 % accuracy after only 5 minutes of training. Later in 2013, our code based VEPs allowed users to control a robotic device with an accuracy of 98 % in a continuous control task and play World of Warcraft. Around this time, g.tec also became more active with ECoG recordings, which have led to several publications and the cortiQ system. The high spatial resolution of ECoG recordings has made it possible to decode much finer finger movements than noninvasive recordings, and to analyze under-explored brain regions like the fusiform face area in real-time using high-gamma activity.

In 2014, g.tec introduced wireless dry and wet EEG recording systems using active electrodes. This major achievement is still boosting BCI performance and user experience worldwide by improving the signal to noise ratio and ease of use. But what does the future hold for brain-computer interfacing? There are many exciting new directions, and g.tec is focused on extending BCIs with non-invasive and invasive neuromodulation and stimulation technology to further increase accuracy and to broaden application areas.

Enjoy using g.tec's BCI technology in your own research projects!

Christoph Guger & Günter Edlinger
CEOs of g.tec medical engineering

g.tec medical engineering Austria

g.tec medical engineering was founded in 1999 as a spin-off from the Technical University in Graz, Austria. Christoph Guger and Günter Edlinger developed the first commercial Brain-Computer Interface (BCI) system at this time. As a producer of state-of-the-art invasive and non-invasive BCI systems with sales and research partners worldwide, g.tec is a leader in the fields of BCI, medical devices, neurotechnology, neurorehabilitation and biosignal processing with branches in Schiedlberg and Graz (Austria), Barcelona (Spain), and New York (USA).

g.tec's BCI systems are realized by four major principles: slow waves, steady-state visual evoked potentials (SSVEP), motor imagery (MI) and evoked potentials (EP). The hardware and software whith g.tec's BCI technology can be used in clinical environments or for research purposes such as the analysis of the brain, heart or muscle activity, brain assessments of severe brain injuries and disorders of consciousness, motor rehabilitation after stroke, neuromarketing, deep brain stimulation, brain mapping, neuro prosthesis, communication, painting and closed-loop invasive and non-invasive BCI experiments.

g.tec's products and research activities have been widely described in peer-reviewed research publications, demonstrating the quality of tools and methods and the unlimited possibilities and the impact of brain-computer interface technology.

Read more about g.tec's worldwide BCI research, distributors and products online: www.gtec.at

g.tec's user ready BCI systems

In addition to research products, g.tec offers CE-certified and FDA-cleared user ready systems that can be used in clinical environments such as hospitals, rehabilitation centers or operating rooms.

recoveriX – motor rehabilitation after stroke: www.recoveriX.at
mindBEAGLE – brain assessment and communication: www.mindBEAGLE.at
cortiQ – brain mapping for the operating room & neuro monitoring unit: www.cortiQ.at
Unicorn – the brain interface: www.unicorn-bi.com

Contact g.tec to learn more about these products: office@gtec.at

The BCI Award

The international annual BCI Award, endowed with 6,000 USD, is one of the top accolades in BCI research. The Award was created to recognize outstanding and innovative research in the field of Brain-Computer Interfaces.

The Award is open to any brain-computer interface research worldwide, and 12 projects are nominated before the winner is announced. The BCI Award Ceremony usually takes place at the BCI Meeting in Asilomar, which is organized by the BCI Society, or the BCI Conference in Graz, which is organized by the Technical University of Graz, Austria. All nominated projects get the chance to publish their work in the "BCI State-Of-the-Art" yearly book series by Springer.

Mikhail A. Lebedev, PhD
Senior Research Scientist
Duke University Medical Center,
Department of Neurobiology

"The BCI Award is a very prestigious prize that attracts leading groups developing neural prostheses. I have seen a steady increase in the award's popularity and the quality of submitted projects. Importantly, nominated projects are presented in an annual book series, which presents a collection of the best BCI studies conducted each year. I foresee that the BCI Award will become an equivalent of a Nobel prize in the field of brain interfaces, and it will define the key directions in this growing research field."

The BCI Award Foundation organizes the annual BCI Award and guarantees scientific objectivity by assigning an independent, international jury consisting of world-leading BCI experts who work with invasive and non-invasive BCI in both research and clinical environments to judge the submitted projects. The BCI Award Foundation is a non-profit organization founded in 2017, located in Austria, and is chaired by Gerwin Schalk, Deputy Director of the National Center for Adaptive Neurotechnologies, and Christoph Guger, CEO g.tec medical engineering.

Read more about the BCI Award: www.bci-award.com

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01 Biosignal Amplifiers

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g.HEADstage Miniaturized Pre-Amplifier **17**

g.HIAMP
MULTICHANNEL AMPLIFIER

PRODUCT HIGHLIGHTS

- Fully integrated into g.tec software components for real-time analysis
- Supports active and passive EEG electrodes and ECoG grids
- 80-256 DC coupled wide-range input channels, able to record any type of signal (EEG, ECoG, EMG, EOG/spikes, connected various sensors)
- 256 channels perfectly synchronized with 24 bit resolution
- Integrated impedance measurement for active and passive electrodes
- TMS compatible
- Easy configuration and setup via high-speed online data processing for SIMULINK
- Driver package/API available
- FDA cleared and CE certified medical product

g.HIamp is a 256 channel biosignal amplifier for invasive and non-invasive measurements of brain functions that is FDA cleared and CE approved. The amplifier has 256 ADC converters with 24 bit resolution, providing excellent signal resolution and a wide input sensitivity to measure EEG, ECoG, ECG, EMG, and EOG without any saturation. External sensors can also be connected. All channels are DC coupled. Internally, signal processing is performed with the fastest floating-point DSP and a sophisticated real-time kernel. The amplifier relies on a very high oversampling to reduce the noise as much as possible by averaging samples.

256 channels can be analyzed in real-time with the g.tec Highspeed Processing for Simulink toolbox. This provides faster and more accurate control of BCI systems that use Common Spatial Patterns (CSP). g.HIamp is equipped with 16 digital trigger channels and a HOLD input for artifact suppression (e.g. during electrical or magnetic stimulation).

g.HIamp provides 80, 144 or 256 channels per unit and can be used with passive or active electrodes. The difference between these options is just the electrode connector box (headbox). Each block of 64 channels is connected via a multi-pole medical safety connector to the electrode interface box. For ECoG grids and strips, special interface connectors are available.

TECHNICAL SPECIFICATIONS

Size	197 (L) × 197 (W) × 90 (H) mm
Weight	1,875 g
Interface	USB
Digital inputs	2 × 8 digital trigger inputs, 1 × HOLD input (for artifact suppression)
Supply	5 V DC, medical mains power supply
Sensitivity	85.7 nV / ±340 mV
Noise level	<0.5 µV rms 1–30 Hz
Amplifier type	real DC coupled
256 × ADC	24 bit (38.4 kHz internal sampling per channel)
DAC	calibration signal
Input channels	256 mono-polar / 128 bi-polar (per device, software selectable)
Input impedance	>100 MOhm
Input connectors	standard safety connectors for passive electrodes, 2-pin connectors for active electrodes
Applied part	CF
Safety class	II
Certification and Standards	FDA cleared and CE certified medical product EN60601-1, EN60601-1-2, EN60601-2-26, EN60601-2-40, EN ISO 14971

INPUT CHANNEL PROPERTIES

g.HIamp uses wide-range DC-coupled amplifier technology in combination with 24-bit sampling. The result is an input voltage of ±340 mV with a resolution of 85.7 nV! This means that every electrophysiological signal can be recorded directly, without additional hardware. Neither high electrode offset voltage nor large artifacts resulting from electrical or magnetic stimulation will saturate the amplifier inputs. This feature is important for various artifact treatment and correction algorithms. The use of digital filters avoids hardware related variations between channels.

ACCURACY AND DATA QUALITY

The amplifier drives each ADC at 614.4 kHz, which is much higher than the required sampling frequency. Then, the floating-point DSP internally performs the oversampling and averages samples to increase the signal-to-noise ratio. The floating-point DSP also performs real-time bandpass filtering and notch filtering of the data. Several hundred different bandpass filters are predefined. Bipolar derivations can be calculated by the DSP to work with a very high CMRR. g.HIamp uses two additional co-processors for a steep anti-aliasing filter that guarantees a superior signal-to-noise ratio. All these features together make it possible to record even high-gamma activity in the kHz range! The amplifier uses 256 ADC for the 256 channels, and hence all signals are sampled exactly at the same time point to avoid any time delay between channels. This is especially important for brain mapping procedures.

SOFTWARE OPTIONS & PLUGINS

g.tec provides a broad spectrum of software solutions for different groups of users (e.g. engineers, researchers & scientists, physiologists, and medical staff, along with software developers & programmers). g.HIamp is integrated into the main core of BCI2000 and OpenVIBE and supports the LSL (lab streaming layer) as well as a plugin for Dewesoft X that allows you to acquire data with g.HIamp inside the Dewesoft data acquisition system for automotive applications.

CHANNEL COUNT

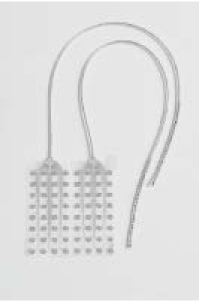
g.HIamp can be ordered with 64+16, 128+16 or 256 channels. The 64+16 channel version comes with one 64 and one 16 channel connector box. The 128+16 version comes with two 64 channels and one 16 channel connector box, and the 256 channel version comes with four 64 channel boxes.

SKIN-ELECTRODE IMPEDANCE

g.HIamp uses a new principle for impedance measurement that can determine the skin-electrode impedance for both passive and active electrodes. It works for both gel or dry electrodes provided by g.tec, and even for ECoG grids. The impedance values are color coded, and all 256 channels are shown in one window, which is updated every few seconds! The impedance check can also beep if an electrode was successfully mounted. This allows very fast assembly of electrodes during real-time impedance control.

ECOG AND SPIKES

Ad-Tech, PMT, Unique Medical and CorTec grid electrodes can be used for ECoG recordings. g.HEADstage can be used for neural spike recordings.



CONNECT ACTIVE/PASSIVE ELECTRODES

A useful feature of the g.HIamp is that the main amplifier unit can be used with different electrode connector boxes. Therefore, the main amplifier unit must be purchased only once, and can be used for many different applications:

- passive electrode connector box – comes with 64 channels and is connected to one of the 4 groups of the g.HIamp. It can be used with standard 1.5 mm safety connectors, which are standard for EEG and ECoG electrodes.
- passive electrode connector box with 16 channels – comes with 16 channels and is connected to one of the 4 groups of the g.HIamp. This connector box can provide additional inputs for external sensors.
- active electrode connector box - comes with 64 channels and is connected to one of the 4 groups of the g.HIamp. It has 2-pin connectors to support all g.tec active electrodes, such as g.LADYbird or g.SCARABEO (not for medical use).
- passive TMS box – allows EEG recordings with Transcranial Magnetic Stimulation (TMS); comes with 64 channels and is connected to one of the 4 groups of the g.HIamp. It can be used with standard 1.5 mm safety connectors, which are standard for EEG and ECoG electrodes. The box contains additional filters to suppress artefacts.

TMS AND TDCS COMPATIBILITY

g.HIamp can record EEG with passive and active electrodes while tDCS is applied. TMS recordings are done with the TMS headbox for g.HIamp and a post-processing artifact removal algorithm integrated in g.BSanalyze, which robustly eliminates the discharge artifact within a few ms.

g.HIamp Research Edition

g.HIamp RESEARCH is the non-certified version of g.HIamp. Therefore, it is less expensive, and intended for research applications only. The device has freely accessible and configurable features, although any kind of ECoG experiments are excluded.

User Experience

Dr. Aysegul Gunduz,
University of Florida, USA

"g.HIamp allows us to perform robust intra-operative recordings to ensure cortical and subcortical electrodes are placed in the correct functional regions, which is critical various clinical applications and research directions at the University of Florida Hospital."

Application Examples

RECORDING EEG DURING TMS AND TDCS

tDCS is compatible with both passive and active electrodes. There is a strong DC component in the raw data with tDCS, but it could be removed with a proper filter. As a result of the strong electromagnetic field, transcranial magnetic stimulation (TMS) can cause large discharge artifacts in the EEG due to amplifier characteristics and skin/ electrode capacitance/impedance. Therefore, g.tec has developed two remedies for this issue: a dedicated TMS headbox for g.HIamp that minimizes the amplifier-related artifact, and a post-processing artifact removal algorithm integrated in g.BSanalyze software that robustly eliminates discharge artifacts in already contaminated data within seconds.

BRAIN MAPPING AND EPILEPSY MONITORING

Dr. Kyousuke Kamada has been professor and chairman of the Department of Neurosurgery at the Asahikawa Medical University in Hokkaido, Japan since 2010. His professional career includes research periods at the Hokkaido University, the University of Erlangen-Nürnberg and The University of Tokyo, and his main research includes functional brain mapping and brain-computer interfaces. Dr. Kamada, an expert in high-gamma mapping procedures, utilizes g.HIamp to make functional brain maps in real-time. With g.HIamp, he evaluates motor and even language-related functions at the bed side in the monitoring unit or in the operating room.

RECORD HIGH-FREQUENCY OSCILLATIONS

High-frequency oscillations (HFOs) can be recorded with the Electrocorticogram (ECoG) with implanted electrode grids in epilepsy patients. The HFOs occur in frequencies between 80-500 Hz. Hence, recording HFOs requires a high-quality biosignal amplifier with a high sampling frequency and a very good signal-to-noise ratio and resolution. HFOs can be found in normal brain structures, but also in pathological networks, and mapping these networks is important for presurgical planning in epilepsy patients. Therefore, brain surgeons need to distinguish physiological from pathological HFOs. Recently, this was realized by the University of Houston with unsupervised machine learning techniques. This technology can detect the repetitive waveforms of pathological HFOs within a few minutes, which is an important step for a valid clinical biomarker.

Liu, S., Gurses, C., Sha, Z., Quach, M.M., Sencer, A., Bebek, N., Curry, D.J., Prabhu, S., Tummala, S., Henry, T.R. and Ince, N.F., 2018. Stereotyped high-frequency oscillations discriminate seizure onset zones and critical functional cortex in focal epilepsy. Brain, 141(3), pp.713-730.


A
B
C
D

g.USBAMP
BIOSIGNAL ACQUISITION AND PROCESSING

PRODUCT HIGHLIGHTS

- 16 DC-coupled wide-range input channels per unit, 4 independent grounds, record any type of signal (EEG/ECoG/ECG/EMG/EOG/spikes/...), connect various sensors, stack units for 32/48/64 channels.
- 24-bit resolution with simultaneous sampling of all channels with up to 38.4 kHz, digital signal filtering and preprocessing, connect via USB 2.0.
- Works with passive and with active electrodes, 8 digital trigger inputs/unit, 4 digital outputs/unit, new simplified synchronization of units.
- Internal digital bandpass and notch filters, built-in calibration unit and impedance checking.
- Easy configuration and setup via the software, high-speed online data processing for SIMULINK available, recommended by BCI2000 & approved under OpenViBE
- Driver package/API available
- FDA cleared and CE certified medical product

g.USBamp is a high-performance and high-accuracy biosignal amplifier and acquisition/processing system. With g.USBamp, you can record activity from the brain, eyes, heart, muscles, and more - including respiration, galvanic skin response, temperature, and many other physiological and physical parameters. Due to its technical specifications and various software options, this instrument has become a widely used standard for many different fields of research, including neuropsychology, life science, medical research and biofeedback/neurofeedback/BCI research.

g.USBamp is USB enabled and supports 16 simultaneously sampled biosignal channels at 24 bit resolution. A total of 4 independent grounds guarantee there is no interference between the recorded signals. The amplifier connects easily to the USB socket on your PC/notebook and can immediately be used for data recording. You can also build a multi-channel system with more than 16 channels using multiple g.USBamp devices. A synchronization cable guarantees that all devices are sampling at exactly the same frequency.

The amplifier has an input range of ± 340 mV, which allows recording of DC signals without saturation. Digital inputs and outputs allow the recording of trigger channels together with the biosignal channels to easily pass analysis results to the outside world. A short-cut input allows you to connect the amplifier inputs quickly to the ground potential to protect the amplifier against overflows, which may occur in operating rooms with gamma knives or other environments.

TECHNICAL SPECIFICATIONS

Weight	1000 g
Size	197 × 155 × 40 mm
Color	Color of choice
Sensitivity	85.7 nV / ± 340 mV
Amplifier type	real DC coupled
16 × ADC	24 Bit (38.4 kHz internal sampling per channel)
2 × DAC	12 bit
Noise level	< 0.4 µV rms 1–30 Hz
Input channels	16 mono- / 8 bi-polar (per device, software selectable)
Input impedance	> 100 MOhm
Input connectors	standard safety connectors and system connectors
Applied part	CF
Safety class	II
Certification and Standards	FDA-cleared, CE certified medical product EN60601-1, EN60601-1-2, EN60601-2-26, EN60601-2-40, EN ISO 14971

INPUT CHANNEL PROPERTIES

g.USBamp uses wide-range DC-coupled amplifier technology in combination with 24-bit sampling. The result is an input voltage range of +/- 340 mV with a resolution of < 85,7 nV! This means that any electrophysiological signal can be recorded directly, without additional hardware. Neither high electrode offset voltage nor large artifacts resulting from electrical or magnetic stimulation will saturate the amplifier inputs. This feature is an important requisite for various artifact treatment and correction techniques. The use of digital filters avoids hardware-related variations between channels. g.tec's active electrode system can also be connected directly, as well as all of our sensors (e.g. GSR, skin temperature, blood pressure, oxygen saturation, respiration effort and airflow, pulse plethysmography, acceleration, limb movements, snoring sounds, and many more).

ACCURACY AND DATA QUALITY

Each of the 16 analog to digital converters operates at 2.4576 MHz. Oversampling 64 times yields the internal sampling rate of 38,400 Hz (per channel and for all channels!). In addition, a powerful floating point Digital Signal Processor performs oversampling and real-time filtering of the biosignal data (between 0 Hz and 2,400 Hz). Therefore, a typical sampling frequency of 256 Hz yields an oversampling rate of 9,600. This results in a very high signal to noise ratio, which is especially critical when recording evoked potentials in the EEG or identifying small amplitude changes in high-resolution ECG recordings. You are measuring far below the noise-range of conventional amplifiers.

ADD MORE CHANNELS OR SPLIT SYSTEMS

To set up a multi-channel system (32/48/64 channels), g.USBamps can be stacked. Just add another 16 channels by connecting one more unit to the system. To assure 100 % simultaneous sampling of all channels, a simple "SYNC cable" is used to interconnect the devices (via a plug in the rear of the g.USBamps). Each input channel can be used for any type of signal (electrophysiological signals, or external physiological or physical sensors). On the other hand, if you have a 64 channel system consisting of 4 amplifiers, you can split the system to have 4 units available.

TEST SIGNAL GENERATION AND CALIBRATION

The amplifier can generate an internal sinusoidal-, rectangular-, sawtooth- or white-noise test signal. The amplitude and frequency of the signal can be modified to test the recording and analysis chain. An internal calibration unit periodically detects offset and gain values for each channel and uses these values for automatic internal correction. This technique yields the highest possible accuracy - especially critical for high resolution EEG and source derivation/localization.

SKIN-ELECTRODE IMPEDANCE

To obtain top-quality EEG recordings, the transition impedance between the skin and the electrode must be checked. The internal impedance testing unit measures the impedance for the individual electrodes and the results are displayed in the software. Bad electrodes can be identified easily and skin treatment and gel application can be performed during the impedance testing.

ECOG AND SPIKES

Ad-Tech, PMT, Unique Medical and Cortec grid electrodes can be used for ECoG recordings. g.HEADstage can be used for neural spike recordings.

SOFTWARE OPTIONS AND TOOLBOXES

g.tec's philosophy is to provide a broad spectrum of software solutions for different groups of users (e.g. engineers, researchers & scientists, physiologists, and medical staff, as well as software developers & programmers). From comfortable Windows-based recording software to our MATLAB/SIMULINK Highspeed Online-Processing environment and device drivers as well as APIs, you will find the appropriate tools for your application. g.USBamp is also supported by some open source research communities such as OpenViBE and BCI2000. g.USBamp further supports the LSL (Lab Streaming Layer).

TMS AND TDCS COMPATIBILITY

g.USBamp can record EEG with passive and active electrodes while tDCS is applied. TMS recordings can be done with g.USBamp, and a post-processing artifact removal algorithm integrated in g.BSanalyze, which robustly eliminates the discharge artifact within a few milliseconds.

Application Examples

The first Cybathlon took place on October 8th, 2016 at the ETH Zurich. People with disabilities competed side by side at the Brain-Computer Interface Race (BCI Race). Pilot Numa Poujouly from the Team BrainTweakers from École Polytechnique Fédérale de Lausanne (EPFL) in Switzerland won Gold in the BCI Race using his brain waves to control an avatar along a race-track on a virtual train. The game is called "BrainRunners" and was specially developed for the Cybathlon's BCI Race. The Brain Tweakers have been using high-quality g.tec equipment.

g.USBamp Research Edition

g.USBamp RESEARCH is the non-certified version of g.USBamp. Therefore, it is less expensive and intended to be used for research applications only. The device has freely accessible and configurable features, although any kind of ECoG experiments are excluded.

User Experience

Natalie Mrachacz-Kersting, PhD, Associate Professor
Aalborg University, Denmark

"We have used the g.USBamps for approximately four years now, and the quality of the signals surpasses our greatest expectations. Last year, we also invested in the g.Nautilus system, and have been able to move from more stringent laboratory conditions to real world settings, where BCIs are becoming more prominent. I would highly recommend both systems to anyone involved in BCI research."


g.GAMMAbox

g.MOBILAB+

WIRELESS BIOSIGNAL ACQUISITION

g.MOBIlab+ is the perfect tool for recording multimodal biosignal data on a standard PC or notebook. This allows investigation of brain-, heart-, and muscle- activity, eye movement, respiration, galvanic skin response, pulse and other body signals. g.MOBIlab+ is available in two versions: the 8 channel EEG and the multi-purpose version. A switch can be connected for external triggering of the data. g.MOBIlab+ is not a medical device. However, the product meets the IEC 60601-1 standard, as it is a more rigorous standard.

g.MOBIlab+ becomes even more powerful with the software options that g.tec provides for Windows. Programmers can use the C or MATLAB APIs to integrate the device into their own software programs. Simulink is used to analyze the biosignal data in real-time and to run BCI experiments, and the recording software for the PC is used to visualize and store biosignal data.

PRODUCT HIGHLIGHTS

- Acquire EEG, ECG, EOG, EMG and other signals–even outside your lab
- Online visualization and storage of up to 16 channels
- Various software solutions available (driver/API, recording software, MATLAB/SIMULINK)
- Transmit online biosignal data wirelessly via Bluetooth 2.0 to a notebook/PC
- Log data directly on an internal flash card memory (Mini-SD card)
- Integrate the device into your real-time system under SIMULINK (BCI, neuro-, biofeedback)
- Recommended by BCI2000 & approved under OpenViBE

TECHNICAL SPECIFICATIONS

Weight	360 g
Size	155 × 100 × 40 mm
Additional inputs/outputs	4 digital inputs/outputs, 4 digital inputs (TTL), +5 V
Power supply	4 standard AA batteries or accumulators (25–100 hours operation time)
Data acquisition	ADC with 16 Bit and 256 Hz/channel, serial interface (RS232), Bluetooth 2.0 class I (+)
Internal storage card	Micro-SD flash memory card up to 2 GB, accessible via battery compartment
Standards	IEC 60601-1
g.MOBIlab+ 8 channel EEG	
EEG Channels	8
Sensitivity	0.5–100 Hz
Filters	500 μV (monopolar)
g.MOBIlab+ Multi-purpose version	
Analog inputs	2 channels, Filters: DC-100 Hz, Sensitivity: ±250 mV (monopolar)
EEG Channels	2
Sensitivity	500 μV (bipolar)
Filters	0.5–100 Hz
EEG/EOG channels	2
Sensitivity	2 mV (bipolar)
Filters	0.5–100 Hz
ECG/EMG channels	2
Sensitivity	5 mV (bipolar)
Filters	0.5–100 Hz

EXCELLENT DATA QUALITY

g.MOBIlab+ is equipped with low-noise biosignal amplifiers and a 16-bit A/D converter (256 Hz), which guarantees excellent data quality and a high signal-to-noise ratio. For sophisticated data analyses, g.MOBIlab-data can be imported directly into g.BSanalyze, the toolbox for advanced biosignal processing and analyses. The data can also be converted into ASCII-format for other programs like MS-Excel or foreign toolboxes.

WIRELESS RECORDING/FLASH CARD

g.MOBIlab+ now provides two additional features that open new application fields and make the system even more mobile. New wireless data transfer tools let you send data to your notebook or desktop PC with Bluetooth technology. Monitor biosignals under every imaginable experimental condition. Use g.MOBIlab+ as a powerful biosignal data logger. After visually checking data quality on the screen, the device can be disconnected from the computer. Data are stored on a flash memory card.

User Experience

Mag. Erika Mondria
Head of Brain Lab,
Ars Electronica Center
Linz, Austria

"I am using g.MOBIlab+ with intendiX at the Ars Electronica Center in a public exhibition! Even though this is a very crowded environment, it delivers fast and accurate data from each participant."

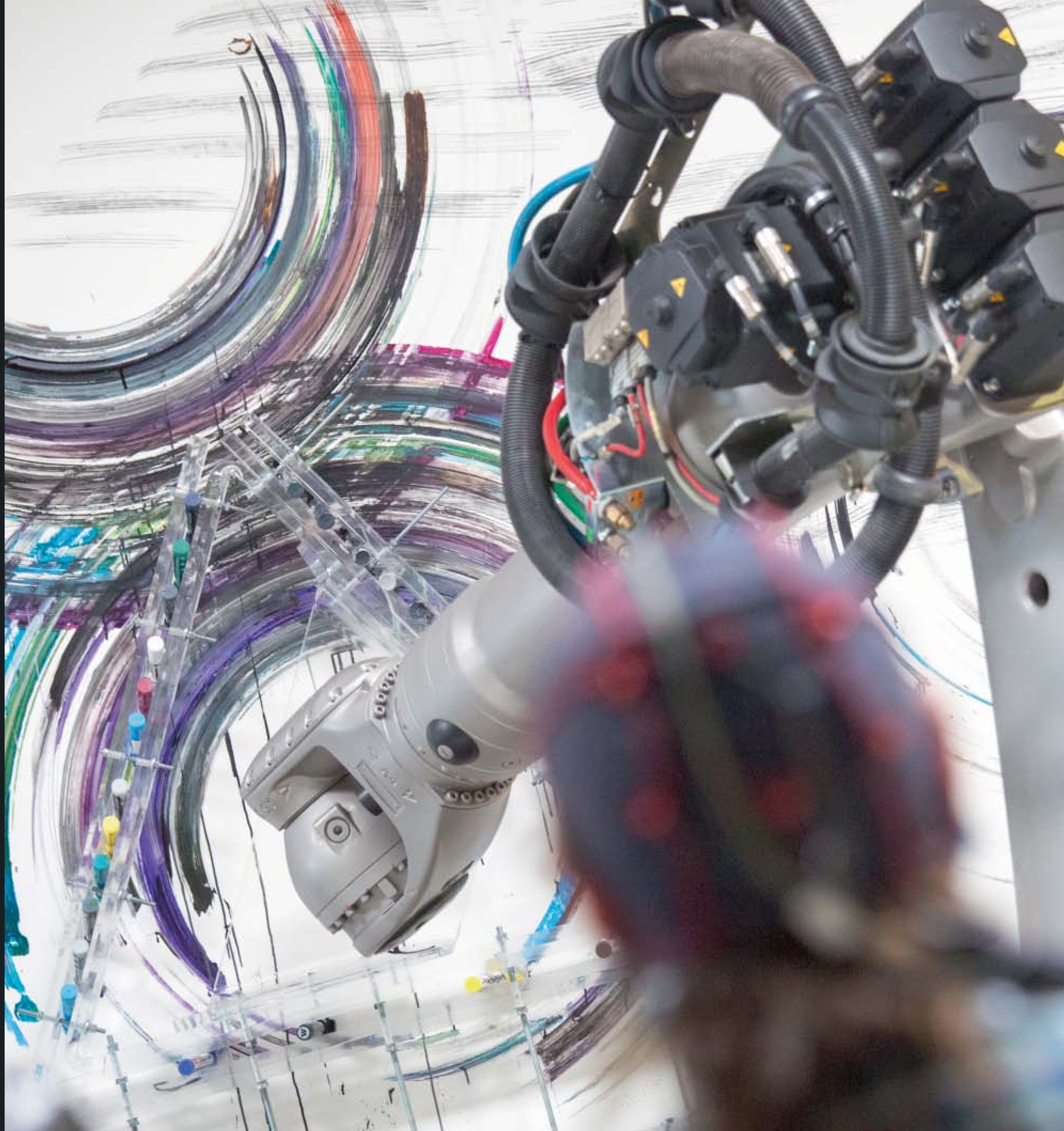
Application Examples

MEASURE BIOSIGNALS RELIABLY – EVEN IN THE HIMALAYAS!

During an Austrian expedition to Chulu Far West in Nepal (6,419 m), g.MOBIlab+ was used to measure the effects of high altitude on both EEG and ECG parameters. The expedition started in Besi Sahar at an altitude of 700 m near Annapurna I. The team gained between 300 and 600 m each day and settled in to basecamp at 4,800 m. After one night in base camp, the high camp was established at 5,600 m on the Chulu glacier. At 3 AM, the team started to climb Chulu Far West and reached the summit at 11 AM. g.MOBIlab+ was used to record 2 EEG channels over sensorimotor areas and 1 ECG channel from 2 expedition members. The persons performed a self-paced finger movement every 10 seconds. The onset and offset of each movement was recorded by an external switch connected to g.MOBIlab.

PAINTING WITH THE EEG

The Serbian artist Dragan Ilic equipped a KUKA robot with hundreds of pencils, and used it to create numerous works of art with BCI software and g.MOBIlab+. He selects drawing commands just by thinking, and the robot paints on a vertical and a horizontal wall guided by Dragan's mind. The performance was shown during the ARS Electronica Festival in Linz, and visitors could also control the device.



g.HEADSTAGE MINIATURIZED PRE-AMPLIFIER

PRODUCT HIGHLIGHTS

- 16 channels
- Extremely small board
- Low weight
- Aggregation boards help interface different electrodes types
- High quality neuronal activity recordings
- LED slot to support easier video tracking
- Very high signal-to-noise ratio

TECHNICAL SPECIFICATIONS

Weight	<3 g
Size	23 × 23 mm
Input channels	16 monopolar
Filter	0.5–6,000 Hz
Safety class	Internally powered
Applied part	BF
Operation mode	S1

The 16-channel g.HEADstages allow the recording of action potentials/ spikes with g.HIamp or g.USBamp. The boards are extremely small and lightweight and are connected via a very flexible cable to the amplifier. This allows the animal to move with almost no restrictions. The electronic system produces recordings with very little noise and very high input impedance, thereby providing top quality data. The channels have very similar gain, and thus a very high Common Mode Rejection Ratio is obtained. The g.HEADstages can also be used for biosignal recordings like EEG or ECG in animals.

g.HEADstages are available with system connectors or with single channel connectors that can be interfaced to electrodes/wires easily. The devices are connected to the g.SPIKEsens power supply and filtering box that is connected to the amplifier. One g.SPIKEsens box supports up to 16 channels. Several g.HEADstages can be used simultaneously. The g.SPIKEsens box filters the signal between 0.5 Hz and 6000 Hz. Voltage Noise Density at 1 kHz is only 10 nV/SQRT(Hz). Aggregation boards can be used to interface the head-stages with different electrodes like twisted wires, silicon electrodes and/or multi-electrode arrays.

Importantly, the flexible cable can be disconnected from the device. This allows you to replace the cable if it is destroyed by an animal or any other cause.

The g.HEADstage is offered in two different types:

- g.HEADstage, 16 channels with multi-pin connector
- g.HEADstage, 16 channels with golden-pin connector

Micro-wires and micro-electrode arrays (MEAs) have high impedances and must be very stable on the animal's heads. Therefore, the electrodes are connected with a very flexible cable to the input of the head-stage amplifier that has very high input impedance. It is important that this input impedance is orders of magnitude higher than the electrode impedance to pick up the neural activity correctly. Then, operational amplifiers with precise gain are used to amplify the spikes and to drive the cable that connects the animal to the main recording system. The precise gain is especially important for a high common-mode rejection ratio (CMRR) (100 dB). The pre-amplifiers also eliminate distortions in the signal such as power line interference, electromagnetic interference, and cable artifacts.

Application Example

RECORDING OF PLACE CELLS IN RATS

In-vivo recordings of action potentials (spikes) in rats is possible with the g.HEADstages, the biosignal amplifier g.USBamp and the real-time processing software g.USBamp High-Speed Online Processing for Simulink. An example is the real-time reconstruction of rats' movement trajectories while they are foraging for food in an arena. The rat's path is investigated with a video camera-based tracking system that transmits the x- and y- positions to a recording computer. Simultaneously, the neuronal activity is recorded with tetrodes (electrodes consisting of 4 wires) placed in the CA1 region of the hippocampus. This is a typical setup for place and grid cell recordings. These neurons increase their firing activity only when the animal is at a specific location in its environment, and this area where a neuron fires is called place field. By recording from many of these place and grid cells, the rat's position in the arena can be decoded using BCI technology.

Find g.tec's complete product list online in the Download section of www.gtec.at.

02 Wireless EEG Systems

g.Nautilus Pro 29

g.Nautilus Research 30

g.Nautilus Multi-Purpose 31

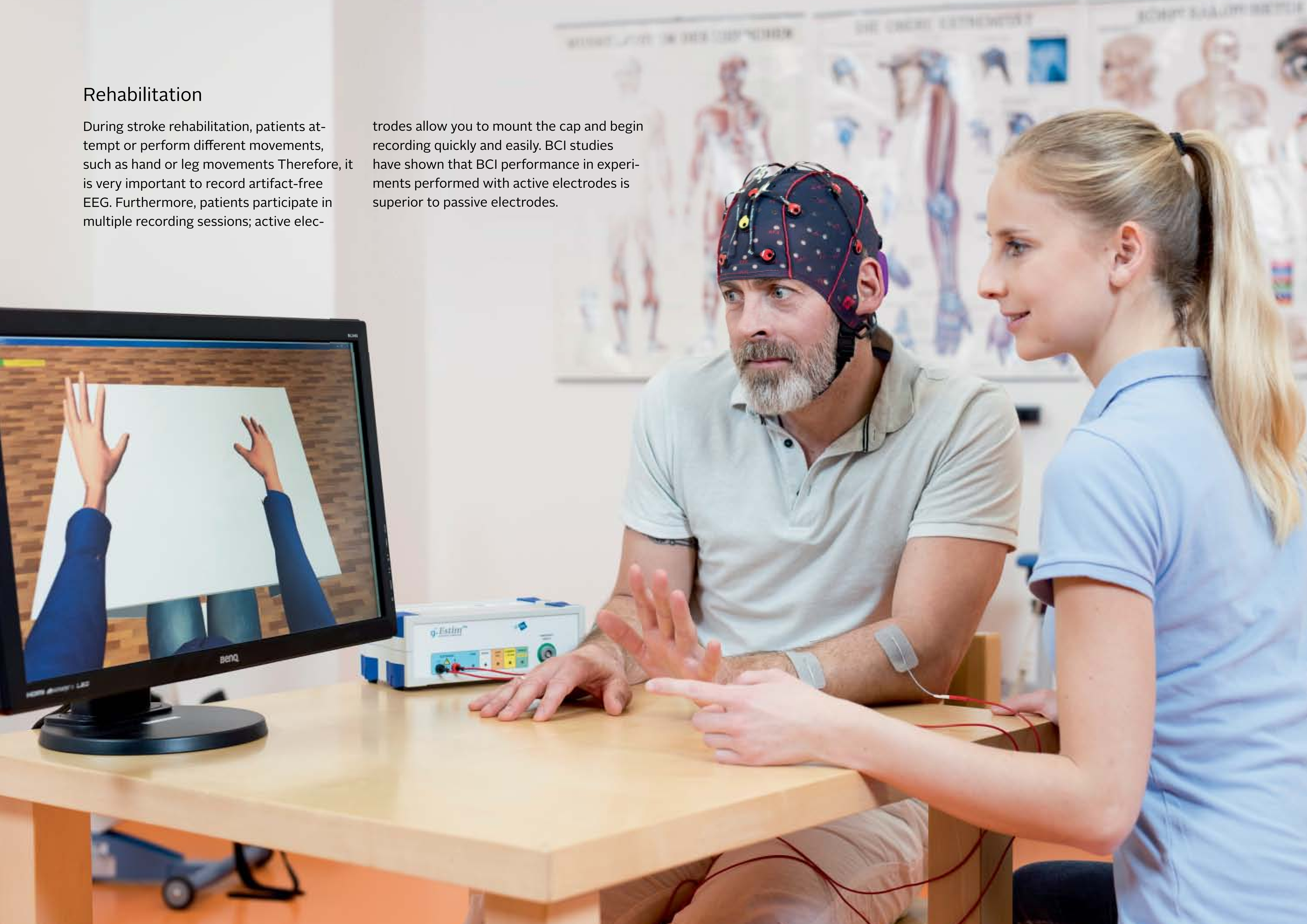
g.Nautilus fNIRS 32

Unlimited Possibilities of Wireless EEG

Wireless EEG and biosignal acquisition systems are becoming increasingly important in medical and clinical environments, especially since more and more studies are conducted in the field instead of the lab. Therefore, g.tec developed g.Nautilus. Its design is completely different from all other devices, and it sets a new standard of usability. The tiny and lightweight device is attached to the EEG cap to avoid cable movements and to allow completely free movements. In combination with dry or gel-based active electrode technology, users get top quality EEG recordings from 8-64 channels within few minutes.

Rehabilitation

During stroke rehabilitation, patients attempt or perform different movements, such as hand or leg movements Therefore, it is very important to record artifact-free EEG. Furthermore, patients participate in multiple recording sessions; active electrodes allow you to mount the cap and begin recording quickly and easily. BCI studies have shown that BCI performance in experiments performed with active electrodes is superior to passive electrodes.



Assessment

Disorders of Consciousness (DOC) patients are normally seated or lying in bed, and therefore a wireless solution is easier to mount than a wired EEG system. These patients may also suffer from uncontrollable movements, which could pull on the electrodes and degrade both the EEG quality and the clinical assessment. Wireless EEG systems reduce data loss due to artifacts, which is especially important for this patient group, where clean recordings are very difficult to acquire. A g.Nautilus with 16 active electrodes can be mounted within 1-2 minutes, which makes it particularly well suited for assessing brain activity in persons with DOC or other conditions that may limit their available time for recording, such as ADHD.

Control

The high-resolution EEG system with 64 channels enables exoskeleton control with motor imagery, P300 and SSVEP based BCI systems. The system has electrodes over the most important brain regions for finding control signals (motor cortex, central areas, visual cortex) for every type of BCI. The high number of electrodes can also be used for spatial filtering of the data to further improve control quality.

Communication

Communication systems for locked-in patients might be used on a daily basis and might be the only link to the outside world. Therefore, both rapid mounting and high data quality are essential. Dry electrode systems allow for a rapid setup with 8 EEG electrodes, and can provide high-quality data even at home. Battery life is also important. The battery can provide 6–8 hours of continuous recording, and the completely sealed housing makes usage safer and easier.

Sports Science & Medicine

If you're interested in sports applications, you need a system that is lightweight and highly robust to movement and challenging real-world environments. g.Nautilus weighs about as much as a climbing carabiner and has very compact packaging. The dry EEG version is well suited for high-altitude medicine because it does not require any hair washing, which is difficult in remote locations. For many sports, very good contact between the head and the electrode is crucial, and hence we recommend the gel version for these applications. If the g.Nautilus is well prepped with gel, people can even jump and run without seeing artifacts in the data.

Response/Aviation

g.Nautilus can be used in aviation because it's easy to set up, highly portable, and can provide high-quality data despite movements and the very noisy electromagnetic environment of an operating aircraft. Therefore, the system can easily be used in cars, plains, flight simulators and even high-gravity simulators for pilots and astronauts. VR is often used to simulate different aviation scenarios. Persons are embedded in a virtual environment where embodiment is increased when they are not wired up to bulky equipment. A BCI system in VR allows the user to navigate or control the scenario without touching everything. g.Nautilus also works nicely with eye-trackers and video cameras, so that electrophysiological parameters can be analyzed for neuromarketing applications.

Wireless EEG for Kids

g.Nautilus opens up many new research areas that were not possible beforehand. For example, it can be used easily with children because it sits comfortably on the head and children do not try to remove it. Just like adults during sports, kids often run and produce a lot of other movement, and lower-quality systems will generate a lot of motion artifact.

Recording EEG during TMS and tDCS

g.Nautilus allows you to record EEG with passive and active electrodes while tDCS is applied. TMS recordings can be done with g.Nautilus and a post-processing artifact removal algorithm integrated in g.BSanalyze that robustly eliminates the discharge artifact within a few milliseconds.

g.NAUTILUSPRO

WIRELESS BIOSIGNAL ACQUISITION

g.Nautilus PRO is a CE-certified and FDA cleared wireless biosignal acquisition system and medical device for clinical use. It's available as a flex-print solution with 8/16/32 prefixed dry or wet electrode positions for faster montage and to avoid errors. The dry electrode version is based on the worldwide proven g.SAHARA technology and the gel-based electrode version comes with g.LADYbird electrodes.

- g.Nautilus PRO 8/16/32, g.LADYbird prefixed channels with g.LADYbird active electrodes
- g.Nautilus PRO 8/16/32, g.SAHARA, prefixed channels with g.SAHARA active dry electrode technology

PRODUCT HIGHLIGHTS

- g.SAHARA dry EEG electrodes
- g.LADYbird gel-based EEG electrodes
- 8/16/32 channels wireless EEG with 3-axis accelerometer
- 24-bit accuracy at 500 Hz sampling rate
- A new benchmark in usability
- The only wireless system with active electrode technology
- Internal impedance check with active electrodes
- Waterproof device with contactless charging
- 10 hours continuous recording and 2-3 hours charging
- 2.4 GHz digital transmission, range: 10 meters indoor
- Full integration into g.tec's software environment
- CE certified and FDA cleared medical device

TECHNICAL SPECIFICATIONS

Weight	< 110 g without electrode grid
Size	78 (L) × 60 (W) × 26 (H) mm
Color	8 ch RED, 16 ch PURPLE, 32 ch BLUE, CSP16mB BLACK
Sensitivity	±2.25 V, ±1.125 V, ±750 mV, ±562.5 mV, ±375 mV, ±187.5 mV (software selectable)
Interface	Wireless 2.4 GHz ISM band
Digital inputs	8 digital trigger inputs at Base Station
Supply	Built-in lithium-ion battery, runtime > 10 h with 32 channels, inductive charging according to the QI standard of the Wireless Power Consortium
Amplifier type	Real DC coupled
32 × ADC	24 Bit (1.024 MHz internal sampling per channel)
Noise level	< 0.6 µV RMS between 1 and 30 Hz (at highest input sensitivity)
Input channels	32 mono-polar / 16 bi-polar channels with GND and REF (software selectable)
Input impedance	DC > 100 MOhm
Applied part	BF
Safety class	II
Certification and Standards	CE certified and FDA cleared medical device IEC60601-1 3rd, IEC60601-1-2, IEC62304, IEC60601-2-26, ISO 14971 10993-1, 62366, 2010-2012 IEEE Recommended Practice for Neurofeedback Systems

User Experience

Music and the mind

The LIVELab at McMaster Institute for Music and the Mind (MIMM) is engaged in neuroscientific research that aims to understand the positive role of music training, movement and performance. Researchers study music in a live setting using g.Nautilus to learn how performers interact, how audiences move during a performance and the social and emotional impact of these experiences.

Measuring emotional response in Dolby Laboratories

Dolby Laboratories is widely known for producing great sound in cinemas, and has been around since 1965. Inside San Francisco, more than a hundred labs are working on enhancements of the technology. One of these projects is using g.Nautilus to study people while they are watching videos. These scientists try to better understand what makes you engaged, what makes your skin blush, increases your heart-rate or gives you goose bumps.

g.NAUTILUS RESEARCH

WIRELESS BIOSIGNAL ACQUISITION

g.Nautilus RESEARCH is the non-certified version of g.Nautilus PRO. Therefore, it is less expensive, and intended to be used for research applications only. The device offers flexible cables to configure the electrode positions as you wish. A dry electrode version based on the worldwide proven g.SAHARA electrodes is available, as well as a version with gel-based g.SCARABEO electrodes with 8/16/32/64 channels.

- g.Nautilus 8/16/32/64, with g.SAHARA dry electrode technology that allows flexible positioning of the electrodes on the cap
- g.Nautilus 8/16/32/64, with a g.SCARABEO electrode system that allows flexible electrode positioning

PRODUCT HIGHLIGHTS

- g.SAHARA dry EEG electrodes
- g.SCARABEO gel based EEG electrodes
- Flexible solution: position the electrodes as you wish; kids' cap available
- 64/32/16/8 channel wireless EEG with 3-axis accelerometer
- 24 bit accuracy at 500 Hz sampling rate (8/16/32 channels)
- 24 bit accuracy at 250 Hz sampling rate (64 channels)
- A new benchmark in usability
- The only wireless system with active technology
- g.tec's unique internal impedance check
- Waterproof device with contactless charging
- 6 hours (64 channels), 10 hours (8, 16, 32 channels) continuous recording and 2–3 hours charging
- 2.4 GHz digital transmission, range: 10 meters indoor
- Full integration into g.tec's software environment
- Used for research applications only

TECHNICAL SPECIFICATIONS

Weight	< 140 g without electrode grid (64 channels) < 110 g without electrode grid (8, 16, 32 channels)
Size	78 (L) × 60 (W) × 36 (H) mm (64 channels) 78 (L) × 60 (W) × 26 (H) mm (8, 16, 32 channels)
Color	BLACK
Sensitivity	±2.25 V, ±1.125 V, ±750 mV, ±562.5 mV, ±375 mV, ±187.5 mV (software selectable)
Interface	Wireless 2.4 GHz ISM band
Digital inputs	8 digital trigger inputs at Base Station
Supply	Built-in lithium-ion battery, runtime > 6 h with 64 channels (> 10 h with 8/16/32 channels), inductive charging according to the QI standard of the Wireless Power Consortium
Amplifier type	Real DC coupled
64 × ADC	24 Bit (1,024 MHz internal sampling per channel)
Noise level	< 0.6 µV RMS between 1 and 30 Hz (at highest input sensitivity)
Input channels	Up to 64 mono-polar / 32 bi-polar channels with GND and REF (software selectable)
Input impedance	DC > 100 MOhm
Safety class	II

g.NAUTILUS MULTI-PURPOSE

WIRELESS BIOSIGNAL ACQUISITION

The g.Nautilus multi-purpose version allows you to acquire both EEG and other biosignals along with data recorded simultaneously from 4 detachable channels, which can connect to other sensors such as ECG/EOG/EMG electrodes or sensors to measure GSR, respiration, and many other signals. This version is available with dry or gel-based electrodes, both of which allow flexible positioning.

- g.Nautilus Multi-Purpose 8/16/32/64, with g.SAHARA active dry electrode technology with 4 detachable channels
- g.Nautilus Multi-Purpose 8/16/32/64, with g.SCARABEO electrode system with 4 detachable channels

PRODUCT HIGHLIGHTS

- record EEG, ECG, EOG, EMG with one wireless device
- combine ExG measurements with external sensors

TECHNICAL SPECIFICATIONS

Weight	< 140 g without electrode grid (64 channels) < 110 g without electrode grid (8, 16, 32 channels)
Size	78 (L) × 60 (W) × 36 (H) mm (64 channels) 78 (L) × 60 (W) × 26 (H) mm (8, 16, 32 channels)
Color	BLACK
Sensitivity	±2.25 V, ±1.125 V, ±750 mV, ±562.5 mV, ±375 mV, ±187.5 mV (software selectable)
Interface	Wireless 2.4 GHz ISM band
Digital inputs	8 digital trigger inputs at Base Station
Supply	Built-in lithium-ion battery, runtime > 6 h with 64 channels (> 10 h with 8/16/32 channels), inductive charging according to the QI standard of the Wireless Power Consortium
Amplifier type	Real DC coupled
64 × ADC	24 Bit (1,024 MHz internal sampling per channel)
Noise level	< 0.6 µV RMS between 1 and 30 Hz (at highest input sensitivity)
Input channels	Up to 64 mono-polar / 32 bi-polar channels with GND and REF (software selectable)
Input impedance	DC > 100 MOhm
Safety class	II

g.NAUTILUS FNIRS

WIRELESS BIOSIGNAL ACQUISITION

PRODUCT HIGHLIGHTS

- Combined fNIRS and EEG measurements with a single wireless system
- g.SCARABEO gel based EEG electrodes
- LED based fNIRS sensors for the forehead and for central positions
- Flexible solution: position the electrodes as you wish
- 32/16/8 channel wireless EEG with 3-axis accelerometer
- 24 bit accuracy at 500 Hz sampling rate for EEG
- 10 Hz sampling rate for (8 channel) fNIRS
- A new benchmark in usability
- The only wireless system with active technology
- g.tec's unique internal impedance check
- 10 hours continuous EEG recording and 2–3 hours charging (32 channel version); 1.5 hours (high power LED)–8 hours (low power LED) of fNIRS recording
- Wireless digital transmission, range: 10 meters indoor
- Full integration into g.tec's software environment
- Used for research applications only

g.Nautilus fNIRS is a wireless EEG and fNIRS (functional near-infrared spectroscopy) acquisition system. fNIRS can assess the oxygenation status and hemodynamics of the brain non-invasively. The oxygenation depends on how the brain reflects light, which changes as brain areas become more active. Researchers can thus infer brain activity in real-time based on changes in blood oxygenation and other factors. The fNIRS measures oxy-, deoxy- and total hemoglobin. The EEG instead measures the electrical activity of the brain and provides high temporal resolution, unlike fNIRS.

The system combines both signals in a single device, which sets a new standard of usability. In combination with g.tec's active electrode technology, users get top-quality EEG recordings from 32/16/8 EEG channels and 8 fNIRS channels within a few minutes.

- g.Nautilus fNIRS 8/16/32, with g.SCARABEO electrode system plus 8 fNIRS channels

TECHNICAL SPECIFICATIONS

Weight	< 140 g without electrode/optode grid
Size	78 (L) × 122 (W) × 40 (H) mm
Color	BLACK
Sensitivity	±2.25 V, ±1.125 V, ±750 mV, ±562.5 mV, ±375 mV, ±187.5 mV (software selectable)
Interface	Wireless 2.4 GHz ISM band
Digital inputs	8 digital trigger inputs at Base Station
EEG Supply	Built-in lithium-ion battery, runtime > 10 h, inductive charging according to the QI standard of the Wireless Power Consortium
fNIRS Supply	Exchangeable lithium-ion battery
Amplifier type	Real DC coupled
32 × ADC	24 Bit (1,024 MHz internal sampling per channel)
Noise level	< 0.6 µV RMS between 1 and 30 Hz (at highest input sensitivity)
Input channels	Up to 32 mono-polar / 16 bi-polar channels with GND and REF (software selectable)
Input impedance	DC > 100 MOhm
Safety class	II

03 Invasive & Non-Invasive Electrical Stimulators

g.Estim PRO Cortical Stimulator **36**

g.Estim FES Functional Electrical Stimulator **38**


OP 4

Invasive and non-invasive stimulation techniques are important for several different applications, and can be used in many important applications in neuroscience and rehabilitation research

BRAIN MAPPING WITH PERIPHERAL AND INTRACRANIAL BRAIN STIMULATION

Invasive stimulation of the cortex, and non-invasive nerve and muscle stimulation, have all been very helpful in our understanding of brain function. By stimulating the periphery, cortical responses can be produced, whereas stimulating the brain can produce motor movements. Both mapping strategies help us better understand cortical functions and perform brain-mapping experiments with a closed-loop system.

BRAIN MAPPING WITH ELECTRICAL CURRENT STIMULATION

Intracortical brain stimulation is often performed in patients with epilepsy or tumor to identify the eloquent cortex. Doctors may stimulate motor regions that are responsible for movements of the finger, arm, leg, or other areas, and then observe the resulting movement. Doctors can also stimulate sensory regions to induce sensation and ask what the patient experienced. To map brain areas responsible for language, patients may be asked to name pictures while doctors stimulate the auditory cortex. If this stimulation interferes with the naming task, doctors have a better idea which regions produce language.

MEDIAN NERVE STIMULATION

Median nerve stimulation may be performed by putting stimulating electrodes onto the arm close to the median nerve. This produces a hand movement and a somatosensory evoked potential (SEP) in the brain, which is measured with an ECoG area over the corresponding area. The central sulcus can be identified by detecting a phase reversal of the SEP in the recorded signal, which is an important landmark for neurosurgery.

FUNCTIONAL ELECTRICAL STIMULATION

Functional electrical stimulation (FES) can also trigger movements of different areas of the body. After a doctor or therapist mounts stimulation electrodes over the corresponding muscle or muscle group, the FES system can send a current through the muscles to initiate movement. This technique can be applied in stroke patients or spinal cord injury patients to reduce spasticity and help encourage movement.

User Experience

Gerwin Schalk, PhD
Deputy Director and Scientist, NCAN National Center for Adaptive Neurotechnologies, New York, USA

"The g.Estim PRO is opening completely new directions for our research, because its function can be precisely controlled by experimental software. This allows highly specific manipulation of cortical function in basic neuroscience as well as clinical applications."

Vivek Prabhakaran, MD, PhD
University of Wisconsin-Madison, USA

"We use the g.Estim FES in our research study involving stroke patients with upper extremity deficits. It is a solid and reliable system that is easy to use in our research."

g.ESTIMPRO
CORTICAL STIMULATOR

g.Estim PRO is a constant current, biphasic electrical stimulator intended to stimulate neural tissue during functional brain mapping procedures prior to cortical resections in the vicinity of essential cortex. The device is CE certified (Europe) and FDA-cleared (USA) for use in human patients for investigations like electrical cortical stimulation (ECS) mapping. Therefore, g.Estim PRO must be used by medically trained and qualified personnel within a medical environment.

g.Estim PRO has an applied part of type BF with connectors for bipolar stimulation electrodes (anode and cathode). The device is controlled by a computer via an USB connection. It also has digital outputs for synchronization with other devices. A hand-switch allows you to manage stimulation manually. A foot-switch can also be used to immediately enable/disable stimulation.

g.Estim PRO includes an impedance check and measures the actually applied stimulation current and voltage for verification purposes. With its 80V compliance voltage, it is perfectly suited for use with standard as well as high-impedance electrodes, and is able to produce the required stimulation current. For closed-loop experiments, a g.USBamp or g.HIamp is used with g.HIsys to record EEG/ECoG data, perform real-time analysis and control the g.Estim PRO for cortical stimulation (for research purposes only).

HAND SWITCH

The hand switch is an accessory for the g.Estim FES. Users connect the hand switch to the hand/foot switch input of the g.Estim FES. With the hand switch, you can start stimulation by pressing the blue STIMULATE button after the device has been set "active" via the software and the "active" LED is on. During stimulation, the hand switch allows users to abort stimulation by pressing the grey ABORT button.

FOOT SWITCH

The foot switch is another accessory for the g.Estim FES that can be connected to the hand/foot switch input of the g.Estim FES. When the foot switch is used and pressed, the stimulator accepts a cue to start stimulation from the software or from devices connected to the digital input ports. When the foot switch is released, stimulation is aborted.

PRODUCT HIGHLIGHTS

- Delivers bi-phasic constant current pulses
- Stand-alone device that can be controlled in real-time from a computer system
- Can send triggers to other devices for synchronization
- Includes electrode impedance check and stimulation current monitoring
- CE-certified and FDA-cleared medical device for use in human patients

TECHNICAL SPECIFICATIONS

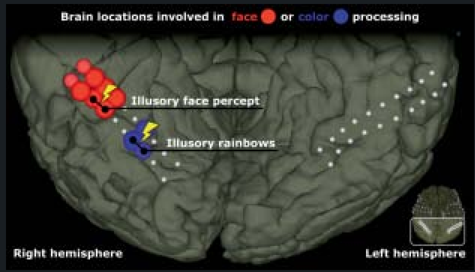
Stimulus current output	±0.2–15 mA (±10 % or 50 µA whichever greater)
Phase shape	rectangular
Phase duration	0.1–1.0 ms in 10 µs increments (±10 % or ±20 µs whichever greater)
Pulse rate	2–100 pulses/second in 0.1 increments (±10 %) (Pulse onset interval from 500 ms down to 10 ms)
Train duration	1 pulse–20 seconds
Power supply	2 × 9 V battery, USB-connection
Certification and Standards	IEC 60601-1, IEC 60601-1-2, IEC 60601-2-40, IEC 62304, IEC 62366, ISO 14971

Application Example

FUNCTIONAL LOCALIZATION IN THE HUMAN BRAIN

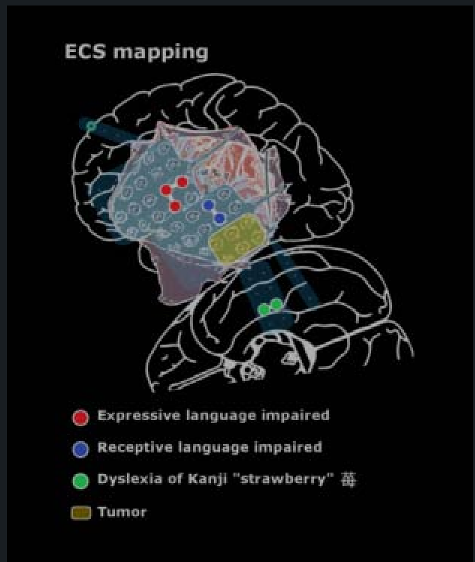
The human brain handles a myriad of mental processes and cognitive tasks, including several tasks required for visual perception. Many studies investigated the role of individual brain regions during dedicated mental processes to try to determine whether a specific brain region is exclusively engaged in a specific process. A recent study addressed that question by electrically stimulating the ventral temporal area of a patient who underwent surgical treatment for epilepsy. Electrical stimulation of color- and face-selective sites, which were identified by visual evoked responses in the brain waves, affected only color and face percepts, respectively. The patient reported effects such as illusory faces on top of objects and distorted perception of faces during stimulation of face-selective regions, and the appearance of illusory rainbows near color-preferring sites. These findings support the theory that the brain at least partly consists of specialized regions that are exclusively and causally engaged in a dedicated, specific mental process.

Credits: Schalk, G., Kapeller, C., Guger, C., Ogawa, H., Hiroshima, S., Lafer-Sousa, R., Saygin, Z.M., Kamada, K. and Kanwisher, N., 2017. Facephenes and rainbows: Causal evidence for functional and anatomical specificity of face and color processing in the human brain. Proceedings of the National Academy of Sciences, p.201713447.



ECS MAPPING

The technique is also used for tumor resections to identify the eloquent cortex, including expressive and receptive language regions. ECS is used to temporarily impair these functions while the patient performs a task such as answering questions or naming pictures. During the resection, the neurosurgeon tries not to remove these functional regions.



DEEP BRAIN STIMULATION (DBS)

Treatment for patients suffering Essential Tremor or Parkinson's Disease can include a Deep-Brain Stimulation (DBS) device. These devices emit short electrical pulses to directly stimulate brain tissue. In this approach, depth electrodes are implanted into the brain using a neuro-navigation system. The coordinates are extracted based on each patient's anatomy. The exact positioning of the stimulation electrodes is essential for effectively helping the patient. The DBS control device is usually implanted in the patient's chest, and is connected to the stimulation electrode mechanism in the brain. The effects of Essential Tremor or Parkinson's Disease can then be attenuated by the systematic stimulation of the relevant brain area. This can dramatically improve patients' quality of life by enabling them to move more freely through their daily activities. Every year, thousands of surgeries like this are performed worldwide.

The approach also bears some disadvantages. The electrodes are inserted into the brain until a certain position is reached, and the effects of the disease attenuate. However, this procedure occurs without consideration of relevant functional brain regions, and is therefore rather approximate. Next, the stimulation is performed steadily, and thus the brain is continually affected until the stimulator has to be exchanged when its battery is empty.

g.tec developed a research system that allows doctors to position the stimulation electrode based on precise knowledge of functional brain region and optimize the electrical stimulation to provide more flexible stimulation on demand. The optimization of stimulation parameters and timing reduced battery use, and thus the need for battery replacement. This procedure also paves the way for scientific studies for the optimization of DBS.

g.tec's biosignal amplifiers and electrical stimulators can be used for setting up closed-loop systems to optimize DBS. Real-time analysis of biosignal data (local field potentials and/or multi-/single- unit activity) acquired from a variety of brain regions can be done to control the stimulation. It's also possible to analyze the brain activity in real-time and stimulate different electrode positions for performance optimization. This would lead to better positioning and control of DBS electrodes and nearby brain areas, which in turn could further reduce tremor and other effects of Parkinson's Disease, reduce battery power consumption via event-related stimulation, and enable rapid prototyping for scientific research in DBS.

g.ESTIMFES
FUNCTIONAL ELECTRICAL STIMULATOR

The g.Estim FES is a constant-current, biphasic electrical stimulator and is intended for temporary reduction of muscle spasms, prevention or retardation of disuse atrophy, increasing local blood flow in the treatment area, muscle re-education, prevention of post-surgical phlebo-thrombosis through immediate stimulation of calf muscles, and maintaining or increasing range of motion.

g.Estim FES has an applied part of type BF with connectors for bipolar stimulation electrodes (anode and cathode). The device is controlled by a computer via an USB connection. It also has digital outputs for synchronization with other devices. An optional hand-switch allows you to perform stimulation manually. Alternatively, an optional foot-switch can be used to explicitly enable/disable stimulation. g.Estim FES includes an impedance measurement function and contains a high-impedance stop mechanism that stops stimulation when electrode contact becomes loose.

For closed-loop experiments, g.USBamp, g.HIamp or g.Nautilus with g.HIsys is used to record EEG/ECoG data, perform real-time analysis and to control the g.Estim FES for muscle or nerve stimulation.

HAND SWITCH

The hand switch is an accessory of the g.Estim FES. Users connect the hand switch to the hand/foot switch input of the g.Estim FES. The hand switch allows them to start stimulation by pressing the blue STIMULATE button after the device has been set active via the software and the "active" LED is on. During stimulation, the hand switch allows users to abort stimulation by pressing the grey ABORT button.

FOOT SWITCH

The foot switch is another accessory of the g.Estim FES and can be connected to the hand/foot switch input of the g.Estim FES. When the foot switch is used and pressed, the stimulator accepts a cue to start stimulation from the software or from devices connected to the digital input ports. When the foot switch is released, stimulation is aborted.

STIMULATION ELECTRODES

FES electrodes are fixed on the position where the muscle should be stimulated.

PRODUCT HIGHLIGHTS

- Delivers bi-phasic constant current pulses
- Stand-alone device that can be controlled from a computer system
- Can send triggers to other devices for synchronization
- Includes electrode impedance check and stimulation current monitoring
- CE-certified and FDA-cleared medical device for use in humans

TECHNICAL SPECIFICATIONS

Stimulus current output	±1–60 mA (±10 %)
Phase shape	rectangular
Work time	2–20 s in 0.5 s increments (±10 % accuracy)
Rest time	2–50 s in 0.5 s increments (±10 % accuracy)
Phase duration	50–400 µs in 10 µs increments (±10 % or ±10 µs whichever greater)
Pulse rate	1–100 pulses/second in 1 pulse increments (±10 %) (Pulse period from 1 s down to 10 ms)
Rising/falling ramps	0–10 s in 0.5 s increments (±5 % accuracy)
Power supply	2 × 9 V battery, USB-connection
Certification and Standards	IEC 60601-1, IEC 60601-1-2, IEC 60601-2-10, IEC 62304, IEC 62366, ISO 14971

Application Examples

SPINAL CORD INJURY

The g.Estim FES may be indicated for muscle stimulation when muscles that are partly or fully paralyzed due to central nervous system injury should be contracted to generate movement, such as in patients with spinal cord injury. The BCI system can be used to detect the patient's motor imagery and can trigger the FES to produce the required hand movement.

Gaurav Sharma, PhD
Battelle Memorial Institute
in Ohio, USA

"The goal of this project was to develop technologies that can enable a paralyzed person to regain voluntary control of his/her own limbs using signals recorded from within the brain. The neural bypass technology developed at Battelle uses signals recorded using an implanted brain-computer interface (BCI), machine learning algorithms to decode the signals, and a custom designed neuromuscular electrical stimulation sleeve to stimulate the muscles to evoke the movement that the participant is thinking about. Using this technology, our participant was able to regain control of his hand to grasp, manipulate and transfer different objects that are relevant to the activities of daily living. With use of this investigational technology, our participant, who has a C5/C6 level spinal cord injury (SCI), gained wrist and hand function consistent with a C7-T1 level of injury."

In 2016, Gaurav Sharma from Battelle Memorial Institute in Ohio (USA) won the BCI Award 2016 with his project about an implanted BCI for real-time cortical control of wrist and finger movements. Battelle is the world's largest independent, non-profit research and development organization. It was founded in 1925 in Columbus, Ohio (USA). Battelle's mission is to translate scientific discovery and technology advances into societal benefits. Gaurav Sharma is part of the Medical Devices Group at Battelle and the lead investigator on the NeuroLife™ program.

NEUROREHABILITATION

FES is used in rehabilitation programs that aim to help persons regain control of lost functions and/or substitute lost functions with other abilities. FES can be used for the neurorehabilitation of stroke patients with BCI technology. In this application, the patient is instructed to imagine right or left hand movement, which the BCI system can detect. Then, the system triggers a hand movement with the FES, which pairs cognitive processes with motor movements. The patient's hand is really moving! The patient can feel and see the movement, which helps the patient re-learn the connection between thinking about moving and actually moving. This is a big advantage over hand movements that aren't coordinated with motor imagery. Furthermore, FES can also be applied on other muscle groups that should be treated.

REDUCE SPASTICITY

After spinal cord injury or stroke, patients may experience spasticity in their hands, which can be painful. In this case, FES can be applied with a lower intensity for several minutes to reduce the muscle spasm.

Find g.tec's complete product list in the Download section of www.gtec.at

04 External Trigger Generation

g.STIMbox Digital Stimulation Box **42**

g.TRIGbox Multimodal Trigger Box **43**

g.STIMBOX
DIGITAL STIMULATION BOX

PRODUCT HIGHLIGHTS

- µC controlled inputs and outputs for accurate timing
- Digital outputs can produce precisely-timed paradigms
- Digital inputs can be acquired and used within the recording system
- Direct control of inputs/outputs from a computer via USB
- 14 digital inputs (TTL) and 16 digital outputs (TTL)
- Digital outputs usable for tactile or visual stimulation
- C API, MATLAB API and Simulink drivers

The g.STIMbox is used to generate and record trigger signals. You can easily program a wide variety of paradigms to meet your needs, and execute them with high temporal precision. At the same time, trigger signals from external devices can be recorded using the 14 digital inputs of the device. Therefore, the g.STIMbox is an ideal extension for electrophysiological research systems that require additional digital inputs and outputs. The device provides versatile cinch connectors for 8 of the 16 outputs that can be used very conveniently, e.g. with LEDs for visual stimulation, to connect electrical or vibro-tactile stimulators or other devices triggered by 5V pulses. Compact devices like the g.SSVEPbox, which require several output/input channels, are connected using the SUB-D ports of the device.

The 14 digital inputs can be used to record signals from external devices. Here, as above, 8 of the 14 digital inputs are implemented as cinch connectors. The g.STIMbox is connected to the recording computer via USB, offers synchronous and asynchronous operation modes, and comes with a C-Application Programming Interface (API), a MATLAB-API and a Simulink-block.

Highly accurate stimulation frequencies can be defined and are calculated on the g.STIMbox (e.g. 10 Hz for SSVEP stimulation). This can help you implement highly precise SSVEP stimulation, as required for BCI experiments.

TECHNICAL SPECIFICATIONS

Digital inputs	14
Digital outputs	16
Interface	USB
Power supply	USB or external power supply
Frequency range	1–50 Hz for SSVEP stimulation

VISUAL STIMULATION AND PUSHBUTTON

For the g.STIMbox, small input/output devices are available, which are connected to single cinch-connectors and provide basic functionality. The pushbuttons, which are connected to input channels, can be used for many purposes, such as conveying feedback from test subjects into the recording system. The single LED boxes, which are connected to output channels, can be used for visual stimulation.

VIBRO-TACTILE STIMULATION

g.VIBROstim is a compact vibro-tactile stimulator unit to be connected to the output of g.STIMbox. It can be attached to the body (e.g. upper/lower limbs, torso) with Velcro straps or adhesive tape. The intended use is to provide tactile stimulation to the skin for short term applications in research.

SSVEP STIMULATION

The g.SSVEPbox is a stimulation device for Steady-State Visual Evoked Potentials. It can be connected to the g.STIMbox digital outputs. Four ultra-bright, dimmable LEDs provide precise stimulation, and four smaller LEDs indicate which LED is the target LED. The flickering frequencies can be freely configured via software (e.g. with the g.STIMbox MATLAB API). If the g.SSVEPbox is used for BCI experiments, then a paradigm can be realized in Simulink that indicates the target LED in training mode. In real-time control mode, the user can choose the target LED and thus communicate freely. This setup allows many applications, such as moving a robotic device forward, backward, left and right.

Application Example

ROBOTIC CONTROL

If you want to control a robotic system with a steady-state visual evoked potential (SSVEP) based BCI, use the g.STIMbox and connect 4 LEDs. Then, define 4 different stimulation frequencies for the LEDs. We recommend avoiding the alpha region, because the alpha rhythm is often stronger than SSVEP signals in that frequency range. We also recommend choosing frequencies that are not multiples of each other (such as 8 and 16 Hz). For example, you might use 14, 16, 18 and 20 Hz for your four stimulation frequencies.

Use g.HIsys to acquire the EEG data from electrodes placed over the visual cortex and to analyze the SSVEP signals. Then, calibrate the BCI system by instructing the person to look at each LED a couple times while focusing on that LED. After the calibration, the 4 LEDs can be used to move the robot forward, backward, left or right.

To design a visual evoked potential (VEP) experiment, just connect a strobelight or similar device to the digital output and connect one digital output to the biosignal amplifier to have an exact trigger between the EEG data and the flash. Then use g.HIsys to extract, visualize and store the VEPs.

g.TRIGBOX

MULTIMODAL TRIGGER BOX

PRODUCT HIGHLIGHTS

- Simply use PowerPoint for stimulus/paradigm setup and presentation
- > 4 kV isolation between trigger inputs and outputs
- Use various trigger sources from visual, auditory, electrical or tactile stimulators
- Connect to a data acquisition system, g.MOBIlab+, g.HIamp, g.Nautilus or g.USBamp
- Compatible with many other user-specific systems
- Use one encoded trigger channel for up to 16 different experimental conditions

TECHNICAL SPECIFICATIONS

Trigger output voltage	TTL +5 V, BSL 200 mV
Input voltage (low level)	±0.5 mV to ±200 mV (4 inputs)
Input voltage (high level)	±100 mV to ±5 V (4 inputs)
Trigger output duration	Min. 20 ms
Supply	9 V battery or power supply
Current consumption	~40 mA
Low battery indicator	~7 V
Isolation voltage	> 4 kV (input/output)

The g.TRIGbox is a device that generates trigger pulses from various sensors or input signals. Input and output lines are isolated from each other. The trigger outputs can be connected to digital or analog inputs of a data acquisition system (such as g.USBamp, g.HIamp, g.Nautilus or g.MOBIlab+).

Thus, g.TRIGbox provides precise detection and recording of almost any type of stimulation in your experimental paradigms. With its wide range of possible input signals and sensors, you can use various trigger sources such as sound card outputs, microphones, piezoelectric or inductive sensors, response buttons, various logic signals (TTL, C-MOS, ...) provided by external stimulators, visual markers from the computer monitor, LED indicators, strobe lights, or slide projectors. The threshold levels are adjustable separately for each channel. 4 LEDs indicate the proper detection for each channel.

The output signals of the g.TRIGbox are rectangular pulses with a minimum length of 20 ms, assuring a reliable recording of all events even at low sampling frequencies. An additional analog encoded trigger output enables the recording of up to 16 different experimental conditions. In this case, the output signal displays 16 different output voltage levels to be decoded during data analysis (e.g. with g.BSanalyze).

The optical sensors, which can be fixed on the computer screen, allow the quick and comfortable generation of experimental paradigms and stimulation patterns for psychophysiological studies. Special stimulation software is no longer necessary. A simple and easy approach is provided via PowerPoint for stimulus presentation.

Application Example

EXPERIMENTS WITH CRIMINALS

A P300 experiment to identify a "criminal" can be set up pretty easily with the g.TRIGbox. Create a PowerPoint presentation with 50 images of people that the criminal might know (targets) and people that the criminal will not know (non-targets). You should have about five times more non-targets than targets. Put the visual sensor on the screen to precisely detect the slide transition (put little markers in the PowerPoint slides in black and white). The g.TRIGbox will generate a TTL pulse whenever the slide is changed. This pulse is sent to the biosignal amplifier and recorded along with the EEG data. The real-time system can calculate EPs of all the target-images and compare it with the non-target images. The biggest P300 will be visible for the target images that the criminal knows. With this approach, you can then determine whether a new "probe" image is familiar.

Find g.tec's complete product list online in the Download section of www.gtec.at

05 Active Electrode Systems

g.GAMMAsys Active Electrode System 46

g.SCARABEO Active Electrodes 48

g.LADYbird Active Electrodes 49

g.GAMMAclip Active Electrodes 50

g.SAHARAsys Active Dry Electrode System 50


g.GAMMAbox

g.GAMMASYS
ACTIVE ELECTRODE SYSTEM

g.GAMMAsys was designed to make experimental setups for EEG/ECG/EMG/EOG recording fast and easy, while still using a comfortable cap that provides very high signal quality.

g.GAMMAsys is designed to work with all g.tec amplifiers. It includes different types of active and passive electrodes that are connected via g.GAMMAbox to g.USBamp or g.MOBIlab+ and can be mounted with the g.GAMMAcap onto the head for EEG recordings, or can be mounted on the body for ECG/EMG/EOG recordings. The g.GAMMAcap can be configured with electrodes for a certain experiment (such as the P300 speller), and the electrodes remain inside the cap even during cleaning. This makes preparation and cleaning very fast, which speeds up experiments considerably. A typical setup time for a P300 speller experiment (10 electrodes) is about 2 minutes–just put on the cap and inject the gel. After the cap is removed, the gel almost disappears after some time, and gel is removed completely by washing the hair.

PRODUCT HIGHLIGHTS

- Avoid or reduce artefacts from movements and electromagnetic interference
- Fastest electrode montage for multi-channel recordings
- Flexible material, comfortable to wear; one size fits most people
- System can be used instead of standard passive electrodes
- No abrasive skin treatment required; just inject a drop of gel
- Electrodes remain in the cap, which allows fast montage and cleaning
- Single electrodes can be replaced easily
- 74 standard + 86 intermediate positions; user can add positions freely
- 0–10 kHz

TECHNICAL SPECIFICATIONS

g.GAMMAcap	head circumference
Small	50–54 cm
Medium	54–58 cm, fits 95 % of adult subjects
Large	58–62 cm
g.GAMMAcap for kids	head circumference
Mini	32–36cm
Midi	37–43 cm
Maxi	44–48 cm
g.GAMMAbox	
Channels	16
Filter	DC – 10 kHz
Battery supply	9 V
Sockets	2-pin safety

g.SCARABEO
ACTIVE ELECTRODES

g.SCARABEO electrodes are active EEG electrodes with a small form factor to support high-density recordings. The electrode is inserted into a holder ring of the g.GAMMAcap and can be easily removed and plugged into other positions to equip a cap for a certain experiment. Typically, the electrodes remain plugged in to minimize mistakes and to speed up electrode mounting. The g.SCARABEO electrodes with the holder rings can also be assembled on the body with adhesive washers for EMG, ECG or EOG recordings.

PRODUCT HIGHLIGHTS

- Compact active electrode for high-density EEG and multi-purpose applications
- Fully compatible with g.GAMMAsys and g.HIamp's active headbox
- Touchproof sintered Ag/AgCl-ring electrode in a durable molded housing
- Super-fast and reliable setup: fill-and-ready
- Usable with g.GAMMAcap or with adhesive washers
- Simultaneous impedance check of all channels with g.HIamp

TECHNICAL SPECIFICATIONS

Amplification	Inside the electrode
Cables	Required 1.5 kV protection
Connector	2-pin safety

g.LADYBIRD
ACTIVE ELECTRODES

g.LADYbird electrodes are active EEG electrodes with a bigger reservoir for longer recordings with up to 64 channels. The electrode is inserted directly into the g.GAMMAcap and remains plugged in to minimize mistakes and to speed up electrode mounting. The g.LADYbird electrodes can also be assembled on the body with adhesive washers for EMG, ECG or EOG recordings.

PRODUCT HIGHLIGHTS

- Compact active electrode for high-density EEG and multi-purpose application
- Fully compatible with g.GAMMAsys and g.HIamp's active headbox
- Touchproof sintered Ag/AgCl-ring electrode in a durable molded housing
- Super-fast and reliable setup: fill-and-ready
- Usable with g.GAMMAcap or with adhesive washers
- Simultaneous impedance check of all channels with g.HIamp

TECHNICAL SPECIFICATIONS

Amplification	Inside the electrode
Cables	Required 1.5 kV protection
Connector	2-pin safety

g.GAMMACLIP

ACTIVE ELECTRODES

The g.GAMMAclip contains an amplifier inside and allows you to attach disposable EMG/ECG electrodes for high quality recordings. The active electrode system greatly reduces noise produced by movements and interference with other devices, and thereby provides very high-quality data, even in challenging usage situations.

PRODUCT HIGHLIGHTS

- Compact active clip for recordings with disposable electrodes
- Fully compatible with g.GAMMAsys and g.HIamp's active headbox
- Super-fast and reliable setup

TECHNICAL SPECIFICATIONS

Amplification	Inside the clip
Cables	Required 1.5 kV protection
Connector	2-pin safety

g.SAHARASYS

ACTIVE DRY ELECTRODE SYSTEM

Normally, the electroencephalogram (EEG) is recorded from the surface of the head with gel-based electrodes to provide a low electrode-skin impedance. If passive electrodes are used, the skin must be abraded beforehand to reduce the impedance. With active electrodes, which contain an amplifier inside, the electrode gel is injected between the electrode material and the skin. This allows the electrode system to be mounted more quickly.

One of the main advantages of gel-based active electrodes is their robust signal quality, but the main disadvantages are the long mounting time and the need to wash the cap and the user's hair after the recording. g.tec thus developed a dry electrode system that does not require electrode gel. The patented g.SAHARA electrode system consists of an 8 pin electrode made of a special golden alloy. The pins have sufficient length to reach through the hair to the skin. The golden alloy and the 8 pins reduce the electrode-skin impedance. The electrode itself can be connected with a clip to the active electrode system on top of it.

EEG recordings may be obtained from frontal, central, parietal and occipital regions of the head. Therefore, electrodes are usually mounted in a cap that holds the electrodes on the skin with a constant pressure at every recording location. EEG electrodes are typically positioned according to the international 10/20 system. g.tec hence developed the 2nd generation of the g.GAMMAcap, with a total of 160 positions according to an extended 10/20 system, to allow a very flexible electrode montage.

The design of the g.SAHARA electrode system allows users to just plug the electrode and the clip into the cap at the desired location.

PRODUCT HIGHLIGHTS

- The first and only dry electrode system that works for all frontal, central, occipital, temporal and parietal sites
- The first dry active electrode available on the market
- Patented technology
- The first and only dry system successfully tested with all major BCI approaches in group studies, reported in peer-reviewed papers
- Same cost range as an active EEG electrode with gel–but requires no gel
- Captures the whole EEG frequency spectrum from 0.1–40 Hz
- Mount the cap in under one minute!
- No more need to wash the hair or cap!
- Able to pick up frequency spectra for P300, motor imagery and SSVEP based BCIs

TECHNICAL SPECIFICATIONS

Amplification	Inside the electrode clip
Cables	Required 1.5 kV protection
Connector	2-pin safety
Pin length	7 mm or 16 mm
Number of pins	8

The clip fits very well in the electrode and holds the electrode precisely within the cap. g.SAHARA electrodes are available with different pin lengths. This is very useful for different head shapes and hair thicknesses. For example, users with some hairstyles may prefer to use shorter versions at central regions and longer versions at parietal sites.


g.tec

Application Example

Brain-computer interfaces (BCI) usually rely on the P300, motor imagery or steady-state visually evoked potentials (SSVEP), measured with the electroencephalogram (EEG), to control external devices. The EEG is measured non-invasively with electrodes mounted on the human scalp using conductive electrode gel for optimal impedance and data quality. But using gel also entails some disadvantages: long mounting time, skin abrasion (with passive electrodes) and the need to wash the hair and cap after the recording. Therefore, a dry active electrode system was developed and compared to gel based active electrodes. Numerous subjects performed P300, motor imagery and SSVEP based BCI experiments. Evoked potentials, event-related desynchronization, power spectrum and accuracies were compared for dry and gel-based electrodes. The peer-reviewed, published studies showed that the new dry electrodes can pick up the corresponding frequency ranges of the EEG data for all three BCI approaches, and also showed that subjects' accuracy with BCI systems was about the same for gel and dry electrodes. However, the dry electrodes did not require extensive cap mounting time, skin abrasion, or hair washing. Nevertheless, dry electrodes are more sensitive to noise, movements of cables and electrostatic charges. Therefore, carefully mounting the cap and maintaining and a well-controlled environment are important.

Credits: C. Guger, G. Krausz, B.Z. Allison, G. Edlinger, Comparison of dry and gel based electrodes for P300 brain-computer interfaces, Frontiers Neuroscience, 2012

User Experience

Christoph Guger,
CEO g.tec medical engineering

"The Frontiers article comparing dry and gel electrodes for BCIs has been cited more than 97 % of all Frontiers articles, which shows the importance of this topic."

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06 Body Sensors

Temperature Sensor	**55**
Blood Pressure Monitoring Sensor	**55**
Snoring Sensor	**55**
Respiration Airflow Sensor	**55**
Respiration Effort Sensor	**55**
Oxygen Saturation Sensor	**55**
Galvanic Skin Response Sensor	**56**
Acceleration Sensor	**56**
Limb Movement Sensor	**56**

EEG, EOG and EMG can be measured with electrodes attached to the human body. The electrodes pick up the electrical activity of the underlying neurons. Different sensors are required to measure other signals from the body. Therefore, g.tec provides various sensors for physiological and physical signals. All sensors provide analog output signals, and are designed to be connected directly to the amplifier inputs or to the analog inputs of the data acquisition system. For safety reasons, all sensors, adapter cables and interface boxes are equipped with DIN 1.5-mm touchproof safety connectors.

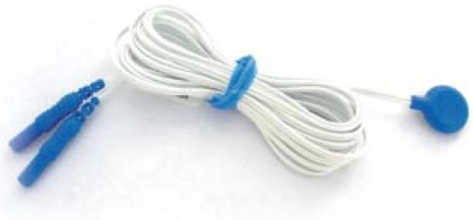
TEMPERATURE SENSOR

The temperature sensor can be used to measure skin temperature between 20–45 °C (accuracy 0.2 °C). The sensor is already calibrated and provides an output voltage of 0–200 mV.

BLOOD PRESSURE MONITORING SENSOR

g.CNAP is a system for non-invasive BP recording and can be used as a stand-alone system as well. The analog output signal (continuous BP in mmHg) can be recorded with other parameters and biosignals with g.tec systems.

SNORING SENSOR



Piezo-electric snoring sensor picks up tracheal sounds for sleep research. The sensor can be placed on the neck of the patient.

RESPIRATION AIRFLOW SENSOR

This thermistor sensor is placed in front of nose and mouth and measures temperature changes in inhaled and exhaled air. The resulting respiration signal is very robust against movement artifacts.

RESPIRATION EFFORT SENSOR

Piezo-electric crystal sensor in a robust belt system. Can be used to record chest and abdominal respiration waveforms independently. Our respiration sensors connect directly to amplifier inputs.

OXYGEN SATURATION SENSOR

Two light sources with different wave lengths are used to measure the saturation of oxygen in the blood (SpO2) and the pulse. A sensor for the index finger or ear-lobe is available. A calibrated output signal is provided.

GALVANIC SKIN RESPONSE SENSOR

This method is also called EDA (electro-dermal activity) or skin conductance, where two small electrodes are placed on fingers without gel. The isolated circuit guarantees no interference with other electrodes on the body. Technical details: 0–30 µS, 1 µS (micro MHO) calibration button.

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ACCELERATION SENSOR

The acceleration sensor can be applied on the subject's body or directly in a simulator, vehicle or airplane to monitor g-forces, acceleration and vibration. Technical details: 3-axes, ±3 g acceleration.

LIMB MOVEMENT SENSOR

The piezo-electric sensor is placed on the ankle to detect movements of the feet during sleep to investigate restless leg syndrome (RLS) and periodic limb movements (PLMs).

07 Software Components for g.tec's BCI Environment

g.HIsys High-Speed Online Processing for SIMULINK **59**

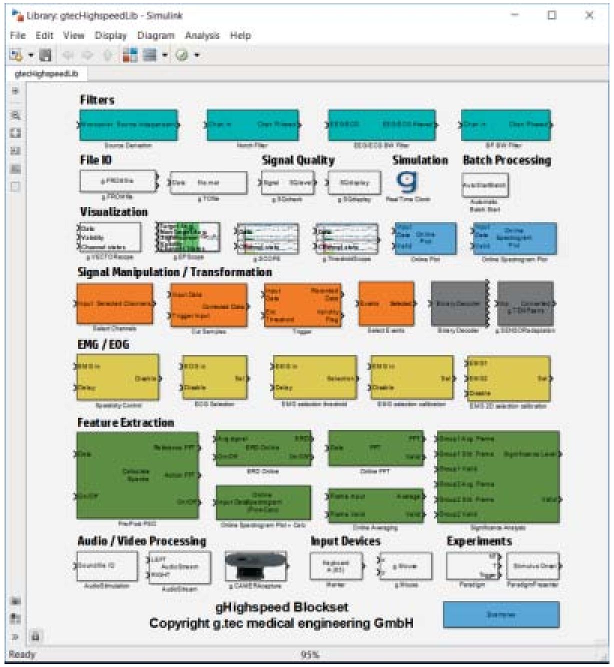
g.Recorder Biosignal Recording Software **65**

g.BSanalyze Offline Biosignal Analysis for MATLAB **66**

g.NEEDaccess Network Enabled Easy Data Access **76**

g.tec designed several software tools that fully integrate the g.HIamp, g.Nautilus, g.USBamp and g.MOBIlab+ for real-time experiments and off-line studies. For developers and programmers, there are APIs for Windows based programming languages as well as for MATLAB. Powerful online/real-time signal acquisition and processing is provided by our High-Speed Online Processing environment for SIMULINK. Comfortable hardware configuration, signal visualization and storage is possible with g.Recorder, g.tec's recording software under Windows. Special plugins for g.Recorder allow online parameter extraction and visualization for clinical research. Offline biosignal analysis with specialized toolboxes for EEG, ECG, classification, high resolution mapping and CFM (cerebral function monitor) analysis is provided with g.BSanalyze (available for MATLAB or stand-alone).

g.HISYS
HIGH-SPEED ONLINE PROCESSING FOR SIMULINK



Online biosignal processing and recording with maximum system speed. Easy setup and rapid prototyping for bio-feedback/ neurofeedback and Brain-Computer Interface (BCI) applications. Full SIMULINK functionality, with easy set-up of user-specific applications.

The g.HIsys Highspeed Online Processing for Simulink lets you collect biosignal data like EEG, ECoG, EMG, EOG and ECG within a Simulink model for further real-time processing and is available for g.MOBIlab+, g.HIamp, g.USBamp and g.Nautilus. Therefore, the device driver blocks for these devices are copied into the Simulink model and are connected to other blocks that do the signal analysis. Then, the model is started, and the device driver guarantees real-time processing.

This Rapid Prototyping environment speeds up the development cycle dramatically, and your first real-time experiments can begin within a few hours. The Highspeed Online Processing blockset allows you to use all standard SIMULINK blocks in your model and to write your own blocks in MATLAB or C.

The device driver block gives you access to all amplifier specific settings like sampling frequency, digital I/O lines, bandpass and notch filtering. Just double-click the g.MOBIlab+, g.HIamp, g.USBamp or g.Nautilus block to perform the settings. Then, click on Play in the SIMULINK model to start the biosignal acquisition. Additionally, g.HIsys comes with many useful blocks for pre-processing, transformation, analysis and storage.

Data can be visualized with Scope blocks and stored on the hard disk in MATLAB format. The model works with double precision accuracy. g.MOBIlab+ can store the data during acquisition on an SD card inside the unit.

PRODUCT HIGHLIGHTS

- Acquire and process EEG, ECoG, ECG, EMG, EOG and spike data directly within Simulink
- Wireless biosignal data acquisition with g.MOBIlab+ and g.Nautilus
- Add your own sophisticated data processing algorithms graphically
- Benefit from the Rapid Prototyping environment for developing, testing and releasing your biosignal applications
- No compilation of the Simulink model is necessary for real-time analysis
- Use standard Simulink blocks for online analysis
- Add your own algorithms, such as MATLAB S-Functions or C S-Functions
- Store data to the MATLAB workspace or to a MATLAB file
- Display Evoked Potentials in real-time
- Acquire eye-movement data together with biosignals
- Create closed-loop experiments with g.tec's stimulators
- Use the g.tec toolboxes with ready to go applications

g.HIsys Block Library

g.HIsys comes with specialized blocks for biosignal analysis that are needed in many real-time experiments. The library contains blocks for plotting data, pre-processing (source derivation, Notch filter, bandpass filter), transformation (pre-post trigger, cut samples, select channels), feature extraction (on-line averaging, ERD online, online FFT, Pre/Post PSD, spectrogram, significance analysis), output signals through muscle activity (spasticity control, EOG selection, EMG selection) and a binary decoder.

FILTERS

The source derivation, notch filter, EEG/ECG BW filter and BP BW filter blocks allow you to remove artifacts from the data or to extract certain components.

FILE IO

The g.FROMfile and g.TOfile blocks are highly optimized blocks for quickly streaming data, which is especially important for a high number of channels or high sampling rates (up to 38.4 kHz per channel). The blocks also allow you to define a maximum file size to avoid unnecessarily large data-sets.

SIGNAL QUALITY

The g.SQcheck and g.SWdisplay allow you to perform real-time artifact detection and to identify whether the data are clean during the experiment.

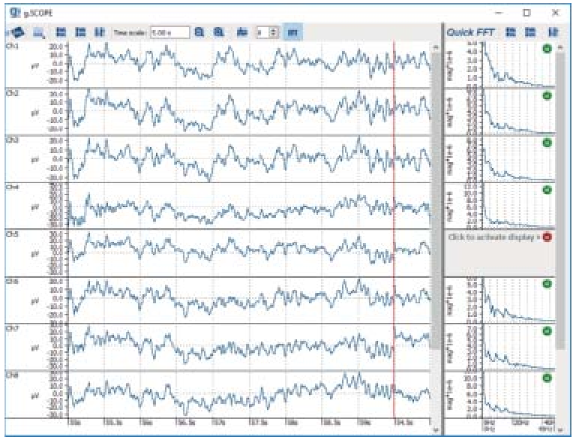
SIMULATION

The Real Time clock allows you to run the Simulink model without an amplifier connected and to simulate real-time behavior.

BATCH PROCESSING

The Batch Processing block allows to specify necessary off-line processing steps for a certain Simulink model. When the Simulink model is stopped, the processing is automatically performed.

VISUALIZATION



The g.VECTORscope allows you to visualize signal averages of multiple channels. The g.EPscope can show EPs from target and non-target signals and perform a statistical analysis. The g.SCOPE is used to visualize raw biosignal data, and the g.THRESHOLDscope allows you to visualize biosignal data and manually define a triggering threshold. The Online Plot and Online Spectrum Plot are used to visualize EPs and spectrum data.

SIGNAL MANIPULATION/TRANSFORMATION

The Select Channels blocks allow you to perform the signal processing steps on a sub-set of channels, the Cut Samples block is used for EPs to select a pre- and post-stimulus interval and the Trigger block allows you to select epochs for EPs. The Select Events block selects event codes from the incoming events. For each change of the incoming event code (from zero to a non-zero value), the event codes are compared to specified event codes for selection. The Binary Decoder converts data into binary format e.g. to generate trigger signals. The g.SENSORadaption block converts input data from a g.tec sensor (such as a temperature sensor, g.Sensor, GSR sensor and SpO2 sensor) into meaningful outputs corresponding to the sensor.

EMG/EOG

Spasticity Control allows you to check the EMG contraction level. EOG Selection allows you to control a device with eye-blinks and eye-movements. EMG selection threshold calculates the RMS and allows you to trigger on muscle movements. EMG selection calibration allows you to calibrate on certain muscle movements to generate triggers, if the threshold is crossed, and EMG 2D selection calibration allows 2D muscle control.

FEATURE EXTRACTION

Feature extraction blocks allows you to calculate the power spectrum, ERD, FFT, averages and to perform a significance analysis.

AUDIO/VIDEO PROCESSING

The AudioStimulation block presents a set of pre-recorded sound files via a low-latency sound driver to create different types of audio stimulation. The sound files can be enabled using a given sound ID. The g.AudioStream block sends stereo CD quality sound output to the standard speakers from Simulink. The g.CAMERAcapture block allows you to record videos together with biosignals.

INPUT / OUTPUT

The Marker block is for keyboard and mouse markers in Simulink. The block checks the system for keyboard and mouse events and generates markers accordingly. Multiple blocks can be used to look for different events. The g.Mouse block can generate cursor movements via Simulink, similar to mouse control.

EXPERIMENTS

The Paradigm block can be used for audio, picture, video and text paradigms. The Paradigm Presenter allows you to run multimodal paradigms with videos, audio, text, images and DIO with g.STIMbox.

EXAMPLES

Examples contains many ready-to-go Simulink models.

Toolboxes

g.tec develops many toolboxes that run under g.HIsys. These toolboxes contain all real-time processing code and allow to interact with g.BSanalyze to calibrate BCI systems or to perform off-line analysis.

G.RTANALYZE REAL-TIME ANALYSIS

g.RTanalyze is a biosignal processing blockset for use with Simulink. The g.RTanalyze blocks can be used for on-line simulations under Simulink and for real-time applications with Highspeed Online Processing for Simulink. Drag and drop the pre-processing, parameter estimation and classification algorithms into your SIMULINK real-time application to accelerate your research, encourage creativity and reduce project costs. The blockset enables you to quickly compare multiple algorithms. Use the blocks as templates and make your own modifications.

The blockset is divided into general purpose blocks and biosignal processing blocks. General purpose blocks are derivations, filters and different algebraic blocks. Biosignal processing blocks are used for pre-processing, parameter estimation and classification of off-line or real-time EEG, ECG, EMG, respiration or galvanic skin response data.

Included parameter estimation blocks are: Hjorth parameters, Barlow parameters, Bandpower, Variance and Adaptive Autoregressive Models with RLS, Kalman and LMS algorithms, minimum energy, EMG co-activation index and EMG spasticity. All important methods for BCIs based on P300, motor imagery, SSVEP/SSSEP and slow cortical potentials are included. The ECG block allows you to calculate heart-rate and heart-rate variability parameters. Furthermore, respiration rate/deepness and the change rate of galvanic skin response can be calculated. The blockset contains also blocks to control a system with EOG and EMG activity for human computer interaction.

The apply classifier block allows you to use linear and non-linear classifiers for the on-line classification of parameters. Examples are linear discriminant analysis or support vector machine based classifiers calculated in g.BSanalyze. The classifier block also performs a statistical analysis to realize a zero class for BCI control. This means that the BCI system will not make a decision if the subject is not paying attention. Furthermore, blocks for majority voting and change rate calculation are included.

G.DISTRIBUTEDEEG

g.DISTRIBUTEDeeg allows you to record biosignal data using the g.tec amplifier g.USBamp from different distributed PCs (DataPCs) in the network and transmit the recorded data to a central evaluation / data storage PC (EvalPC). Data acquired from the DataPCs are synchronized using the OSC protocol for distributed systems, and the data are transmitted to the EvalPC using the UDP network interface.

MULTI-DEVICE ACQUISITION

g.HIsys also supports the acquisition from multiple g.tec amplifiers of similar or different types. This means a g.Nautilus can be used with a g.USBamp or g.HIamp, even with different sampling frequencies. You can also use multiple g.HIamps, g.USBamp or g.Nautilus in one single Simulink model. In Simulink, every amplifier is set up with a certain, individual sampling frequency. The amplifier block delivers the data samples in real-time to a Scope, to the signal analysis or to store the data. This allows you to work with more

than 256 channels e.g. for ECoG studies, and it also allows you to record from multiple users at the same time on one single computer. This makes the online data quality control much easier, requiring only one computer for data storage that can analyze data from multiple users.

CAMERA CAPTURE

The g.CAMERAcapture block allows you to record a video from a webcam in MATLAB/Simulink and to synchronize the video with the biosignal data. The synchronization is done using the video frame number, which is output from the g.CAMERAcapture block and saved with the biosignal data. The biosignals and video can be read with g.BSanalyze for offline analysis


g.tec

INVASIVE & NON-INVASIVE STIMULATION

For many BCI experiments, it is essential to control an electrical stimulator in real-time depending on the analysis results of the EEG, ECoG or spike data read in by g.HIamp, g.USBamp or g.Nautilus.

G.ESTIM PRO SIMULINK INTERFACE

g.tec provides an intracranial stimulator with 80 V compliance voltage for electrical stimulation of the cortex with ECoG grids or strips or for depth electrodes. This can be used e.g. to stimulate the sensory cortex to add a touch feeling if robotic devices are controlled with the BCI or for deep brain-stimulation experiments e.g. with Parkinson patients. Stimulation parameters such as on-set time or stimulation current can be set and triggered in real-time from Simulink.

G.ESTIM FES SIMULINK INTERFACE

Non-invasive stimulation is used e.g. to stimulate hand movements when the person imagines a hand movement. In this case, a Functional Electrical Stimulator is used with surface stimulation electrodes. The g.Estim FES Simulink interface allows you to set all required parameters of the FES stimulator and to trigger the stimulator from Simulink. Importantly, the stimulator also measures the stimulation current to confirm that the actual current can be delivered (depending on the electrode impedance).

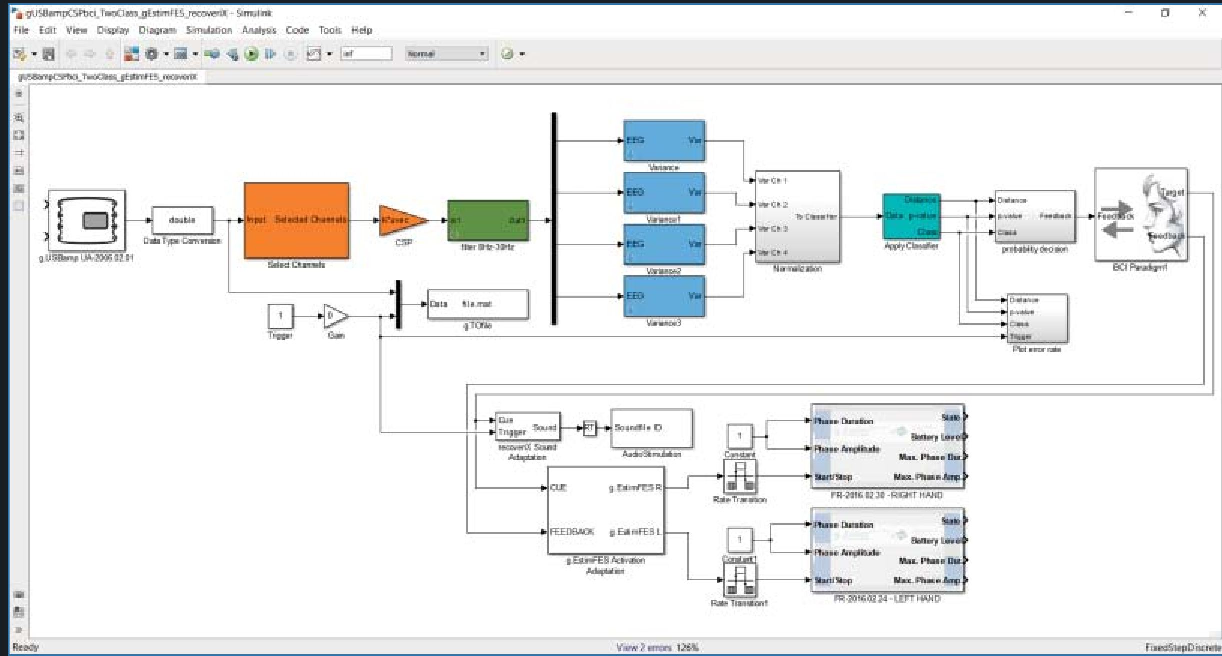
The g.Estim FES Simulink Interface provides a graphical interface to the g.Estim FES hardware, which can be used under Simulink to specify the properties of the electrical stimulator. The Simulink block allows you to specify the Phase Duration, the Phase Amplitude in real-time or via a graphical user interface and allows to start and stop the stimulation. The block provides the state (on/off), the battery level, the Max. Phase Duration and the Max. Phase Amplitude to the user. Use the FES Control Panel to manually set the stimulation parameters and to start and stop the stimulation. The applied charge density is also visualized in the window.

G.EYETRACKING INTERFACE

The g.EYEtracking Interface for SIMULINK allows you to acquire eye gaze and x-, y-coordinates of the eye together with biosignal data. The signals can be visualized, stored and analyzed in real-time in SIMULINK and offline in MATLAB. The g.EYEtracking Interface for g.HIsys allows users to acquire biosignal data such as EEG, ECG, EMG, eyetracking information, and other signals in real-time. It provides a block to read gaze data from the eye-tracker simultaneously with other biosignal data coming from g.USBamp, g.HIamp or g.Nautilus wireless EEG system with dry or wet electrodes.

G.UDPINTERFACE

The exchange of data between different computer systems is important for many applications. The g.UDPinterface for MATLAB/Simulink provides ready-to-use Simulink blocks and MATLAB functions to transmit data from a biosignal recording device to other applications like a Virtual Reality system or another MATLAB instance on another PC. The g.UDPinterface can be used to exchange data between 2 Simulink applications running on two different PCs or notebooks.



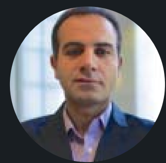
EXCAVATOR CONTROL

During the Ars Electronica Festival, g.HIsys was used to control an excavator! Visitors could use their P300s and related signals to direct the excavator. The BCI system was calibrated with 5 min EEG data in g.BSanalyze and the g.HIsys used this information to make a real-time decision about the users' intent.

MOVEMENT CONTROL

The Simulink model can read in 16 EEG channels. The data are converted to double precision and a CSP filter is applied to perform a motor imagery BCI analysis. Then, the data are bandpass filtered and the variance of the most important CSP channels is calculated. Then, the data are normalized and classified to provide a feedback output to the BCI user. If the subject imagines a right or left hand movement and the BCI detects it correctly, then a FES stimulation of the right or left hand is performed. The BCI Paradigm block controls the experimental procedure. The data are stored in MATALB format.

User Experience

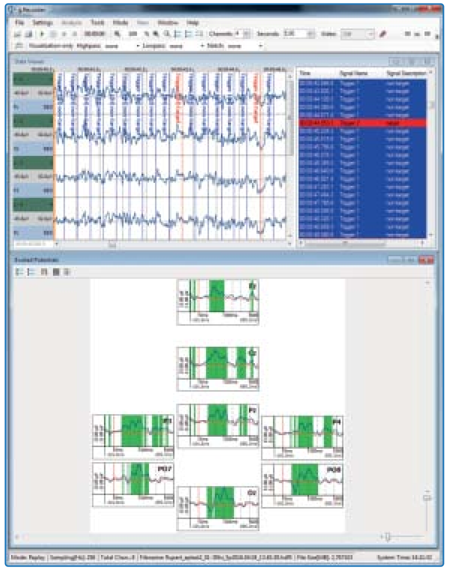


Prof. Nima Mesgarani,
Columbia University,
New York City, USA

"The g.tec g.HIsys environment allows my lab to rapidly develop new applications. Biomedical engineering students here at Columbia University use the rapid prototyping environment during their education to get familiar with data acquisition, real-time processing and signal analysis."

g.RECORDER

BIOSIGNAL RECORDING SOFTWARE



PRODUCT HIGHLIGHTS

- Support for various g.tec biosignal amplifiers
- Multi-modal biosignal visualization and recording
- Synchronized storage of biosignal data, triggers and video
- Configuration and setup of hardware parameters
- Storage of header information and subject/patient data
- User/Admin mode for save operation
- Intelligent file management and search functions
- Stand-alone program
- Data format supported by EMSE® and BESA®
- Real-time EP calculation with statistical analysis
- Online filters for visualization
- Load topographic information for result presentation

g.Recorder supports all g.tec biosignal acquisition devices and provides tools for easy configuration and setup, data visualization, storage, and review. Signals and parameters can be checked in the display mode, stored to disk, and later reviewed in the offline/replay mode. With the extended version of g.Recorder, video data can also be stored simultaneously with the biosignals, and the following parameters can be computed online:

- CSA: Compressed Spectral Array (explorative analysis of signal properties and data quality for long-term recordings)
- HR: Heart Rate (based on automatic R-peak detection from the ECG raw signal)
- HRV: Heart Rate Variability (HR and HRV parameters reflect the state of the autonomous nervous system)
- EP: Online EP calculation with statistical analysis

The extended version adds monitoring Cerebral Function/aEEG (amplitude integrated EEG) with automatic pattern classification. This is used to monitor the ongoing brain functions of premature infants in the neonatal intensive care unit. This additional plug-in to g.Recorder is called g.FEATUREmonitor. In addition to the online classification, there is also an offline CFM-toolbox available, as a part of g.BSanalyze (g.tec's biosignal analysis software package). The generated data format supports analysis with EMSE® and BESA® Software.

EVOKED POTENTIAL VIEWER

The Evoked Potentials viewer provides a convenient way to display evoked potentials. The viewer displays averaged data frames for each acquired analog input channel. An evoked potentials plot is created for each acquired channel. The time frame represents a defined time period, consisting of a pre-trigger period, a post-trigger offset and a post trigger period. The viewer can display the trigger appearance and an averaged time frame for target and non-target evoked potentials. Significant differences between target and non-target evoked potentials can be calculated and highlighted.

COMPATIBILITY WITH G.NAUTILUS WIRELESS EEG SYSTEMS

g.Recorder now supports data acquisition from the variety of available g.Nautilus wireless EEG amplifiers. This includes display, processing, recording and review (depending on the purchased g.Recorder extensions) of EEG signals measured by the wireless headset and the additional channels provided, like acceleration data. Impedance measurement can be performed for the analogue EEG channels, and the base station's digital inputs can be fed in as trigger channels.

Application Example

EEG AND TMS

An important application is the recording of EEG activity while a patient receives TMS (transcranial magnetic stimulation) pulses. For example, the TMS coil may positioned over the motor cortex to generate a finger movement, which leads to an SEP in the EEG. g.Recorder allows you to select a high sampling frequency of all the EEG channels and acquire the data without filtering. Furthermore, the exact timing of the TMS pulse can be read in via the TTL inputs of the amplifier. After the recording, ERPs can be calculated and artifact removal algorithms can be applied to get clean EEG data and study the effect of the TMS stimulation.

g.BSANALYZE
OFFLINE BIOSIGNAL ANALYSIS FOR MATLAB

g.BSanalyze is an interactive environment for multimodal biosignal data processing and analysis in the fields of clinical research and life sciences. g.BSanalyze has been on the market for more than ten years, and is used in more than 70 countries. It is the most comprehensive package available to analyze non-invasive and invasive brain-, heart- and muscle-functions and dysfunctions. The package won several international awards. The new version includes many new functions such as topographic plots, CCA, new filters, an importer for cortiQ files, updates for Result2D, and more!

PRODUCT HIGHLIGHTS

- Interactive and intuitive graphical user interface for EEG, ECoG, EOG, EMG, ECG, spikes, and physical data analyses and documentation under MATLAB as well as a stand-alone version
- Extensive tools for data processing in time, space, and frequency domains
- Powerful 2D and 3D visualization tools to rapidly generate publication ready figures
- Enhancement of power with g.tec's specialized EEG, aEEG, ECG, SPIKE, CLASSIFY and High-Resolution EEG toolboxes
- Flexibility to integrate other MATLAB toolboxes, as well as customers' specific algorithms
- Analyse data from g.Recorder, g.HIsys, MATLAB and C API and many other third-party recording devices
- The only package that supports all BCI principles such as P300, motor imagery, SSVEP/SSSEP, slow cortical potentials, acVEP
- Optimized for high-gamma activity analysis
- Discharge artefact removal algorithms for TMS experiments

TOOLBOXES OF G.BSANALYZE

g.BSanalyze consists of a base version for data import, visualization, transformation and pre-processing and has several dedicated toolboxes:

- EEG toolbox: specialized functions for pre-processing, analysis and parameter extraction for EEG data
- ECG toolbox: find QRS complexes and calculate heart rate variability parameters
- Classify toolbox: classify parameters with linear and non-linear methods including statistical analysis for zero class detection
- High-resolution EEG: map EEG activity on realistic head models
- CFM toolbox: calculate amplitude integrated EEG
- SPIKE toolbox: analyze spikes, multi-unit activity and positions to map physiological parameters

The package comes with many sample biosignal data-sets, including P300, SSVEP, motor imagery, CSP BCIs, Tilt-Table, EPs, multi-unit activity, CFM, and ERD/ERS.

MORE THAN 100 FUNCTIONS

g.BSanalyze's graphical user interface includes more than 100 state-of-the art functions for defining electrode montages, spatial or temporal filter designs, artifact treatment, quality control, spectral analysis, coherence, correlation, bandpower analysis, ERD/ERS analyses, EP analyses, visualization, data set classification, and other goals. It is the only package that supports all BCI principles: P300, SSVEP/SSSEP, cVEP, motor imagery and slow cortical potentials. You can load and save your preferred processing steps within a script program and automatically process your data in g.BSanalyze batch mode.

g.BSanalyze's processing capabilities allow you to extract relevant features from your multimodal data and define useful parameters for post-processing. Use these parameters directly with g.BSanalyze's classification tools to assign distinct classes to your data with linear and non-linear classifiers. The combination of the graphical user interface and the programming environment makes g.BSanalyze a truly unique package for biosignal analyses. The stand-alone version of g.BSanalyze can run without a MATLAB installation, but batch processing in the MATLAB command window is not possible.

Base Version Features

DATA VISUALIZATION

Data ruler, Undo (1-step, multi-step), Journal file, Full header access, High speed data scrolling (trial x channel/channel x trial), Assign and edit data attributes and markers, Epoching (free/multi trial/multi channel mode), Data scoring, Quick analyses of epochs, Assign comments, Attribute jumper, Data status monitor, Data player, Zoom, Data scaling (auto, amplifier, manual, type specific.)

DATA FILE I/O AND PRINTING

Import filter: recoveriX, mindBEAGLE, cortiQ, MATLAB, EDF, BKR, ASCII, RDF, CNT, TFM, MOBILAB, AXONA, MIT, Block import, Full support for third-party formats, Export ASCII, Assign class labels, Plot data, Printer options.

TRANSFORMATION

Cut trials-samples-channels, Sort data, Merge data sets, Arithmetic operations, Data triggering (on multiple triggers), Untrigger data.

PRE-PROCESSING

DC-correction, Smoothing/Rectifying, Data de-trending, Remove drift, Down- and up-sampling, Filter data (highpass, lowpass, bandpass, bandstop), Filter design with graphic support, Spatial filtering, Moving average, Baseline correction.

TOOLS

Stimulus/response detector, Reaction time analysis, Single trial analysis, Trigger finder.

The Data Editor shows the biosignal time series and allows you to scroll through the data. The menu gives access to the analysis functions and every single step is reported in the MATLAB command window.

ARTIFACT TREATMENT

Overflows, Zerolines, Eventfinder with automatic attribute/marker assignment, Artifact removal with ICA/spatial filters, Automatic artifact epoch detection.

BATCH MODE

Automatic generation of journal files, Batch mode processing for multiple data sets, Automated Batch Starter.

ANALYZE

Independent Component Analysis (ICA), Principal Component Analysis (PCA).

General Analyze Features

ANALYZE FUNCTIONS

Data quality (histogram, distribution and statistic measures), Average across trials (EP analysis, baseline correction, SNR, graph comparison, ...), power spectrum analysis and significance test of differences, Wavelet analysis.

PARAMETER EXTRACTION

Adaptive autoregressive (AAR) parameters, Signal variance, Bandpower, Exponential window, Cross correlation and CC-based template matching, Minimum energy.

RESULT VISUALIZATION

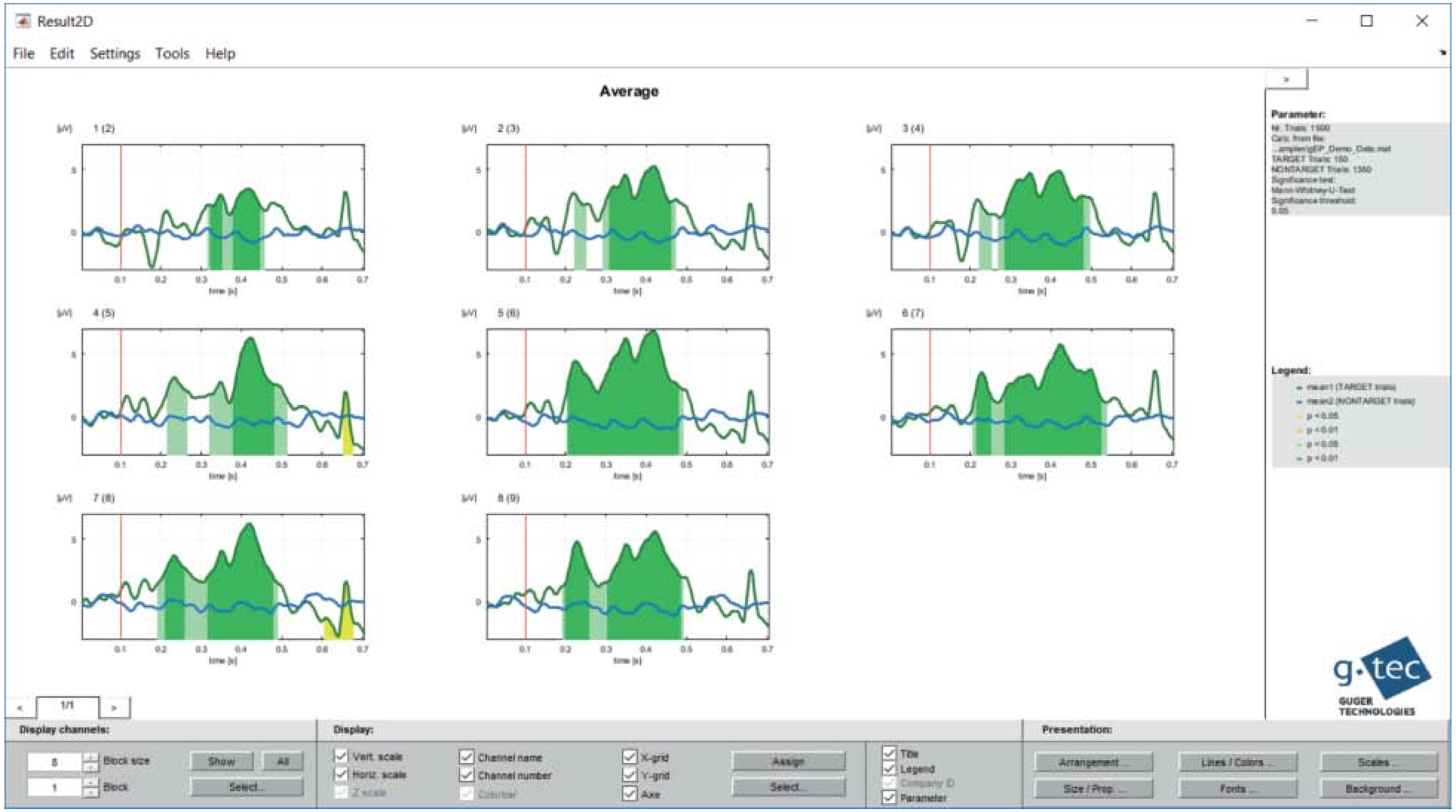
2D plots of analysis results, Layout editor, Copy and measure, Background image, ASCII export, Clone plots, Topography, Header editor.

PRE-PROCESSING

Source derivation.

MONTAGE CREATOR

Edit topography/electrode positions according to the international 10-20 system or free electrode system, Specify source derivations (BIP/CAR/LAR/LAP,...), Edit geometry data.



The g.Result2D result viewer shows the ERPs from 8 channels. Each channel shows the ERPs elicited by the target stimuli in green, and ERPs to non-target stimuli in blue. Sections with statistically different differences between these two lines are shaded in green. The result viewer can also topographically arrange the results.

ECG Toolbox Features

ECG SPECIFIC ANALYZE FUNCTIONS

Coherence, Event-related coherence, Event-related ECG changes.

QRS/R-PEAK DETECTOR

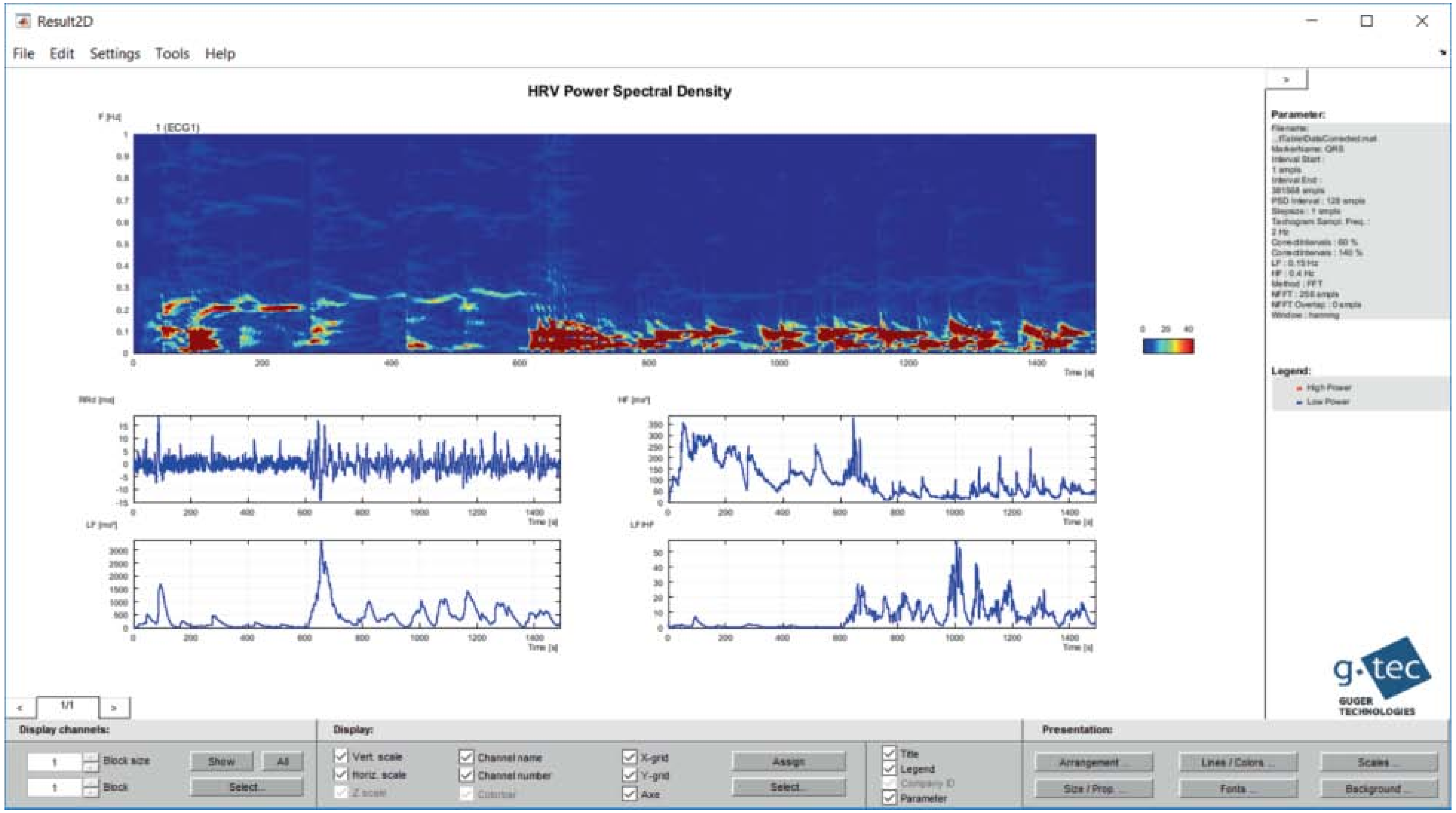
Automatic R-peak detection and marker assignment.

PARAMETER EXTRACTION

Tachogram

HEART RATE/HEART RATE VARIABILITY

HR/HRV time domain parameters, Geometric measures, RR difference measures, Segmented measures, Poincaré plots, HR/HRV frequency domain parameters, Power measures, Normalized measures, HRV time-frequency maps.



g.Result2D shows the heart-rate variability analysis (HRV) in frequency domain of a tilt table experiment. The analysis shows the reactions of the low frequency and high frequency HRV parameters.

EEG Toolbox Features

ARTIFACT TREATMENT

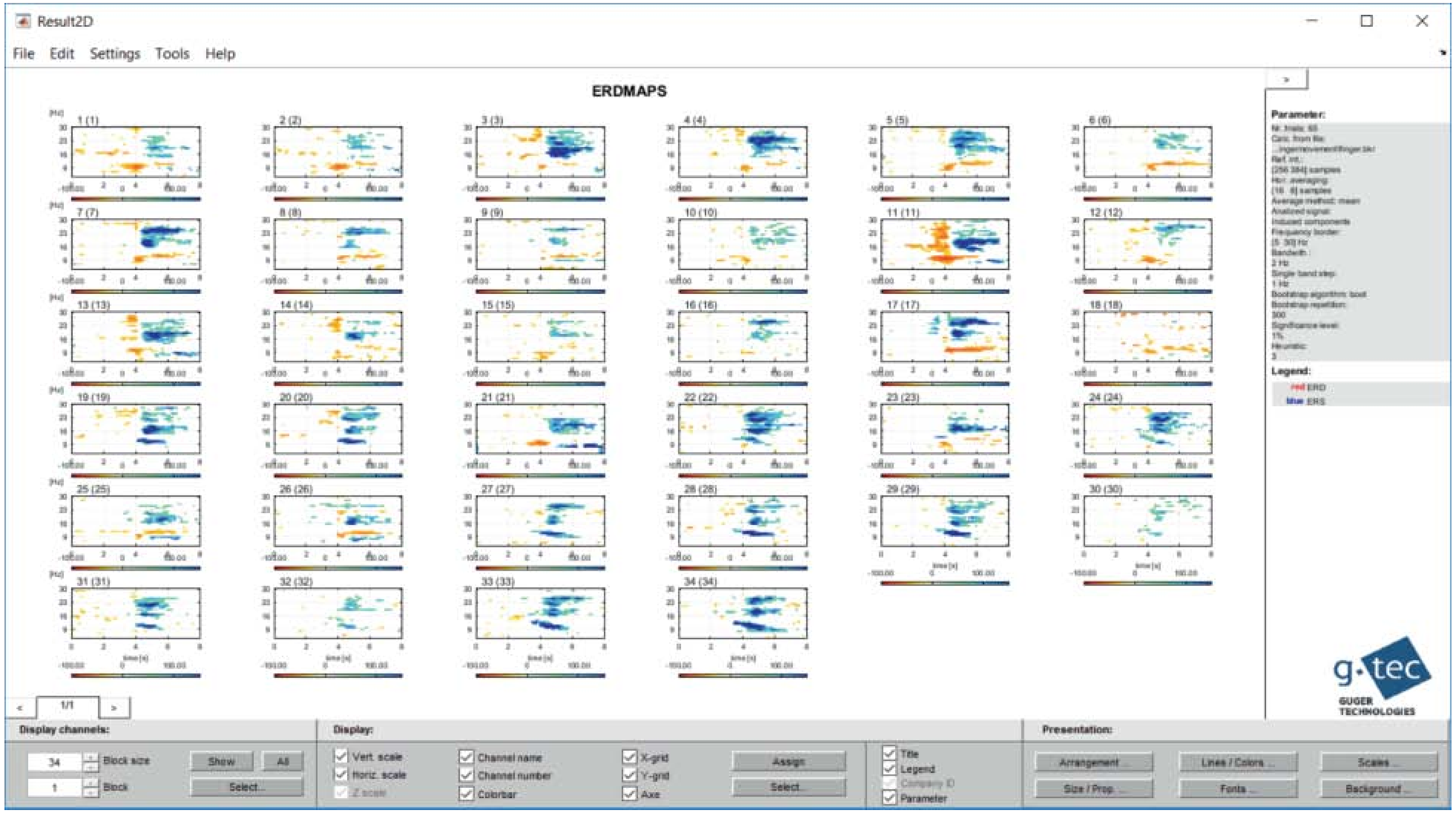
TMS artifact removal.

EEG SPECIFIC ANALYSIS FUNCTIONS

Coherence, Event-related coherence, ERD/ERS analysis with significance test, ERD/ERS time-frequency maps with bootstrap test for significance, ERD/ERS time-frequency maps with complex demodulation, ERD/ERS time-frequency maps with wavelets, ERD/ERS time-frequency maps with Hilbert transformation, Common spatial patterns (CSP), Mean frequency, Phase-locking value, Averaging function with statistical comparison of different classes, EP calculation (ASSR, MMN, BAEP, P300, N400, ...).

PARAMETER EXTRACTION

Hjorth parameters, Barlow parameters, Running fractal dimension, Temporal and spatial complexity, Minimum energy for SSVEP- and SSSEP-based BCI, P300 BCI accuracy.



g.Result2D show the ERD/ERS analysis of a finger tapping task. The EEG was recorded with 32 channels. Red colors show an ERD in the alpha frequency range and blue colors show an ERS in the beta regions. The ERS is also called beta rebound and occurs after the finger movement.

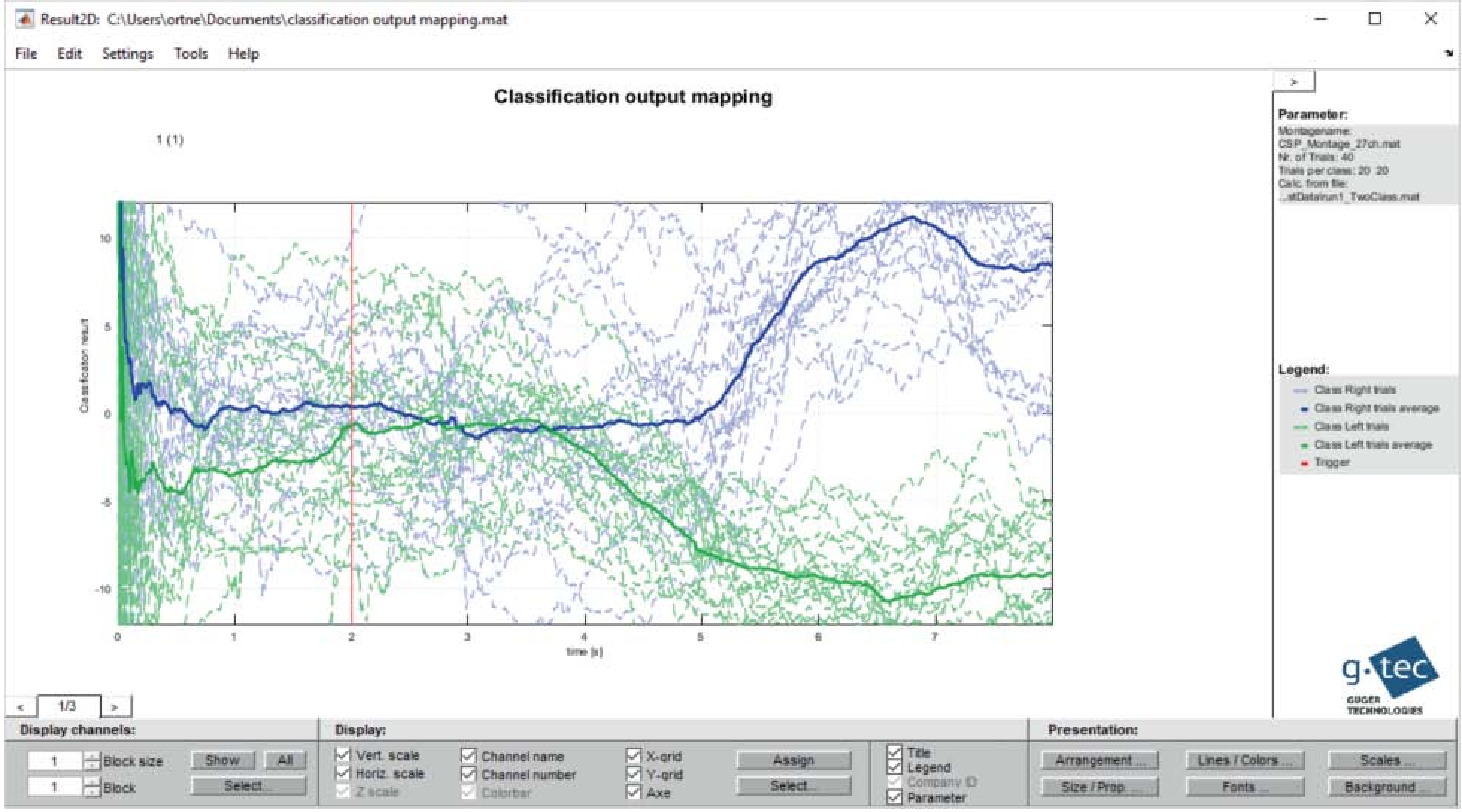
Classify Toolbox Features

TOOLS

Generate feature matrix, Generate time segment feature matrix, Test classifier, Apply classifier, Store classifiers for online application (biofeedback, BCI, ...)

METHODS

Multi-class linear discriminant analysis, Minimum distance classifier, Backpropagation neural network, Receiver operator curves, Radial basis function, Distinction sensitive learning vector quantization (DSLVQ), DSLVQ for feature weighting, K-means clustering, Support vector machine, Change rate/majority voting, Zero-class, P300-accuracy, Plot classification result mapping.



Result2D shows the result of a motor imagery BCI task. The subject imagined left hand and right hand movements (80 times each). The red line shows the onset of the imagination and the blue and green lines are the averages of the single movement imaginations. After 2 seconds, the two classes can be well separated and used as a BCI control signal.

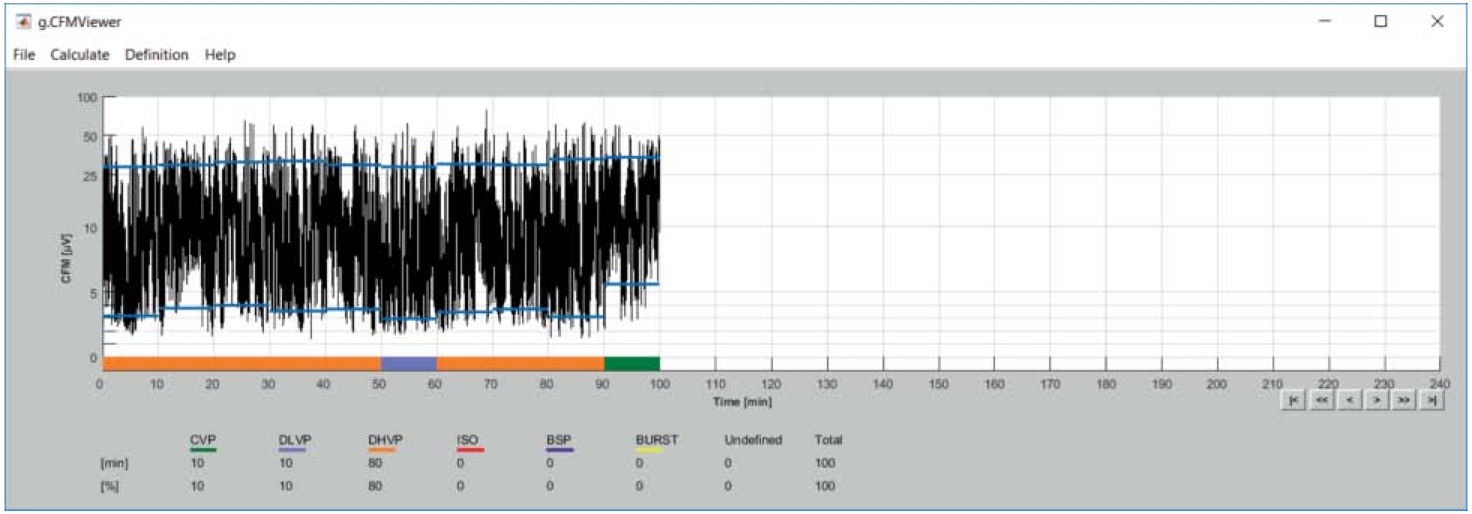
CFM Toolbox Features

OFFLINE ANALYSIS OF NEONATE EEG

The CFM (aEEG) signal can be computed from selected data segments. The CFM traces are displayed in a viewer window for visual inspection.

AUTOMATIC CFM SEGMENTATION

CFM traces can be classified automatically. The following classes are assigned to data segments of a predefined length (e.g. 10 min): CVP (continuous voltage pattern), DLVP (discontinuous low voltage pattern), DHVP (discontinuous high voltage pattern), ISO (isoelectric pattern), BSP (burst suppression mode), BURST (bursts). Criteria for automatic segmentation can be adjusted/optimized for special applications or derivation techniques.



The g.CFMViewer shows the amplitude integrated EEG of a 100 minute recording of a neonate in the intensive care unit. The trace mostly shows a DHVP pattern and two segments of DLVP and CVP. The aEEG gives a time compressed view of the brain status of these patients.

High Resolution EEG Toolbox Features

PRE-PROCESSING

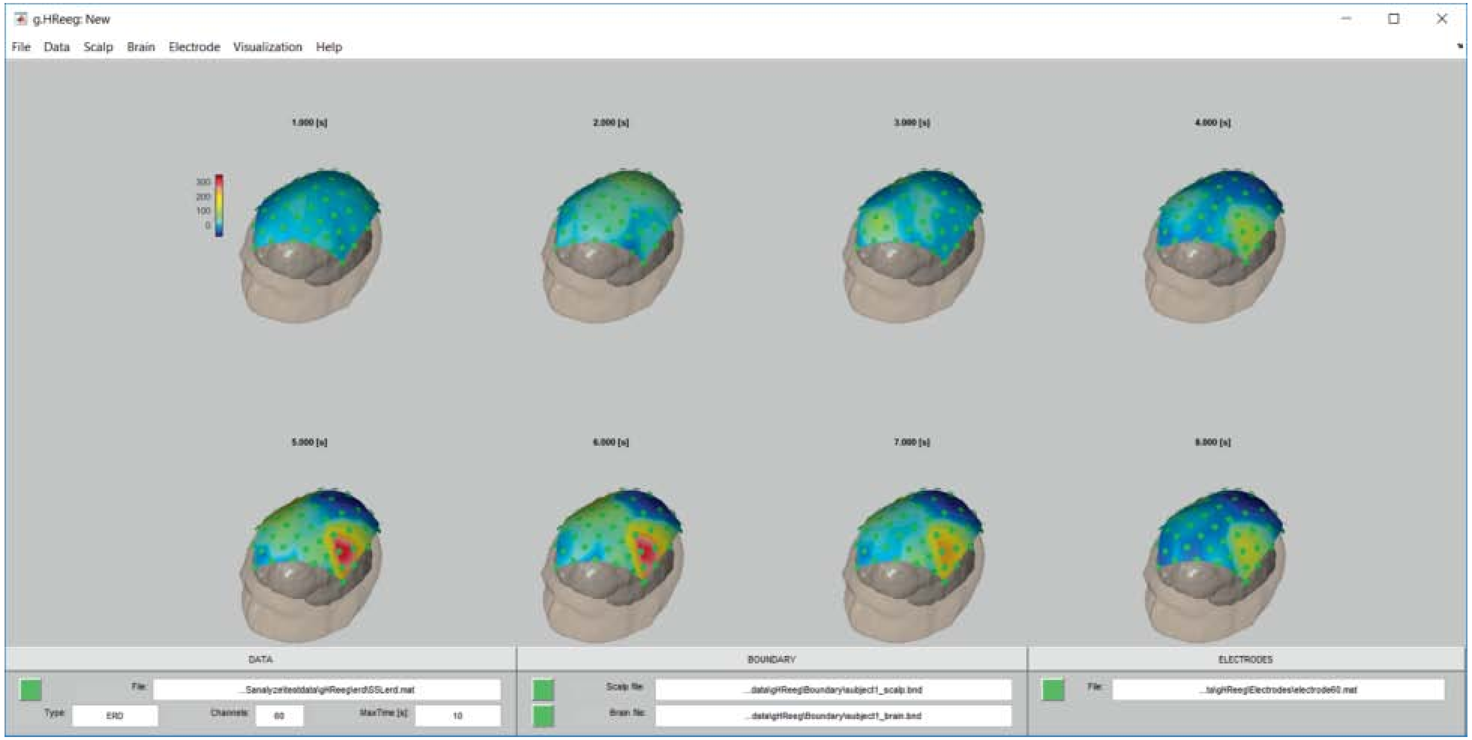
High resolution spline Laplacian derivations for ERD/ERS, ERP, etc.

ANATOMICAL MODELING

Generation of realistic anatomical multi-layer models from segmented CT/MRI data, Fit electrode positions to models, Edit geometry data.

RESULT MAPPING

2D and 3D mapping of results for different model layers, Edit transparency and colors, Free rotation of models/maps, Generate time series.



g.HReeg shows the time course of a right hand movement imagination that results in an ERD over the left sensorimotor area.

Spike Toolbox Features

NEURONAL ACTIVITY PROCESSING

Firing rate of neural cells

PSTH – PERISTIMULUS TIME HISTOGRAM

Firing histogram to identify active regions

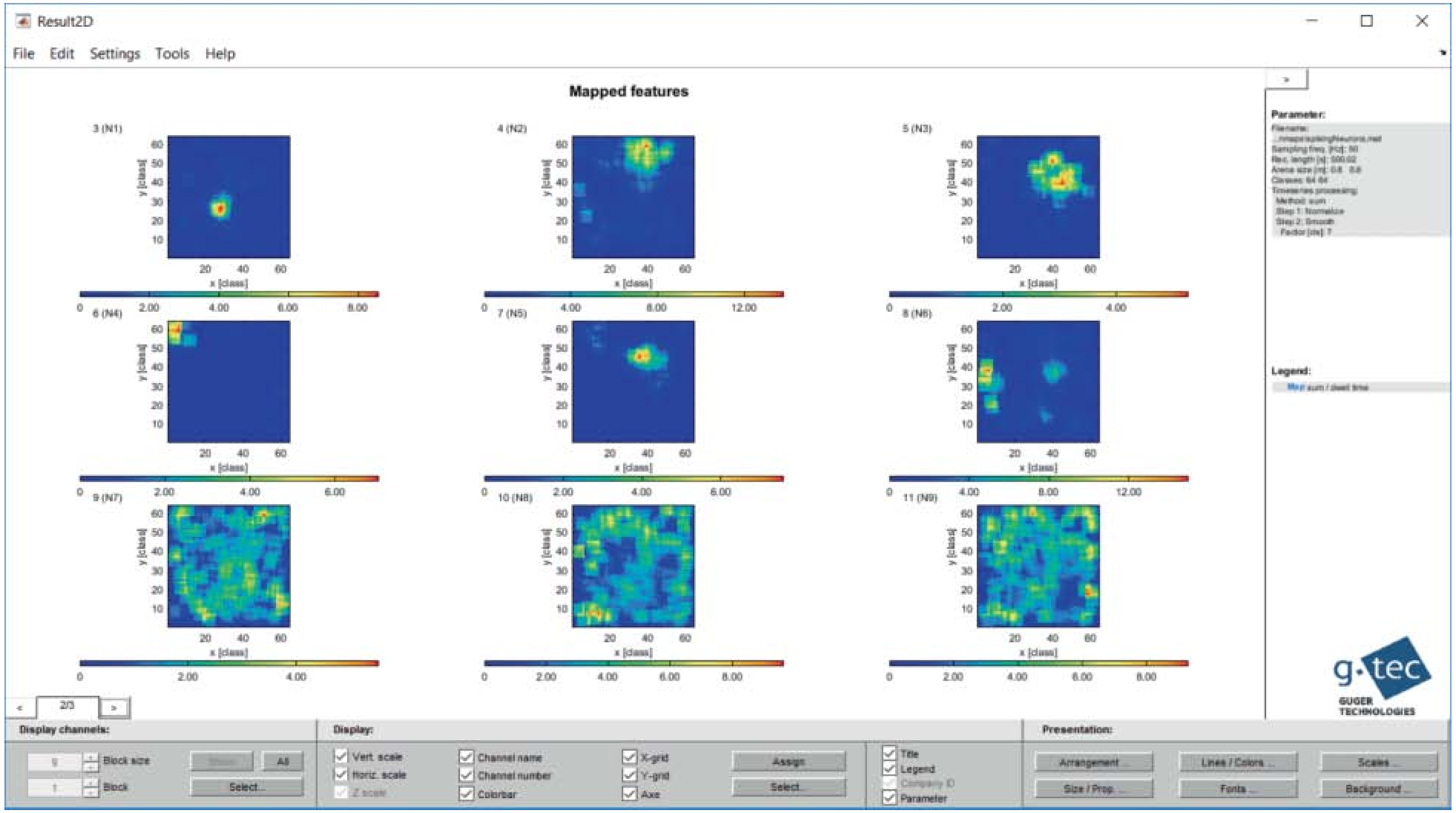
ANALYZE POSITION DATA

Movement trajectories, Visits per class, Class probability, Dwell time

CALCULATE DIFFERENT MAP PARAMETERS

Firing fields, Skaggs index, Spatial coherence, Spatial selectivity, Mean non-zero-rate, Maximum activity, Minimum activity

CALCULATE SPEED



g.Result2D shows the firing fields of place cells of a foraging rat in a rectangular maze. Neurons N1-N6 show isolated and good place fields, while neurons N7-N9 are less specific. Neuron N2 decodes the area close to the border of the maze very well, while N4 decodes a corner of the maze.

g.NEEDACCESS
NETWORK ENABLED EASY DATA ACCESS

g.NEEDaccess is a server that facilitates simple and platform independent data acquisition from (multiple) devices over a network or direct connection, which considerably reduces workload.

g.NEEDaccess allows you to acquire data easily from g.tec devices without having to take care of low-level aspects of data acquisition. The server handles acquisition and preprocessing of data such that the user receives data ready to analyze.

Since data acquisition is also realized over the network, it is now possible to collect the acquired data on a different computer than the one connected to the g.tec device (if both are connected to the network). Moreover, the server is able to provide data from a single acquisition simultaneously for multiple clients. Thus, multiple users across different systems can simultaneously review data in real-time.

The reference implementation of the server's network API provides a wide range of functions that ease data acquisition and also support device-specific operations. The Client API provides a high-level C and .NET library to facilitate integration in your own projects, which handle communication with the server using the network API underneath. Besides the network-based access to the server, direct access with increased communication speed is also possible.

PRODUCT HIGHLIGHTS

- Platform independent data acquisition for g.tec devices
- Data acquisition from multiple devices
- Easily access ready-to-analyze data
- Remote access to data acquisition devices
- Client C/C++ and MATLAB API available

MATLAB API

The toolbox is a device driver that lets users read biosignal data like EEG, ECoG, EMG, EOG and ECG within the MATLAB environment. MATLAB is a very flexible development environment, which allows you to easily set up your own signal acquisition and analysis by utilizing all available toolboxes from MATLAB (like Statistics, Neural Networks, and Signal Processing). One of the key advantages of the API for MATLAB is that it is fully integrated into MATLAB. Therefore, you can start data acquisition within minutes, and build your application easily and quickly.

The API for MATLAB is available for g.HIamp, g.USBamp, g.Nautilus and g.MOBIlab+ (only MATLAB 32 bit, requires data acquisition toolbox).

PRODUCT HIGHLIGHTS

- Acquire EEG, ECoG, ECG, EMG, EOG data directly within MATLAB
- Control g.HIamp, g.USBamp, g.Nautilus and g.MOBIlab+ from the MATLAB command line
- Write your own MATLAB programs for on-line visualization and signal analysis
- Easily use the MATLAB API to handle g.tec amplifiers
- Data can be read directly into MATLAB for further off-line processing
- Speed up your development time – from months to hours

TECHNICAL SPECIFICATIONS

The API for MATLAB contains commands that provide full access to the amplifier. There are commands for reading the data, setting the bandpass and Notch filters, changing the sampling frequency of the amplifier, defining bipolar derivations and calibrating the system.

FEATURES

- Connect Devices to the Computer: This function returns all g.tec devices available at a defined endpoint (IP address and port). Host and local IP and corresponding ports are required to use this function.
- Measure Impedance: g.NEEDaccess allows the measurement of channel impedances for g.Nautilus, g.HIamp and g.USBamp.
- Get Available Channels: This allows you to check which EEG channels are available.
- Get Available Filters: This command reads out all available bandpass and notch filters.
- Get Supported Sampling Rates: This reads out supported sampling frequencies.
- Get Device Info: This command reads out the serial number of the device.
- Get Scaling: This reads out the scaling factor and offset for each EEG channel.
- Set Configuration: This sets the configuration of the devices.
- Start Data Acquisition: This starts the data acquisition with the settings provided.
- Stop Data Acquisition: This stops the data acquisition.
- Get Data: This command reads out EEG data during data acquisition.

C API

The Application Programming Interface (API) allows you to access the amplifier from many programming environments. The API has functions to fully control the amplifier from C, C++, Visual Basic, LabView and many more programming languages. The API is available for Windows operating systems. It enables you to program your own sophisticated biosignal acquisition and data processing applications. Sample programs and the well documented source code in the electronic manual serve as a template for your programs. The device driver package contains demo programs that show you how to use of all functions and help to get started with the API.

The C API is available for g.HIamp, g.Nautilus, g.USBamp and g.MOBIlab+.

PRODUCT HIGHLIGHTS

- Acquire EEG, ECoG, ECG, EMG, EOG data in your own programs
- Available for Windows
- Include your own sophisticated data processing algorithms
- Develop stand-alone programs for biosignal analysis

Find g.tec's complete product list online in the Download section of www.gtec.at

08 Complete BCI Solutions

Brain-Computer Interface System **80**

g.PHYSIOobserver **88**

Automotive/Aerospace Neurophysiology Lab **90**

BCI Lab **92**

ECoG Lab **94**

Multi-User Hyperscanning and BCI Lab **96**

EP Lab **98**

BCI Teaching Lab **100**

BRAIN-COMPUTER INTERFACE SYSTEM

PRODUCT HIGHLIGHTS

- Complete BCI research system for EEG and ECoG
- Ready to go paradigms for spelling, robot and cursor control
- Seamless integration of real-time experiments and off-line analysis
- Runs with g.MOBIlab+, g.USBamp, g.HIamp or g.Nautilus technology
- Open source paradigms let you make adaptations and develop applications easily
- MATLAB/Simulink Rapid Prototyping environment speeds up development times from months to days
- BCI technology proven across hundreds of subjects and labs
- Zero class enabled for SSVEP, P300 and motor imagery
- The only environment that supports all BCI approaches (P300, SSVEP/SSSEP, Motor Imagery, cVEP, slow waves)
- Recommended setup for a fully equipped BCI lab plan available
- Integrates invasive and non-invasive stimulation for closed-loop experiments
- Multi-device feature to record from multiple subjects or different g.tec biosignal amplifiers

A BCI provides a new communication channel between the human brain and a computer. Mental activity involves electrical activity, and these electrophysiological signals can be detected with techniques like the Electroencephalogram (EEG) or Electrocorticogram (ECoG). The BCI system detects these changes and transforms them into control signals, which can be used for moving objects, writing letters, opening doors, changing TV channels, controlling devices and other everyday household activities. This helps people with limited mobility increase their independence and enables completely paralyzed patients who suffer from disorders of consciousness (DOC), severe brain injuries, or locked-in syndrome to communicate with their environments. Furthermore, BCI technology can be used as a tool to assess the remaining cognitive functions of these patients. BCIs are also used for motor rehabilitation after stroke and brain mapping procedures.

g.tec's BCI environment provides complete MATLAB-based research and development systems, including all hard- and software components needed for data acquisition, real-time and offline data analysis, data classification and neurofeedback. A BCI system can be built with g.MOBIlab+, g.USBamp, g.HIamp or g.Nautilus.

With the software package g.HIsys High-Speed Online Processing under Simulink, you can read the biosignal data directly into Simulink. Simulink blocks are used to visualize and store the data. The parameter extraction and classification can be performed with standard Simulink blocks, the g.RTanalyze library or self-written S-functions. After EEG data acquisition, the data can be analyzed with g.BSanalyze, the EEG and classification toolbox. By using BCI sample applications, you can develop state-of-the-art BCI experiments within a few hours.

User Experience

Dr. Kyousuke Kamada, MD
Asahikawa Medical University, Japan

"g.BCIsys allows my lab to run many different EEG and ECoG studies for BCI control and passive functional mapping of epilepsy and tumor patients. The integration with intracranial electrical stimulation is especially important for me."

Motor imagery

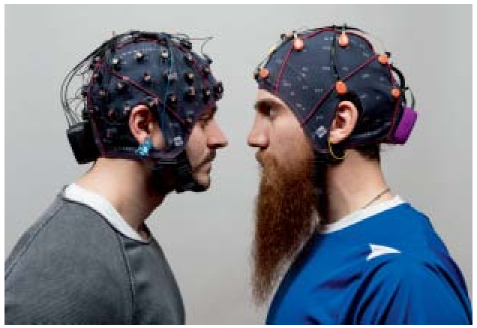
One of the most common types of Brain-Computer Interface (BCI) systems relies on motor imagery (MI). The user is asked to imagine moving either the right or left hand. This produces specific patterns of brain activity in the EEG signal, which an artificial classifier can interpret to detect which hand the user imagined moving. This approach has been used for a wide variety of communication and control purposes, such as spelling, navigation through a virtual environment, or controlling a cursor, wheelchair, orthosis, or prosthesis.

MOTOR REHABILITATION WITH ROBOTIC DEVICES

Training with motor imagery (MI) is known to be an effective therapy in stroke rehabilitation, even if no feedback about the performance is given to the user. Providing additional real-time feedback can encourage Hebbian learning, which increases cortical plasticity, and could improve functional recovery. The MI based Brain-Computer Interface (BCI) can be linked to a rehabilitation robot or exoskeleton. When the user imagines a certain type of movement, the BCI system can detect this movement imagery and trigger devices to provide feedback.

PING-PONG GAME

When playing Ping-pong, two persons are connected to the BCI system and can control the paddle with motor imagery. The paddle moves upwards via left hand movement imagination and downwards via right hand movement imagination. The algorithm extracts EEG bandpower features in the alpha and beta ranges of two EEG channels per person. Therefore, in total, 4 EEG channels are analyzed and classified.



HIGH-GAMMA MAPPING AND CONTROL

While most BCIs rely on the EEG, some of the latest work has drawn attention to BCIs based on ECoG. ECoG based systems have numerous advantages over EEG systems, including (i) higher spatial resolution, (ii) higher frequency range, (iii) fewer artifacts, and (iv) no need to prepare users for each session of BCI use, which usually requires scraping the skin and applying electrode gel. Recent research has demonstrated, over and over, that ECoG can outperform comparable EEG methods because of these advantages. Scientific work showed that ECoG methods can not only improve BCIs but also help us address fundamental questions in neuroscience. A few efforts have sought to map “eloquent cortex” with ECoG. That is, scientists have studied language areas of the brain while people say different words or phonemes. Results revealed far more information than EEG based methods and have inspired new ECoG BCIs that are impossible with EEG BCIs. Other work explored the brain activity associated with movement. This has been very well studied with the EEG, leading to the well-known dominant paradigm that real and imagined movement affects activity in the 8-12 Hz range. ECoG research showed that this is only part of the picture. Movement also affects a higher frequency band, around 70-200 Hz, which cannot be detected with scalp EEG. This higher frequency band is more focal and could lead to more precise and accurate BCIs than EEG methods could ever deliver.

P300

The P300 is another type of brain activity that can be detected with the EEG. The P300 is a brainwave component that occurs after a stimulus that is both important and relatively rare. In the EEG signal, the P300 appears as a positive wave 300 ms after stimulus onset. The electrodes are placed over the posterior and occipital areas, where the P300 is most prominent.

SMART HOME CONTROL

The BCI is connected to a Virtual Reality (VR) system that presents a virtual 3D representation of the smart home with different control elements (TV, music, windows, heating system, phone). This allows the subjects to move through the environment. Users can perform tasks like playing music, watching TV, opening doors, or moving around. Therefore, seven control masks are available: a light mask, a music mask, a phone mask, a temperature mask, a TV mask, a move mask and a "go to" mask.

SPELLING

The P300 paradigm presents e.g. 36 letters in a 6 × 6 matrix on the computer monitor. Each letter (or row or column of letters) flashes in a random order, and the subject has to silently count each flash that includes the letter that he or she wants to communicate. As soon as the corresponding letter flashes, a P300 component is produced inside the brain. The algorithms analyze the EEG data and select the letter with the highest P300 component.

Then, this letter is written onto the screen. Normally, between 2-15 flashes per letter are required for high accuracy. The number depends on many factors, including the electrodes and their scalp positions, the data processing parameters, and the height of the individual subject's P300 brainwave. The P300 speller is available as Simulink model that allows you to modify the system and as a ready-to-go application for patients' usage (intendiX).

HYPERSCANNING–CONNECTING MINDS

The P300 speller was used for a demonstration called "Hyperscanning" that represents an important step toward direct cooperation between people through their minds. By combining the brainwave signals across many people, the system manages to substantially improve communication speed and accuracy. This approach could be used for cooperative control for many different applications. People might work together to play games or draw paintings, or could work together for other tasks like making music, voting or otherwise making decisions, or solving problems. Someday, users might put their heads together for the most direct "meeting of the minds" ever.

P300

AUDITORY AND VIBRO-TACTILE STIMULATION

P300 BCIs based on visual stimuli do not work with patients who lost their vision. Therefore, auditory paradigms can be implemented using a frequent stimulus with a certain frequency and an infrequent stimulus with another frequency. The user is asked to count how many times the infrequent stimulus occurs. Like with the visual P300 speller, the infrequent stimuli also produce a P300 response in the EEG. The same principle can be used for vibrotactile stimulation if e.g. the right hand is frequently stimulated and the left hand is infrequently stimulated. The EEG will exhibit a P300 if the user is paying attention to the infrequent stimuli. This auditory and vibrotactile setup can assess whether the patient is able to follow instructions and experimental procedures. To answer yes and no questions, it is necessary to extend the vibrotactile setup to 3 stimulators. The user can concentrate on one of the infrequent stimulators to say (in this case) yes or no.

AVATAR CONTROL

Avatar control has been developed through the research project VERE (Virtual Embodiment and Robotic Re-Embodiment). The VERE project is concerned with embodiment of people in surrogate bodies so that they have the illusion that the surrogate body is their own body–and that they can move and control it as if it were their own. There are two types of embodiment: (i) robotic embodiment and (ii) virtual embodiment. In the first type, the person is embodied in a remote physical robotic device, which they control through a BCI. For example, a patient confined to a wheelchair or bed, who is unable to physically move, may nevertheless re-enter the world actively and physically through such remote embodiment. In the second type, the VERE project used the intendiX ACTOR protocol to access the BCI output from within Unity to control both the virtual and robotic avatars.

The BCI is part of the intention recognition and inference component of the embodiment station. The intention recognition and inference unit takes inputs from fMRI, EEG and other physiological sensors to create a control signal together with access to a knowledge base, taking into account body movements and facial movements. This output is used to control the virtual representation of the avatar in Unity and to control the robotic avatar. The user gets feedback showing the scene and the BCI control via the HMD or a display. The BCI overlay, for example, allows users to embed the BCI stimuli and feedback within video streams recorded by the robot and the virtual environment of the user's avatar. The user is situated inside the embodiment station, which also provides different stimuli such as visual, auditory and tactile. The setup can also be used for invasive recordings with the Electrocorticogram (ECoG). The avatar control is promising from a market perspective because it could be used in rehabilitation systems, such as for motor imagery with stroke patients. To run these experiments, g.HIsys and Unity are required.

Code-Based BCI

BCI systems can also use pseudo-random stimulation sequences on a screen (code-based BCI). Such a system can be used to control a robotic device. The user is seated in front of a computer monitor and connected with active EEG electrodes to a biosignal amplifier. The amplifier sends the EEG data to the BCI system that allows the subject to control a robotic device in real-time. The code-based BCI system can reach a very high online accuracy, which is promising for real-time control applications that require a continuous control signal.

The code-based BCI principle is available in g.HIsys as an add-on toolbox cVEP. The toolbox can analyze EEG data in real-time and provide code-flickering icons to remote screens via the SOCI module. This allows you to integrate control icons in external applications that are programmed e.g. in Unity. All parameter estimation and classification algorithms are integrated in this toolbox to help you quickly develop your own application.

SSVEP

Steady state visual evoked potentials (SSVEP)-based BCIs use several stationary oscillating light sources (e.g. flickering LEDs, or phase-reversing checkerboards), each of which oscillates at one unique frequency. When a person gazes at one of these lights, or even focuses attention on it (for example, the light that is assigned to the “move forward” command), then the EEG activity over the occipital lobe will show an increase in power at the corresponding frequency. g.tec’s algorithms determine which EEG frequency component(s) are higher than normal, which reveals which light the user was observing and thus which movement command the user wanted to send. This system includes a “no-control” state as well. When the user does not look at any oscillating light, the robot doesn't move.

SOCI Protocol

The SOCI module (Screen Overlay Control Interface module) is especially useful for Virtual Reality (VR) applications and similar applications where merging BCI controls with the application’s native interface is essential for an improved and optimal user experience. Using SOCI, the platform can be configured to remotely display its stimuli and feedback on various different devices and systems. The SOCI can be embedded in host applications to directly interact with BCI controls inside the displayed scene. It generates CVEP, SSVEP stimuli and supports single symbol, row column and random patterns for P300 stimulation.

Hybrid BCI

Hybrid BCIs combine different input signals to provide more flexible and effective control. g.HIsys supports (i) mouse control, (ii) EMG 1D and 2D control, (iii) EOG 1D control and (iv) eye-tracker control, as well as the standard BCI signals.

EMG and EOG are recorded via the biosignal amplifier and are analyzed with g.RTanalyze to generate the control signals, while the mouse and the eye-tracker use external devices that are interfaced with g.HIsys. The combination of these input signals can make BCIs faster, more accurate, and more flexible. Hybrid BCIs have been gaining attention in the research literature recently, and there remain many opportunities for interesting hybrid BCI studies.

EOG/EMG Control

The g.EOGEMGcontrol module provides a set of BCI type models that use eye motion (EOG) signals or muscular contraction (EMG) signals to select individual symbols initiate commands and control external devices.

CCEP

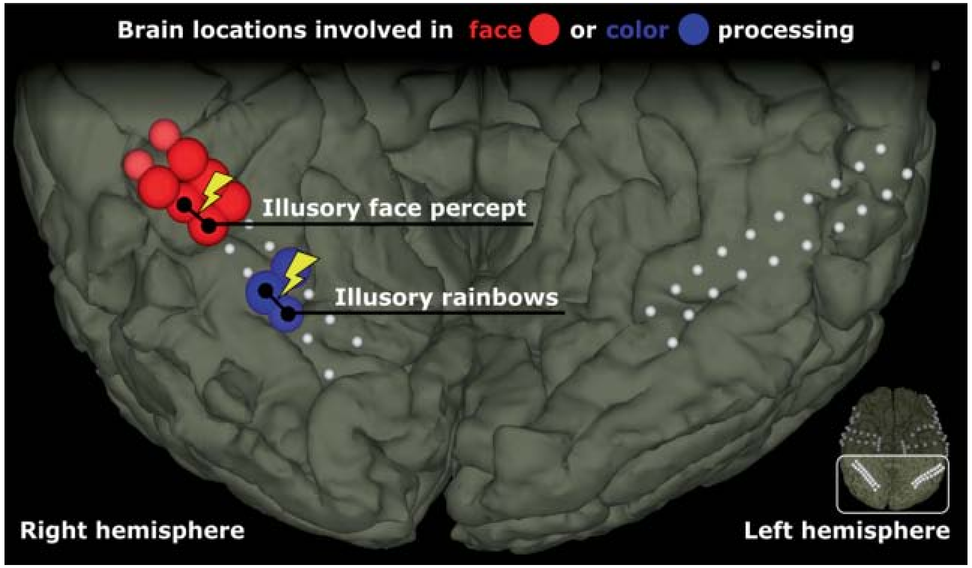
To record CCEPs, subdural ECoG grids are implanted directly on the cortex on the dominant hemisphere. Then, conventional electrical cortical stimulation mapping is used to identify e.g. Broca’s area. Next, a bipolar stimulation is performed on Broca’s area, which elicits CCEPs over the motor cortex and over the auditory cortex. Electrode channels showing an EP over the motor cortex indicate the mouth region required to say words and sentences. EPs over the auditory cortex indicate electrode positions representing the regions responsible for hearing and for understanding e.g. questions (Wernicke’s area, receptive language area). Overall, the CCEP procedures allows doctors to rapidly map out a whole functional cortical network, which provides important information for neuro-surgical and BCI applications.

Fusiform Face Area

High-gamma activity allows doctors to map the temporal base of the cortex. This is useful to find the fusiform face area, an area responsible to identifying faces, and nearby regions responsible for coding colors, shapes, characters, etc. This region can also be used for real-time decoding. In this example, Dr. Ogawa (Asahikawa Medical University Japan) shows different faces, Kanji characters and Arabic characters to the patient with the ECoG implant (high-resolution ECoG on the temporal base on the left and right hemispheres). The patient just observes the images, and the BCI system decodes high-gamma activity from the ECoG electrodes. The BCI is thereby able to identify which image the patient is seeing in real-time. This worked whether the patient saw other people's real faces or his own face in the mirror.

Unity Toolbox

The Unity toolbox allows you to control Virtual Reality 3D content with g.BCIsys in real-time. g.tec provides games (Mastermind, Spacetraveller, Avatar) that can be controlled with the P300, SSVEP or motor imagery based BCIs. The BCI Simulink models communicate in real-time with Unity. g.tec also provides a full body 3D g.Avatar, whose limbs can be controlled with the BCI system. The toolbox can also interact with the SOCI module to overlay graphical content with P300, SSVEP, cVEP or motor imagery controls. This allows the user to use the BCI controls in the highly immersive VR environment. The toolbox is available for the Oculus Rift HMD. Mastermind uses the SOCI toolbox and allows P300 control, Spacetraveller uses the cVEP toolbox and allows direct control, and g.Avatar uses the CSP toolbox and allows control with the motor imagery BCI.



g.PHYSIOOBSERVER

The g.PHYSIOobserver is a complete system to classify different states of a subject based on physiological parameters. The system contains all necessary components to quantify emotions, workload, physical tasks and many other things. The g.PHYSIOobserver works with many different sensors and electrodes to measure physiological and physical parameters of a subject, and can derive a wide variety of parameters from these signals. A key feature of the system is that it allows you to run experimental paradigms that are synchronized with physiological signals. The paradigms allow you to bring the subject into specific states of emotions, workload, memory tasks, etc., while all parameters are captured. These states can be chosen by the experimenter.

Then, a classification algorithm is trained on these parameters during the different states and tries to discriminate them. Finally, the accuracy is calculated, which provides an objective measure of the quality of the classification. The g.PHYSIOobserver works in real-time, and can therefore track the subject's current state on-line. This information can be transmitted to other applications or devices, including real-time feedback systems.

PRODUCT HIGHLIGHTS

- Train the g.PHYSIOobserver with different tasks
- Classifies physiological parameters in real-time to determine the state of the subject
- Gives accuracy as an objective measure
- Select from a large variety of different parameters
- Send the classification result to other applications to execute closed-loop experiments

Technical Specifications

The g.PHYSIOobserver is able to measure ECG, EEG, EMG, GSR, respiration, temperature, acceleration and oxygen saturation with g.USBamp, g.HIamp, g.Nautilus or g.MOBIlab+. This biosignal data is transmitted via USB or wireless to the recording computer that is storing and visualizing the data for inspection. The recording computer also controls the experimental paradigm that instructs the subject about different tasks (e.g. calculating). The real-time processing system extracts parameters from the biosignal data such as heart rate, heart rate variability, respiration rate, inhalation time, change rate of GSR, etc. and classifies the data. Finally, the classification result predicts the subject's current state. This result is updated in real-time and can also be transmitted to other applications or the experimenter.

The experimental paradigms are presented by default on a computer screen that gives the instructions to the subject. You can also use a head-mounted device, a Virtual Reality system from g.tec, or a custom exoskeleton system. Furthermore, the system can work with eye- and movement-trackers, to give tone, electrical or tactile stimulation. A microphone can be connected to log subject responses.

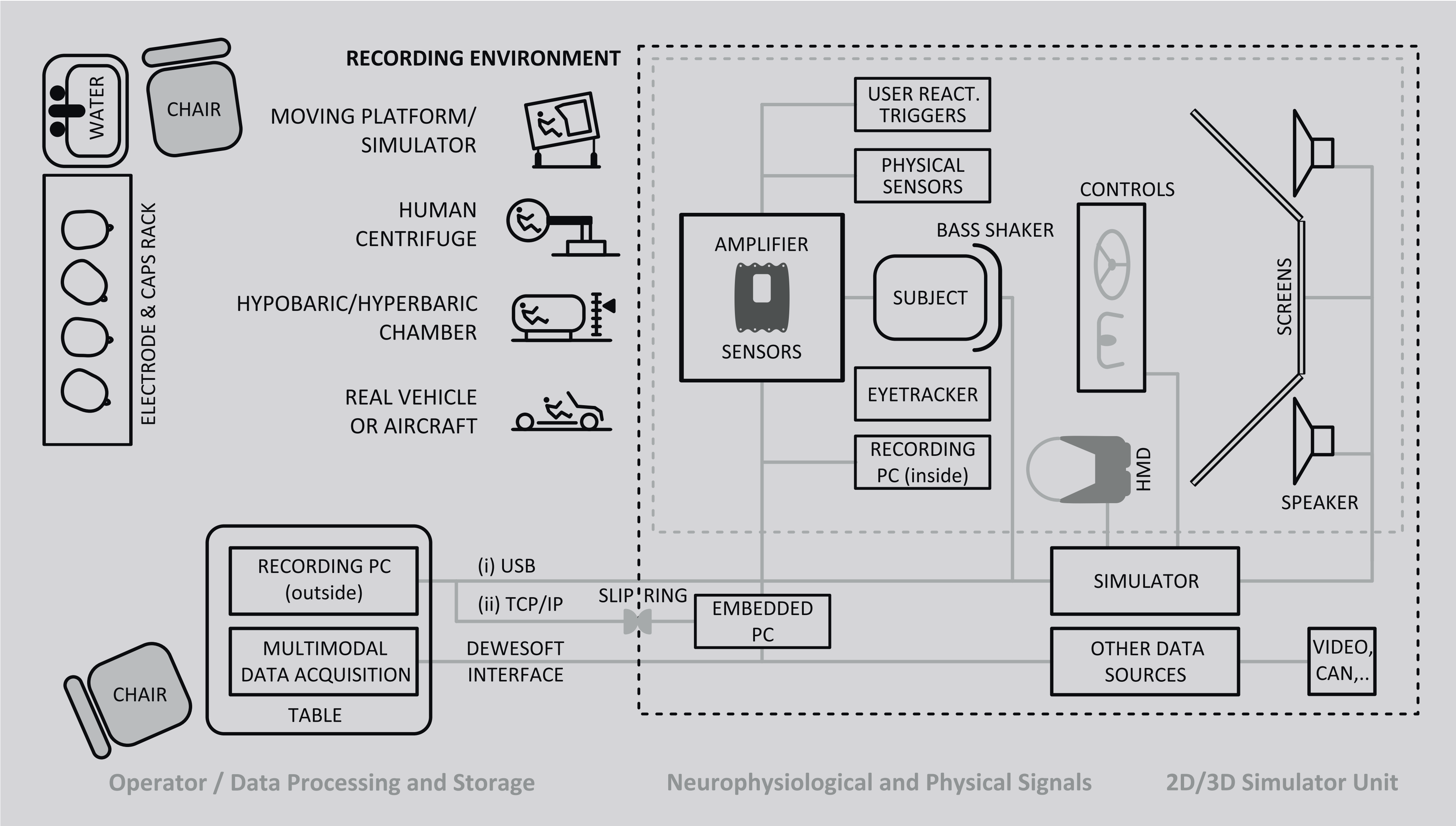
The UDP interface allows you to send the classification result, and the calculated parameters, to other applications to support real-time loops.

Application Examples

First, place all the electrodes and sensors on the subject. Then, start the experimental paradigm, during which the subject receives instructions from the computer screen and has to perform specific predefined tasks.

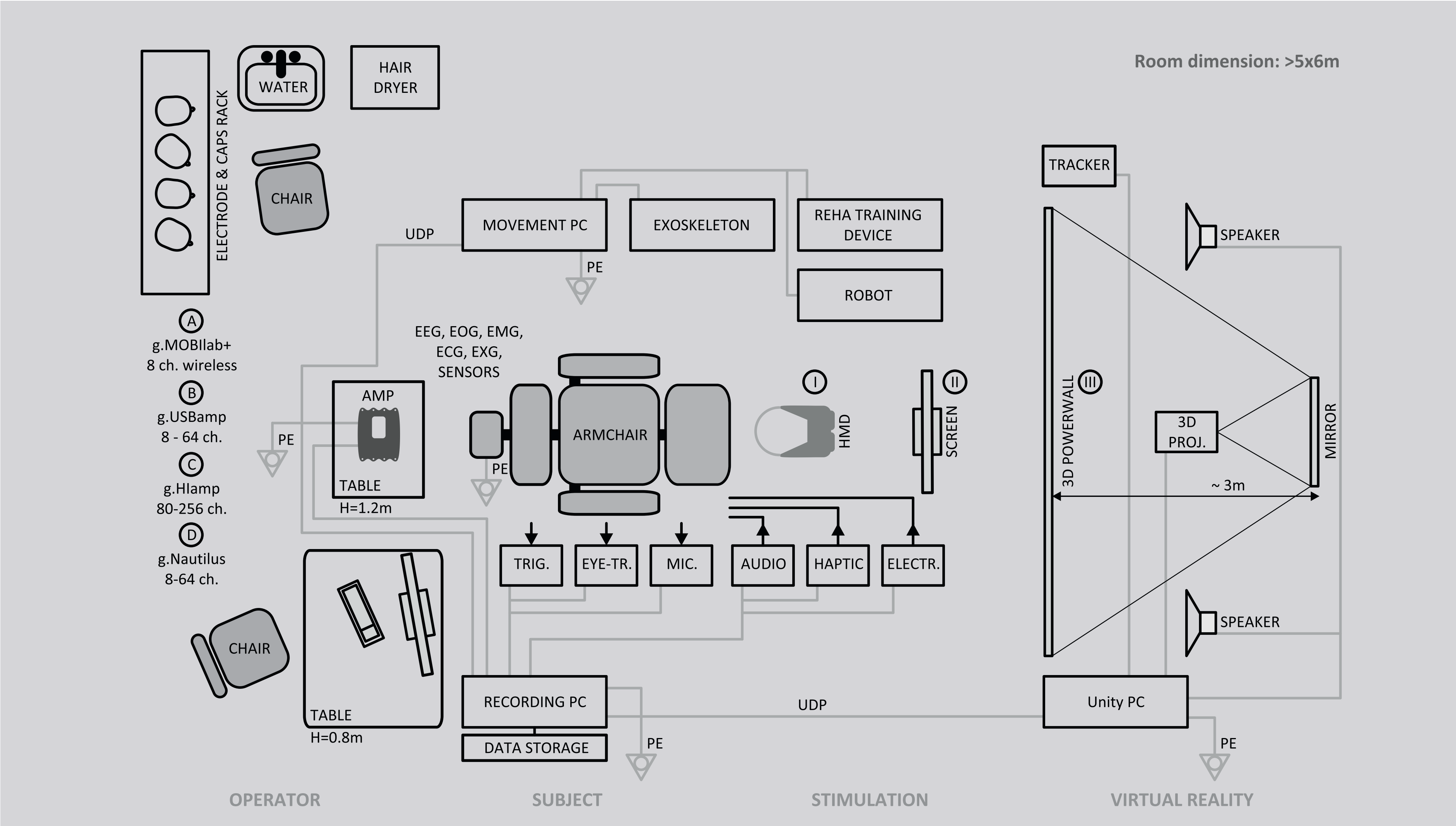
Meanwhile, all of the subject's biosignal data is acquired along with synchronization triggers. When the paradigm stops, the off-line analysis begins to calculate parameters. With these parameters, a classification algorithm is trained, which discriminates between the different states of the experimental paradigm and gives an accuracy level to quantify the separability. If the accuracy is not good enough then (i) additional sensors or electrodes can be used, (ii) the paradigm can be improved, or (iii) additional parameters can be added. When the accuracy meets the expectations of the experimenter, then the g.PHYSIOobserver is ready for real-time tests. The paradigms are started again, and now the system gives a real-time prediction of the current state of the subject with a certain likelihood. The parameters, as well as the predicted state, can be sent to other applications. Finally, the accuracy can be calculated again to see if the system can discriminate the different states.

AUTOMOTIVE / AEROSPACE NEUROPHYSIOLOGY LAB



Study psychological and physiological reactions of car drivers, pilots or other subjects under extreme conditions

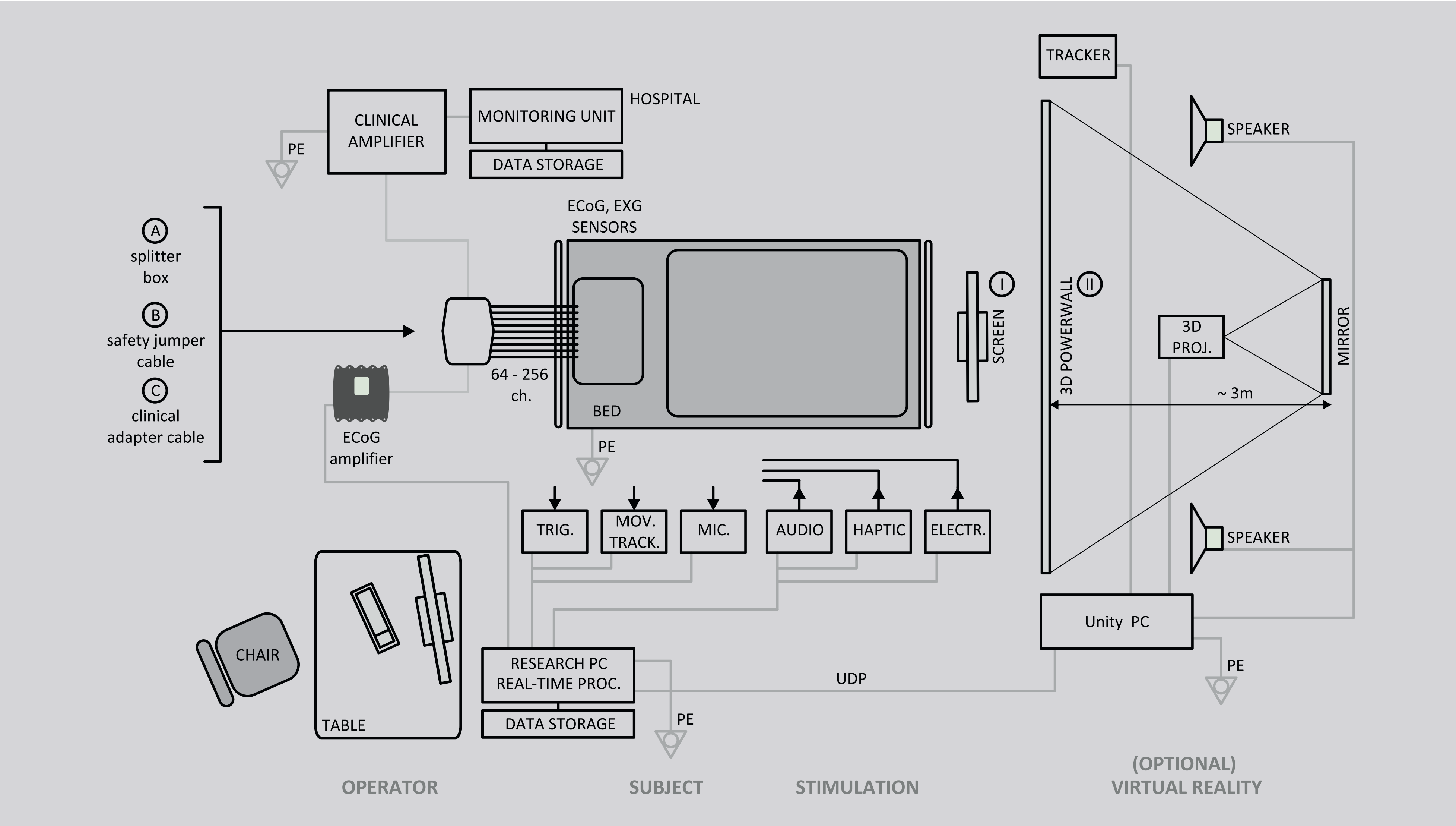
BCI LAB



Develop new applications with the full range of available state-of-the-art BCI technology

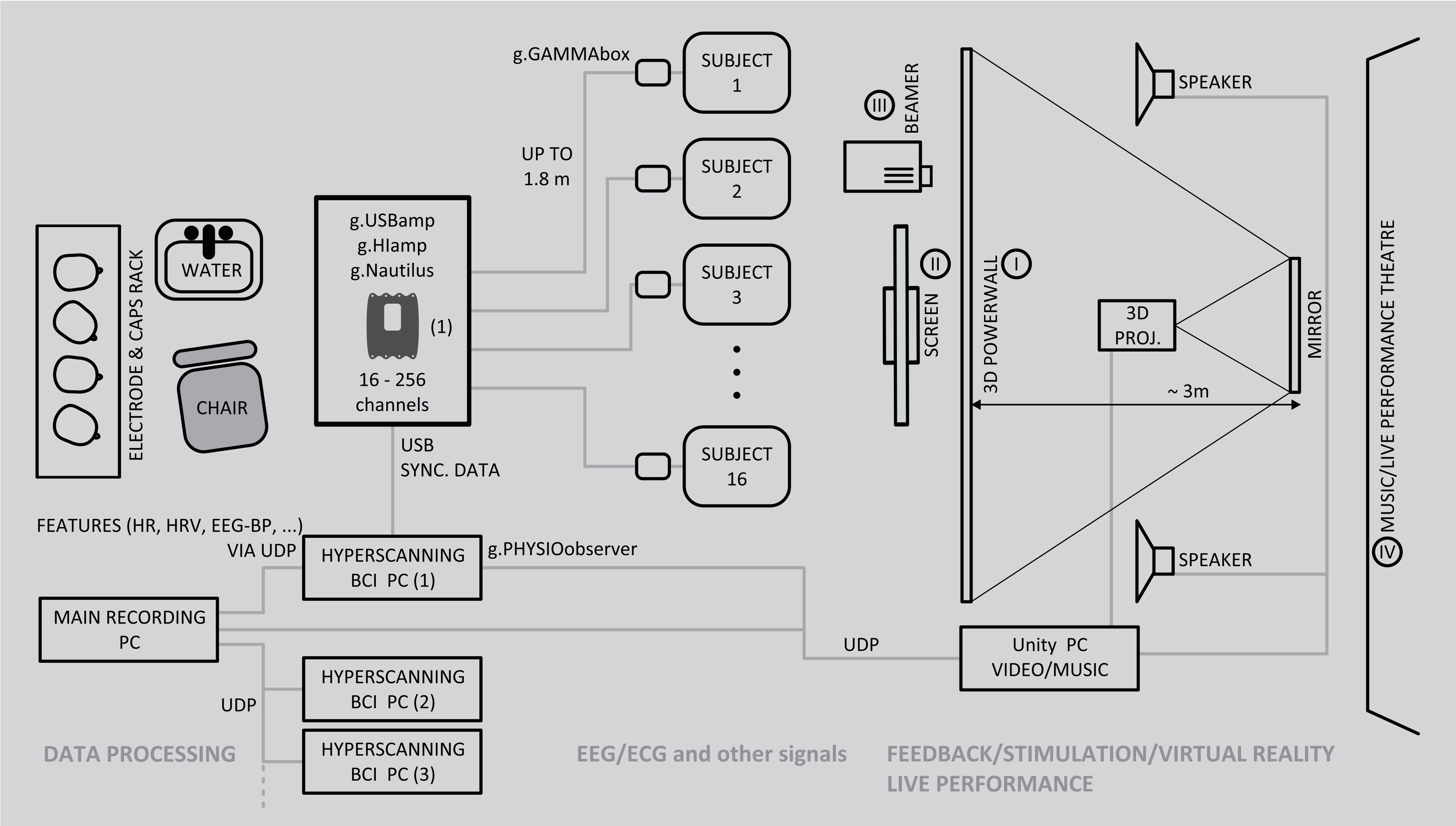

OP 4
g.Estim

ECOG LAB



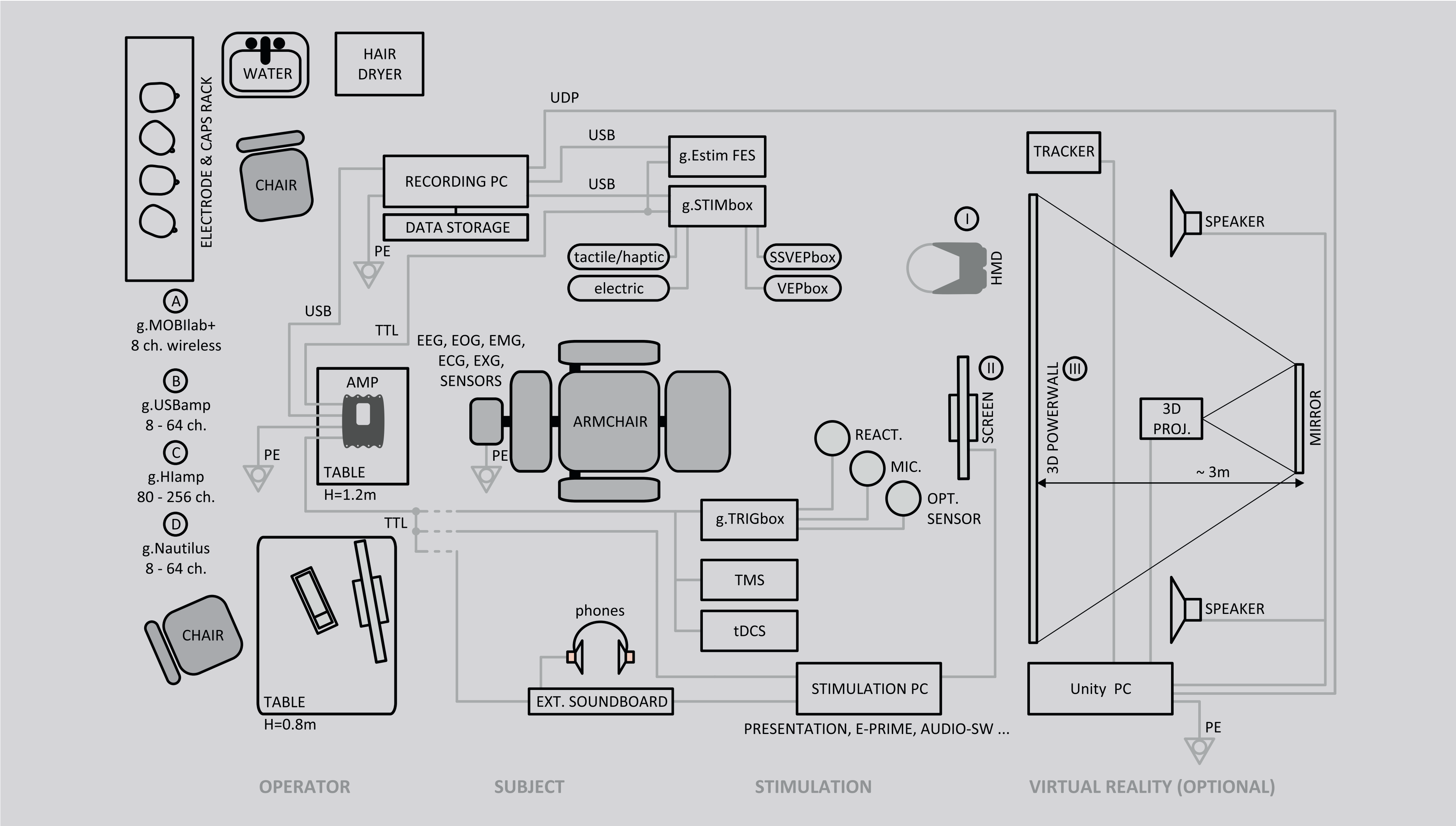
Advanced real-time ECoG research without disconnecting the patient from the clinical monitoring system

MULTI-USER HYPERSCANNING AND BCI LAB



Investigate responses from multiple subjects by synchronous recording of brain and peripheral parameters

EP LAB



Work on sophisticated EP studies with any kind of stimulation

BCI TEACHING LAB

PRODUCT HIGHLIGHTS

- Complete BCI solutions for teaching and research with EEG and ECoG
- Ready to go paradigms for spelling, robot and cursor control
- Make your students and lab members ready for neuroengineering
- Unique interdisciplinary teaching approach that brings students from different backgrounds together
- Expert talks at your site to inspire students
- Seamless integration of real-time experiments and off-line analysis
- Out of the box solution to run experiments quickly
- Installation and training
- The only environment that supports all BCI approaches (P300, SSVEP, motor imagery, slow waves)
- MATLAB/Simulink Rapid Prototyping environment speeds up the development time

g.tec offers complete solutions for your professional academic teaching- and research-lab! The BCI teaching lab is designed for universities to run biomedical engineering, neuroscience, physiology, psychology, medicine, computer science, signal processing, robotics or brain-computer interface lectures, across 1 or 2 terms. Students can quickly get started running ready-to-go experiments with P300, SSVEP or motor imagery to learn all necessary tasks. Students will also be assigned problem-solving challenges during the teaching lectures. The BCI Teaching Lab features videos, expert talks, and hands-on experience that provide a range of methods to inspire users and develop innovative solutions. After successful completion of the first term, students develop their own BCI solution and interface the system with Facebook, a robotic device, or another system to complete the second term at the university. After these two steps, students are ready for doing a master thesis in the area of BCIs, working on EEG acquisition, paradigm design, signal processing, application development or validating the effectiveness of their new solutions.

The BCI Teaching Lab creates an interdisciplinary environment where students with different backgrounds (electrical or biomedical engineering, mechanical engineering, computer science, neuroscience, psychology, biology, journalism, etc...) get a chance to interact and work as a team. This interdisciplinary approach allows more students to learn about BCI technology, providing a new and immersive teaching opportunity with a great value for universities.

User Experience

Dr. Brendan Allison
University of California,
San Diego, US

“The BCI teaching labs are a great way to learn the different skills needed for real-time BCIs and other biomedical signal processing applications.”

BCI TEACHING LAB
TECHNICAL SPECIFICATIONS

The system is MATLAB-based and includes all hardware and software components needed for data acquisition, real-time and off-line data analysis, data classification and provides neurofeedback.

The teaching lab BCI system comes with a g.USBamp with 16 channels. The amplifier transmits the data over USB to the computer. With the software package High-Speed On-line Processing under SIMULINK, you can read the biosignal data directly into SIMULINK. SIMULINK blocks are used to visualize and store the data. The parameter extraction and classification can be performed with standard SIMULINK blocks, the g.RTanalyze library or self-written S-functions. After the EEG data acquisition, the data can be analyzed with g.BSanalyze, the EEG and classification toolbox.

With ready-to-use BCI sample applications, you can develop state-of-the-art BCI experiments within a few hours. g.tec started to develop BCI systems more than 15 years ago. Therefore, all important BCI functions are included in the package and can easily be used and modified.

TL 16 systems	TL 8 systems	TL 4 systems	BCI Teaching Lab Version	
16	8	4	Complete 16-ch g.USBamp systems	Hardware
16	8	4	Caps with active electrode systems, gel, consumables	
16	8	4	Sensors for respiration, air flow, and GSR	
16	8	4	Hardware sets required for BCI examples, stimulators, I/O	
16	8	4	Complete PC sets with pre-installed software	
12	6	3	Sync cables to use multiple amplifiers together	
☐	☐	☐	Eye-tracker systems	
16	8	4	g.HIsys, High-Speed Online Processing for SIMULINK	Software
16	8	4	g.RTanalyze, real-time processing/analysis/classification blocksets	
16	8	4	g.BSanalyze, offline processing, analysis and classification	
16	8	4	SIMULINK models for BCI (P300, SSVEP, motor imagery, CSP, hybrid BCI, ping-pong game, EMG/EOG control, Reha-BCI, hyperscanning, g.PHYSIOobserver, vibro-tactile BCI, ACTOR protocol, ...)	
16	8	4	g.UDPinterface for network data exchange between systems	
5	3	1	Full subscription with software updates (years)	
☐	☐	☐	g.EYEtracker interface for SIMULINK	
18	9	6	BCI webinars	Teaching
6	3	2	BCI expert talks at your institution	
✔	✔	✔	Lecture materials with solutions (EEG, BCI, EP, PHYSIOobserver)	
✔	✔	✔	Video collection of 10 BCI application examples	
✔	✔	✔	BCI PowerPoint slides for teaching	
✔	✔	✔	Lab plans	
✔	✔	✔	BCI-Award book	
✔	☐	☐	BCI Wolpaw book	
✔	✔	✔	On-site installation & training	Service & Support
3	2	1	Supported master theses at g.tec	
2	1	☐	Student internship at g.tec	
✔	✔	✔	Listing as certified teaching partner (website, press release)	
✔	✔	✔	Teaching lab certificate	
✔	✔	✔	Student certificates for examinations	
✔	✔	✔	Preferred member for free conference batches	
✔	✔	✔	Briefing for BCI-Award submission	
✔	✔	✔	BCI lab user-story published in newsletter	
get the special discount!	get the special discount!	get the special discount!	**BCI Teaching Lab Package Prices**	

✔ ... included
☐ ... optional

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Facharztprüfung Allgemeinmedizin
in Fällen, Fragen und Antworten
Hauskrankenpflege
THE CRUSH SYNDROME
Sparwasser
Weidner
Urologie
QUANTITATIVE METHODS IN HEALTH CARE MANAGEMENT
Larsen Anästhesie
Buchrückgabe
Buchrückgabe
VAIO
Handbuch der Universitäten und Fachhochschulen
Ambulante Pflege
Brunen/Herold
RECENT ADVANCES IN
Edited by Reza Fazel-Rezai

BCI LECTURES

The g.tec lectures allow researchers, professors and users to quickly learn how to run a BCI and perform experiments. The lectures are perfectly suited for teaching because of the separation of tasks and solution manuals. The lectures are divided into two parts. The first part is a manual that contains the theoretical background, hands-on examples and several tasks to solve. The second part is a manual which contains only the solutions for the tasks.

Lecture 1: The Electroencephalogram (EEG)

The Electroencephalogram (EEG) is a tutorial that introduces the reader to EEG recordings and analysis methods. The reader will learn how to assemble electrodes correctly, set up the recording equipment appropriately and make high-quality EEG recordings. Furthermore, several EEG experiments have to be performed, which will provide hands-on experience and understanding of state-of-the-art EEG analysis topics.

Average time to perform the lecture: 450 min
Pages of lecture: 47
Pages of solutions for lecture: 24

CONTENTS

- Learn to assemble electrodes according to the 10-20 system
- Learn to assemble electrodes with EEG caps and active electrodes
- Test the impedance of the EEG electrodes
- Learn how to connect the electrodes to the amplifier and to make monopolar and bipolar recordings
- Learn how to test the recording setup
- Learn to recognize alpha and beta rhythms
- Learn to recognize artifacts in the EEG recording
- Learn to eliminate artifacts from the EEG recording
- Investigate the alpha block during a mental task
- Investigate hemispheric differences during language and spatial processing
- Learn how hyperventilation affects the EEG
- Learn the EEG differences of introverts and extraverts

Lecture 2: The Brain-Computer Interface (BCI)

The Brain-Computer Interface (BCI) is a tutorial which introduces the reader to BCI experiments and analysis methods. The reader will learn how to analyze BCI data in off-line and on-line mode and to set up real-time Simulink models for BCI experiments. Experiments will be introduced that can be used to acquire EEG data for training the computer on subject specific patterns, and for real-time feedback to control a cursor. Several examples of parameter extraction algorithms like bandpower, Hjorth and adaptive autoregressive models (AAR) will be explained. Classification algorithms like linear discriminant analysis (LDA) and neural networks (NN) are also part of the lecture. The reader has to perform several tasks to provide experience with a range of state-of-the-art BCI processing steps.

Average time to perform the lecture: 465 min
Pages of lecture: 89
Pages of solutions for lecture: 28

CONTENTS

- Learn pre-processing steps for BCI data analysis
- Calculate the power spectrum and event-related desynchronization of EEG data
- Extract features from different EEG channels
- Train different classifiers to discriminate the features
- Compare feature extraction and classification algorithms
- Conduct BCI experiments without feedback to get data for pattern recognition
- Perform real-time BCI experiments with cursor feedback
- Learn to write processing batches for fast off-line analysis
- Extract reactive frequency components out of the EEG data
- Modify real-time analysis models for optimal performance
- Train yourself to reach high BCI classification accuracy

Lecture 3: The Electrocardiogram (ECG)

The ECG lecture is intended to give a practical entry to state-of-the-art ECG processing. The reader is confronted with common tasks of modern ECG analysis and is taught how to practically solve the problems. Each lesson starts with a theoretical part to provide enough knowledge to solve the tasks.

Average time to perform the lecture: 760 min
Pages of lecture: 58
Pages of solutions for lecture: 71

CONTENTS

- Measure Einthoven-, Goldberger- and Wilson-derivations
- Perform 12 lead derivations
- Learn to identify and avoid artifacts in the ECG signals
- Calculate single beat intervals and amplitudes
- Perform automatic QRS complex detection
- Program an off-line and on-line QRS complex detector
- Analyze tilt table experiments
- Detect arrhythmias and abnormalities

Lecture 4: Evoked Potentials (EP)

The Lecture Evoked Potentials explains the recording and analysis of auditory steady-state responses (ASSRs), the auditory P300 response and brainstem auditory evoked potentials (BAEP). Each of these methods is important in clinical electroencephalography. The auditory P300 response can also be used as interaction method within a Brain Computer Interface (BCI).

Average time to perform the lecture: 430 min
Pages of lecture: 85

CONTENTS

- Configure the auditory stimulator correctly for EPs
- Record and analyze P300 responses
- Record and analyze MMN
- Record and analyze ASSRs
- Record and analyze BAEPs
- Record and analyze SSEPs
- Perform step-by-step the off-line analysis
- Run analysis batches to evaluate the captured EPs

Lecture 5: Physio observer

This lecture explains the recording and evaluation of physiological and cognitive parameters. With biosignals like ECG, GSR, respiration, EEG, physiological parameters like heart- rate and cognitive indices like the EEG band power, it is possible to recognize various mental and physical states of a person in real-time. This leads to a better human-computer interaction and human- robot cooperation.

Average time to perform the lecture: 240 min
Pages of lecture: 65
Pages of solutions for lecture: 19

CONTENTS

- Configure the physio observer to run experimental paradigms
- Perform a circle training experiment
- Perform high altitude medicine experiments

Lecture 6: g.Nautilus Sports

This lecture demonstrates how the g.Nautilus wireless biosignal amplifier can be used to record EEG signals during sports exercise. It uses an auditory paradigm similar to the ones presented in the Evoked potentials lecture to demonstrate the stability and low number of artefacts achievable with the g.Nautilus device during physical exercises.

Average time to perform the lecture: 120 min
Pages of lecture: 39
Pages of solutions for lecture: 15

CONTENTS

- Configure the g.Nautilus device to run experimental paradigms
- Record the EEG while the subject simultaneously performs physical exercise and follows an EP paradigm
- Calculate the jitter in displaying the auditory stimuli and display the observed EP signals.

WORKSHOPS

If your lab plans to organize a workshop or satellite event at your institution, g.tec will be happy to send a researcher who can talk about brain-computer interfaces, spike recordings, real-time physiology analysis, Virtual Reality systems, functional mapping with ECoG, and related topics. Every workshop can be booked as half-day or full-day workshop.

- **Workshop 1**: Brain-computer interface
- **Workshop 2:** Spike and ECoG recordings
- **Workshop 3**: Coma/Consciousness assessment
- **Workshop 4**: Passive functional mapping
- **Workshop 5**: Stroke rehabilitation

CUSTOMER TRAINING

g.tec's research systems are powerful tools and open a wide range of possible applications. This is why g.tec provides training opportunities at g.tec offices in Austria, Barcelona and New York. Get a general introduction to your systems, see some basic experiments and application examples or discuss special hardware- and software solutions with our developers, programmers and application engineers. The training is most effective if you come with your own g.tec system to guarantee that all the settings are performed correctly on your system. All branches offer space for groups of up to 40 members of your team for the training. Just contact us to schedule your training. We are happy to help you plan your travel and accommodation.

- **Course 1:** Off-line biosignal analysis (EEG, ECG, GSR, respiration) with g.BSanalyze
- **Course 2:** Measuring biosignal data (EEG, ECG, GSR, respiration, EMG, EOG, ECoG, pulse, SpO2, etc.) with g.USBamp/g.MOBIlab+
- **Course 3:** Running BCI (P300, motor imagery, SSVEP) experiments in real-time
- **Course 4:** Measuring EPs (BAEP, ASSR, P300, N200,...)
- **Course 5:** Extending the biosignal analysis with custom software modules under MATLAB/Simulink
- **Course 6:** Acquiring and analyzing spikes
- **Course 7:** Running Virtual Reality and physiology experiments
- **Course 8:** Coma assessment and communication with BCIs
- **Course 9:** Passive functional mapping with ECoG
- **Course 10:** Motor rehabilitation with BCIs

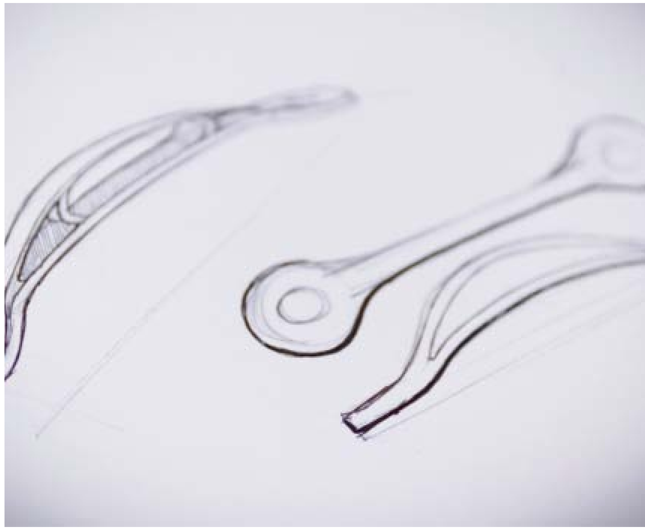
BR41N.IO

THE BRAIN-COMPUTER INTERFACE DESIGNERS HACKATHON

The BR41N.IO Brain-Computer Interface Designers Hackathon is organized by g.tec neurotechnology GmbH, and was created to teach current and future developments and unlimited possibilities of Brain-Computer Interfaces in creative or scientific fields. BR41N.IO aims to help participants understand how artificial intelligence, life science, art, technology and neuroscience come together, leading to new BCI designs and headpieces.

The BR41N.IO hackathon teaches engineers, programmers, designers, and other participants how to build and program their own fully functional EEG-based Brain-Computer Interface (BCI) to control external devices, robots or orthoses. Participation only requires basic knowledge in Brain-Computer Interfaces, machine learning, programming or design. We'll provide all of the required systems and software.

Dates and registration details: www.br41n.io



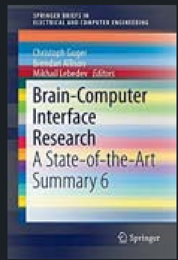
10 Scientific References

The high quality of g.tec's products has been validated in peer-reviewed scientific publications with authors and groups around the world. Find scientific references and publications online at FrontiersIn and ResearchGate

https://loop.frontiersin.org/people/1735/publications
www.researchgate.net/profile/Christoph_Guger

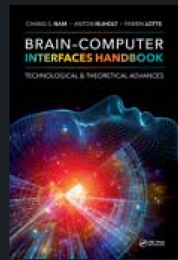
SMART WHEELCHAIRS AND BRAIN-COMPUTER INTERFACES

Mobile Assistive Technologies combines the fields of neuroscience, rehabilitation and robotics via contributions from experts in their fields to help readers develop new mobile assistive technologies. It provides information on robotics, control algorithm design for mobile robotics systems, ultrasonic and laser sensors for measurement and trajectory planning. This field is ripe for contributions from BCI researchers. A full view of this new field is provided, presenting the latest research in the field of smart wheelchairs, potential control mechanisms and human interfaces that covers mobility, particularly powered mobility, smart wheelchairs, sensors, control mechanisms, and human interfaces.



BRAIN-COMPUTER INTERFACE RESEARCH: A STATE-OF-THE-ART SUMMARY 6

This book presents compact and informative descriptions of the most promising new projects in brain-computer interface (BCI) research. As in earlier volumes in this series, the contributions come from many of the best-known groups in BCI research. Each of these chapters provides an overview of a project that was nominated for the most prestigious award in the BCI community: the Annual BCI Research Award. The book also contains an introduction and discussion with a review of major trends reflected in the awards. This volume introduces a new type of contribution, namely a chapter called "Trends in BCI Research" that summarizes a top trend in the BCI research community. This year's "Trends in BCI Research" chapter addresses BCI technology to help patients with disorders of consciousness (DOC) and related conditions, including new work that goes beyond communication to diagnosis and even prediction.



BRAIN-COMPUTER INTERFACES HANDBOOK: TECHNOLOGICAL AND THEORETICAL ADVANCES

This handbook is a valuable resource to anyone involved with improvement of people's lives by replacing, restoring, supplementing and improving motor activity, and understanding the neural bases of such functions. While there are several other resources available, there is no handbook such as this one. This handbook addresses the recent and rapid changes in the field of brain computer interfaces (BCIs). Due to these changes, interest in BCI has grown enormously, including interest from computer science researchers with a background in computational intelligence, human-computer interaction, and entertainment technology.

11 Contact

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