Brain Computer Interface & Neuromuscular Diseases/Disorders

In this edition of reSearch we explore the topic of brain computer interface (BCI) technology for individuals with neuromuscular diseases/disorders. Brain computer interface (BCI), also known as brain- or mind-machine interface, is a direct communication interface system between an external device and the brain, which allows an individual to communicate with, or control a computer or other electronic device, using his or her brainwaves without movement from the neuromuscular system. (Retrieved from: http://www.brainvision.co.uk/blog/2014/04/the-brief-history-of-brain-computer-interfaces). There are two types of BCI systems: invasive and noninvasive. Invasive systems require a surgical procedure to implant electrodes on or near the surface of the brain; whereas, noninvasive systems involve the use of a cap (similar in appearance to a fabric swimming cap) that keep applied electrodes in place on the scalp. The noninvasive systems require the use of a conductive gel and provide little or no discomfort other than needing to wash the gel out of the hair after use. Whether the BCI system is invasive or noninvasive, the process is the same—the brain signals picked up by the electrodes are sent to the computer and software translates these signals into computer commands. (Retrieved from: http://www.alsa.org/als-care/resources/publications-videos/factsheets/brain-computer-interface.html).

This edition of reSearch provides a “snapshot” of over 20 years of research on BCI. This “snapshot” presents a general overview of the BCI and its use with persons with neuromuscular diseases/disorders (i.e., amyotrophic lateral sclerosis [ALS], locked-in syndrome [LIS], stiff person syndrome [SPS], multiple sclerosis [MS], etc.). The combined search terms for this edition of reSearch included: brain computer interface, BCI, neuromuscular diseases/disorders, ALS, MS, locked-in, stiff person, and motor neuron. A listing of over 200 additional descriptor terms between the NARIC, CIRRIE, ERIC, Cochrane, IEEE Explore, and PubMed databases can be found at the end of this document.


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NIDILRR Funded Projects Related to Brain Computer Interface & Neuromuscular Diseases/Disorders

In addition to document searches, we searched our NIDILRR Program Database to locate grantees/projects related to BCI & NMD. The search resulted in six currently funded and six projects that are no longer active. Project information and their publications are offered as additional resources for our patrons.

Advanced Rehabilitation Research Training Center on Neuro-musculoskeletal Rehabilitation
Project Number: H133P070007
Phone: 973/324-3550
Email: pbarrance@kesslerfoundation.org.
www.kesslerfoundation.org/researchcenter/postdoctoralfellowshipprogram.php.

Advanced Rehabilitation Research Training in Neuromuscular and Neurodevelopmental Disorders
Project Number: H133P110005
Phone: 916/734-5292

Development of an Intelligent Assistive Robotic System for Individuals with Multiple Sclerosis
Project Number: H133G120275
Phone: 407/882-2820
Email: abehal@ucf.edu.
www.eecs.ucf.edu/~abehal.

Rehabilitation Engineering Research Center on Augmentative and Alternative Communication (The RERC on AAC)
Project Number: H133E140026
Phone: 814/863-2010
Email: jcl4@psu.edu.
reerc-aac.psu.edu.

Rehabilitation Research and Training Center in Neuromuscular Diseases (RRTC-NMD)
Project Number: H133B090001
Phone: 916/734-4280
Email: scott.branum@ucdmc.ucdavis.edu.

University of Maryland Advanced Neuromotor Rehabilitation Research Training (UMANRRT)
Project Number: H133P100014
Phone: 410/706-1771
Email: mmartinez@som.umaryland.edu.

These projects have completed their research activities and are now closed.

An Adaptive Haptic Interface for Individuals with Disabilities
Project Number: H133S040119
Phone: 434/973-1215
Email: olowin@barron-associates.com.

Assistive Computer Interfaces for Persons with Movement Disorders
Project Number: H133G30064
Phone: 410/955-7093
Email: nthakor@eureka.wbme.jhu.edu.

Brain Computer Interface to Enable Improved Communication Access
Project Number: H133S120039
Phone: 763/515-5355
Email: triehle@koronisbiotech.com.

Personalized Synthetic Speech Using ModelTalker: Development and Evaluation
Project Number: H133G990182
Phone: 302/651-6835
Email: bunnell@asel.udel.edu.
www.asel.udel.edu/speech.

Preparations for In-Home Testing of Brain-Computer Interfaces Operating Assistive Technology
Project Number: H133G090005
Phone: 734/936-7170
Email: janeh@umich.edu.
www.umich.edu/~umdbi.

A Synergy-Based Brain Computer Interface to Reanimate Paralyzed Hands
Project Number: H133F100001
Phone: 610/306-8539
Email: rkv3@pitt.edu.

ABSTRACT: Study evaluated the impact of a hybrid control on usability of a P300-based brain-computer interface (BCI) system that was designed to control an assistive technology software and was integrated with an electromyographic channel for error correction. The 11 participants in this pilot study included 8 healthy and 3 severely motor-impaired subjects. The three people with severe motor disability were identified as potential candidates to benefit from the proposed hybrid BCI system for communication and environmental interaction. To investigate the improvement in usability, two modalities of BCI system control were compared: a P300-based and a hybrid P300 electromyographic-based mode of control. System usability was evaluated according to the following outcome measures within three domains: (1) effectiveness (overall system accuracy and P300-based BCI accuracy); (2) efficiency (throughput time and users’ workload); and (3) satisfaction (users’ satisfaction). The information transfer rate and time for selection were also considered. Results obtained in healthy participants were in favor of a higher usability of the hybrid control as compared with the non-hybrid. A similar trend was indicated by the observational results gathered from each of the three potential end-users. The proposed hybrid BCI control modality could provide end-users with severe motor disability with an additional option to exploit some residual muscular activity.


ABSTRACT: Study evaluated the ability of an individual with incomplete locked-in syndrome enrolled in the BrainGate Neural Interface System pilot clinical trial to communicate using neural point-and-click control. Neural interface systems, also called brain-computer interfaces (BCIs), are devices that connect the nervous system to an external device for the purpose of restoring mobility and communication to individuals with paralysis and anarthria (inability to speak) resulting from neurological disorders. A general-purpose interface was developed to provide control of a computer cursor in tandem with one of two on-screen virtual keyboards: (1) a standard QWERTY keyboard and (2) the BrainGate Radial Keyboard, which has been designed to improve typing performance and ease-of-use for neural point-and-click communication. The participant used this interface to communicate face-to-face with research staff by using text-to-speech conversion, and remotely using an Internet chat application. The Radial Keyboard was compared to the standard QWERTY keyboard in a balanced copy-spelling task. Results showed that the Radial Keyboard yielded a significant improvement in typing accuracy and speed, enabling typing rates greater than 10 correct characters per minute. Furthermore, the participant reported strongly preferring the Radial Keyboard over the QWERTY keyboard, citing its speed and ease of use. This study demonstrates the first use of an intracortical BCI for neural point-and-click communication by an individual with incomplete locked-in syndrome.


Project Number: H133G090005

ABSTRACT: Article reports on the Virtual Users’ Forum, including initial results from ongoing research
being conducted by two brain-computer interface (BCI) groups, with a goal of encouraging widespread use of participatory action research in all BCI efforts. More than 300 researchers gathered at the 2013 International BCI Meeting to discuss current practice and future goals for BCI research and development. The authors organized the Virtual Users’ Forum at the meeting to provide the BCI community with feedback from users. Online surveys and in-person interviews were used to solicit feedback from people with disabilities who are expert and novice BCI users. Their responses were organized into four major themes: current (non-BCI) communication methods, experiences with BCI research, challenges of current BCIs, and future BCI developments. Two authors with severe disabilities gave presentations during the Virtual Users’ Forum, and their comments are integrated with the other results. While participants’ hopes for BCIs of the future remain high, their comments about available systems mirror those made by consumers about conventional assistive technology. They reflect concerns about reliability (e.g., typing accuracy/speed), utility (e.g., applications and the desire for real-time interactions), ease of use (e.g., portability and system setup), and support (e.g., technical support and caregiver training). People with disabilities, as target users of BCI systems, can provide valuable feedback and input on the development of BCI as an assistive technology. To this end, participatory action research should be considered as a valuable methodology for future BCI research.


NARIC Accession Number: J70937

ABSTRACT: This case study demonstrated independent brain-computer interface (BCI) home use by a 73-year-old patient with amyotrophic lateral sclerosis in the locked-in state and the effect it has on quality of life. The P300 BCI-controlled Brain Painting application was installed at the patient’s home. Family and caregivers were trained in setting up the BCI system. After every BCI session, the end user indicated subjective level of control, loss of control, level of exhaustion, satisfaction, frustration, and enjoyment. To monitor BCI home use, evaluation data of every session were automatically sent and stored on a remote server. Satisfaction with the BCI as an assistive device and subjective workload was indicated by the patient. Usability of the BCI was evaluated in terms of its effectiveness, efficiency, and satisfaction. The influence of the BCI on quality of life of the end user was assessed. The patient painted in about 200 BCI sessions (1 to 3 times per week) with a mean painting duration of 81.86 minutes. In most of the BCI sessions, the end user’s satisfaction was high. Dissatisfaction occurred mostly because of technical problems at the beginning of the study or varying BCI control. The subjective workload was moderate. Brain Painting had a positive impact on the patient’s competence, adaptability, and self-esteem. Results demonstrate that independent home use of a BCI-controlled painting application is feasible and positively influences quality of life and supports social inclusion of the patient.


NARIC Accession Number: J70941

ABSTRACT: Study evaluated the feasibility and usability of an assistive technology (AT) prototype operated with a P300-based brain-computer interface (BCI) to provide users with different degrees of muscular impairment resulting from amyotrophic lateral sclerosis (ALS) with communication and environmental control applications. The functionalities of the AT prototype were implemented to control electronic devices available at an apartment-like space designed to be fully accessible by people with motor disabilities for occupational therapy, placed in a neurologic rehabilitation hospital. The AT prototype was evaluated by eight end-users with ALS using three experimental conditions based on: (1) a widely validated P300-based BCI alone; (2) the AT prototype
operated by a conventional/alternative input device tailored to the specific end-user’s residual motor abilities; and (3) the AT prototype accessed by a P300-based BCI. These three conditions were presented to all participants in three different sessions. System usability was evaluated in terms of effectiveness (accuracy), efficiency (written symbol rate, time for correct selection, workload), and end-user satisfaction (overall satisfaction) domains. A comparison of the data collected in the three conditions was performed. Effectiveness and end-user satisfaction did not significantly differ among the three experimental conditions. Condition three was less efficient than condition two as expressed by the longer time for correct selection. Results indicate that a BCI can be used as an input channel to access an AT by persons with ALS, with no significant reduction of usability.


NARIC Accession Number: J70943
ABSTRACT: Study assessed awareness in four subjects in a minimally conscious state after brain injury, using an electroencephalogram (EEG)-based brain-computer interface (BCI), and determined whether these patients may learn to modulate sensorimotor rhythms with visual feedback, stereo auditory feedback, or both. The initial EEG-based assessment included imagined hand movement or toe wiggling and was used to activate sensorimotor areas and modulate brain rhythms during 90 trials for each subject. Within-subject and within-group analyses were performed to evaluate significant activations. A within-subject analysis was performed involving multiple BCI technology training sessions to improve the capacity of the user to modulate sensorimotor rhythms through visual and auditory feedback. Awareness detection was determined from sensorimotor patterns that differed for each motor imagery task. BCI performance was determined from the mean classification accuracy of brain patterns by using a BCI signal processing framework and assessment of performance in multiple sessions. All subjects demonstrated significant and appropriate brain activation during the initial assessment, and real-time feedback was provided to improve arousal. Consistent activation was observed in multiple sessions. The EEG-based assessment showed that patients in a minimally conscious state may have the capacity to operate a simple BCI-based communication system, even without any detectable volitional control of movement.

NARIC Accession Number: J70940
Project Number(s): H133G090005; H133N110002
ABSTRACT: Study surveyed people with spinal cord injury (SCI) to determine their priorities for brain-computer interface (BCI) applications and design features along with the time investment and risk acceptable to obtain a BCI. Forty people with SCI participated, including of 30 individuals identified from the SCI research registry who were surveyed by telephone and 10 participants from a BCI usage study who were surveyed in person before BCI use. Descriptive statistics of functional independence, living situations and support structures, ratings of importance of different task and design features, and acceptable levels of performance, risk, and time investment were calculated from the survey data. Participants were classified as having low function or high function based on their Functional Independence Measure motor scores. Results indicated that BCIs were of interest to 96 percent of the low-function group. Emergency communication was the top priority task. The most important design features were “functions the BCI provides” and “simplicity of BCI setup.” Desired performance was 90 percent accuracy, with standby mode errors no more than once every 4 hours and speeds of more than 20 letters per minute. Dry electrodes were preferred over gel or implanted electrodes. Median acceptable setup time was 10 to 20 minutes, satisfying 65 percent of participants. Creating BCI functions appropriate to the needs of those with SCI will be of ultimate importance for BCI acceptance with this population.
Daly, J.J., Huggins, J.E. (2015). Brain-computer interface: Current and emerging rehabilitation applications. Archives of Physical Medicine and Rehabilitation, 96(3, Supplement 1), S1-S7. NARIC Accession Number: J70935 ABSTRACT: Article introduces a journal supplement that reviews research on the development and capabilities of brain-computer interface (BCI) for rehabilitation. A BCI can be defined as a system that translates “brain signals into new kinds of outputs.” After brain signal acquisition, the BCI evaluates the brain signal and extracts signal features that have proven useful for task performance. The articles in this supplement provide examples of work conducted using a variety of BCI technology applications, including communication, leisure activities, and motor learning. These articles arose from presentations at the 2013 International Brain-Computer Interface Meeting, which was held June 3 through June 7, 2013, in Pacific Grove, California.

Fried-Oken, M., Mooney, A., Oken, B., & Peters, B. (2015). A clinical screening protocol for the RSVP keyboard brain-computer interface. Disability and Rehabilitation: Assistive Technology, 10(1), 11-18. NARIC Accession Number: J71072 ABSTRACT: Article describes the development of a screening protocol that identifies the sensory, motor, cognitive, and communication skills that people with locked-in syndrome (PLIS) require in order to use the RSVP Keyboard™ brain-computer interface (BCI). A multidisciplinary clinical team of seven individuals representing five disciplines identified the requisite skills for use of the RSVP Keyboard™. They chose questions and subtests from existing standardized instruments for auditory comprehension, reading and spelling, modified them to accommodate nonverbal response modalities, and developed novel tasks to screen visual perception, sustained visual attention and working memory. Questions were included about sensory skills, positioning, pain interference and medications. The result is a compilation of questions, adapted subtests and original tasks designed for this new BCI system. It was administered to 12 PLIS and 6 healthy controls. Administration required one hour or less. Yes/no choices and eye gaze were adequate response modes for PLIS. Healthy controls and nine PLIS were 100 percent accurate on all tasks; three PLIS missed single items. The results indicate that the RSVP BCI screening protocol is a brief, repeatable technique to identify the presence/absence of skills for BCI use by patients with different levels of locked-in syndrome.

Erdogmus, D., Fowler, A., Fried-Oken, M.B., Miller, M., Mooney, A., Oken, B.S., Orhan, U., Peters, B., & Roark, B. (2014). Brain-computer interface with language model-electroencephalography fusion for locked-in syndrome. Neurorehabilitation and Neural Repair, 28(4), 387-394. NARIC Accession Number: J68504 ABSTRACT: Study developed the RSVP Keyboard to address the communication needs of individuals with locked-in syndrome (LIS), using a noninvasive brain-computer interface (BCI) that involves rapid serial visual presentation (RSVP) of symbols and a unique classifier with electroencephalography (EEG) and language model fusion. BCIs use brain signals to provide a nonmotor communication channel for people with severely limited motor control. The RSVP Keyboard is the first BCI device developed with several unique features for people with LIS. Individual letters are presented at 2.5 per second. Computer classification of letters as targets or non-targets based on EEG is performed using machine learning that incorporates a statistical language model for letter prediction via Bayesian fusion enabling targets to be presented only one to four times. After screening, subjects first calibrated the system, and then completed a series of balanced word generation mastery tasks that were designed with five incremental levels of difficulty, which increased by selecting phrases for which the utility of the language model decreased naturally. Six participants with LIS and nine healthy controls completed the experiment. All LIS participants successfully mastered spelling at level 1 and one subject achieved level 5. Six of nine control participants achieved level 5. Findings suggest that individuals with incomplete LIS may benefit from an EEG-based BCI system that relies on EEG classification and a statistical language model. Steps to further improve the system are discussed.

NARIC Accession Number: J68305
Project Number: H133G090005

ABSTRACT: Study assessed the performance impact of using a brain-computer interface (BCI) as a plug-and-play input device to operate commercial assistive technology (AT). BCIs are intended to enable people with severe physical impairments to communicate and to operate technology without moving their bodies. Thirty-three participants (11 with amyotrophic lateral sclerosis and 22 controls) were asked to operate two devices (a commercial communication aid and a separate laptop computer) using a BCI. Results were compared to traditional BCI operation by the same users. Performance was assessed using both accuracy and BCI utility, a throughput metric. Ninety-five percent confidence bounds on performance differences were calculated using a linear mixed model. The observed differences in accuracy and throughput were small and not statistically significant. The confidence bounds indicate that if there is a performance impact of using a BCI to control an AT device, the impact could easily be overcome by the benefits of the AT device itself. The results suggest that BCI control of AT devices is possible, and the performance difference appears to be very small. BCI designers are encouraged to incorporate standard outputs into their design to enable future users to interface with familiar AT devices.

2013


NARIC Accession Number: J66657
Project Number: H133G090005

ABSTRACT: Study explored whether amyotrophic lateral sclerosis (ALS), a disorder associated primarily with the degeneration of the motor system, is associated with alterations in frontoparietal communication that can be assessed with electroencephalography during a cognitive task. Eleven individuals with ALS and 9 age-matched controls performed the cognitive task of operating a brain-computer interface while electroencephalography was recorded over three sessions. Using normalized symbolic transfer entropy, directed functional connectivity was measured from frontal to parietal (feedback connectivity) and parietal to frontal (feedforward connectivity) regions. Results showed that feedback connectivity was not significantly different between groups, but feedforward connectivity was significantly higher in individuals with ALS. This result was consistent across a broad electroencephalographic spectrum, and in theta, alpha, and beta frequency bands. Feedback connectivity has been associated with conscious state and was found to be independent of ALS symptom severity in this study, which may have significant implications for the detection of consciousness in individuals with advanced ALS. The authors suggest that increases in feedforward connectivity represent a compensatory response to the ALS-related loss of input such that sensory stimuli have sufficient strength to cross the threshold necessary for conscious processing in the global neuronal workspace.

2012


NARIC Accession Number: J64436

ABSTRACT: Study assessed the feasibility of using an electroencephalography (EEG)-based brain-computer interface (BCI) system, including a robotic arm, for reaching/grasping assistance in patients with tetraplegia. The study involved three consecutive phases: training/calibration, feedback, and robot control. Nine patients underwent EEG-BCI preliminary training and robot control sessions. Statistics entailed multiple linear regressions and cluster analysis. A questionnaire-based follow-up, including patients’ perception of their EEG-BCI control capacity, was continued up to 14 months after initial experiments.
Results indicated that EEG-BCI training/calibration-phase classification accuracy averaged 81.0 percent. Feedback training sessions averaged 70.5 percent accuracy for 7 subjects who completed at least one feedback training session. Seven (77.7 percent) of the 9 subjects reported having felt control of the cursor; and 3 subjects (33.3 percent) felt that they were also controlling the robot through their movement imagination. No significant side effects occurred. BCI performance was positively correlated with beta EEG spectral power density. Another possible influence was the American Spinal Injury Association Impairment Scale sensory score; higher sensory deficit may mean a slightly increased ability to perform motor imagery-based BCI.

Blain-Moraes, S., Gruis, K.L., Huggins, J.E., Schaff, R., & Wren, P.A. (2012). Barriers to and mediators of brain-computer interface user acceptance: Focus group findings. Ergonomics, 55(5), 516-525. NARIC Accession Number: J63934 Project Number(s): H133G090005; H133N110002; H133P090008; H133P090013 ABSTRACT: Article explores human factor issues involved in designing and evaluating brain-computer interface (BCI) systems for users with severe motor disabilities. BCIs are designed to enable individuals with severe motor impairments such as amyotrophic lateral sclerosis (ALS) to communicate and control their environment. By translating signals recorded directly from the brain into computer output or environmental control, BCIs may enable a motionless, voiceless individual to articulate autonomy and subjectivity, communicate and develop relationships, thereby continuing to affirm their personhood. A focus group was conducted with 8 individuals with ALS who were familiar with BCI technology and nine of their caregivers to determine the barriers to and mediators of acceptance of BCI. Two key categories emerged: personal factors and relational factors. Personal factors, which included physical, physiological and psychological concerns, were less important to participants than relational factors, which included corporeal, technological, and social relations with the BCI. The importance of these relational factors was analyzed with respect to published literature on actor-network theory and disability, and concepts of voicelessness and personhood. Future directions for BCI research are recommended based on the emergent focus group themes.

2011

Andrade, A.O., Bourhis, G., Losson, E., Navas, E.L.M., Pinheiro Jr., C.G., & Pino, P. (2011). Alternative communication systems for people with severe motor disabilities: A survey. Biomedical Engineering Online, 10(31). NARIC Accession Number: J66400 Available in full-text at: http://www.biomedical-engineering-online.com/content/10/1/31. ABSTRACT: Article provides a review of the way three bioelectrical signals (electromyographic, electrooculographic, and electroencephalographic) have been utilized in alternative communication with patients suffering severe motor impairment. It also offers a comparative study of the various methods applied to measure the performance of alternative and augmented communication (AAC) systems. Communication aid devices using electromyographic signals can be subdivided into three major groups: mouse emulation, speech recognition, and switch-based control device. Being a manifestation of eye movements, electrooculographic signals are processed to identify gaze, usually for cursor control on the screen. However, the most popular method for gaze estimation is using infrared cameras, through the reflection in the eye structures and their geometric relations. For people with severe motor disability such as locked-in syndrome, it often becomes impossible to communicate or control a muscular activity. However, these people generally keep cerebral and sensory functions intact. A solution to overcome this is to use electroencephalography associated with the cerebral activity to control an interface. This type of interface using the cerebral waves is usually called brain-computer interface. The article concludes with a review of the methods reported in the literature aiming at measuring the performances of AAC systems with and without the use of human-machine interaction models.

2006

Inc.), a neuromotor prosthesis (NMP) in a man with tetraplegia. An NMP is a type of brain-computer interface designed to restore lost motor function in paralyzed humans by routing movement-related signals from the brain to external effectors. NMPs require that intention-driven neuronal activity be converted into a control signal that enables useful tasks. Neuronal ensemble activity recorded through a 96-electrode array implanted in the subject’s primary motor cortex demonstrated that intended hand motion modulates cortical spiking patterns three years after spinal cord injury. Decoders were created to produce a neural cursor with which the subject opened simulated e-mail and operated devices such as a television. The subject also used neural control to open and close a prosthetic hand, and perform basic tasks with a multi-jointed robotic arm.

2001


ABSTRACT: Article describes the validation of a training procedure designed to enable verbal communication through self-regulation of slow cortical potentials. Two male patients with late-stage amyotrophic lateral sclerosis (ALS) learned voluntary control of their slow cortical potentials using a brain-computer interface wherein electric brain activity is used to control a cursor on a computer screen. Within 3 to 8 weeks, both had learned to use this skill to select letters or words and communicate them. The protocol may be a model for training other brain-computer interface techniques.

1995


ABSTRACT: Paper presenting a case description of the use of a brain-computer interface (BCI) by a man with amyotrophic lateral sclerosis (ALS). The man learned to use EEG activity over the sensorimotor cortex to control cursor movement on a video screen. His development of control was facilitated by off-line topographic and frequency analysis of EEG data recorded during training. This analysis led to improvements in the online algorithm that converted EEG activity into cursor movement, and enabled the user to move the cursor more rapidly and accurately. The authors conclude that BCI technology might be an alternative communication option for those with ALS. This paper was presented at the 1995 annual conference of the Rehabilitation Engineering and Assistive Technology Society of North America (RESNA).

Full-text copies of these documents may be available through NARIC's document delivery service.

To order any of the documents listed above, note the accession number and call an information specialist at 800/346-2742.

There is a charge of 5 cents for copying and shipping with a $5 minimum on all orders.
2002


ABSTRACT: In this paper a system is described which uses a brain-computer interface (BCI) and thus enables the persons with amyotrophic lateral sclerosis (ALS) to control home appliances, and to use computer with speech programs to communicate through articulation of pre-selected words. The ActiveHome from X10, which controls various home appliances through a computer, is used. The ease-of-use, ease-of-learning, rate-of-error, and amount of time required for task completion, were evaluated. (CIRRIE Abstract).

1999


ABSTRACT: An EEG-based brain-computer interface (BCI) is a direct connection between the human brain and the computer. Such a communication system is needed by patients with severe motor impairments (e.g. late stage of Amyotrophic Lateral Sclerosis) and has to operate in real-time. This paper describes the selection of the appropriate components to construct such a BCI and focuses also on the selection of a suitable programming language and operating system. The multichannel system runs under Windows 95, equipped with a real-time Kernel expansion to obtain reasonable real-time operations on a standard PC. Matlab controls the data acquisition and the presentation of the experimental paradigm, while Simulink is used to calculate the recursive least square (RLS) algorithm that describes the current state of the EEG in real-time. First results of the new low-cost BCI show that the accuracy of differentiating imagination of left and right hand movement is around 95 percent.

1996


ABSTRACT: The paper describes the EEG-based Brain Computer Interface (BCI) in which the EEG drives a communication channel between the brain and an electrical appliance. A pilot study was conducted to explore the use of this method with an equipment used to test persons with motor difficulties. The results demonstrated that the imagination of movement results creates similar EEG patterns as does the preparation of a real movement. (CIRRIE Abstract).

2013


ERIC Number: EJ1005025

Electroencephalography (EEG) is a non-invasive method for measuring brain activity and is a strong candidate for brain-computer interface (BCI) development. While BCIs can be used as a means of communication for individuals with severe disabilities, the majority of existing studies have reported BCI evaluations by able-bodied individuals. Considering the many differences in body functions and usage...
scenarios between individuals with disabilities and able-bodied individuals, involvement of the target population in BCI evaluation is necessary. In this review, 39 studies reporting EEG-oriented BCI assessment by individuals with disabilities were identified in the past decade. With respect to participant populations, a need for assessing BCI performance for the pediatric population with severe disabilities was identified as an important future direction. Acquiring a reliable communication pathway during early stages of development is crucial in avoiding learned helplessness in pediatric-onset disabilities. With respect to evaluation, augmenting traditional measures of system performance with those relating to contextual factors was recommended for realizing user-centered designs appropriate for integration in real-life. Considering indicators of user state and developing more effective training paradigms are recommended for future studies of BCI involving individuals with disabilities.

1993

ERIC Number: EJ477675
This paper describes a computer-assisted communication system successfully used in three cases of “locked in syndrome” (in which the only reliable motor functions are eye movements). The paper concludes that patients who survive locked in syndrome for several weeks should be given the chance to communicate via a suitable system.

2014

ID: CN-01053775
ABSTRACT: OBJECTIVE: Previous work has shown that it is possible to build an EEG-based binary brain-computer interface system (BCI) driven purely by shifts of attention to auditory stimuli. However, previous studies used abrupt, abstract stimuli that are often perceived as harsh and unpleasant, and whose lack of inherent meaning may make the interface unintuitive and difficult for beginners. We aimed to establish whether we could transition to a system based on more natural, intuitive stimuli (spoken words ‘yes’ and ‘no’) without loss of performance, and whether the system could be used by people in the locked-in state. APPROACH: We performed a counterbalanced, interleaved within-subject comparison between an auditory streaming BCI that used beep stimuli, and one that used word stimuli. Fourteen healthy volunteers performed two sessions each, on separate days. We also collected preliminary data from two subjects with advanced amyotrophic lateral sclerosis (ALS), who used the word-based system to answer a set of simple yes-no questions. MAIN RESULTS: The N1, N2 and P3 event-related potentials elicited by words varied more between subjects than those elicited by beeps. However, the difference between responses to attended and unattended stimuli was more consistent with words than beeps. Healthy subjects’ performance with word stimuli (mean 77 percent ± 3.3 s.e.) was slightly but not significantly better than their performance with beep stimuli (mean 73 percent ± 2.8 s.e.). The two subjects with ALS used the word-based BCI to answer questions with a level of accuracy similar to that of the healthy subjects. SIGNIFICANCE: Since performance using word stimuli was at least as good as performance using beeps, we recommend that auditory streaming BCI systems be built with...
word stimuli to make the system more pleasant and intuitive. Our preliminary data show that word-based streaming BCI is a promising tool for communication by people who are locked in.

2004
ID: CN-00502182
ABSTRACT: Mason and Birch have developed a direct brain-computer interface for intermittent control of devices such as environmental control systems and neuroprotheses. This EEG-based brain switch, named the LF-ASD, has been used in several off-line studies, but little is known about its usability with real-world devices and computer applications. In this study, able-bodied individuals and people with high-level spinal injury used the LF-ASD brain switch to control a video game in real time. Both subject groups demonstrated switch activations varying from 30 percent to 78 percent and false-positive rates in the range of 0.5 percent to 2.2 percent over three 1-hour test sessions. These levels correspond to switch classification accuracies greater than 94 percent for all subjects. The results suggest that subjects with spinal cord injuries can operate the brain switch to the same ability as able-bodied subjects in a real-time control environment. These results support the findings of previous studies.

2014
ABSTRACT: People affected by spinal cord injury (SCI) are usually unable to move their lower limbs due to inactive control of the muscles from the brain. This lack of movement may lead to further moral and physical complexities such as cardiovascular diseases, bone demineralization and bedsores. Physiotherapy based exercise and training are conventionally advised to such plegic patients, which, hereby, has not been shown to be have ample recovery efficiency. Alternatively, Functional electrical stimulation (FES) is a relatively newer technique which uses electrical signals to energize the neurons and excite the tissues in the muscles while producing the corresponding contraction in them. FES alone however requires specific electrical devices to generate and supply certain electrical signals similar to that of generated by human brain. This needs some additional devices to be used as the control system for FES to identify and issue the commands as required from time to time. A brain-computer interface (BCI) is a direct communication pathway between the brain and an external device. It uses electrodes, placed on the scalp, to collect signals from the brain structure. A combination of BCI and FES can be a vital solution to cater this issue, as the paralyzed patient can use his own brain electroencephalogram (EEG) as a control system to perform the required movements. This paper discusses their advantages, short comings and latest research advances in this field. Firstly, the significance of FES devices is being introduced and the different technological techniques reported in literature are discussed. Secondly, human brain is introduced as a control system to be employed within BCI systems to generate the required EEG signal activity. Finally, an incorporation of both FES and BCI is suggested to overcome the presiding issues regarding efficient control of the muscles.
2013


ABSTRACT: It is impossible for severely disabled people to browse or learn through the Internet due to the mere lack of independent control of the mouse. This paper proposes a brain computer interface (BCI) to aid severely disabled individuals, such as people disabled by amyotrophic lateral sclerosis, in browsing or learning on the Internet. By analyzing specific components of event-related potentials, cursor control can be achieved. The cursor can be controlled by brain waves in a user-friendly manner to move or click on the web page. The major contributions of this research include: (1) designing a BCI for disabled people, (2) embedding the BCI’s cursor controller into a web page, (3) conducting clinical experiments, (4) analyzing the experimental results, system accuracy, and effectiveness, and (5) evaluating the system’s practicability and giving suggestions for future work. There are two innovative technologies proposed in this research: (1) a specific component of ERPs located at O1, the N2P3 (the difference between the peak and trough of N200 and P300), was used to differentiate targeted from non-targeted (non-selected) signals, (2) instead of a fixed position style BCI, a movable watermark style BCI which follows the cursor was designed. The novel technique supported by a user-friendly interface helps the disabled have contact with the outside world resulting in positive emotions.


ABSTRACT: Over two million people are affected by neural diseases such as multiple sclerosis, amyotrophic lateral sclerosis, spinal cord injury, cerebral palsy, and other diseases impairing the neural pathways that control muscles. Indeed, these diseases cause severe paralysis and the persons suffer from what is called “locked-in syndrome.” Consequently, a Brain Computer Interface (BCI) can be used as an alternative communication channel. This project belongs to a Brain Computer Interface research. More precisely, it focuses on the development of noninvasive platform of electroencephalographic signals in terms of acquisition, pre-processing, feature extraction for providing an alternative communication channel for patient with severe motor disabilities.

2012


ABSTRACT: A novel system which uses brain computer interface (BCI) technology and an iPhone to control wheelchair is developed. This system is developed with an aim to assist people suffering from spinal cord injuries, and amyotrophic lateral sclerosis, due to the inability to move limbs and body caused by death of nerve cells. The proposed system uses an iPhone to process the brain signals (EEG), specifically the attention signals, and direct corresponding commands to an assistive device, such as wheelchair, wirelessly. Comparing to other BCI system comprises of a bulky laptop and multi-electrodes, the proposed system is portable, cost-effective and ease of use. Potentially, not only people who are suffering from spinal cord injuries can benefit from this system, it extended to assisting elderly or people suffering from limb muscle disorder. The system structure and experimental results will be illustrated in this paper. No similar system is reported yet.

2011


ABSTRACT: As the use of biomedical signals is incredibly increasing in both clinical and nonclinical
applications. They have a great deal in the development of devices that can be controlled by information inferred from thoughts. One of the current hot topics for research is the Brain Computer Interface (BCI) on basis of EEG signals. BCI is a technology that makes humans to control computer or other devices on basis of information inferred from thoughts. BCIs have given new hopes to people who suffer from locked-in syndrome and motor disabilities by providing alternative means of communication channels. The existing BCIs are Multi-channel, thus very expensive in terms of cost and processing speed, which make them difficult for domestic use. The aim of this research paper is to introduce a very cheap, simple and a robust single channel BCI that could prevail in the market. We propose a very low-cost EEG-based BCI that is designed to help severely disabled people communicate with others by means of text and SMS. To make it simple and affordable, the number of channels is limited to one and signal is acquired through homemade silver electrodes and then fed to the computer through the soundcard for further processing and features extractions. The experimental results show that the proposed system is capable enough to provide a very low cost, yet reliable, communication means and a suitable BCI for domestic use. Its average accuracy is 87 percent. The potential uses for the technology are almost limitless. Instead of communication system, disabled users could have robotic wheelchair, allowing them to move and directly interact with the environments thus it can be used for clinical and nonclinical purposes.

ABSTRACT: Integration between Brain Computer Interface and mobile devices allows the development of mobile applications for people with severe neuromuscular diseases. These applications can increase their quality of life. This paper presents a mobile application that enables disabled people to make a phone call to a desired contact on their phone’s address book solely using their brain activity.

2010

ABSTRACT: A Brain Machine Interface is a communication system which connects the human brain activity to an external device bypassing the peripheral nervous system and muscular system. It provides a communication channel for the people who are suffering with neuromuscular disorders such as amyotrophic lateral sclerosis, brain stem stroke, quadriplegics and spinal cord injury. In this paper, a simple BMI system based on EEG signal emanated while visualizing of different colors has been proposed. The proposed BMI uses the color visual tasks and aims to provide a communication through brain activated control signal for a system from which the required task operation can be performed to accomplish the needs of the physically retarded community. The ability of an individual to control his EEG through the color visualization enables him to control devices. The EEG signal is recorded from 10 voluntary healthy subjects using the noninvasive scalp electrodes placed over the frontal, parietal, motor cortex, temporal and occipital areas. The obtained EEG signals were segmented and then processed using an elliptic filter. Using spectral analysis, the alpha, beta and gamma band frequency spectrum features are obtained for each EEG signals. The extracted features are then associated to different control signals and a neural network model using back propagation algorithm has been developed. The proposed method can be used to translate the color visualization signals into control signals and used to control the movement of a mobile robot. The performance of the proposed algorithm has an average classification accuracy of 95.2 percent.

ABSTRACT: Assistive technologies have a major impact in the life of people with severe neuromuscu-
lar diseases in order to provide or extend functional abilities of people with special needs. Such technologies promote independent life, social inclusion and improve quality of life of disabled people. Brain-Computer Interface (BCI) is a recent technology that allows the direct communication between the brain and the environment. The development of systems that integrates BCI, smart devices and pervasive services enables motor disabled people to control devices anytime and anywhere. This paper presents an architecture for the development of BCI-aware pervasive systems to control multimedia devices. The user needs an electroencephalography device and a smart device to interact with any multimedia device. This paper brings the implementation of a BCI-aware pervasive system that enables users to control the XBMC media center to play music or videos.


ABSTRACT: For individuals with mobility limitations, powered wheelchair systems provide improved functionality, increased access to healthcare, education and social activities. Input devices such as joystick and switches can provide the necessary input required for efficient control of the powered wheelchair. For persons with limited dexterity, or fine control of the fingers, access to mechanical hardware such as buttons and joysticks can be quite difficult and sometimes painful. For individuals with conditions such as Traumatic Brain Injury, Multiple Sclerosis or Amyotrophic lateral sclerosis voluntary control of limb movement maybe substantially limited or completely absent. Brain Computer Interfaces are emerging as a possible method to replace the brains normal output pathways of peripheral nerves and muscles, allowing individuals with paralysis a method of communication and computer control. This study involves the analysis of non-invasive electroencephalograms (EEG) arising from the use of a newly developed Human Machine Interface for powered wheelchair control. Using a delayed response task, binary classification of left and right movement intentions were classified with a best classification rate of 81.63 percent from single trial EEG. Results suggest that this method may be used to enhance control of HMI’s for individuals with severe mobility limitations.


ABSTRACT: This paper presents the satellite television remote control system based on brain-computer interface. The Brain Controlled Satellite Television Remote System (BCSTRS) is a real time system that can help the patients suffering from Amyotrophic Lateral Sclerosis (ALS) to select TV channels or adjust volume using their brain waves. In this paper we propose an algorithm including data acquisition and process, feature extraction, pattern recognition and SVM classifier. Experiments demonstrated that the BCSTRS is able to achieve an averaged information transfer rate of approximately 18 b/min and 5 healthy subjects can control the BCSTRS efficiently with an average accuracy of 90 percent.


ABSTRACT: A brain computer interface (BCI) can be used by persons with severe neuromuscular disorders to control external devices such as computers or neuro-prosthesis. To improve accuracy, however, most of BCIs need multi-channels, wet sensors, big and complex systems. It makes most use of BCIs restricted to laboratory and medical area. In this paper, to solve the limitation, mindset (neurosky headset) that is a commercially available BCI is adopted and the emergency call system for severely disabled persons using attention/meditation signal is developed. In addition, to operate on a wide range of disabilities under a wide range of environmental conditions, algorithms of determining trigger method and threshold level are proposed. The usefulness of the system and the proposed algorithms is verified by experiment result.
ABSTRACT: Recently, CNN reported on the future of brain-computer interfaces (BCIs). BCIs are devices that process a user’s brain signals to allow direct communication and interaction with the environment. BCIs bypass the normal neuromuscular output pathways and rely on digital signal processing and machine learning to translate brain signals to action (Figure 1). Historically, BCIs were developed with biomedical applications in mind, such as restoring communication in completely paralyzed individuals and replacing lost motor function. More recent applications have targeted nondisabled individuals by exploring the use of BCIs as a novel input device for entertainment and gaming. The task of the BCI is to identify and predict behaviorally induced changes or “cognitive states” in a user’s brain signals. Brain signals are recorded either noninvasively from electrodes placed on the scalp [electroencephalogram] or invasively from electrodes placed on the surface of or inside the brain. BCIs based on these recording techniques have allowed healthy and disabled individuals to control a variety of devices. In this article, we will describe different challenges and proposed solutions for noninvasive brain-computer interfacing.

2009


ABSTRACT: Brain computer interface is a system that offers also a support to the patients with neuromuscular diseases as amyotrophic lateral sclerosis. In this paper are presented some works with the aim to integrate brain computer interfaces and mobile robots. The two aim of this project are: (1) to test an improved BCI experience through the help of a physical robot, so that brain signals are stronger stimulate, and (2) to use a remote robot controlled by a highly paralyzed patient via a BCI through a friendly graphic user. Some preliminary experiments are presented in this paper about one of the possible application: a robotic museum guide (PeopleBot and Pioneer3 robot), that can transmit remote visual perceptions to the patient.

2008


ABSTRACT: The objective of this research was to develop a brain computer interface (BCI) communication device for amyotrophic lateral sclerosis (ALS) patients. The device was designed to meet the needs of ALS patients, and to be used at a clinical level. Initial tests were performed by ALS patients, and the result was accounted for in the experimental production of the communication device. Lastly, the device was evaluated by able-bodied examinees and ALS patients. For able-bodied examinees, the device scored a high rate of correct sessions. When an ALS patient was the user, the correction rate was not as well, but it would have scored highly if a correct parameter was chosen.

2007


ABSTRACT: Amyotrophic lateral sclerosis, or ALS, is a degenerative disease of the motor neurons that eventually leads to complete paralysis. We are developing a wheelchair system that can help ALS patients, and others who can’t use physical interfaces such as joysticks or gaze tracking, regain some autonomy. The system must be usable in hospitals and homes with minimal infrastructure modification. It must be safe and relatively low cost and must provide optimal
interaction between the user and the wheelchair within the constraints of the brain-computer interface. To this end, we have built the first working prototype of a brain-controlled wheelchair that can navigate inside a typical office or hospital environment. This article describes the BCW, our control strategy, and the system’s performance in a typical building environment. This brain-controlled wheelchair prototype uses a P300 EEG signal and a motion guidance strategy to navigate in a building safely and efficiently without complex sensors or sensor processing.


ABSTRACT: For a long time, researchers have been working on a marriage of human and machine that sounds like something out of science fiction: a brain-computer interface. BCIs read electrical signals or other manifestations of brain activity and translate them into a digital form that computers can understand, process, and convert into actions of some kind, such as moving a cursor or turning on a TV. Several academic and corporate researchers are now working to commercialize the technology, while other projects are taking innovative approaches to BCIs that could create interesting products or services in the not-too-distant future. The technology holds great promise for people who can’t use their arms or hands normally because they have had spinal cord injuries or suffer from conditions such as amyotrophic lateral sclerosis or cerebral palsy. BCI could help them control computers, wheelchairs, televisions, or other devices with brain activity.


ABSTRACT: Brain-Computer Interfaces (BCI) are developed to help locked-in patients, who lose control of their bodies and are unable to perform simple tasks such as speech, locomotion, and can’t even effectively interact, with their environment. BCI shows promise in allowing these individuals to interact with a computer using EEG. A Brain Computer Interface is a communication system in which messages or commands that an individual sends to the external world do not pass through the brain’s normal output pathways of peripheral nerves and muscles. This type of interface would increase an individual’s independence, leading to an improved quality of life and reduced social costs. A system is created to allow individuals, with the help of BCI, to control wide variety of home appliances via a computer, and allows tasks such as light switching and turning appliances on and off.

2006


ABSTRACT: The ultimate goal of brain-computer interface (BCI) technology is to provide communication and control capacities to people with severe motor disabilities. BCI research at the Wadsworth Center focuses primarily on noninvasive, electroencephalography (EEG)-based BCI methods. We have shown that people, including those with severe motor disabilities, can learn to use sensorimotor rhythms (SMRs) to move a cursor rapidly and accurately in one or two dimensions. We have also improved P300-based BCI operation. We are now translating this laboratory-proven BCI technology into a system that can be used by severely disabled people in their homes with minimal ongoing technical oversight. To accomplish this, we have improved our general-purpose BCI software (BCI2000), online adaptation and feature translation for SMR-based BCI operation, the accuracy and bandwidth of P300-based BCI operation; reduced the complexity of system hardware and software and begun to evaluate home system use in appropriate users. These developments have resulted in prototype systems for everyday use in people’s homes.

Abstract: Training severely paralyzed patients to use a brain-computer interface (BCI) for communication poses a number of issues and problems. Over the past six years, we have trained 11 patients to self-regulate their slow cortical brain potentials and to use this skill to move a cursor on a computer screen. This paper describes our experiences with this patient group including the problems of accepting and rejecting patients, communicating and interacting with patients, how training may be affected by social, familial, and institutional circumstances, and the importance of motivation and available reinforcers.


Abstract: The mission of the Georgia State University Brain Lab is to create and adapt methods of human-computer interaction that will allow brain-computer interface (BCI) technologies to effectively control real-world applications. Most of the existing BCI applications were designed largely for training and demonstration purposes. Our goal is to research ways of transitioning BCI control skills learned in training to real-world scenarios. Our research explores some of the problems and challenges of combining BCI outputs with human-computer interface paradigms in order to achieve optimal interaction. We utilize a variety of application domains to compare and validate BCI interactions, including communication, environmental control, neural prosthetics, and creative expression. The goal of this research is to improve quality of life for those with severe disabilities.


Abstract: Assistive devices are essential in enhancing the quality of life for individuals who have severe disabilities, such as quadriplegia and amyotrophic lateral sclerosis, or who have had massive brainstem strokes. However, the effectiveness of these systems is dependent on preserved residual movements or speech. In the absence of means to repair the damaged nervous system, three options exist for restoring function: (1) augmenting the capabilities of remaining pathways, (2) detouring around points of damage, or (3) providing the brain with new channels for communication and control. The paper reviews the use of machine learning methods for development of assistive technology. Three projects are described, representing the three options listed above. In each of them machine learning methods are employed to help with pattern recognition and classification. The three projects are: automatic speech recognition of dysarthric speech, control strategies for FES-assisted
locomotion (functional electrical stimulation), and an EEG-based computer access. Although these three projects may look very different from each other, the structure of their experimental set-ups, and their potential for application in assistive devices are very similar. All experimental set-ups consist of sensory signal acquisition, signal processing for feature extraction, and data processing by machine learning techniques for pattern recognition and classification. In addition, all three projects deal with digital signal processing and machine learning method applications in development of man-machine interfaces.

Documents from the National Library of Medicine PubMed search at www.pubmed.com are listed below:

2015


ABSTRACT: INTRODUCTION: Brain-machine interfaces (BMIs) use brain activity to control external devices, facilitating paralyzed patients to interact with the environment. In this review, we focus on the current advances of non-invasive BMIs for communication in patients with amyotrophic lateral sclerosis (ALS) and for restoration of motor impairment after severe stroke. BMI FOR ALS PATIENTS: BMI represents a promising strategy to establish communication with paralyzed ALS patients as it does not need muscle engagement for its use. Distinct techniques have been explored to assess brain neurophysiology to control BMI for patients’ communication, especially electroencephalography (EEG) and more recently near-infrared spectroscopy (NIRS). Previous studies demonstrated successful communication with ALS patients using EEG-BMI when patients still showed residual eye control, but patients with complete paralysis were unable to communicate with this system. We recently introduced functional NIRS (fNIRS)-BMI for communication in ALS patients in the complete locked-in syndrome (i.e., when ALS patients are unable to engage any muscle), opening new doors for communication in ALS patients after complete paralysis. BMI FOR STROKE MOTOR RECOVERY: In addition to assisted communication, BMI is also being extensively studied for motor recovery after stroke. BMI for stroke motor recovery includes intensive BMI training linking brain activity related to patient’s intention to move the paretic limb with the contingent sensory feedback of the paretic limb movement guided by assistive devices. BMI studies in this area are mainly focused on EEG- or magnetoencephalography (MEG)-BMI systems due to their high temporal resolution, which facilitates online contingency between intention to move and sen-
sory feedback of the intended movement. EEG-BMI training was recently demonstrated in a controlled study to significantly improve motor performance in stroke patients with severe paresis. Neural basis for BMI-induced restoration of motor function and perspectives for future BMI research for stroke motor recovery are discussed.

PMID: 26182228
ABSTRACT: OBJECTIVE: Locked-in syndrome (LIS) usually follows a brainstem stroke and is characterized by paralysis of all voluntary muscles (except eyes’ movements or blinking) and lack of speech with preserved consciousness. Several tools have been developed to promote communication with these patients. The aim of the study was to evaluate the current status regarding communication in a cohort of LIS patients. DESIGN: A survey was conducted in collaboration with the French Association of Locked-in syndrome (ALIS). SUBJECTS AND METHODS: Two hundred and four patients, members of ALIS, were invited to fill in a questionnaire on communication issues and clinical evolution (recovery of verbal language and movements, presence of visual and/or auditory deficits). RESULTS: Eighty-eight responses were processed. All respondents (35 percent female, mean age = 52±12 years, mean time in LIS = 10±6 years) reported using a yes/no communication code using mainly eyes’ movements and 62 percent used assisting technology; 49 percent could communicate through verbal language and 73 percent have recovered some functional movements within the years. CONCLUSION: The results highlight the possibility to recover non-eye dependent communication, speech production and some functional movement in the majority of chronic LIS patients.


PMID: 25959328
ABSTRACT: By focus group methodology, we examined the opinions and requirements of persons with ALS, their caregivers, and health care assistants with regard to developing a brain-computer interface (BCI) system that fulfills the user’s needs. Four overarching topics emerged from this analysis: (1) lack of information on BCI and its everyday applications, (2) importance of a customizable system that supports individuals throughout the various stages of the disease, (3) relationship between affectivity and technology use, and (4) importance of individuals retaining a sense of agency. These findings should be considered when developing new assistive technology. Moreover, the BCI community should acknowledge the need to bridge experimental results and its everyday application.

PMID: 25372874
ABSTRACT: Brain-computer interfaces (BCI) have the potential to permit patients with amyotrophic lateral sclerosis (ALS) to communicate even when locked in. Although, as many as half of patients with ALS develop cognitive or behavioral dysfunction, the impact of these factors on acceptance of and ability to use a BCI has not been studied. We surveyed patients with ALS and their caregivers about BCIs used as assistive communication tools. The survey focused on the features of a BCI system, the desired end-use functions, and requirements. Functional, cognitive, and behavioral data were collected from patients and analyzed for their influence over decisions about BCI device use. Results showed that behavioral impairment was associated with decreased receptivity to the use of BCI technology. In addition, the operation of a BCI system during a pilot study altered patients’ opinions of the utility of the system, generally in line with their perceived performance at controlling the device. In conclusion, these two findings have implications for the engineering design and clinical care phases of assistive device deployment.
ABSTRACT: OBJECTIVE: Despite recent ground-breaking findings on the genetic causes of amyotrophic lateral sclerosis (ALS), and improvements on neuroimaging techniques for ALS diagnosis have been reported, the main clinical intervention in ALS remains palliative care. Brain-computer interfaces (BCIs) have been proposed as a channel of communication and control for ALS patients. The present meta-analysis was performed to test the evidence of BCI effectiveness in ALS, and to investigate whether the promising aims emerged from the first studies have been reached. METHODS: Studies on ALS patients tested with BCIs, until June 2013, were searched in PubMed and PsychInfo. The random-effect approach was used to compute the pooled effectiveness of BCI in ALS. A meta-regression was performed to test whether there was a BCI performance improvement as a function of time. Finally, BCI effectiveness for complete paralyzed ALS patients was tested. Twenty-seven studies were eligible for meta-analysis. RESULTS: The pooled classification accuracy (C.A.) of ALS patients with BCI was about 70 percent, but this estimation was affected by significant heterogeneity and inconsistency. C.A. did not significantly increase as a function of time. C.A. of completely paralyzed ALS patients with BCI did not differ from that obtained by chance. CONCLUSIONS: After 15 years of studies, it is as yet not possible to reliably establish the effectiveness of BCIs. SIGNIFICANCE: Methodological issues among the retrieved studies should be addressed and new well-powered studies should be conducted to confirm BCI effectiveness for ALS patients.

2014

ABSTRACT: Brain-computer interface (BCI) has proven to be a useful tool for providing alternative communication and mobility to patients suffering from nervous system injury. BCI has been and will continue to be implemented into rehabilitation practices for more interactive and speedy neurological recovery. The most exciting BCI technology is evolving to provide therapeutic benefits by inducing cortical reorganization via neuronal plasticity. This article presents a state-of-the-art review of BCI technology used after nervous system injuries, specifically: amyotrophic lateral sclerosis, Parkinson’s disease, spinal cord injury, stroke, and disorders of consciousness. Also presented is transcending, innovative research involving new treatment of neurological disorders.

ABSTRACT: OBJECTIVE: Steady-state visually evoked potential (SSVEP)-based brain-computer interfaces (BCIs) allow healthy subjects to communicate. However, their dependence on gaze control prevents their use with severely disabled patients. Gaze-independent SSVEP-BCIs have been designed but have shown a drop in accuracy and have not been tested in brain-injured patients. In the present paper, we propose a novel independent SSVEP-BCI based on covert attention with an improved classification rate. We study the influence of feature extraction algorithms and the number of harmonics. Finally, we test online communication on healthy volunteers and patients with locked-in syndrome (LIS). APPROACH: Twenty-four healthy subjects and six LIS patients participated in this study. An independent covert two-class SSVEP paradigm was used with a newly developed portable light emitting diode-based ‘interlaced squares’ stimulation pattern. MAIN RESULTS: Mean offline and online accuracies on healthy subjects were respectively 85 ± 2 percent and 74 ± 13 percent, with eight out of twelve subjects succeeding to communicate efficiently with 80 ± 9 percent accuracy. Two out of six LIS patients reached an offline accuracy above the chance level, illustrating a response to a command. One out of four LIS patients could communicate online. SIGNIFICANCE: We have demonstrated the feasibility of online communication with a covert SSVEP paradigm that is truly independent of all neuromuscular functions. The potential clinical use of the presented BCI system as a diagnostic (i.e., detecting command-following) and communication tool for severely brain-injured patients will need to be further explored.


**ABSTRACT:** Brain-computer interfaces (BCIs) might restore communication to people severely disabled by amyotrophic lateral sclerosis (ALS) or other disorders. We sought to: (1) define a protocol for determining whether a person with ALS can use a visual P300-based BCI, (2) determine what proportion of this population can use the BCI, and (3) identify factors affecting BCI performance. Twenty-five individuals with ALS completed an evaluation protocol using a standard 6 × 6 matrix and parameters selected by stepwise linear discrimination. With an 8-channel EEG montage, the subjects fell into two groups in BCI accuracy (chance accuracy 3 percent). Seventeen averaged 92 (± 3) percent (range 71-100 percent), which is adequate for communication (G70 group). Eight averaged 12 (± 6) percent (range 0-36 percent), inadequate for communication (L40 subject group). Performance did not correlate with disability: 11/17 (65 percent) of G70 subjects were severely disabled (i.e. ALSFRS-R < 5). All L40 subjects had visual impairments (e.g. nystagmus, diplopia, ptosis). P300 was larger and more anterior in G70 subjects. A 16-channel montage did not significantly improve accuracy.

In conclusion, most people severely disabled by ALS could use a visual P300-based BCI for communication. In those who could not, visual impairment was the principal obstacle. For these individuals, auditory P300-based BCIs might be effective.


**ABSTRACT:** Brain-computer interfaces (BCIs) provide communication that is independent of muscle control, and can be especially important for individuals with severe neuromuscular disease who cannot use standard communication pathways or other assistive technology. It has previously been shown that people with amyotrophic lateral sclerosis can successfully use BCI after all other means of independent communication have failed. The BCI literature has asserted that brainstem stroke survivors can also benefit from BCI use. This study used a P300-based event-related potential spelling system. This case study demonstrates that an individual locked-in owing to brainstem stroke was able to use a noninvasive BCI to communicate volitional messages. Over a period of 13 months, the participant was able to successfully operate the system during 40 of 62 recording sessions. He was able to accurately spell words provided by the experimenter and to initiate dialogues with his family. The results broadly suggest that, regardless of the precipitating event, BCI use may be of benefit to those with locked-in syndrome.


**ABSTRACT:** **OBJECTIVE:** The P300-based brain-computer interface (BCI) is designed to help patients with motor disabilities to control their environment, and it has been used successfully in patients with amyotrophic lateral sclerosis (ALS). However, some ALS patients were unable to use the visual P300-BCI with the conventional row/column presentation. In this study, we evaluated the effect of a newly developed region-based two-step P300 speller, which has a larger flashing area than the conventional visual array. METHODS: Seven ALS patients and seven age- and sex-matched able-bodied control subjects were required to input hiragana characters using our P300 BCI system. We prepared two types of input procedures, the conventional row/column (RC) speller and the two-step speller, and evaluated their online performance. RESULTS: The mean online accuracy of the ALS patients was 24 percent for the RC condition and 55 percent for the two-step condition. The accuracy of the control subjects was 71 and 83 percent for the RC and two-step condition, respectively. Accuracy in ALS patients was significantly lower than that in the control subjects, and the new
visual stimuli significantly increased accuracy of ALS patients. Using the new speller, two ALS patients showed an initial accuracy sufficient for practical use (>70 percent). The other two ALS patients, who performed better in the first trial using the new speller, continued to experience the BCI system, and their mean accuracy increased to 92 percent. CONCLUSIONS: The two-step procedure for the visual P300 BCI system provided significantly increased accuracy for ALS patients compared with a conventional RC speller. SIGNIFICANCE: The new region-based two-step P300 speller was effective in ALS patients, and the system may be beneficial to expand their range of activities.

2013


ABSTRACT: Our objective was to investigate the relationship between brain-computer interface (BCI) communication skill and disease progression in amyotrophic lateral sclerosis (ALS). We sought also to assess stability of BCI communication performance over time and whether it is related to the progression of neurological impairment before entering the locked-in state. A three years follow-up, BCI evaluation in a group of ALS patients (n = 24) was conducted. For a variety of reasons only three patients completed the three years follow-up. BCI communication skill and disability level, using the Amyotrophic Lateral Sclerosis Functional Rating Scale-Revised, were assessed at admission and at each of the three follow-ups. Multiple non-parametric statistical methods were used to ensure reliability of the dependent variables: correlations, paired test and factor analysis of variance. Results demonstrated no significant relationship between BCI communication skill (BCI-CS) and disease evolution. The patients who performed the follow-up evaluations preserved their BCI-CS over time. Patients’ age at admission correlated positively with the ability to achieve control over a BCI. In conclusion, disease evolution in ALS does not affect the ability to control a BCI for communication. BCI performance can be maintained in the different stages of the illness.


PMID: 23653884

Available in full-text at: [http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3642748.](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3642748.)

ABSTRACT: Brain-machine interfaces (BMIs) are on the horizon for clinical neurosurgery. Electrocorticography-based platforms are less invasive than implanted microelectrodes, however, the latter are unmatched in their ability to achieve fine motor control of a robotic prosthesis capable of natural human behaviors. These technologies will be crucial to restoring neural function to a large population of patients with severe neurologic impairment - including those with spinal cord injury, stroke, limb amputation, and disabling neuromuscular disorders such as amyotrophic lateral sclerosis. On the opposite end of the spectrum are neural enhancement technologies for specialized applications such as combat. An ongoing ethical dialogue is imminent as we prepare for BMI platforms to enter the neurosurgical realm of clinical management.


PMID: 23528484

ABSTRACT: OBJECTIVE: Some patients suffering from severe neuromuscular diseases have difficulty controlling not only their bodies but also their eyes. Since these patients have difficulty gazing at specific visual stimuli or keeping their eyes open for a long time, they are unable to use the typical steady-state visual evoked potential (SSVEP)-based brain-computer interface (BCI) systems. In this study, we introduce a new paradigm for SSVEP-based BCI, which can be potentially suitable for disabled individuals with impaired oculomotor function. APPROACH: The proposed electroencephalography (EEG)-based BCI
system allows users to express their binary intentions without needing to open their eyes. A pair of glasses with two light emitting diodes flickering at different frequencies was used to present visual stimuli to participants with their eyes closed, and we classified the recorded EEG patterns in the online experiments conducted with five healthy participants and one patient with severe amyotrophic lateral sclerosis (ALS).

MAIN RESULTS: Through offline experiments performed with 11 participants, we confirmed that human SSVEP could be modulated by visual selective attention to a specific light stimulus penetrating through the eyelids. Furthermore, the recorded EEG patterns could be classified with accuracy high enough for use in a practical BCI system. After customizing the parameters of the proposed SSVEP-based BCI paradigm based on the offline analysis results, binary intentions of five healthy participants were classified in real time. The average information transfer rate of our online experiments reached 10.83 bits min\(^{-1}\).

A preliminary online experiment conducted with an ALS patient showed a classification accuracy of 80 percent. SIGNIFICANCE: The results of our offline and online experiments demonstrated the feasibility of our proposed SSVEP-based BCI paradigm. It is expected that our ‘eyes-closed’ SSVEP-based BCI system can be potentially used for communication of disabled individuals with impaired oculomotor function.

2012


ABSTRACT: The paper presents some speculations on the loss of voluntary responses and operant learning in long-term paralysis in human patients and curarized rats. Based on a reformulation of the ideomotor thinking hypothesis already described in the 19th century, we present evidence that instrumentally learned responses and intentional cognitive processes extinguish as a consequence of long-term complete paralysis in patients with amyotrophic lateral sclerosis (ALS). Preliminary data collected with ALS patients during extended and complete paralysis suggest semantic classical conditioning of brain activity as the only remaining communication possibility in those states.


PMID: 22438708

ABSTRACT: A brain-computer interface (BCI) is a hardware and software communications system that permits cerebral activity alone to control computers or external devices. The immediate goal of BCI research is to provide communications capabilities to severely disabled people who are totally paralyzed or ‘locked in’ by neurological neuromuscular disorders, such as amyotrophic lateral sclerosis, brain stem stroke, or spinal cord injury. Here, we review the state-of-the-art of BCIs, looking at the different steps that form a standard BCI: signal acquisition, preprocessing or signal enhancement, feature extraction, classification and the control interface. We discuss their advantages, drawbacks, and latest advances, and we survey the numerous technologies reported in the scientific literature to design each step of a BCI. First, the review examines the neuroimaging modalities used in the signal acquisition step, each of which monitors a different functional brain activity such as electrical, magnetic or metabolic activity. Second, the review discusses different electrophysiological control signals that determine user intentions, which can be detected in brain activity. Third, the review includes some techniques used in the signal enhancement step to deal with the artifacts in the control signals and improve the performance. Fourth, the review studies some mathematic algorithms used in the feature extraction and classification steps which translate the information in the control signals into commands that operate a computer or other device. Finally, the review provides an overview of various BCI applications that control a range of devices.


PMID: 22325364

ABSTRACT: Brain-computer interfaces (BCIs) acquire brain signals, analyze them, and translate them into commands that are relayed to output devices that carry out desired actions. BCIs do not use...
normal neuromuscular output pathways. The main goal of BCI is to replace or restore useful function to people disabled by neuromuscular disorders such as amyotrophic lateral sclerosis, cerebral palsy, stroke, or spinal cord injury. From initial demonstrations of electroencephalography-based spelling and single-neuron-based device control, researchers have gone on to use electroencephalographic, intracortical, electrocorticographic, and other brain signals for increasingly complex control of cursors, robotic arms, prostheses, wheelchairs, and other devices. Brain-computer interfaces may also prove useful for rehabilitation after stroke and for other disorders. In the future, they might augment the performance of surgeons or other medical professionals. Brain-computer interface technology is the focus of a rapidly growing research and development enterprise that is greatly exciting scientists, engineers, clinicians, and the public in general. Its future achievements will depend on advances in three crucial areas. Brain-computer interfaces need signal-acquisition hardware that is convenient, portable, safe, and able to function in all environments. Brain-computer interface systems need to be validated in long-term studies of real-world use by people with severe disabilities, and effective and viable models for their widespread dissemination must be implemented. Finally, the day-to-day and moment-to-moment reliability of BCI performance must be improved so that it approaches the reliability of natural muscle-based function.

2011


ABSTRACT: Universal design principles advocate inclusion of end users in every design stage, including research and development. Brain-computer interfaces (BCIs) have long been described as potential tools to enable people with amyotrophic lateral sclerosis (ALS) to operate technology without moving. Therefore the objective of the current study is to determine the opinions and priorities of people with ALS regarding BCI design. This information will guide BCIs in development to meet end-user needs.

A telephone survey was undertaken of 61 people with ALS from the University of Michigan’s Motor Neuron Disease Clinic. With regard to BCI design, participants prioritized accuracy of command identification of at least 90 percent (satisfying 84 percent of respondents), speed of operation comparable to at least 15-19 letters per minute (satisfying 72 percent), and accidental exits from a standby mode not more than once every 2-4 hours (satisfying 84 percent). While 84 percent of respondents would accept using an electrode cap, 72 percent were willing to undergo outpatient surgery and 41 percent to undergo surgery with a short hospital stay in order to obtain a BCI.

In conclusion, people with ALS expressed a strong interest in obtaining BCIs, but current BCIs do not yet provide desired BCI performance.

2010


PMID: 21096887

ABSTRACT: For individuals with mobility limitations, powered wheelchair systems provide improved functionality, increased access to healthcare, education and social activities. Input devices such as joystick and switches can provide the necessary input required for efficient control of the powered wheelchair. For persons with limited dexterity, or fine control of the fingers, access to mechanical hardware such as buttons and joysticks can be quite difficult and sometimes painful. For individuals with conditions such as traumatic brain injury, multiple sclerosis or amyotrophic lateral sclerosis voluntary control of limb movement maybe substantially limited or completely absent. Brain Computer Interfaces (BCI) are emerging as a possible method to replace the brains normal output pathways of peripheral nerves and muscles, allowing individuals with paralysis a method of communication and computer control. This study involves the analysis of non-invasive electroencephalograms (EEG) arising from the use of a newly developed Human Machine Interface (HMI) for powered wheelchair control. Using a delayed response task, binary classification
of left and right movement intentions were classified with a best classification rate of 81.63 percent from single trial EEG. Results suggest that this method may be used to enhance control of HMI’s for individuals with severe mobility limitations.


**ABSTRACT: OBJECTIVE:** Patients usually require long-term training for effective EEG-based brain-computer interface (BCI) control due to fatigue caused by the demands for focused attention during prolonged BCI operation. We intended to develop a user-friendly BCI requiring minimal training and less mental load.

**METHODS:** Testing of BCI performance was investigated in three patients with amyotrophic lateral sclerosis (ALS) and three patients with primary lateral sclerosis (PLS), who had no previous BCI experience. All patients performed binary control of cursor movement. One ALS patient and one PLS patient performed four-directional cursor control in a two-dimensional domain under a BCI paradigm associated with human natural motor behavior using motor execution and motor imagery. Subjects practiced for 5-10 min and then participated in a multi-session study of either binary control or four-directional control including online BCI game over 1.5-2 h in a single visit.

**RESULTS:** Event-related desynchronization and event-related synchronization in the beta band were observed in all patients during the production of voluntary movement either by motor execution or motor imagery. The online binary control of cursor movement was achieved with an average accuracy about 82.1+/−8.2 percent with motor execution and about 80 percent with motor imagery, whereas offline accuracy was achieved with 91.4+/−3.4 percent with motor execution and 83.3+/−8.9 percent with motor imagery after optimization. In addition, four-directional cursor control was achieved with an accuracy of 50-60 percent with motor execution and motor imagery.

**CONCLUSION:** Patients with ALS or PLS may achieve BCI control without extended training, and fatigue might be reduced during operation of a BCI associated with human natural motor behavior. **SIGNIFICANCE:** The development of a user-friendly BCI will promote practical BCI applications in paralyzed patients.


PMID: 20805058

**ABSTRACT:** An electroencephalographic (EEG) brain-computer interface (BCI) internet browser was designed and evaluated with 10 healthy volunteers and three individuals with advanced amyotrophic lateral sclerosis (ALS), all of whom were given tasks to execute on the internet using the browser. Participants with ALS achieved an average accuracy of 73 percent and a subsequent information transfer rate (ITR) of 8.6 bits/min and healthy participants with no prior BCI experience over 90 percent accuracy and an ITR of 14.4 bits/min. We define additional criteria for unrestricted internet access for evaluation of the presented and future internet browsers, and we provide a review of the existing browsers in the literature. The P300-based browser provides unrestricted access and enables free web surfing for individuals with paralysis.


PMID: 21095775

**ABSTRACT:** Brain-computer interfaces (BCIs) open a new valuable communication channel for people with severe neurological or motor degenerative diseases, such as ALS patients. On the other hand, the ability to teleoperate robots in a remote scenario provides a physical entity embodied in a real environment ready to perceive, explore, and interact. The combination of both functionalities provides a
system with benefits for ALS patients in the context of neurorehabilitation or maintenance of the neural activity. This paper reports a BCI telepresence system which offers navigation, exploration and bidirectional communication, only controlled by brain activity; and an initial study of applicability with ALS patients. The results show the feasibility of this technology in real patients.

Available in full-text at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2996245.
ABSTRACT: Brain-computer interfaces (BCIs) enable paralyzed patients to communicate; however, up to date, no creative expression was possible. The current study investigated the accuracy and user-friendliness of P300-Brain Painting, a new BCI application developed to paint pictures using brain activity only. Two different versions of the P300-Brain Painting application were tested: A colored matrix tested by a group of ALS-patients (n = 3) and healthy participants (n = 10), and a black and white matrix tested by healthy participants (n = 10). The three ALS-patients achieved high accuracies; two of them reaching above 89 percent accuracy. In healthy subjects, a comparison between the P300-Brain Painting application (colored matrix) and the P300-Spelling application revealed significantly lower accuracy and P300 amplitudes for the P300-Brain Painting application. This drop in accuracy and P300 amplitudes was not found when comparing the P300-Spelling application to an adapted, black and white matrix of the P300-Brain Painting application. By employing a black and white matrix, the accuracy of the P300-Brain Painting application was significantly enhanced and reached the accuracy of the P300-Spelling application. This drop in accuracy and P300 amplitudes was not found when comparing the P300-Spelling application to an adapted, black and white matrix of the P300-Brain Painting application. By employing a black and white matrix, the accuracy of the P300-Brain Painting application was significantly enhanced and reached the accuracy of the P300-Spelling application. ALS-patients greatly enjoyed P300-Brain Painting and were able to use the application with the same accuracy as healthy subjects. P300-Brain Painting enables paralyzed patients to express themselves creatively and to participate in the prolific society through exhibitions.

PMID: 20583947
ABSTRACT: Our objective was to develop and validate a new brain-computer interface (BCI) system suitable for long-term independent home use by people with severe motor disabilities. The BCI was used by a 51-year-old male with ALS who could no longer use conventional assistive devices. Caregivers learned to place the electrode cap, add electrode gel, and turn on the BCI. After calibration, the system allowed the user to communicate via EEG. Re-calibration was performed remotely (via the internet), and BCI accuracy assessed in periodic tests. Reports of BCI usefulness by the user and the family were also recorded. Results showed that BCI accuracy remained at 83 percent (r = -.07, n.s.) for over 2.5 years (1.4 percent expected by chance). The BCI user and his family state that the BCI had restored his independence in social interactions and at work. He uses the BCI to run his NIH-funded research laboratory and to communicate via e-mail with family, friends, and colleagues. In addition to this first user, several other similarly disabled people are now using the BCI in their daily lives. In conclusion, long-term independent home use of this BCI system is practical for severely disabled people, and can contribute significantly to quality of life and productivity.

2009

PMID: 19351359
ABSTRACT: Using brain-computer interfaces (BCI) humans can select letters or other targets on a computer screen without any muscular involvement. An intensively investigated kind of BCI is based on the recording of visual event-related brain potentials (ERP). However, some severely paralyzed patients who need a BCI for communication have impaired vision or lack control of gaze movement, thus making a BCI depending on visual input no longer fea-
sible. In an effort to render the ERP-BCI usable for this group of patients, the ERP-BCI was adapted to auditory stimulation. Letters of the alphabet were assigned to cells in a 5 x 5 matrix. Rows of the matrix were coded with numbers 1 to 5, and columns with numbers 6 to 10, and the numbers were presented auditorily. To select a letter, users had to first select the row and then the column containing the desired letter. Four severely paralyzed patients in the end-stage of a neurodegenerative disease were examined. All patients performed above chance level. Spelling accuracy was significantly lower with the auditory system as compared with a similar visual system. Patients reported difficulties in concentrating on the task when presented with the auditory system. In future studies, the auditory ERP-BCI should be adjusted by taking into consideration specific features of severely paralyzed patients, such as reduced attention span. This adjustment in combination with more intensive training will show whether an auditory ERP-BCI can become an option for visually impaired patients.

2008


ABSTRACT: PURPOSE OF REVIEW: Communication with patients suffering from locked-in syndrome and other forms of paralysis is an unsolved challenge. Movement restoration for patients with chronic stroke or other brain damage also remains a therapeutic problem and available treatments do not offer significant improvements. This review considers recent research in brain-computer interfaces (BCIs) as promising solutions to these challenges. RECENT FINDINGS: Experimentation with nonhuman primates suggests that intentional goal directed movements of the upper limbs can be reconstructed and transmitted to external manipulandum or robotic devices controlled from a relatively small number of microelectrodes implanted into movement-relevant brain areas after some training, opening the door for the development of BCI or brain-machine interfaces in humans. Although noninvasive BCIs using electroencephalographic recordings or event-related-brain-potentials in healthy individuals and patients with amyotrophic lateral sclerosis or stroke can transmit up to 80 bits/min of information, the use of BCIs - invasive or noninvasive - in severely or totally paralyzed patients has met some unforeseen difficulties. SUMMARY: Invasive and noninvasive BCIs using recordings from nerve cells, large neuronal pools such as electrocorticogram and electroencephalography, or blood flow based measures such as functional magnetic resonance imaging and near-infrared spectroscopy show potential for communication in locked-in syndrome and movement restoration in chronic stroke, but controlled phase III clinical trials with larger populations of severely disturbed patients are urgently needed.


PMID: 18571984

ABSTRACT: OBJECTIVE: The current study evaluates the efficacy of a P300-based brain-computer interface (BCI) communication device for individuals with advanced ALS. METHODS: Participants attended to one cell of a N x N matrix while the N rows and N columns flashed randomly. Each cell of the matrix contained one character. Every flash of an attended character served as a rare event in an oddball sequence and elicited a P300 response. Classification coefficients derived using a stepwise linear discriminant function were applied to the data after each set of flashes. The character receiving the highest discriminant score was presented as feedback. RESULTS: In Phase I, six participants used a 6 x 6 matrix on 12 separate days with a mean rate of 1.2 selections/min and mean online and offline accuracies of 62 percent and 82 percent, respectively. In Phase II, four participants used either a 6 x 6 or a 7 x 7 matrix to produce novel and spontaneous statements with a mean online rate of 2.1 selections/min and online accuracy of 79 percent. The amplitude and latency of the P300 remained stable over 40 weeks. CONCLUSIONS: Participants could communicate with the P300-based BCI and performance was stable over
many months. SIGNIFICANCE: BCIs could provide an alternative communication and control technology in the daily lives of people severely disabled by ALS.


PMID: 18835541

ABSTRACT: Recent advances in analysis of brain signals, training patients to control these signals, and improved computing capabilities have enabled people with severe motor disabilities to use their brain signals for communication and control of objects in their environment, thereby bypassing their impaired neuromuscular system. Non-invasive, electroencephalogram (EEG)-based brain-computer interface (BCI) technologies can be used to control a computer cursor or a limb orthosis, for word processing and accessing the internet, and for other functions such as environmental control or entertainment. By re-establishing some independence, BCI technologies can substantially improve the lives of people with devastating neurological disorders such as advanced amyotrophic lateral sclerosis. BCI technology might also restore more effective motor control to people after stroke or other traumatic brain disorders by helping to guide activity-dependent brain plasticity by use of EEG brain signals to indicate to the patient the current state of brain activity and to enable the user to subsequently lower abnormal activity. Alternatively, by use of brain signals to supplement impaired muscle control, BCIs might increase the efficacy of a rehabilitation protocol and thus improve muscle control for the patient.

2007


PMID: 17605682

ABSTRACT: Brain-computer interface (BCI) systems support communication through direct measures of neural activity without muscle activity. BCIs may provide the best and sometimes the only communication option for users disabled by the most severe neuromuscular disorders and may eventually become useful to less severely disabled and/or healthy individuals across a wide range of applications. This review discusses the structure and functions of BCI systems, clarifies terminology and addresses practical applications. Progress and opportunities in the field are also identified and explicated.

2006


PMID: 17082507

ABSTRACT: Neural Internet is a new technological advancement in brain-computer interface research, which enables locked-in patients to operate a Web browser directly with their brain potentials. Neural Internet was successfully tested with a locked-in patient diagnosed with amyotrophic lateral sclerosis rendering him the first paralyzed person to surf the Internet solely by regulating his electrical brain activity. The functioning of Neural Internet and its clinical implications for motor-impaired patients are highlighted.

2005


PMID: 15911809

ABSTRACT: People with severe motor disabilities can maintain an acceptable quality of life if they can communicate. Brain-computer interfaces (BCIs), which do not depend on muscle control, can provide communication. Four people severely disabled by ALS learned to operate a BCI with EEG rhythms recorded over sensorimotor cortex. These results suggest that a sensorimotor rhythm-based BCI could help maintain quality of life for people with ALS.

2003

or other device. Successful operation requires that the user encode commands in these signals and that the BCI derive the commands from the signals. Thus, the user and the BCI system need to adapt to each other both initially and continually so as to ensure stable performance. Current BCIs have maximum information transfer rates up to 10-25bits/min. This limited capacity can be valuable for people whose severe disabilities prevent them from using conventional augmentative communication methods. At the same time, many possible applications of BCI technology, such as neuroprosthesis control, may require higher information transfer rates. Future progress will depend on: recognition that BCI research and development is an interdisciplinary problem, involving neurobiology, psychology, engineering, mathematics, and computer science; identification of those signals, whether evoked potentials, spontaneous rhythms, or neuronal firing rates, that users are best able to control independent of activity in conventional motor output pathways; development of training methods for helping users to gain and maintain that control; delineation of the best algorithms for translating these signals into device commands; attention to the identification and elimination of artifacts such as electromyographic and electro-oculographic activity; adoption of precise and objective procedures for evaluating BCI performance; recognition of the need for long-term as well as short-term assessment of BCI performance; identification of appropriate BCI applications and appropriate matching of applications and users; and attention to factors that affect user acceptance of augmentative technology, including ease of use, cosmesis, and provision of those communication and control capacities that are most important to the user. Development of BCI technology will also benefit from greater emphasis on peer-reviewed research publications and avoidance of the hyperbolic and often misleading media attention that tends to generate unrealistic expectations in the public and skepticism in other researchers. With adequate recognition and effective engagement of all these issues, BCI systems could eventually provide an important new communication and control option for those with motor disabilities and might also give those without disabilities a supplementary control channel or a control channel useful in special circumstances.
Quick Looks

Online Resources Related to Brain Computer Interface & Neuromuscular Diseases/Disorders

Brain computer interface (BCI), also known as brain- or mind-machine interface, is a direct communication interface system between an external device and the brain, which allows an individual to communicate with or control a computer or other electronic device using his or her brainwaves without movement from the neuromuscular system. Individuals with neuromuscular diseases/disorders (NMD) such as amyotrophic lateral sclerosis (ALS), locked-in syndrome, stiff person syndrome, multiple sclerosis, etc. may benefit from BCI technologies. For more information about the use of the BCI as well as NMD we recommend the following resources:

ABLEDATA
ABLEDATA provides objective information about assistive technology products and rehabilitation equipment available from domestic and international sources.
Phone: 800/227-0216 (V), 703/356-8038 (V), 703/992-8313 (TTY
Email: abledata@neweditions.net.

ALS Association (ALSA)
Toll Free: 800/782-4747, 202/407-8580
Contact ALSA:
Locate a Local Chapter:
www.alsa.org/community/chapters.

American Parkinson Disease Association (APDA)
Toll Free: 800/223-2732, 718/981-8001
Email: apda@apdaparkinson.org.
Locate a Local Resources:
www.apdaparkinson.org/local-resources.

The Brief History of Brain Computer Interfaces
www.brainvision.co.uk/blog/2014/04/the-brief-history-of-brain-computer-interfaces

Christopher and Dana Reeve Paralysis Resource Center (PRC)
PRC is promoting the health and well-being of people living with paralysis and their families through comprehensive information resources and referral services.
Toll Free: 800/539-7309
Information Specialists are available from 9 a.m. until 8 p.m. EST (English/Spanish)
Contact: feedback.paralysis.org/feedback/stage_1.
Free Comprehensive guide to paralysis-related topics in English and Spanish: http://tinyurl.com/lxnaxgg.
www.paralysis.org.

ClinicalTrials.gov
A database that provides information about federally and privately supported clinical research in human volunteers. Information provided includes the trial’s purpose, who may participate, locations and phone numbers for more details.
Studies related to BCI: tinyurl.com/pd45jjk.
Studies related to NMD: http://tinyurl.com/pm2g3do.
www.clinicaltrials.gov.

How Brain-computer Interfaces Work
computer.howstuffworks.com/brain-computer-interface.htm

Locked-In Syndrome - Rehabilitation Institute of Chicago Treatment Program
Phone: 312/238-1000

Locked-In Syndrome Information Page from the National Institute of Neurological Disorders and Stroke (NINDS)
www.ninds.nih.gov/disorders/lockedinsyndrome/
lockedinsyndrome.htm. 

The Michael J. Fox Foundation
Toll Free: 800/708-7644
michaeljfox.org.

Multiple Sclerosis Foundation (MSF)
Toll Free MS Helpline: 888/679-6287, Available 9:00 a.m. until 7:00 p.m. EST
Phone: 954/776-6805
Email: support@msfocus.org.
www.msfocus.org.

Muscular Dystrophy Association (MDA)
Toll Free: 800/572-1717
Email: mda@mdausa.org.
Locate a Local Chapter: www.mdausa.org/locate.

National Assistive Technology Technical Assistance Partnership (NATTAP)
State Contact List: www.resnaprojects.org/allcontacts/statewidecontacts.html.

National Institute of Neurological Disorders and Stroke (NINDS)
Toll Free: 800/352-9424, 301/496-5751 (V)

National Multiple Sclerosis Society (NMSS)
Toll Free: 800/344-4867
www.nationalmssociety.org.

National Parkinson Foundation, Inc. (NPF)
Toll Free: 800/473-4636
Email: contact@parkinson.org.
Locate Local NPF Centers & Chapters:

www.parkinson.org/Search-Pages/Chapter-Locator.
www.parkinson.org.

National Spinal Cord Injury Association (NSCIA)
The National Spinal Cord Injury Association, a program of the United Spinal Association, serves as a comprehensive information source for anyone affected by spinal cord injury.
Toll Free: 800/962-9629
Email: info@unitedspinal.org.
Locate a Local Chapter:
www.spinalcord.org/chapters/directory.

The Pass It On Center: A National Collaboration for the Reutilization and Coordination of Assistive Technology
Toll Free: 800/497-8665
Email: info@passitoncenter.org.
Reuse Locations:
www.passitoncenter.org/reuse_locations.php.
Search Terms for the BCI/NMD

- Adaptation
- Amyotrophic lateral sclerosis (ALS)
- Art Therapy
- Assistive Technology
- Attitudes
- Augmentative & Alternative Communication
- Barriers
- Biofeedback
- Brain
- Paralysis
- Case Studies
- Cognition
- Coma
- Communication/Aids/Devices/Skills
- Computer(s)/Applications
- Control Systems
- Daily living
- Degenerative Diseases
- Devices
- Electroencephalography (EEG)
- Electrophysiology
- Environmental Control Systems
- Evaluation
- Eye Movements
- Feasibility Studies
- Feedback
- Home-Based
- Independent living
- Limbs
- Locked-In
- Man-Machine Systems
- Mobility Impairments
- Motor Skills
- Movement Disorders
- Multiple Sclerosis
- Nerves
- Neurofeedback
- Neuroimaging
- Neurological Impairments
- Neuromuscular Diseases/Disorders
- Paralysis
- Parkinson’s Disease
- Physical Disabilities
- Prostheses and Implants
- Quadriplegia
- Qualitative Analysis
- Quality Of Life
- Rare Disorders
- Rehabilitation/Services/Technology
- Robotics
- Sensory Impairments
- Service Utilization
- Severe Disabilities
- Software Systems
- Speech Disorders/Impairments
- Spinal Cord Injuries
- Stroke
- Task Analysis
- Technology
- Traumatic Brain Injury
- Universal Design
- Wheeled Mobility
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- Campbell and Cochrane Collaborations
- PubMed and other National Library of Medicine databases
- Agency for Health Care Policy and Research databases
- Center for International Rehabilitation Research Information and Exchange
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