# Cognitive design of educational brain-computer interfaces

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**Abstract**

This paper represents a conceptual description of the cognitive approach for the design of the brain-computer interface, which can be implemented in educational environments. Study based on performance metrics analysis and interpretation mental dynamics in daily routine inspired model. The central object of interest is the development of brain-computer literacy for neuroplasticity training implementation for efficient working and study activities and improving personal skills.

**Keywords** [1]

Brain-computer interfacing, cognitive network, neuroplasticity, neuro-management, decision-making.

## 1. Introduction

At the present stage of development, the use of most brain-computer interfaces aims to train skills and develop cognitive abilities, as well as collect user data to overcome illiteracy and improve technology. It is also worth noting the success of the introduction of brain-computer interfaces to track well-being, and self-care, as well as combating the complex of hyperactivity or lack of attention of children. The brain-computer interface is also used for navigation and space mastery experiments, consciousness loading, and neuroaesthetics research.

The most important task, that the educational environments enforced with the brain-computer interface can solve is human-computer interaction skills development and training. Also, such networks can provide platforms for needed and implemented workforce abilities of new trends such as neuromanagement. The central subject of those research is the decision-making process and one of the last popular directions of this approach is an implementation of skills and increasing of efficiency of working activity by self-development and training.

The feature of human mental action is neuroplasticity, which allows to increase own activity in work and daily life by consciousness augmentation, which influence is so expected nearest time. The brain-computer literacy becomes really needed to create abilities and to develop neuroplasticity moderation and using it for improving the efficiency of own activities and one of the obvious ways its implementation is educational environments, where students can combine training of special and new skills.

## 2. Related works

There are a lot of real implemented samples of brain-computer interfaces today. A few projects should be named are: a system for car-drive and race (Emotiv and SIMUSAFE), aviation (g.tec and BrainSigns), neuromarketing (Emotiv, BrainSigns, JLL), mental health and self-care (Emotiv, g.tec, BitBrain, NeuroSky, BrainSigns) and advertisement (Emotiv, NeuroSky, g.tec). All these companies have large experience in assistive technologies providing, but they are the ones who inaugurated BCI users' society [1].

The basis of BCI network development and use is well illustrated in *Brain-Neuro-Computer Interface Society report* (2015). This paper is one of the most successful descriptions of today's BCI essence and possible steps for its improvement in human community [2].

The last neuromanagement achievements are improved by BrainSigns and JLL. The first companies established workload idea with EEG for state recognition technology.

The basis of neuromanagement can be found in *Neuromanagement and leadership* (Venturella I. et all, 2018). This work describes EEG analysis of the mental activity in organization study according to the newest tendencies of neuroscience analysis in cognitive sciences as well-being and workload through typical human activity [3].

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For experiment making, there are a few ways to build a study. Upon them is data science from used BCI. Most of the modern systems allow to fix study results in comfortable representation, for example, as raw EEG data appropriate for any next processing or typically classified by study settings. For example, in PsychoPy you can use a simple projecting interface with a comfortable visual development platform for processing data from different devices.

Experiments and tests usually are based on common popular methods with different levels depending on the target tasks field. This research demonstrates a result of training with Stroop test control, but there are a lot of other strategies which can be combined according to the purpose and the capacity of the system.

## 3. Proposed methodology

A typical organization of a modern intelligent environment equipped with a brain-computer interface passes through several stages and has its own structure and features. Depending on the scope of application, different design approaches are used, but the cognitive principles are still stay the basics for intellectual environments organization [4].

### 3.1. The cognitive approach in BCI enforced educational environments design

In educational intelligent systems, the brain-computer interface can be implemented as a complex amplifying component that ensures the optimization of activities in several areas. The first is the brain-computer interface module itself, which adds a new degree of quality to the management of the environment and the operation of information. The second is a mandatory module of training own skills, which helps to realize the skills of mental management in a smart environment and expands cognitive competencies (soft skills). The third is specially focused on a specific application. It is also possible to expand efficiency of the system with the type of hyperscanning, brain-to-brain interaction through the cognitive network, discussion, and competition or game as an organizational approach.

One of the problems with the implementation of brain-computer interfaces is the long-term development of user mental management skills and maintaining cognitive capacity. An indicator of readiness is a low level of brain-computer illiteracy. Good data for activity is a reaction, good health, especially clear neurofeedback of sufficient power [5].

Then brain-assisted intellectual environment must be equipped with means as technical as software for the personal development of BCI-abilities and fit own skills constantly. To achieve these conditions the organization of the BCI-environment should be embodied in efficient projection. The most successful possible realization of such an idea is well argument decision with enough efficiency. A working group of users can be represented as a small functional psychological group. Then for creating the special BCI the patterns for common tasks and features of interaction must be studied, from which the suitable must be selected and brought into the samples base, if machine learning is used for system development. This compliance is regulated with basic standards and recommendations from the distributor of equipment and software [6].

### 3.2. Multitarget BCI networking

The value of individual mental activity features factor, especially in international groups, should be considered. To pretend such causes, the program for common training must be successfully embodied into a real system and necessarily provided with its use.

For the efficient design with correct implementation of the cognitive approach for the educational environment, a few necessary principles must be obligatory observed. The first between them is the immersive component of user's interface. Such condition is necessary to include dual concept as system preset as user's skills provided.

Personal-oriented BCI representation usually has a typical user profile descriptive mode, which can be described as idiolect. A strong well-trained personal profile will be very efficient in the realization of such functional patterns as mental command and identification (personal BCI recognition) [7].

Sure, all profiles can be improved in the testing process with a unique machine learning strategy for achievement of desired aim and level, which must be described at the beginning of design with a clear number of features (competencies) and its quality indicators (represented as Professional Brain view or Cognitive Image).

For small groups (5 persons) we can represent it with "jargon" – proficiency-oriented lexis and own semantics. Usually, such vocabulary is embodied as a command space built with ordered logic-shaped semantics of its interactions. Each command is a cognemic formation into some space of operational abilities globally understood as a space of mental activity with the universal grammar of action execution with trained free will efforts and general translation method namely EEG with chosen technology of signal reception (fNIRS, MEG, SSVEP, P300 etc.) for recognized data input into the environment for the next management realization and interface implementation (Fig. 1) [8].

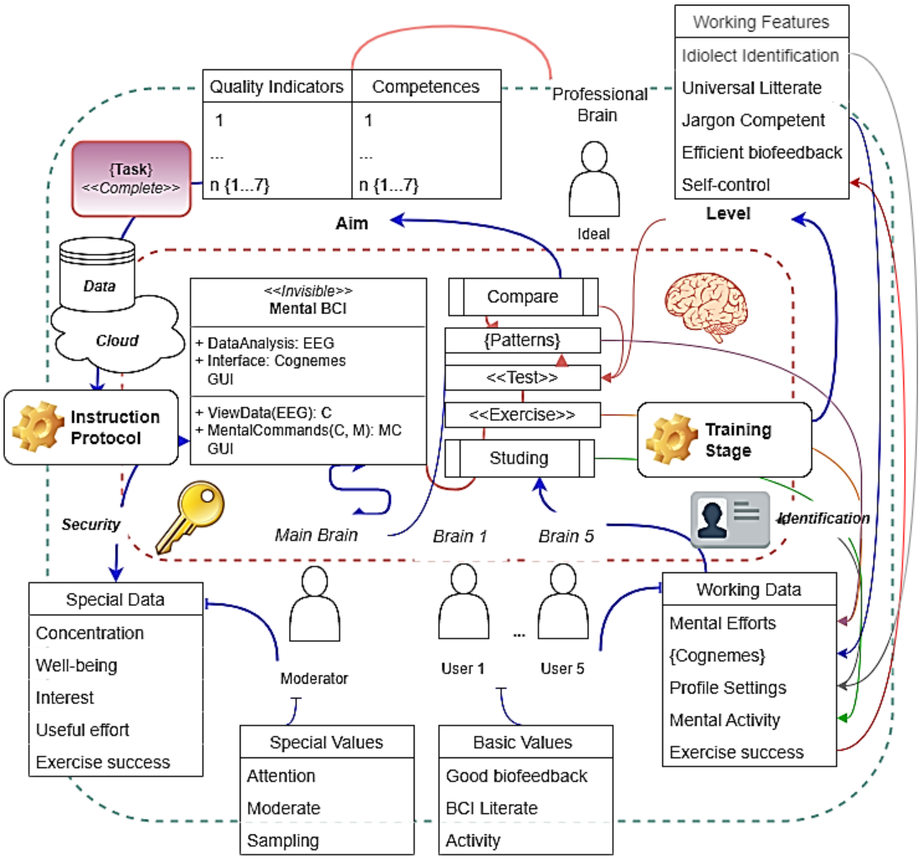


**Figure 1:** Conceptual Scheme of Modern BCI System for Efficient Network

This structure helps to achieve successful multitask interaction and is acceptable for real enterprises and educational networks including developers and agile platforms providing improving quality and evolutional stability at the same time.

Target tasks can be differentiated by some levels of activity and studies can include quality and priority accordance monitor also. For example, basic working actions can be noticed by screen-timing control in combination with pression and recall analysis. Mindfulness tasks can include individual research on personal psychological activity features namely real neuromarketing on the neuroplasticity training process.

## 4. Results

For an illustration of the described method, we studied individual performance metrics dynamics during neuroplasticity training in the improvised environment using EmotivLABs BCI. For the primary and additional research, we have used EmotivBCI and PRO applications, so, our study includes data from different periods and conditions of activity such as routine, tests, stress situations, training, and so on.

Emotiv methods allow to classify a current mental activity based on EEG analysis and represent its results in a few modes. The constant is neuromanagement performance metrics, which illustrated the dynamical representation of activity during the task solving with a used interval of changes in 5 sec. The resultant norms of the efficient performance, collected by the research of 20 attempts with different exercises and training combinations are 54% value for engagement, 21% - exciting, 35% - focus, 21% - interest, 48% - relaxation, and 20% of stress (Figure 2).

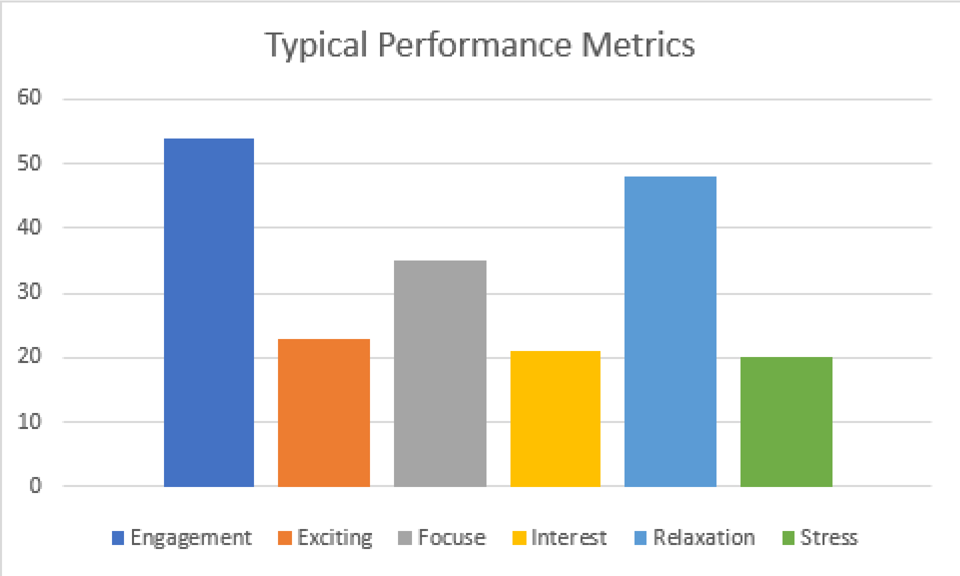


**Figure 2:** Typical Performance Metrics studied by Emotiv BCI analysis through routine activity[2].

Control tests included attention, decision, workload, and emotional metrics. In improvised situations tested persons, who will more flexible, show the higher reaction in decision-making process then untrained. All these results you can find in the Figure 3 graph, based on Stroop test control. As stimuli in this training randomly colored words are used. Then the accuracy is dependent on correct detection of color confirmed by appropriate key pressing or by voice input. Possible absolute BCI can include a biosensual device for throat impulses sensing that allows to read and recognize appropriate lingual activity figures. Also, BCI can be combined with eye-blinking recognition. These directions should have special research and discussion [9].

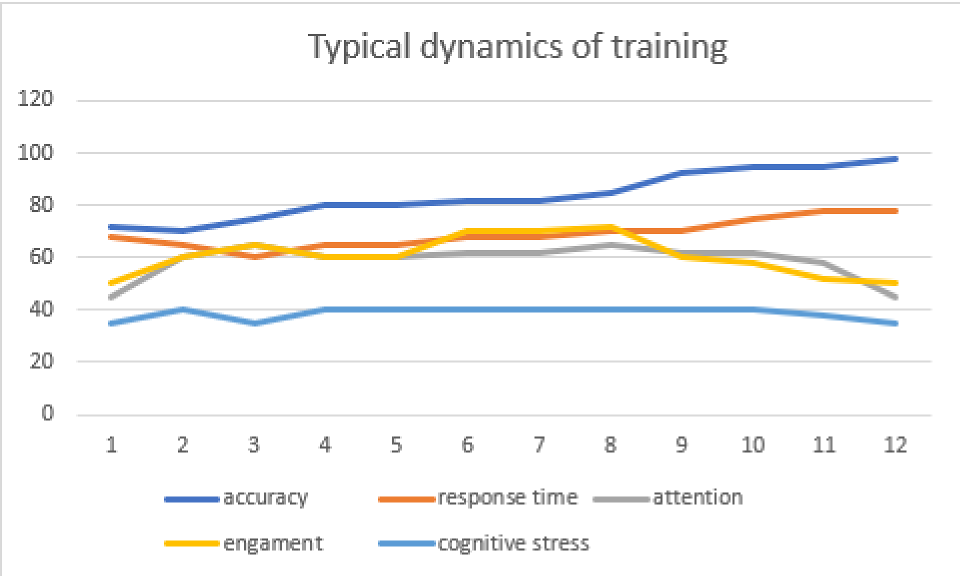


**Figure 3:** Typical dynamics of neuroplasticity in Stroop test training using Emotiv BCI analysis.

By control cuts: 1 – test introduction attempt, first metrics collection, individual image; 2, 3 – correction of individual metrics, development for training; 4, 5 – fixation of skills, current test; 6 – combining with meditation; 7 – stress situation, spontaneous test; 8-12 next 10 attempts training with the same exercises.

[2] All values are demonstrating a rate of workload as a percentage relative to the absolute value of performance. Used indicators based on 5 seconds classified study of EEG data from mental activity during the task solving (means decision-making in case of the test).

## 5. Discussion

The next levels of workload and cognitive organization of efficient network development obviously will include a range of improvements for special tasks and conditions. Research and implementation of hybrid BCI require a separate careful study of software connection for target interests achieving and right system design. Besides, this direction gets closer to the technology of invisible computing and intelligent environments using.

Individuality has a large importance in the development and implementation of cognitive networks based on BCI. The well-trained system must have frequent data collecting and serious processing to provide high-quality data representation and clear settings with flexible functionality. The user profile must have a stable training program with regular updates.

The next development of described approach should continue accordingly to the conditions and requirements of chosen environment. To achieve the needed quality and efficiency of the system it is important to remember that a special attention must be paid to the software choice and system design.

The nearest conceptual approach which obviously should be considered is mindfulness training. Such ideology can improve the strategy of tests and increase the efficiency of the system, especially in long-term projects such as life-long studies.

## 6. Acknowledgments

The cognitive approach can be implemented with obligate changes and decisions suitable to chosen network features and its appointment. The optimal number of users for the system may be changed in a combined mode of design when some features are simplified, and the basic system is playing the role of server and moderator administrates the network.

## 7. References

[1] Timothy K. Lam, Oshin Vartanian, Justin G. Hollands. The brain under cognitive workload: Neural networks underlying multitasking performance in the multi-attribute task battery, Neuropsychologia, Volume 174 (2022). https://doi.org/10.1016/j.neuropsychologia.2022.108350.

[2] Brunner, C., et al. BNCI Horizon 2020: towards a roadmap for the BCI community. (2015) http://bnci-horizon-2020.eu/roadmap

[3] Venturella, I., Fronda, G., Vanutelli, M. E., Balconi, M. Neuromanagement and leadership: an EEG hyperscanning study, Poster, in Proceedings of the "SEPEX – SEPNECA – AIP experimental Joint Conference", (Madrid, 03-06 July 2018), Fundación UNED, Madrid (2018): 64-64 http://hdl.handle.net/10807/131920.

[4] Mykhalchuk, V. The prospects for BCI in e-society. Management of Development of Complex Systems. Issue, 50. (2022) P. 101-106.

[5] Wegemer, Ch. Brain-computer interfaces and education: the state of technology and imperatives for the future. International Journal of Learning Technology. (2019) https://www.inderscienceonline.com/doi/10.1504/IJLT.2019.101848

[6] Kadosh, R.C. (Ed.) The Stimulated Brain: Cognitive Enhancement Using Non-invasive Brain Stimulation, Elsevier, London, UK (2014). https://www.elsevier.com/books/the-stimulated-brain/cohen-kadosh/978-0-12-404704-4

[7] Toppi J, et al. Investigating Cooperative Behavior in Ecological Settings: An EEG Hyperscanning Study. Plos1, (2016). https://doi.org/10.1371/journal.pone.0154236

[8] Jiang, L., Stocco, A., Losey, D.M. et al. BrainNet: A Multi-Person Brain-to-Brain Interface for Direct Collaboration Between Brains. Sci Rep 9, 6115 (2019)

[9] Mykhalchuk, V. Description of cognitive BCI system. github.com (2022). https://github.com/vit-mych/cognitive-network.