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EDITORIAL

Arts and Brain-Computer Interfaces (BCIs)

1. Introduction to artistic brain-computer interfaces (Bcis)

The purpose of this special issue is to address contemporary challenges involved in designing BCI applications related to the creation and experience of art. The use of BCI for communication and control, especially in clinical applications and assistive technology, is well known.[1] In recent years BCI technology has also entered mainstream human-computer interaction research, in particular multimodal interaction research (for example, in entertainment computing). Apart from communication and control,[2] monitoring the affective/cognitive state of a user can help to tune an application environment to the needs and preferences of a particular user or to modify an artistic environment to express a user's emotional desires. Users of artistic BCI technology can be artists who compose art in real time using BCI signals (usually in a multimodal and multimedia context), performers, audience members, or a full audience. Currently there are artistic BCI environments that allow users to play with and modify animations and musifications,[3] and there are examples of BCI control of instruments and tools for artistic expression and exploration.[4,5] In this special issue we have collected contributions that address such artistic BCI applications. In addition, issues related to performing and consuming artistic activity are reported.

Artistic BCI applications date further back than assistive and clinical BCIs. Many years before Kamiya's and Vidal's influential papers on monitoring and controlling alpha activity [6] and using brain activity for control and communication [7] there were experiments by artists on musical composition, fine art, and other creative applications that required brain activity patterns as input. During the early 1970s these applications stirred much interest, and not only in the artistic milieu. During these early BCI years, computer science and, in later years, human-computer interaction research focused on designing and implementing applications that were meant to make administrative, scientific, and industrial control applications more efficient and reduce the human share in such applications. Only after the advent of the personal computer, the Internet and the World Wide Web interest in digital health care and entertainment technology emerged, with a focus on the individual user and taking into account personal information and interaction behavior. Nowadays smart sensors and actuators can be

embedded in devices and environments. They can sense activity and anticipate requests of users. They also allocate information to be displayed to different modalities, including changes in the user's physical environment and its devices and objects. The environment can be oriented toward sports, domestic, professional, educational, recreational, or public activities and more than one user can be involved.

Especially in the human-computer HCI area, with the development of interaction modalities different from the standard keyboard and mouse, interest in brain-computer interfacing received attention. BCI interest and advances did not necessarily seek to replace other input modalities, but instead act as an additional modality that provides extra information about the user and his preferences in order to better understand his interactions with a digital or a digitally enhanced system.[8] Recently human-computer interaction research has looked at domestic and entertainment applications that do not require the robustness and the efficiency of professional work environments. Hence, in addition to monitoring a user's affective state in order to use such information to support user interactions with an application, there is also the need to look at brain activity that is manipulated – either by the user or evoked by the environment – that is meant to issue commands and control the environment.

Knowledge about the affective state of a user or a group of users can be employed to create or modify interactive art. Users, whether they are artists, amateurs, or audience participants, interact with the art forms. There can be involuntary changes in their affective states because of the feedback they receive. But there can also be decisions to change their affective state (trying to relax more, imagine being angry) that aim at conscious changes in the art that is produced.[9] In addition, artists can include in their interaction design and feedback to the user(s) events that evoke information about a user's preferences, interests, and decisions he or she wants to make in order to control the process of creating a piece of art. Obviously, in the latter case we can think of the use of BCI paradigms such as event-related potentials (ERPs) or visual, auditory, and tactile evoked potentials. When a group of users is involved in an artistic BCI there is also the need to devise methods for integrating their joint activity. It requires the fusion of brain signals, the features extracted from the brain signals, or a decision

procedure that combines individual decisions. In a multimodal situation other modalities also have to be taken into account, whether the multimodality is sequential or in parallel.[10]

From the previous paragraphs it should be clear that artistic BCIs that allow a disabled artist to create a traditional piece of art (a painting, a composition, playing an instrument) introduce many new research issues in the BCI research field. Currently we see renewed interest in artistic BCI applications. Artists are using reasonably cheap commercial BCI devices to design installations that require active input from the brains of multiple users or participants in artistic events. Participants receive feedback from the artistic application which helps them to control their brain activity in order to create or modify pieces of interactive art. We have entered a decade where interactive media and performing artists can receive access to BCI tools in which various BCI paradigms are included and can be employed in the design of artistic BCIs.

2. Special issue contributions

From 14 submissions initially received, eight articles were selected for publication after a rigorous two-step review process supported by experts in the areas of brain-computer interface, human-computer interaction, and human factors/ergonomics. The papers in the special issue present empirical and survey studies that explore contemporary research challenges involved in designing, developing, and evaluating BCI applications related to the creation and experience of art.

In the survey paper ‘Defining artistic brain-computer interfaces: expressing and stimulating the user’s affective state’ the main author (Marvin Andujar) together with his co-authors (Chris S. Crawford, Anton Nijholt, France Jackson, and Juan E. Gilbert) presents an overview of application areas for artistic BCIs (for example, in gaming, in smart homes, in human-human interaction, in human-robot interaction, in entertainment, and in the workplace), and discusses the research fields that comprise artistic BCI development and exploration (art, human-computer interaction, neurophysiology, and computer science).

Control is an important issue in BCI applications, and can be limited by typical interdependent BCI weaknesses such as low bit rate, lack of precision, and the need for time-consuming trials. Aside from the expected limitations within a BCI system, the available artistic BCI applications afford users varying levels of creative control through limiting user intention, interaction, or choice. Levels of control are defined and discussed in the paper ‘Artistic brain-computer interfaces: State-of-the-art control mechanisms’ by Amy Wadson and her co-authors (Anton Nijholt, and Chang S. Nam). An over-

view of some of the current artistic BCI applications employing the defined levels of control is given.

Anne-Marie Brouwer (with co-authors Maarten Hogervorst, Boris Reuderink, Ysbrand van der Werf, Jan van Erp) reports on ‘Physiological signals distinguish between reading emotional and non-emotional sections in a novel’. In their research they monitored readers of a novel and compared physiological information (EEG, ECG, skin conductance, respiration) during the reading of emotionally intense fragments and the reading of other, non-emotional fragments. In their conclusion the authors mention that readers’ fluctuating emotions can be detected, but not (yet) in real time. Obviously, a paper like this is not concerned with the control issues we discussed in previous sections of this special issue.

With the next paper in this issue we move from a reader’s brain to the brain of a juggler. This is done in ‘Towards real-time visualization of a juggler’s brain.’ by Giuseppina Schiavone, Ulf Grossekaethefer, Simon à Campo, and Vojkan Mihajlović. In their experiments, the authors study an expert and an intermediate-level juggler using a wearable EEG headset with four dry electrodes while juggling to investigate their brain activity. Their results show the possibility of detecting a specific brain activity signature which opens up opportunities for visualization and audification in order to increase audience understanding and engagement.

An affective brain-computer music interface is discussed in ‘The space between us: evaluating a multi-user affective brain-computer music interface’. In this paper, written by Joel Eaton, Duncan Williams, and Eduardo Miranda, experiments are reported where the affective states of two users (a performer and a listener) are measured during a live musical performance. Based on these affective states, pre-composed musical scores are selected to reflect and induce affect in the users. Their experiments indicate that measures of arousal are controllable by music (as a result of neuro-feedback) and some common emotional ground can be reached. Passive BCI is used, as users are not assumed to intentionally control their brain waves in order to reach this common ground.

The next two papers in this special issue discuss Brain Painting, a P300-based brain-computer interface that is being used by ALS patients in their home environments. The papers, authored by Elisa Mira Holz, Loic Botrel, and Andrea Kübler, are ‘Independent home use of Brain Painting improves quality of life of two artists in the locked-in state diagnosed with amyotrophic lateral sclerosis’ and ‘Brain Painting V2: evaluation of P300-based brain-computer interface for creative expression by an end-user following user-centered design.’ In the first paper a usability study of the system is presented. Two artists diagnosed with ALS intensively used the program and their long-term, expert-independent use in their home environment was evaluated. Results on effectiveness

(control), efficiency, and satisfaction are presented. Based on these results they draw three conclusions: a BCI-controlled application can be accepted as an assistive device, it can be reliably used for a long time in the daily life of a person, and it has a positive impact on the quality of life of end-users. The usability evaluation is part of the user-centered design that the authors have adopted. Following this approach, in the second paper they introduce Brain Painting V2 with several new features that aimed at increasing the degrees of freedom for one of the artists. The authors give a detailed description of the new system and again provide an evaluation in terms of effectiveness, efficiency, and satisfaction. They report that although the control level was not high the artist kept painting regularly with good satisfaction. Some paintings produced by the artist are also presented.

Finally, in ‘Immobilis in mobili: performing arts, BCI and locked-in syndrome’ Andrés Aparicio reports about his work to design a communication interface for an actor who is in a locked-in state. His interest is in the performing arts. Characteristics, including control issues, are discussed for generative and interactive art and for art based on augmentations of the body. A ‘ground’ model for BCI-aided performance is introduced with active BCI for conscious control of the performance space and passive BCI for setting behavior parameters. Two instances of the ground model are detailed: one of them, the ‘director model’, assumes the user directing a performance, the other one, the ‘avatar model’, assumes the user to be an actor. The author considers the models as the first steps in designing a BCI-based play by a performer with locked-in syndrome.

3. Conclusions and acknowledgement

This special issue is a rather modest introduction to the field of artistic BCIs. We nevertheless hope it has introduced many issues that had previously not played a role in traditional, medically oriented BCI research. Such issues are also introduced when we consider the use of BCI for games and entertainment, or BCI for domestic applications. However, the freedom an artist takes, or the freedom that is taken by whoever wants to express his feelings artistically, requires BCI researchers to support such activities by exploring new paths of research. Researchers should seek to embed BCI research into research on human-computer interaction that aims at anticipating, understanding, and supporting someone’s behavior in digitally enhanced physical environments. Many issues we addressed in this Editorial are not yet artistic BCI research topics, let alone general BCI research topics. But it should be clear that in the near future they will be.

As guest editors, we would like to thank all the authors of this special issue for contributing their high-quality work. We would also like to thank the reviewers who have volunteered their time to provide valuable feedback to the authors within the short stipulated time. Many thanks go to the *Brain-Computer Interfaces Journal* editorial support for their help during the preparation of this special issue.

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