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Abstract: This document summarizes the Horizon 2020 BNCI retreat in Hallstatt that brought together key stakeholders in the BCI field. An important outcome was that the applications and end users of BCI technology are often unclear. Therefore it was decided that all partners will create use cases, from which the most promising use cases will be elaborated on. Participants of the retreat were satisfied with the organization of retreat and generally agreed that the retreat was an important step for the BCI field.

Keywords: summary, retreat, Hallstatt, use cases

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Introduction

This document summarises the Horizon 2020 BNCI retreat in Hallstatt.

The aim of the retreat was to bring together key stakeholders in the BCI field. During the retreat these stakeholders could discuss the future of BNCI, and their ideas for a roadmap. Through discussion, participants could provide input for the three work packages and the six application scenarios. An advisory board was present to provide feedback on behalf of external stakeholders.

First, the content presented during retreat will be summarised, following the order and structure of the agenda of the meeting. Then common themes overarching individual agenda items will be presented and summarised.

Program

Welcome

Project coordinator Gernot Müller-Putz opened the retreat and introduced the venue, the participants, and the advisory board. He emphasised the aims of the project (to create a roadmap to support the European commission in making funding decisions). These include: consolidating recent results in BNCI research, to investigate synergies with relevant fields, and to actively support the foundation of an official BCI society. The application scenarios (replace, restore, improve, enhance, supplement and research) that are used to structure the project and the roadmap, were refreshed.

WP2 — Research

The goals of WP2 are to evaluate the current state of the art in paradigms, tools, applications, and to identify requirements for applications for end users, including bottlenecks and solutions for these requirements. An overview of the work for the deliverables was given.

Deliverable 2.1 (D2.1) is called “source documentation”, and includes the FBNCI roadmap, a collection of literature, and a questionnaire. Papers published after the FBNCI roadmap have been collected and categorised. This list will be used to construct a literature review. The work is organised through online forms to collect summary statements. In addition, a questionnaire for BCI researchers was being developed and will be distributed shortly. Future steps are composing the first contribution to the roadmap in the form of D2.2. There is some interaction with WP3 and WP4, which requires coordination of evaluation methods and the format of the roadmap.

Issues to be resolved during the project are how to assess BCI use in healthy end users, how BCIs should be defined (especially in relation to neighbouring fields such as neurofeedback, neuromarketing, neurostimulation, and how to deal with military funded research), whether the BCI research should be a scenario, and if there is something missing in the FBNCI roadmap that needs attention.

WP3 — Industry

The objective of WP3 is to work towards an industry roadmap. Task T3.1 focuses on the BNCI industry ecosystem. For this task, the main industry stakeholders were identified and classified; sectors, target end users, application scenarios, product types, and markets were mapped out. Similarly, standardisation efforts were identified. The next steps were to identify evaluation metrics for BNCI products, and to identify industry motivation and needs. A graphical map showing plans for this work package was shown. Next, a questionnaire for the industry stakeholders was presented, including the BNCI sector in relation to other sectors (automotive & aerospace, medical technology & robotics, technology, and entertainment &

marketing). This questionnaire focuses on such diverse aspects as company size, company location, supply chain breakdown, and target end users.

T3.2 considers the evolution of the BNCI industry towards 2020. The work for this task interacts with WP2 due to the potential transfer of tools and technology from research to industry, and with the future user groups of WP4. A categorisation for applications was presented, with examples of key applications and a qualitative market potential analysis.

T3.3 is about the transfer and exploitation of technology. The work consists of identifying and classifying current success stories, and future exploitation avenues. The aim is to develop practical guidelines and actionable recommendations for exploitation and transfer of technology.

WP4 — End Users

According to a user-centred design (UCD), the successful design of a product (i.e. a BCI solution) must take into account a wide range of stake-holders, ranging from the primary user (end-user) to secondary and tertiary users (including caregivers, medical doctors, industries etc.). For this reason, an entire WP in the project is intended to provide the roadmap with a users' perspective. The objectives of WP4 were presented and the deliverables timeline was outlined. The main contribution of WP4 at this stage of the project is a classification matrix to allow identification of different classes of users among the different application scenarios. Such matrix, together with a state of the art of UCD as applied to BCI, will constitute the content of D4.1 deliverable.

Roadmap structure and visions

The roadmap structure and presentation medium were outlined by Gernot Müller-Putz. The aim is to create an electronic document that can be read from different perspectives. One point of view would be to divide the roadmap into six application scenarios; an orthogonal viewpoint could be created simultaneously by separating the industry, research and end user perspectives. The individual fragments of this roadmap should contain links to other fragments such that they can form a coherent document together. As a medium, an ebook in PDF format was suggested. Each chapter should have its own DOI.

Post-mortem Future BNCI

Brendan Allison, gave a retrospective view on the preceding Future BNCI (FBNCI) project. The European Commission (EC) had rated the project as excellent, and found the expected information in the report, although it was too long and detailed. The EC needed specific recommendations.

The FBNCI project has improved communication within the BCI research cluster: results from surveys with end users where shared, common standards were proposed, and information on events were shared, and there were various follow-up efforts. BNCI Horizon 2020 has some overlap in team members, project structure and roadmap plan with the preceding FBNCI project. FBNCI encouraged discussion and collaboration on hybrid BCIs and provided a foundation for the BCI Society efforts.

Parallel focus sessions

Replace

The replace session was led by Andrea Kübler. About 20 people participated in this session. The session focused on BCI applications that re-instantiate communication in the broadest sense, i.e. from direct communication with another person to internet surfing, gaming, and participation in social networks.

The following stakeholders were identified:

- The end users are people with functional impairments (e.g. patients in locked-in state).
- Caregivers and other persons that interact with primary users are secondary users.
- Professionals stakeholders include the manufacturers of technology, assistive technology (AT) professionals, and IT managers.
- Other stakeholders are insurers, ethical committees, politicians, and associations that are acting in favour of end users' interests.

Research itself is also consumer of BCI technology. Basic research has already shown that patients can control an EEG-driven BCI. Continued research should shift to be application focused, and has to move to the patient's home. Studies on the end users' needs are available, and BCI is seen as one channel to access assistive technology (AT). Hybrid BCIs seem most promising, but the benefits need to be demonstrated. Appropriate metrics for evaluation have to be developed. The function to be replaced should be more precise than "communication and interaction". A discussion should be initiated on the ethical aspects of invasive BCI approaches.

Industrial partners indicated that there is a lack of knowledge transfer to industry, which increases the risk of failure. Further, the target group of the replace scenario appears to be too small. One strategy to overcome this issue is to focus on components that are reusable in different, larger markets (e.g. the gaming and telemedicine market).

Restore

The focus session on restoration was led by José del R. Millán and was aimed at BCI use to restore a lost function. Examples of are restoring motor control, bladder control etc. Basic research shows that the brain delegates low-level tasks, such as walking, to the spinal cord. If the intentions can be decoded, these tasks could be delegated to intelligent prostheses.

Tactile feedback emerged as an important type of feedback in the discussion. More large-scale end-user trials are needed, since it is unknown whether results obtained with healthy subjects generalise to patients. The amount of neuroplasticity that one can reasonably expect is similarly unknown. Deep brain stimulation (DBS) was considered a BCI for restoration purposes if it contains a feedback loop. BCIs can also be used to restore sensory function, for example by using the BCI to guide the frequency of stimulation of cochlear implants.

Overall observations were that healthcare professionals, engineers and end users have to work together to find the best solution for them to restore functions. The industry needs to think about reducing costs. New potential end users still need to be identified.

Enhance

Benjamin Blankertz lead the focus session on BCI applications aimed at enhancing functions using BCI technology. About 30 people were participating in this session. First, the topic was introduced with examples mostly from the Berlin BCI group.

Five main application areas were identified: BNCI for control (e.g. multi-player cooperative games), exploiting mental states (e.g. adjusting the cognitive load, monitor attention, tutoring, dating, state indicator for communication, preconscious warning system), medical tools (e.g. adjusting hearing aids, improve electrical stimulation, diagnosis), feedback of the mental state (e.g. for sports, stress management, wellness, perception), and enhanced product development (e.g. neuro usability, unnoticeable distractions).

The adjusting-the-cognitive-load application was considered in more detail. The aim of this application is to optimise general human-computer interfaces to the state of the user. Among the end-users are workers, divers, IT users, learners, and employers. They benefit by

increased productivity, better health and safety. BCI-based cognitive load adjustment requires comfortable mobile EEG technology, and has to operate robustly.

Improve

The improve focus session was led by Donatella Mattia and had about 20 participants. This session was focused on BCIs that improve the central nervous system (CNS) output. An example would be a BCI device that improves hand movements in stroke patients, which would induce activity-dependent CNS plasticity, thereby improving CNS output. Another example would be neurofeedback training to reduce cortical excitation in epilepsy.

Rehabilitation of motor and cognitive function after stroke dominated the discussion. Other end users were mentioned, such as people suffering from chronic pain and children with a disability due to cerebral palsy, whose CNS output might be improved using BCI technology as well. Several issues need to be addressed to enable these applications, such as a definition of "normal" brain activity, the role of instructions (that are typically absent in neurofeedback training), and development of sensitive outcome measures to adapt training procedures. Also efficacy of therapeutic BCI applications needs to be evaluated.

Strategies to attract EU funding for this particular BCI application were discussed. The large number of end users (e.g. stroke patients) and potential long-term use of the device (e.g. for children with cerebral palsy) emerged as strong points. As causes for the current limited usage with proven efficacy (e.g. ADHD neurofeedback) in clinics, the competing interests of great pharmaceutical companies and lack of knowledge transfer were suggested.

Industry has to be involved to develop usable and cost-effective BCIs, and professional users such as medical doctors and rehabilitation therapists have to participate to guide tool development.

Supplement

The supplement session was lead by Christoph Guger and had about 20 participants. The focus of the supplement session were BCIs to supplement natural neuromuscular output with additional artificial output. For example, a person might use a BCI to control a third (robotic) arm.

Applications were ranked according to number of votes they received from appointed experts specialised in signal processing, BCI systems, assistive technology, markets, and patients/users. Specific use cases were identified for the third arm applications, and a start was made to evaluate the potential of these use cases.

Research

The research session was led by Nick Ramsey. The topic was first introduced with examples of decoding brain activity, such as reconstructing observed images from fMRI activity and the assessment of effects of neurofeedback training through BCI technology.

Feedback and single-trial analysis were found to be important indicators for BCI-based tools. The key is to detect or identify a brain response, and use it for a) calibration of therapeutic manipulations, b) studying learning and neural representations, c) improving human-machine interactions (e.g. cars), d) to mark brain states in real-time to accelerate basic research.

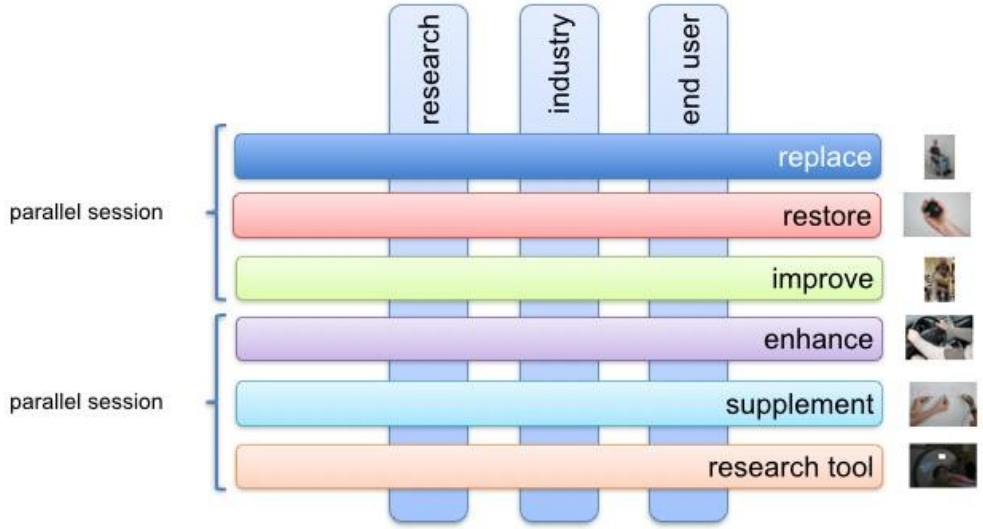
Identified examples of BCIs as a research tool were using a BCI for optimal timing of transcranial magnetic stimulation (TMS) pulses, using a BCI to learn about psychophysical phenomena when brain responses are more accurate than behavioural cues, and using a BCI to track in real time decisions made during shopping.

Summary of WP Leaders Meeting

In the WP meeting the WP leaders discussed the next steps to be taken towards a roadmap. Several options were discussed, but at the end the overall conclusion was to develop high-potential use cases for each intersection of the six application scenarios and work packages research, industry and end users. From these scenarios and uses cases topics and recommendations will be deduced and integrated in the roadmap.

Roadmapping Methodology

Patric Salomon presented a session titled "Roadmapping Methodology" in the slot allocated for the agenda item "consolidation outcome of parallel focus sessions". It started by mapping the intersections between the content in the three content work packages (research, industry and end user) and the six scenarios worked on in the parallel sessions:



All partners were asked to think through the six scenarios to identify new opportunities, and to brainstorm from the point of view of the user, and from the point of view of research ideas. These opportunities are to be described as use cases, described in terms of the opportunity, benefits towards current products/methodologies/cures in the application, the market size, and the competition.

One can backtrack what is needed for these use cases, such as a cost reduction, improved usability, robustness, performing clinical trials, etc. Research and industry has to answer if and when these wish lists can be realised, what is needed (new technologies, material, automation, ethics), and what the limitations would be. Then milestones and intermediate results and dependencies can be defined, and described in the resulting roadmap.

BCI Society

Nick Ramsey introduced the planned BCI Society. The need for such a society was stated at a town hall meeting held during the Asilomar BCI conference (2013). The status is that there is now a small committee and plan of action; bylaws need to be decided upon. For now the focus is on organising meetings, to handle finances for meetings and the website, and to fill the website with content. In the longer term, coordination of media interaction and lobbying is planned. Eventually, guidelines and standards could be developed.

Comments of the Advisory board

The advisory board consists of Pedram Afshar (Medtronic), Peter Levene (Docobo), Boris Hänßler (freelance journalist), Klaus Miesenberger (JKU, AAATE), Rüdiger Rupp

(Heidelberg University Hospital), and Mick Donegan (SpecialEffect). Rüdiger Rupp presented their recommendations based on our website, the content presented at the retreat, general and focus group discussions, and an hour of discussion within the advisory board.

Based on the parallel focus sessions, the advisory board strongly recommends to include a clear description of visionary applications per scenario, and to include evaluation metrics for success to identify the most promising scenarios. Furthermore, they recommend to define short-term, mid-term and long-term goals for each scenario, and to identify key factors for future success for BCIs. **A key issue is to find out what BNCIs offer that other technologies do not.**

More generally, the advisory board recommends to identify common barriers shared by all work packages and scenarios; to determine the most urgent overall research needed by all six scenarios; and to identify barriers for the individual person to get access to the market area. The board recommends to include ethics, privacy and policy/legislation concerns for each scenario and work package combination.

The consortium should observe the outcomes of neuromarketing driven by industry and military research (not directly supported by the EU). Since the project is mostly driven by researchers, we should involve end users and identify the real end user's needs, and invite them to future retreats.

The advisory board supported the idea of publishing the roadmap as (living) e-book, and suggested the inclusion of a user form to collect representative data about user needs and to receive feedback.

Wrap-up discussion, future steps

Gernot Müller-Putz closed the retreat with some final remarks. The retreat was the kickoff for developing scenarios, which has to continue after the retreat taking into consideration the advice of the advisory board. In May/June, another consortium meeting is planned to work on the structure of the roadmap.

Questionnaire

After the retreat, the participants were asked to fill in a feedback form. All of the 22 respondents were satisfied with the retreat organisation, but opinions were divided on how easy it was to travel to the retreat location in Hallstatt. The respondents were happy with the infrastructure available for the meetings, the accommodation and the agenda of the retreat. Not everyone agreed that the retreat was in important step for the BCI field, but in general the respondents were positive on the importance. Most respondents were neutral to positive regarding the time available to have discussions. In the open questions, people often complimented the organisation, and complained on the internet connection. Some remarked that not too many novel ideas were proposed.

Conclusion

A recurring theme in the parallel sessions was that the applications and end users of BCI technology are often unclear. The advisory board aptly advised to find out what BNCIs offer that other technologies do not, and to include a description of visionary applications per scenario. It was decided that all partners will create use cases, from which the most promising use cases will be elaborated on.

Another recurring theme was the need of validation procedures and evaluation metrics to assess the efficacy of BCIs, which was voiced by the advisory board as well.

According to the questionnaire, participants of the retreat were satisfied with the organisation of retreat and generally agreed that the retreat was an important step for the BCI fields.

Appendices

Program Agenda

Monday, March 24, 2014

12:30–13:30	Lunch
13:30–14:00	Welcome address, Introduction, Goals, Expectations (TUG)
14:00–14:30	WP 2 – Research (UMCU)
14:30–15:00	WP 3 – Industry (BDIGITAL)
15:00–15:30	WP 4 – End users (FSL)
15:30–15:45	Coffee break
15:45–16:30	Roadmap structure and visions (TUG)
16:30–17:00	Post-mortem assessment of Future BNCI (UT)
17:00–18:30	Parallel focus sessions (Replace, Restore, Enhance)
19:30–22:00	Dinner (Hotel Heritage)

Tuesday, March 25, 2014

09:00–10:30	Parallel focus sessions (Improve, Supplement, Research Tool)
10:30–10:45	Coffee break
10:45–12:30	Discussion on and consolidation of parallel focus sessions (eMNT)
12:30–13:30	Lunch
13:30–14:00	Session Leaders and WP Leaders meeting
14:00–15:00	Summary of WP Leaders and Discussion (TUG)
15:00–15:30	BCI Society (UMCU)
15:30–17:00	Guided tour through Hallstatt
19:00–22:00	Dinner (Hotel Grüner Baum)

Wednesday, March 26, 2014

09:00–10:45	Comments of the Advisory Board
10:45–11:00	Coffee break
11:00–12:30	Wrap-up discussion, future steps (TUG)
12:30–13:30	Lunch

List of Participants

Pedram Afshar (Medtronic)
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Brendan Allison (Old Dominion University)
Günther Bauernfeind (Graz University of Technology)
Benjamin Blankertz (Berlin Institute of Technology)
Maria Laura Blefari (École Polytechnique Fédérale de Lausanne)
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Febo Cincotti (Fondazione Santa Lucia)
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Doron Friedman (Sammy Ofer School of Communications)
Gangadhar Garipelli (MindMaze)
Lucian Gheorghe (Nissan)
Ivan Gligorijevic (mBrainTrain)
Bernhard Graimann (Otto Bock)
Sebastian Grissmann (Eberhard Karls University Tübingen)
Christoph Guger (g.tec Guger Technologies)
Boris Hänßler (Freelance Journalist)
Rob Hartman (TMSi)
Erwin Hartsuiker (Mind Media)
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Peter Levene (Docobo)
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