The Second
Neuroadaptive Technology Conference

Neuroadaptive Technology

NAT '19

Conference Programme

July 16 – July 18, 2019,
Liverpool, UK

The Second Neuroadaptive Technology Conference

Conference Programme

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Programme

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11:35-11:59	The Automatic Classification of Human Factors Associated with Decisions Involving Risk During Driving Simulation	Alexander Karran HEC Montreal, Canada
12:00-12:24	Towards neuroadaptive technology using time warped distances for similarity exploration of brain data	Erin Solovey *WPI, USA*
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Day Three	**Title**	**Speaker**
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10:40-11:04	Spontaneous Radiofrequency Emission from Nonequilibrium Electron Spins within *Drosophila.*	Luca Turin *BSRC, Greece*
11:05-11:29	Single Session Transcranial Direct Current Stimulation (TDCS) Can Improve Robotic Suturing Skills in Surgical Trainees	Ronak Patel *Imperial College, UK*
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13:50-15:29	LUNCH	Everybody
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Keynotes

Frédéric Dehais

A Neuroergonomic Approach to Monitor Cognition in Complex Real-Life Situation

Tuesday
09:00 – 10:00

ABSTRACT
Neuroergonomics is an emerging field of interdisciplinary research that promotes the understanding of the brain in complex real-life activities. This approach merges knowledge and methods from human factors, cognitive psychology, system engineering, and cognitive neuroscience. Accurate and reliable mental state assessment of human operators during use of complex systems is a prime goal of neuroergonomics that aims to measure the “brain at work”. Understanding the underlying neurocognitive processes of such interaction could be used to improve safety and efficiency of the overall human-machine pairing. We will present recent research conducted at ISAE-SUPAERO using a variety of neuroimaging techniques ranging from fMRI to ultra-portable EEG and fNIRS devices to monitoring cortical activity from well controlled to out-of-the-lab conditions. We will focus on the challenges, common pitfalls and future directions that drive this exciting field of research.

Romy Lorenz

Back to the Lab: Neuroadaptive Technology for Cognitive Neuroscientists

Tuesday
16:35 – 17:35

ABSTRACT
Neuroadaptive technology is widely recognised for its exciting potential to augment human-computer interaction. Besides these applied uses, neuroadaptive technology provides a powerful technique to address basic research questions within the cognitive neurosciences that have been challenging to tackle with conventional methods.

The classic taxonomy of cognitive processes is based on cognitive psychology theory and was developed largely blind to the functional organization of the brain. Therefore, classic cognitive tasks tend to tap multiple cognitive processes that involve multiple brain networks. Resolving this many-to-many mapping problem between cognitive tasks and brain networks is practically intractable with standard functional magnetic resonance imaging (fMRI) methodology as only a small subset of all possible cognitive tasks can be tested. This is problematic, as studying only a fraction from the large space of cognition has resulted in over-specified inferences about functional-anatomical mappings with a misleadingly narrow function being proposed as the definitive role of a network, concealing the broader role a network may play in cognition.

In this talk, I present an alternative approach that resolves these problems by combining real-time fMRI with a branch of machine learning, Bayesian optimization. Neuroadaptive Bayesian optimization is a powerful strategy to efficiently explore many more experimental conditions than is currently possible with standard methodology in a single individual. I will present results from a study where we used this method to understand the unique contributions of two frontoparietal networks in cognition. Our findings deviate from previous meta-analyses and hypothesized functional labels for these networks. Taken together the results form the starting point for a neurobiologically-derived cognitive taxonomy.

In addition, I touch on the potential of the approach in combination with non-invasive brain stimulation (e.g., tACS) and for accelerated biomarker discovery. I conclude my talk by discussing ethical implications associated with neuroadaptive technology.

Graeme Moffat

Lessons Learned from Consumer Neurotechnology at Scale

Wednesday
09:00 – 10:00

ABSTRACT
As we move from early adoption in consumer neurotechnology toward the mainstream, it's clear that the consumer neurotechnologies of today are best understood through the Neuroadaptive Technology framework. This presentation will survey the landscape of neuroadaptive technologies with a particular focus on consumer EEG, including lessons learned from Muse – by far the most widely used consumer neurotechnology platform to date. I will discuss challenges to adoption, including user experience, applications, open vs. closed platforms and their respective impacts on research and utilisation, as well as opportunities for next generation and even more widely used consumer- and health-oriented neuroadaptive technologies. I will also discuss the unique possibilities of neurotechnology data and experimentation at the scale of thousands and, soon, millions of users.

Erin Solovey

Human-Computer Interaction and Neuroadaptive Technology

Wednesday
16:35 – 17:35

ABSTRACT

We are at an exciting time as emerging research is providing more practical brain measurement tools as well as greater understanding of brain function. This will continue through national investments such as the U.S. BRAIN Initiative, as well as the commercialization of wearable technology containing brain sensors. This opens up many research directions and we have seen a growing body of recent human-computer interaction work showing the feasibility of neuroadaptive technology for healthy users, which integrate real-time brain input into interactive systems. In many of these systems, the brain data is detected non-invasively and passively, with no effort from the user, and used as a supplemental input stream to interactive systems, ideally making the systems more in sync with the user, providing appropriate support when needed. However, the interaction techniques and design decisions for their effective use are not well defined. In this talk, I will present some of the challenges and opportunities for considering input from the brain, along with design principles and patterns we have developed from our work. I will also present case studies illustrating the principles and patterns for effective use of brain data in human–computer interaction. Finally, I will discuss future directions of human-computer interaction research to ensure the success and wider adoption of neuroadaptive technology.

Fabien Lotte

Machine Learning and Experimental Tools towards EEG-based Neuroadaptive Technologies

Thursday
09:00 – 10:00

ABSTRACT
Designing NeuroAdaptive Technologies (NAT) requires to be able to estimate one or more mental states from a user's brain signals, to understand the impact of this mental state on the way the user interact with the system, and to adapt this interaction accordingly. This in turns requires 1) suitable experimental protocols to induce the targeted mental states in order to obtain a ground truth, 2) robust machine learning tools to decode this mental state from brain signals and 3) computational models of the user that relates this mental state to the user behaviour and performances, and can take decisions accordingly. In this talk, I will present some of the tools we designed and used for each of these three points. In particular, I will present some experimental protocols to induce mental states such as workload, attention, intrinsic motivation or visual comfort, as well as machine learning tools (e.g., based on spatial filtering, Riemannian Geometry or Convolutional Neural Networks) to robustly decode such states from EEG signals, despite EEG non-stationarity. I will then present our recent work with the active inference computational model, a framework that can be used to simultaneously infer the user's state and take suitable decisions accordingly, in order to design robust NAT.

Abstracts

Interaction

Day 1

Day: Tuesday
Session: Interaction
Time slot: 10:45 – 11:09
Talk no.: 1

TOWARDS AN ETHICAL DEFINITORY FRAMEWORK FOR BOTH TRADITIONAL AND NOVEL HUMAN-COMPUTER INTERACTION PARADIGMS

Laurens Ruben Krol[1,*], Thorsten Oliver Zander[2]

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[2]Zander Laboratories B.V., Amsterdam, The Netherlands
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ABSTRACT
A prevailing definition of human-computer interaction (HCI) concerns the *field* of HCI and not the subject matter, i.e., the interaction itself [1]. It is common to rely on a broad understanding of interaction, as even technical committees tend to define only top-level terms such as "user" and "system" [2]. As a result, HCI does not have a standard framework of terms that allow specific HCI instances or paradigms to be modelled in detail with shared understanding and consistency. This, however, is increasingly necessary given the expansion of HCI into novel areas. We ourselves have referred to implicit control [3] and neuroadaptive technology [4] as being distinct from traditional HCI paradigms in specific ways, while simultaneously firmly anchoring them in the context of HCI developments. Such novel areas of HCI require additional aspects not covered by traditional definitions to be taken into account, as brain-actuated devices make aspects such as volition, intention, emotion, and even consciousness crucial to the type of interaction that can take place.

On the one hand, these increasingly relevant aspects of HCI call for a clear framework of shared understanding about what is and is not "interaction." On the other hand, these uniquely human aspects likely prohibit any definition from being fully technical, formal, or unambivalent. With that in mind, we suggest an updated framework of terminology related to HCI. This framework aims to consistently cover both traditional and novel HCI paradigms, to allow HCI to be modelled at different levels of abstraction, and to convey ethical considerations which exclude abusive paradigms from using the same terms. We thus also suggest that the field of HCI, and neuroadaptive technology in particular, explicitly *not* be a value-free science [5].
Relevant to this conference, we define neuroadaptivity as a property of a computer, which *is neuroadaptive when it acquires implicit input through a brain-computer interface, and uses this input for control.*

The terms *computer, implicit input, brain-computer interface,* and *control* are defined separately, along with smaller constituent terms such as *data, information, communication,* et cetera. For this

abstract, we highlight two more terms.

Implicit input is defined as *any information acquired by the receiving unit that the source did not intend to be acquired by the receiving unit*. This illustrates the above-mentioned issue of including such words as *intent* in formal definitions. At what point can it be said that a human—or a computer—*intended* for something to be received? Nonetheless, this is a key issue for the implicit/explicit distinction. The definition thus makes the distinction in the general case, but cannot provide a complete guideline for judging individual instances.

We define *user* as *a human who is communicating or interacting with a computer, and who has given and not revoked consent for this communication or interaction to take place*. This illustrates our proposal to put ethical considerations into the core of what is or is not HCI, which we deem prudent given the advances of e.g. cognitive probing [4].

At NAT'19, we are open to revisions before complete publication of the framework.

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Day: Tuesday
Session: Interaction
Time slot: 11:10 – 11:34
Talk no.: 2

A NEUROADAPTIVE APPROACH TO ANALGESIC GAMING

Kellyann Stamp[1,*], Stephen Fairclough[2], Chelsea Dobbins, and Helen Poole[2]

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[3] School of Information Technology and Electrical Engineering, The University of Queensland
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ABSTRACT
Painful experiences in a medical setting can be extremely distressing but often unavoidable. The use of medication for pain management is not without its faults – side effects are often found in patients who are receiving analgesic medications such as opioids [1]. Reducing the experience of pain via analgesic technology rather than medications could reduce both the perceived pain of the individual, and the side effects associated with the administration of medication.
Pain is an interruptive function, which means that pain has the ability to override the task goals of an individual – however, for the painful experience to become interruptive, there must first be sufficient attention available for this pain to be perceived [2]. Attention is a limited resource, so if the maximum amount of attention is already being used to complete an unrelated task, then the experience and perception of pain could be reduced[3]. For a distraction task to provide the maximum possible level of distraction, it must provide an immersive experience to a participant. Computer games are known to be one of the most effective distraction tasks – partly due to their active nature, meaning that cognitive and physical effort is a requirement for task completion. Dynamic Difficulty Adjustment (DDA) is used for real-time game adaptation – DDA usually relies on information such as current game score, health, weapons etc. to determine the players skill level, and then adapts the game to match this skill level. DDA is effective in improving immersion because a game that matches a player's skill level will capture and hold a players' attention and encourage them to continue exerting effort in the game [4]. We believe that DDA powered by neuroadaptation could further advance the immersive capabilities of a computer game. To explore this hypothesis, a neuroadaptive driving game was created. The goal of the game was to achieve a high score – this was achieved by avoiding traffic driving towards the player's vehicle. The level of game difficulty was affected by the speed of the cars. Adaptation of game difficulty was determined via a real-time classification. A Biocybernetic loop was created for the development of the neuroadaptive game. This loop received fNIRS signals and game score data, which was pre-processed and classified in MATLAB, and the SVM classification was used to determine how the level of game difficulty should be changed. The neuroadaptive game was compared to a random adaptive version of the same game, where data classification was not used to inform the direction of game change. The Cold Pressor test was used to induce experimental pain. The results of the study indicated that, although a significant main effect was found for pain tolerance between a no-game condition and the two game conditions, there was no statistical significance between a

random adaptive game and a neuroadaptive game. This indicates that further work is required both in the neuroadaptive game, and the comparison game. This begs the question: to what should neuroadaptive games be compared, in order to thoroughly examine their effects.

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Day: Tuesday
Session: Interaction
Time slot: 11:35 – 11:59
Talk no.: 3

INVESTIGATING THE INFLUENCE OF RSVP DISPLAY PARAMETERS ON WORKING MEMORY LOAD USING ELECTROENCEPHALOGRAPHY

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ABSTRACT
Rapid serial visual presentation (RSVP) has become a popular text presentation method as it can speed up reading speed and accommodate wearable displays with limited screen space. It has been claimed to decrease required cognitive effort [1]. RSVP comprises the two basic design dimensions of space, represented by spatial properties such as *Text Alignment*, and time, represented by temporal parameters such as *Presentation Speed* [2]. However, it is not clear how these parameters could contribute to the effectiveness and usability of RSVP-based text representations.

We present a study that investigates how manipulating *Text Alignments* and *Presentation Speed*s could influence text comprehension, self-perceived workload, and cortical activity. The objective is to provide a comprehensive evaluation of the cost and/or benefit of each design parameter on these factors that could individually be argued for the deployment of RSVP In a study, 18 participants read a regular document in a baseline condition and nine documents using RSVP. We ensured that those texts were optimized to evaluate RSVP display parameters and text comprehension [3]. We employed a within-subject design whereby *Text Alignments* were manipulated by a centered word representation and positioning of words around their Optimal Recognition Point (ORP). The ORP is usually located off-center and can also be highlighted in red to increase the readability during RSVP [4] (see Figure 1). Furthermore, *Presentation Speed* was varied for 200 Words per Minute (WPM), 350 WPM, and 500 WPM. Participants rated their self-subjective workload using NASA-TLX questionnaires [5] and answered text-related questions. EEG was measured throughout the whole experiment and operationalized in terms of deviation from brain resting states (i.e., alpha power) and engagement (i.e., theta power).

We compare the reading speed across *Presentation Speeds* and the baseline condition. Our results show that RSVP provides a significant time saving when using 350 WPM ($t(17) = 4.05$, $p < .001$, $d = 0.95$) and 500 WPM ($t(17) = 14.8$, $p < .001$, $d = 3.49$). Participants were slower when reading with 200 WPM ($t(17) = -6.69, p < .001, d = -1.58$). Text comprehension and self-perceived workload showed a linear trend with increasing Presentation Speeds ($t(17) = -2.67, p = .01$; $t(17) = -2.67, p = .01$), whereby text comprehension decreased and self-perceived workload increased

with faster *Presentation Speeds* . We operationalized the theta-alpha ratio as metric for cortical activity. We find a significant effect between 200 WPM and 350 WPM (t(17) = 2.94,p = .018,d = 0.69) and 200 WPM and 500 WPM (t(17) = 3.1,p = .012,d = 0.73). *Text Alignment* did not show a significant effect for all measures. Our results imply that faster *Presentation Speeds* provide a benefit in terms of time savings while decreasing text comprehension and increasing self-perceived workload as a cost. We conclude that *Presentation Speeds* are a critical factor that should be considered before *Text Alignments*. We believe that EEG provides reliable estimates for the usability of RSVP parameters and could be employed to adapt *Presentation Speeds* according to the users' requirements.

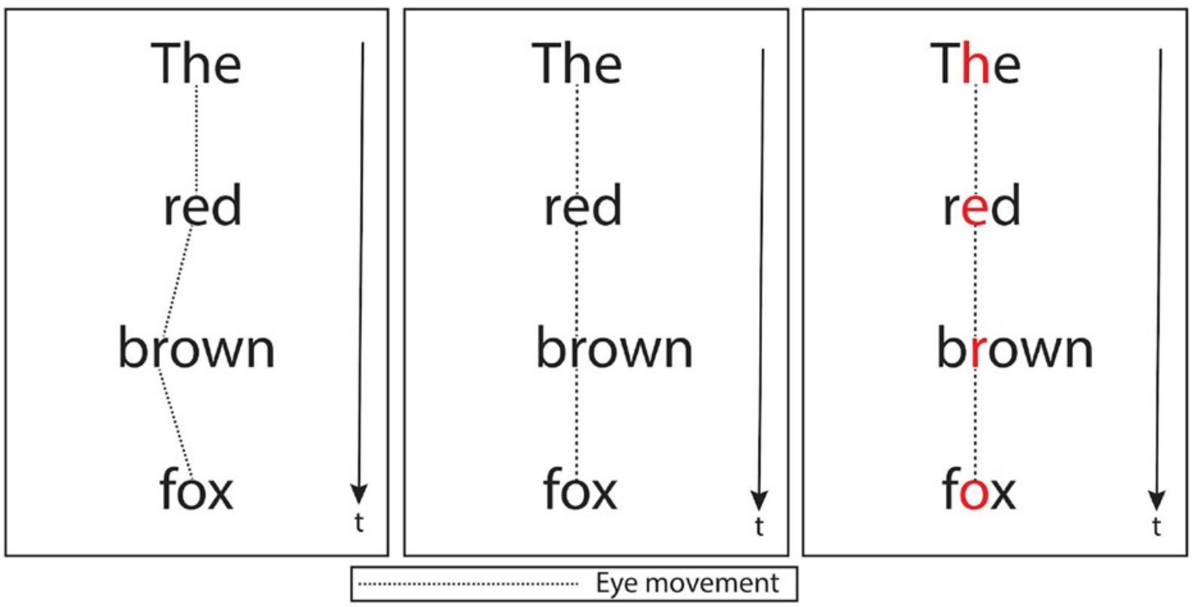

Figure 1. Text Alignments evaluated in the study. Left: Centered text representation. Middle: ORP without highlighted character. Right: ORP with highlighted character. Using a highlighted ORP tends to reduce eye movements.

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Day: Tuesday
Session: Interaction
Time slot: 12:00 – 12:24
Talk no.: 4

TOWARDS BUILDING NEUROADAPTIVE READING APPLICATIONS: ASSESSING DIFFERENCES IN MENTAL WORKLOAD INDUCED BY TEXT READABILITY LEVELS AND PRESENTATION SPEEDS ON SINGLE-SUBJECT LEVEL

Lena M. Andreessen[1,*], Peter Gerjets[2], Detmar Meurers[3] and Thorsten O. Zander[4]

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ABSTRACT
Neuroadaptive technology aims to automatically adapt a machine to changes in its operator's state through ongoing evaluation of neurophysiological activity [1]. One field for application of Neuroadaptive technology are RSVP reading applications where a text in shown to the reader at a fixed screen position one word at a time mostly on portable, small screens (e.g. smartphone). In currently available RSVP reading applications faster reading speeds are overall possible compared to traditional continuous text reading. Changes in reading speed are adjusted manually, distracting the reader from the actual text reading and being cumbersome. A reader-specific optimal reading speed can depend on multiple factors, such as difficulty of the currently read text section, the general reading skill and the current environment of the reader, as well as the reader's current mental state. If such factors, specifically the mental state, could be assessed continuously from a specific reader in a given situation, a user-model of the reader could be build and updated over time. Based on this model, individual neuroadaptive adjustments of e.g. the reading speed or the difficulty of presented text material, could be implemented to create an optimal reading situation for the specific reader, taking changes in user state or text readability into account.

We examined whether a task-independent mental workload classifier [2] can be used to identify text material of different readability levels and text presentation speeds in single-subjects. We recorded EEG data from 64 electrodes as thirteen subjects completed two experimental phases: (1) a mental workload paradigm where phases of low and high workload were induced and (2) a RSVP text reading paradigm, reading twelve texts in blocks of three with a specific text difficulty (easy vs. difficult) and speed (self-adjusted vs. fast (increase of 40%)). We calibrated individual classifiers on the data recorded in (1) and applied them on according data from (2) to examine if the classifier reflects differences in mental workload induced by text difficulty and reading speed. Results suggest that workload predictions of easy texts are lower than those of difficult texts on

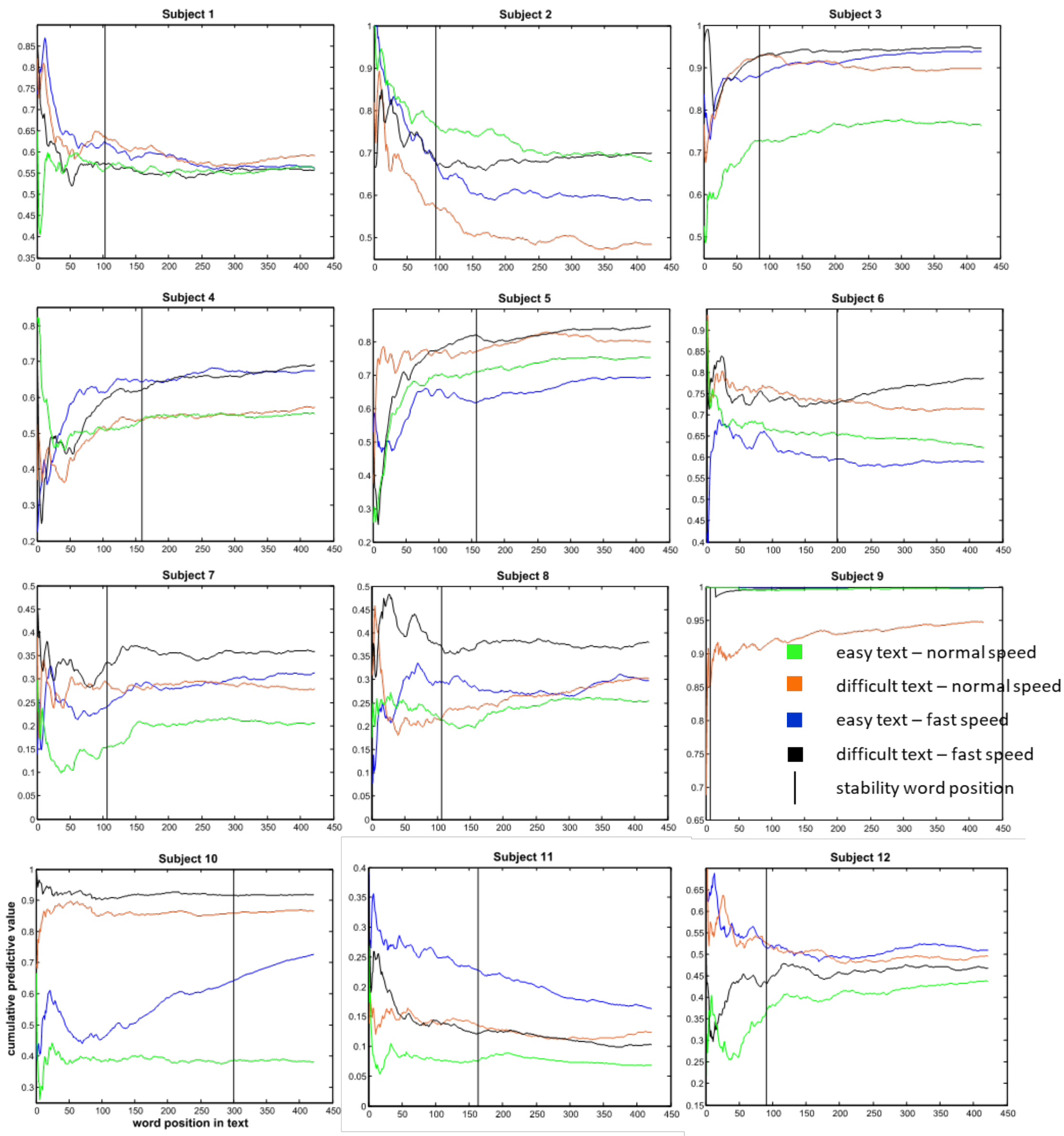

Figure 1. Cumulative mental workload predictive values derived from the classifier output of the mental workload models. Predictive values of all three texts per group were averaged and cumulated for each successive word in the texts. The development of cumulative predictions for all four text reading conditions is shown for the first 422 words in the texts. On the x-axis the text position of the word is displayed. On the y-axis the averaged cumulative mental workload predictions are noted. The individual stability word position is indicated by a vertical black line.

single-subject level and when we consider data from all subjects ($F(1,11)=5.04, p=.046$). Likewise, workload predictions were statistically lower for texts presented at normal speed, than when presented at an increased speed, again on single-subject level and over all subjects ($F(1,11)=11.64$, $p=.006$). We found that approximately 130 words need to be read by an individual for a reliable estimation of the average workload the reading of this text would induce ('word stability position' figure 1). Concluding, we demonstrated that predictions made by the mental workload classifier can be utilized to assess differences in text readability levels and presentation speeds on single-subject level, on average after reading only around 130 words. With this measure a technical system can gain an understanding of the current effect reading a text has to the reader's cognition and adapt itself accordingly. In combination with statistical learning, a user-model of the reader could be built over time to enable individualized neuroadaptive reading systems.

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Day: Tuesday
Session: Interaction
Time slot: 12:25 – 12:49
Talk no.: 5

CAAD MODELLING WITH VISUAL-ERP BCI

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ABSTRACT
This research proposes contributions on the progressive generation of design and architectural features through the exploitation of discriminative neural patterns such as Event-Related Potentials (ERP), and by the implementation of neurofeedbacks, gained through a visual Electro-Encephalography (EEG) -based brain-computer interface (BCI) and Rapid Serial Visual Presentations (RSVP) techniques, for the active modulation of implemented generative models. While the built environment is indisputably aggregating and modulating a wide range of stimuli from the world, It necessarily participates to infer on physiological and psychological states. Several ongoing experiments will be presented in the scope of inverting the concern and ask what can such states provide in the computational modelling of design and architectural artefacts. By opening to this extra-disciplinary corpus of knowledge, a novel way to approach architectural modelling, and the variance of its solutions, can be sought through the notion of Design Beliefs, in opposition to Design Grammars widely used in generative approaches of Computer-Aided Architectural Design (CAAD). The neural phenomena correlated with visual discrimination in such BCI scheme is here generalized and implemented in a computational closed-loop to make use of human cognitive capacities of processing, and discriminating from, rich visual contexts at fast pace and infer on generated states of presented shapes, aggregates of parts, or depictions of spaces. In order to develop such capacities to provoke variance in generated design solutions, an underlying principle model of understanding Vision as Inverse Graphics will be proposed along and which pervades throughout the presented experiments. In the context of CAAD, the term inverse implies here that such model is to be used as a search for features compound of an image, or visual state, to be progressively rendered, by inferring on constantly evolving design beliefs. In regards to the progressive development of encoding design and architectural features with the support of paradigms such as the ERP-oddball in RSVP, this research will continue to refine the described visual context update, by developing a general visual articulation strategy of discrete-continuous visual cues and ensembles of design beliefs for architectural and design models. Eventually seeking to provoke interests incomplementary fields of research.

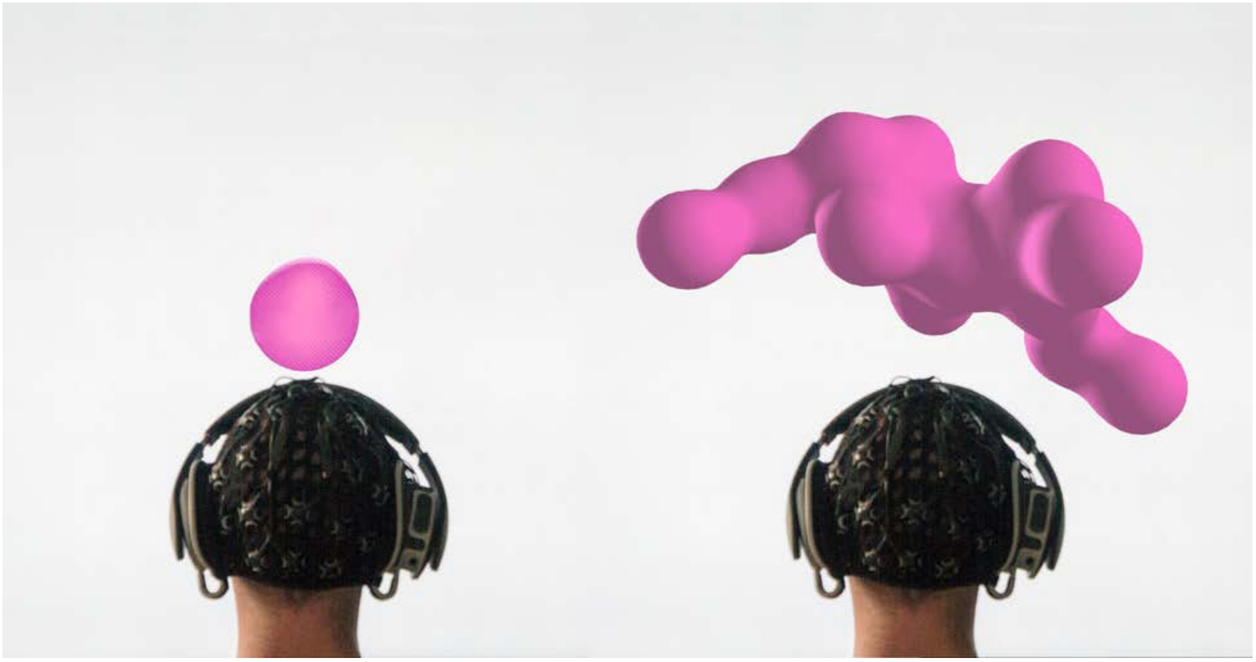

Figure 1. CAAD modelling with vERP-BCI. A shape generation sample.

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Neurofeedback/Biofeedback

Day 1

Day: Tuesday
Session: Neurofeedback / Biofeedback
Time slot: 14:30 – 14:54
Talk no.: 1

MAY ALPHA NEUROFEEDBACK AFFECT MOTOR IMAGERY BCI PERFORMANCE?

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ABSTRACT
The performance variation in motor imagery brain-computer interface (BCI) is one of the challenging issues to be solved. To tackle this issue, the various approaches have been proposed, such as adaptive classifiers, hybrid BCIs, and pre-screening BCI-illiteracy [1]. In addition to those approaches, altering the underlying neural mechanism could be one solution; neurofeedback training (NFT) is a way to self-regulate brain activity in order to shift the current brain state to the desired state [2]. The previous studies have found that central alpha power has a positively correlation to motor imagery BCI performance [3, 4]. However, it was not confirmed whether or not modulating alpha may control motor imagery BCI performance. In this study, we designed alpha neurofeedback game to increase alpha band power, possibly resulting in improvement of motor imagery BCI performance. A total of 23 subjects participated in one-day session experiment, and 21 subjects (2 subjects had stopped the experiment) were used for the analysis (NFT group: 11, Control group: 10). All the subjects performed baseline (eyes-open resting state), and 2-class motor imagery task before/after the NFT (rest for the control). During the NFT, subjects played up-regulating alpha (8-13Hz) neurofeedback racing game and they controlled the speed of the racing car using their alpha activity. In order to investigate the feedback effects, we compared pre/post alpha band power and pre/post motor imagery BCI performances. As a result, there was a statistically significant increment of alpha power for NFT group ($p<0.05$), whereas there was no significance in alpha power for control group. For motor imagery BCI performance, there was no statistical significance between pre/post motor imagery BCI performances for both NFT and control groups. In the individual analysis, we divided NFT group into subjects with increased BCI performance and subjects with decreased BCI performance. Among six subjects with increased BCI performance, five subjects increased baseline alpha band power, showing the positive relationship between increment of alpha and increment of motor imagery BCI performance. For subjects with decreased BCI performance, two out of five subjects decreased baseline alpha band power. From this result, it is expected that alpha modulation may affect motor imagery BCI performance, and it could be used for solving performance variation in motor imagery BCI. In this study, we observed the feasibility of neurofeedback game on alpha band modulation and the relationship between alpha band modulation and motor imagery BCI performance. In order to

make more precise interpretation and evaluate its usability, experimental paradigms considering more subjects and multi-session observation should be designed, which is under way.

ACKNOWLEDGEMENTS
This work was supported by the Institute of Information & Communications Technology Planning & Evaluation (IITP) grant funded by the Korea government (No. 2017-0-00451; Development of BCI based Brain and Cognitive Computing Technology for Recognizing User's Intentions using Deep Learning).

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Day: Tuesday
Session: Neurofeedback / Biofeedback
Time slot: 14:55 – 15:19
Talk no.: 2

DIFFERENTIAL EFFECTS OF NEUROFEEDBACK LATENCY ON THE INCIDENCE RATE, AMPLITUDE AND DURATION OF ALPHA-BURSTS

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ABSTRACT
Latency of sensory feedback has been hypothesized to play a crucial role in reinforcement learning [1]. It has been suggested that the latency of 250-350 ms between a neuronal event and the corresponding feedback is optimal to form an efficient neurofeedback and produce desired neural activity changes [2]. Here, we employed the P4-alpha neurofeedback paradigm to examine how different feedback latencies affect the changes in oscillatory neural activity that occur during neurofeedback training.

Forty healthy right-handed participants (13 males; 24.58 ± 5.3 years) were randomly split into four equal groups. All of them engaged in occipital alpha-rhythm neurofeedback training. The first three groups differed in the value of feedback latency, which was manipulated by adding an extra delay to the preexisting latency composed of the hardware/software delays (~100 ms) and a 100 ms lag caused by band-pass filtering and envelope estimation [3]. Thus, the total latency amounted to 200, 450 and 700 ms in the FB0, FB250 and FB500 groups correspondingly. The fourth group received mock feedback obtained from the previous records of each subject's EEG. We recorded from 32 EEG channels at 500 Hz sampling rate with digital averaged ear reference. Prior to neurofeedback training, we collected resting state data to set spatial filters for eye-movement artifacts suppression and to determine individual alpha-band frequency. The experiment consisted of fifteen two-minute training sessions with 15-second breaks. The neurofeedback was derived as an envelope of the alpha-band filtered P4 data and presented visually as a pulsating outline of the circle on a computer screen. We instructed subjects to make the outline smooth but refrain from developing a specific strategy to aid their performance and, instead, allow an adaptation to occur in an automatic and somewhat subconscious way [4]. We quantified performance by computing the difference in mean value of a parameter in sessions 9-15 and sessions 2-8 referenced to that in sessions 2-8.

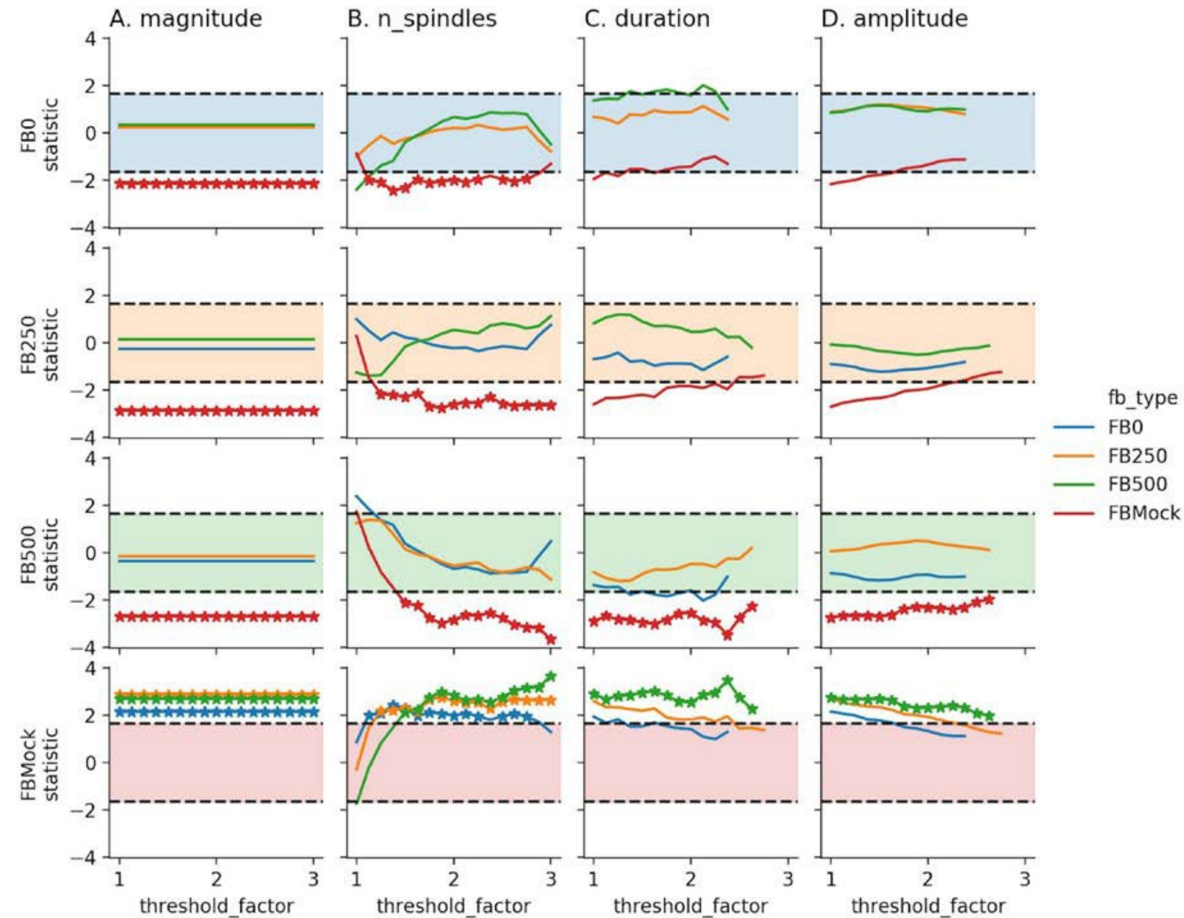

Figure 1. Effects of feedback latency on different parameters of the P4 alpha rhythm. A: Average P4 alpha-band power. B: Number of alpha-bursts per unit time, C: Alpha-burst duration. D: alpha-burst amplitude. Asterisks indicate statistical significance.

All three feedback groups demonstrated a reliable increase in the average alpha power as compared to the mock feedback group (Figure 1.A). No significant average alpha-power differences were observed across these feedback groups. We explored the neurofeedback-induced changes in the pattern of alpha-bursts: burst rate, amplitude, and duration. The alpha-bursts rate increased with neurofeedback training in all three groups (Figure 1.B) and no significant changes in burst duration and amplitude were found in the FB0 and FB250 groups, which agrees with [5]. However, additionally mean burst amplitude and duration grew significantly in the FB500 group (Figure 1.C,D). The statistical significance assessment (rank sum test, $p < 0.05$) incorporated FDR(0.1) correction.

In this study we investigated the effects of long neurofeedback delays and found that alpha-neurofeedback differentially modifies alpha activity, depending on the feedback latency. Interestingly, alpha neurofeedback with the total delay of 700 ms induced the strongest changes in all characteristics of alpha-activity. In the future, short neurofeedback delays should be examined, particularly those below 50 ms that could boost training efficiency because of the improved sense of agency.

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Day: Tuesday
Session: Neurofeedback / Biofeedback
Time slot: 15:20 – 15:44
Talk no.: 3

MULTI-STAGE THEORY OF NEUROFEEDBACK LEARNING

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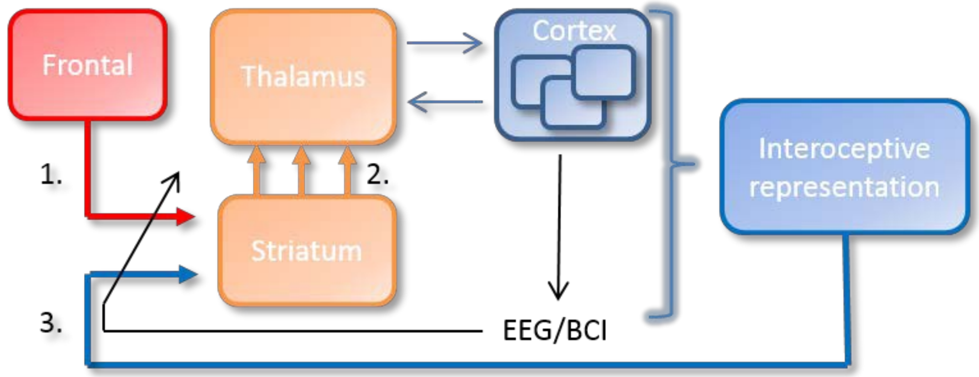
ABSTRACT
Neurofeedback is a training paradigm through which trainees learn to voluntarily influence their brain dynamics. Recent years have seen an exponential increase in research interest into this ability, aiming to address two fundamental questions. First, is the evidence in favour of this training paradigm reliable and do the finding reported in the literature stand up to scrutiny? Second, assuming the existence of the ability, how does it work and how could the success rate of training protocols be improved? Whereas the former question has led to acrimonious debates in the literature and the almost blanket rejection of any research involving EEG neurofeedback, the latter question has surprisingly not be addressed in any substantial manner. In this talk, I will argue that theoretical work is important to not only address the second, but also the first question. I will present a recently formulated multi-stage model of neurofeedback learning (Davelaar, 2018) and demonstrate how this framework guides further work that combines different methodological approaches, from computational modelling through qualitative interviews. The theory assumes three stages that involve different neural networks (see figure 1). In stage 1 the system discovers the appropriate goal representation for increasing the frequency of positive feedback. This stage operates at a within-session timescale and is driven by reward-based learning, which updates fronto-striatal connections. Stage 2 operates on a timescale that covers multiple training sessions and is sensitive to consolidation processes that unfold during sleep. This stage involves updating striatal-thalamic and thalamo-cortical connections. Finally, after stages 1 and 2 have started, stage 3 may be triggered by the awareness of the statistical covariation between interoceptive and external feedback signals. When this awareness emerges, neurofeedback learning may speed up and its effect be maintained well after the conclusion of the training period. Research guided by this framework has uncovered the differential experiential awareness associated with training frontal alpha (Davelaar, et al., 2018), demonstrated how striatal neurons can learn the correct goal representation (Davelaar, 2018), and provided a theory-based approach to the methodology of adaptive thresholding (Davelaar, 2017). Whereas the model accounts for success and failures of specific neurofeedback training attempts, it is also general enough to accommodate human-computer closed-loop situations in which the computer learns to update its internal dynamics.



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Day: Tuesday
Session: Neurofeedback / Biofeedback
Time slot: 15:45 – 16:09
Talk no.: 4

MODULAR BIOFEEDBACK: BUILD YOUR OWN TANGIBLE EXPERIENCE

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ABSTRACT
Thanks to various advances in computer science, applications based on physiological data are entering everyday lives, areas ranging from health care to sport to entertainment to personal usages (see Picard 1995; Fairclough 2009). Sensors can be embedded in wearables such as smartwatches, signal processing and machine learning can occur on evermore ubiquitous smartphones, data can be streamed to the cloud in order to be shared with the entire world or stored for further analysis. Physiological data is private and personal, and yet we might lose control and awareness ofwhere, how and for what purpose it is being recorded; when devices enable remote and covert monitoring of vital signs -- e.g. through walls using electromagnetic waves (Ravichandran et al. 2015) -- or when companies venture in neuro-marketing to subjugate more clients.

In order to tackle some of the societal issues aforementioned, we propose a tangible user interface (Ishii et al. 1997) to act as a mediator with the invisible realm of physiological computing. Inspired as much by playful Lego® as by tangible programming or audio modular synthesizers, we created "bricks" that embody the various atoms composing any application pertaining to biofeedback. Our current set of bricks is composed of three categories: input signals (e.g. breathing, photoplethysmography), processing (e.g. band-pass filtering, peak detection), output (e.g. sounds, visuals), storage (e.g. recording or replaying data), streaming (e.g. to the vicinity through Bluetooth or remotely to Internet).

These atoms are sufficient to reproduce a variety of devices, from a simple breathing guide (i.e. synthetic sinus input + sound output) to more complex introspectibles (e.g. two times [breathing input + PPG input + covariance processing + streaming + visual output] == multiuser relaxation, as in Gervais et al. 2016). Communication between bricks occurs through analog signals, the inner relies on the opensource Arduino ecosystem, the whole is a project that aims at supporting transparency and agency. Indeed, each brick exposes an explicit iconography on its outer layer so as to highlight its purpose and behavior, and the bricks can be freely (re)assembled and customized. The limitations of current form factor are also its strengths. The bulkiness of the bricks let users directly peek at what is inside if they do not trust the labels; exposed pins let them replace the code if they do not trust the existing firmware; off-the-shelf parts give them freedom to replace the

components or interface their own electronics if they do not trust the hardware. The dated communication protocol ensures that data cannot be duplicated ad vitam æternam *thanks to* noise-sensitive analog signals (biodata made biodegradable) and undesired metadata are less likely to leak from a single analog channel. We envision the use of our blocks in educational settings to raise awareness and foster creativity, or to let designers quickly prototype applications related to physiological signals.

During this demonstration, we will let attendees experiment with our modular system in order to discuss with the community the pertinence and the viability of our approach. We would also like to take this opportunity to assess what devices people envision build, how they would use the system and which functionalists are missing.

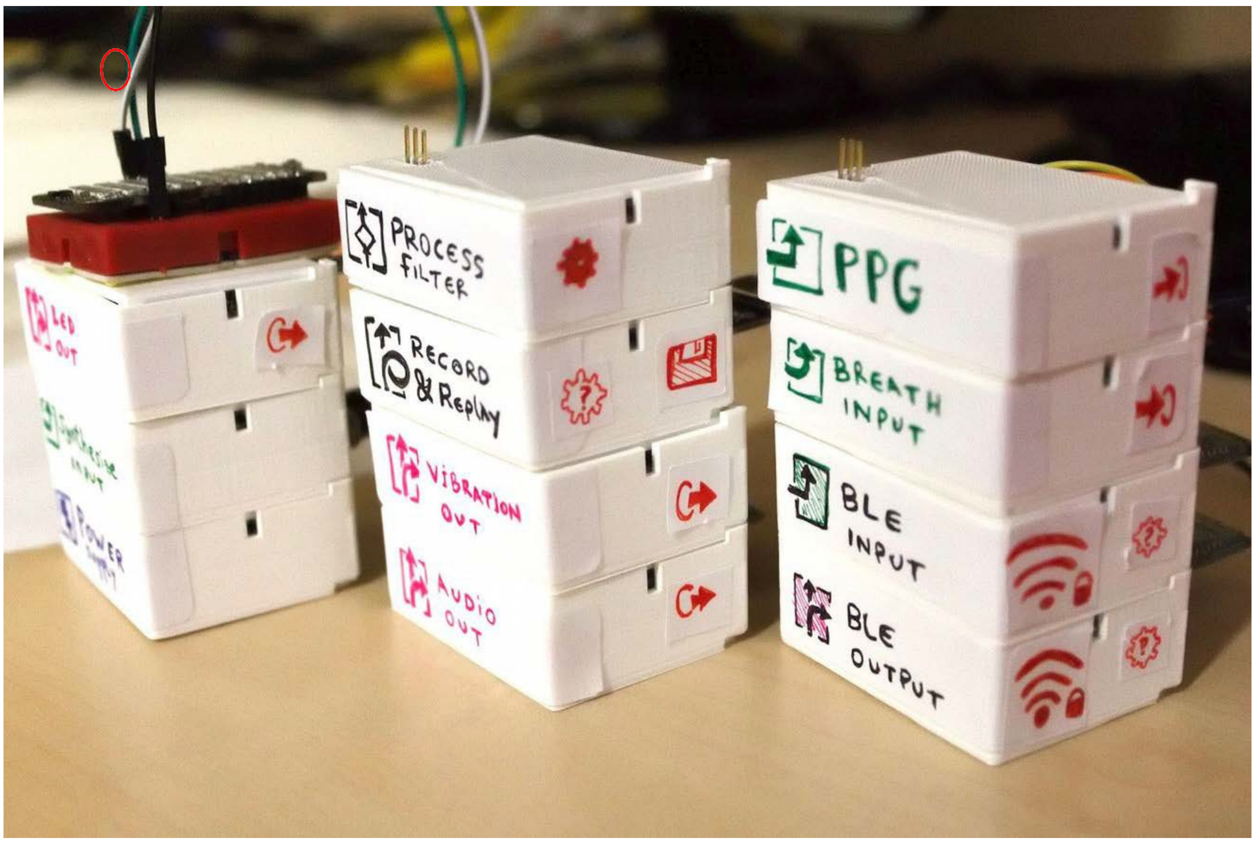

Figure 1.

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Day: Tuesday
Session: Neurofeedback / Biofeedback
Time slot: 16:10 – 16:34
Talk no.: 5

MODELING BIOCYBERNETIC ADAPTATION THROUGH FEEDBACK CONTROL SYSTEMS PRINCIPLES: IMPLICATIONS IN HUMAN-COMPUTER INTERACTION AND VIRTUAL REALITY APPLICATIONS

John E. Muñoz[1,*], Chad L. Stephens[2], Luis E. Velez[3], and Alan T. Pope[2]

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Certain neuroadaptive technologies may usefully be characterized in feedback control system terms. Biocybernetic adaptation technologies are among these. Biocybernetic adaptation [1] employs the "steering" sense of "cybernetic", for example, in physiologically adaptive automation, and serves a transitory adaptive purpose – to better serve the purpose of the system by more fully representing the human operator's overt and covert responses to the system. The focus is on the "biocybernetic loop" – the closed-loop system that is created when a person's physiological information is made available to the person through modulation of the task the person is performing. A closed-loop perspective motivates mapping feedback control systems concepts onto physiological loops.

One objective of this paper is to demonstrate how systems based upon biocybernetic adaptation may be modeled using feedback control principles. For example, controller elements have been used in biocybernetic applications for testing various indices of cognitive engagement [2] and for adjusting the level of automation of a task [3]. Other studies have employed control-theoretic approaches to create adaptive biofeedback games aiming at training self-regulation skills. Parnandi and colleagues [4] used a closed-loop system configuration that modulated game variables by feedback control laws using Proportional-Integrative-Derivative (PID) controllers. The goal of the control system was to maintain the player's arousal around desired levels, thus the physiologically adaptive game enhanced with the PID controller showed effectiveness in reducing the errors and oscillations in the closed-loop system response.

A second objective of this paper is to explore biocybernetic adaptation strategies employed in a virtual reality (VR) simulator that uses a meta-layer of physiological intelligence. The fully immersive, VR-based training simulator (called Biocyber Physical System – BioPhyS), was created to investigate physiological self-regulation in police officers while interacting in a target-shooting scenario. The BioPhyS simulator was interfaced with an engine able to provide physiological intelligence by using biofeedback principles: the Biocybernetic Loop Engine (BL Engine [5]). The overall goal of the target shooting adaptive system is to maximize the time trainees spend in the desirable 100-115 bpm targeted heart rate zone while shooting in VR. The

trainee's experience in producing heart rates in the targeted zone in association with the stimuli of the shooting environment in VR is expected to transfer the trainee's skill at producing optimal heart rate responses to the real-world shooting situation with its similar stimuli.
Since the ultimate goal of the biocybernetic system is to help trainees to converge to the desired psychophysiological states, a PID controller was implemented to optimize the changes of the simulation variables (Figure 1). In the BioPhyS adaptive system, the difference between the trainee's HR response and the target or setpoint HR is used to drive attributes of the simulation task, e.g., target speed or rain intensity, which, in turn, is expected to drive the trainee's HR. The effectiveness of a proportional-integrative-derivative (PID) controller element in improving the accuracy and stability of the BioPhyS closed loop system is investigated.

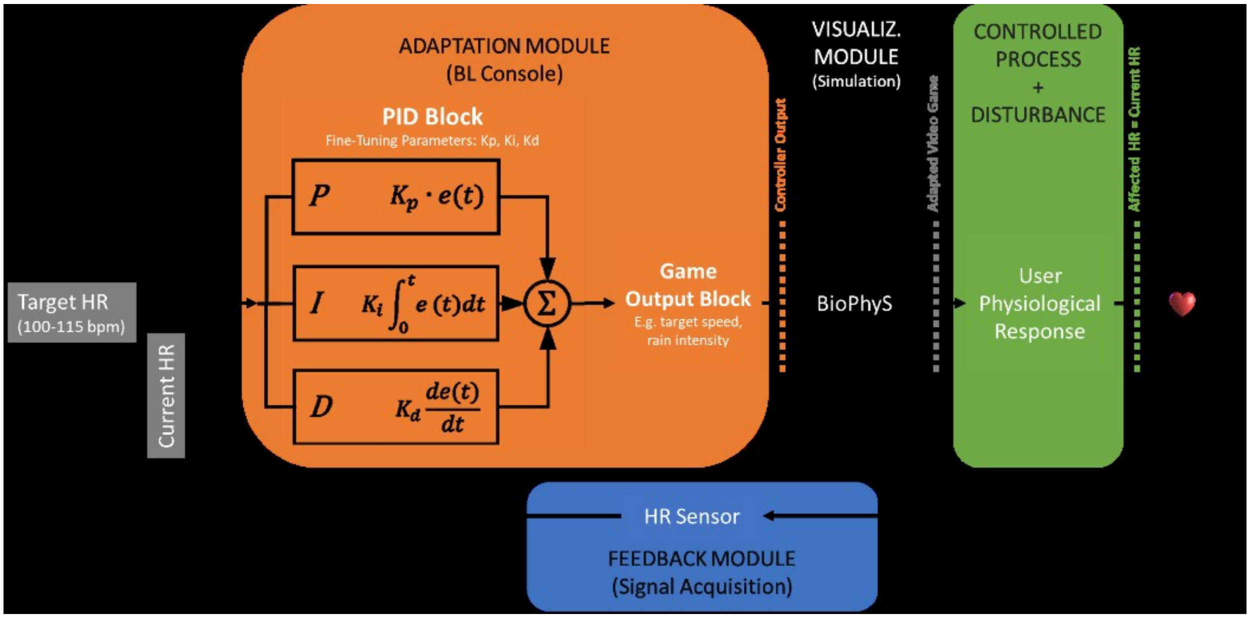

Figure 1. Diagram of the PID controller implemented in the BL Engine and integrated in the BioPhyS simulator for the in-session adaptation. The described scenario shows how the PID controller can create refined adaptations in the BioPhyS simulator, influencing users to have optimal physiological responses while shooting.

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Neuroergonomics

Day 2

Day: Wednesday
Session: Neuroergonomics
Time slot: 10:45 – 11:09
Talk no.: 1

ON THE USE OF PHYSIOLOGICAL MEASURES TO MONITOR OPERATOR DYADS

R. N. Roy*, C. P. C. Chanel, K. J. Verdière, N. Drougard & F. Dehais

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ABSTRACT
The recent field of Neuroergonomics makes use of physiological measures in order to better characterize operators' state in work settings. Thanks to ocular, cardiac and cerebral measures it is therefore possible to evaluate stress, mental fatigue and attentional engagement states. These states have already been characterized in an aeronautical context on a single operator (Roy et al., 2016, 2018; Verdière et al., 2018; Dehais et al., 2018, 2019). Yet, to our knowledge the literature on physiological measures of two or multiple operators in the same work setting, or even in interaction with each other is scarce. Hence, it seems necessary to try and characterize various mental states including cooperation v. no cooperation states for risky tasks such as the ones of the aeronautical domain. The need for such a neuroergonomic approach of multiple operators' mental state assessment will be discussed. Moreover, preliminary results of two ongoing experiments will be presented: a first one that evaluates this cooperation during the realization of a modified version of the Multi-Attribute Task Battery (MATB), and a second one on the cooperation between a pilot and her/his ground operator. A focus will be made on cerebral measures and their classification for workload and cooperation level estimation in order to develop neuroadaptive systems that would take these states into account to enhance work safety and performance.

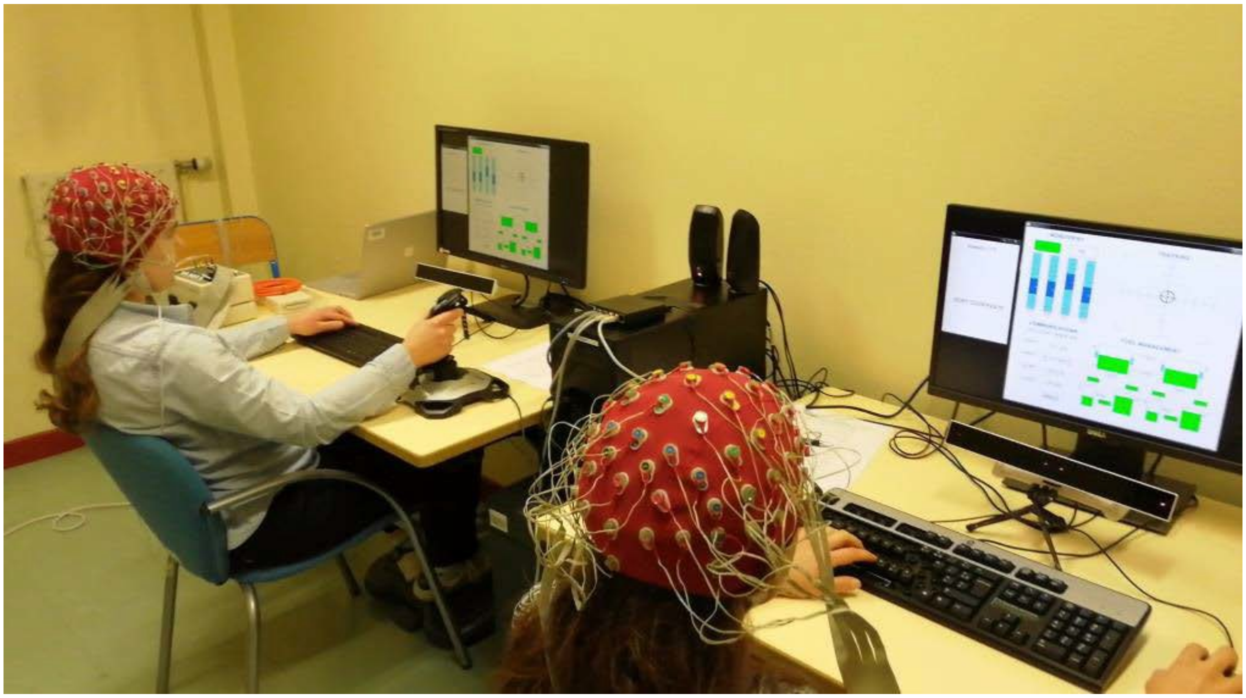

Figure 1. Team performing a modified version of the MATB task

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Day: Wednesday
Session: Neuroergonomics
Time slot: 11:10 – 11:34
Talk no.: 2

EFFECT OF HAPTIC ASSISTANCE STRATEGY ON MENTAL ENGAGEMENT IN FINE MOTOR TASKS

Hemanth Manjunatha[1], Shrey Pareek[2], Amirhossein H. Memar[1], Thenkurussi Kesavadas[2], and Ehsan T. Esfahani[1,*]

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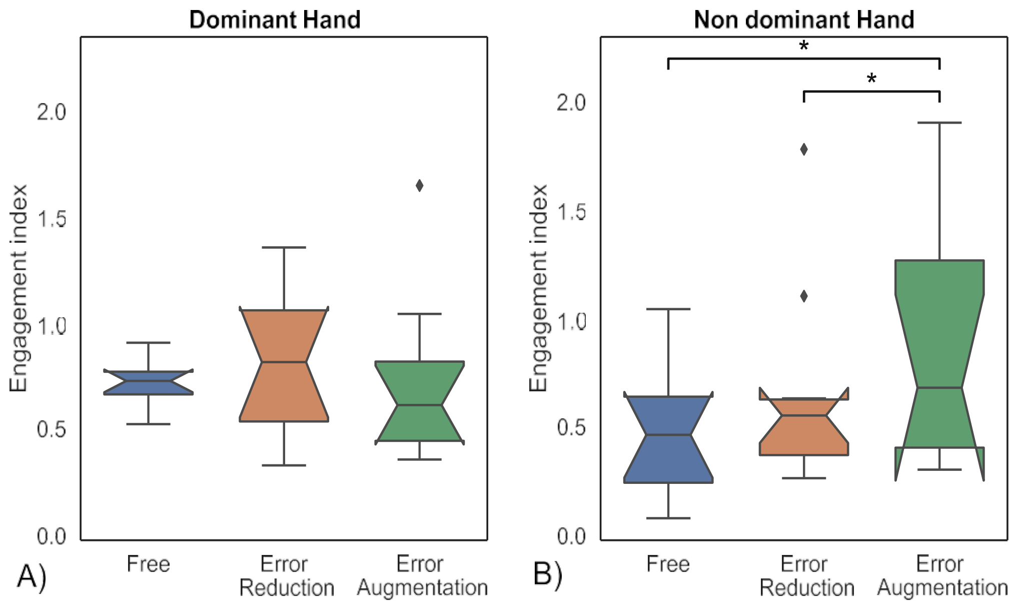
ABSTRACT
This study investigates the effect of haptic control strategies on a subject's mental engagement using EEG during a fine motor rehabilitation task after stroke. Stroke is the fifth leading cause of death in the United States and is a major cause of serious disability for adults and incurred a loss of 34 billion dollars from healthcare and loss of productivity [1]. The hospital-centric rehabilitation process available to these patients is limited and expensive. As a result, a large population of patients is forced to discontinue their physical therapy before full motor recovery. Such patients can considerably benefit from affordable home-based rehabilitation which eliminates the excessive involvement of clinical staff and facilities [2]. Haptic-based rehabilitation systems are one of the main alternatives for home-based rehabilitation. They can mimic the therapist actions by providing force feedback and assistance during fine-motor learning as needed [3].

In most of the robotic/haptic-based rehabilitation platforms, the training strategy falls mainly into two categories: 1) Error-reduction strategies (ER) which decrease the task difficulty (e.g., minimizing the trajectory tracking error) in order to assist the patient to perform the rehabilitation tasks better. 2) Error-augmentation strategies (EA) that increase the task difficulty (e.g., increasing task's error) to evoke a higher voluntary involvement of the patient to accomplish a goal. Regardless of the type of haptic training strategy (EA or ER), the success of the haptic-based therapy may not be necessarily superior to manual physical therapy unless there is active involvement by the patients [4]. For instance, in error-reduction strategy, the assistance may be too much such that the patient may lose engagement and fail to learn the motor primitives necessary for recovery [5]. In error-augmentation strategy, the task can become very difficult and the patient might get distracted and thus fail to learn the motor primitives. Therefore, quantification of mental engagement has a pivotal role in successful robotic rehabilitation, so that the haptic systems maintain good engagement level from the patient during training.

In this study, the considered strategies include an Error-Reduction and an Error-Augmentation control, tested on both dominant and non-dominant hand. The engagement level is extracted from electroencephalogram (EEG) signals recorded using a non-invasive brain-computer interface

(BCI). The ratio of frontal Theta and parietal Alpha power is used as a measure of task engagement. Statistical analysis conducted to test the effect of the control strategy on mental engagement revealed that the choice of the haptic control strategy has a significant effect ($p < 0.05$) on the mental engagement of subjects depending on the type of hand (dominant or non-dominant). Among the evaluated strategies, Error-Augmentation strategy is shown to be more mentally engaging when compared with the Error-Reduction strategy.



Significant differences between engagement indices using different control strategies under (a) dominant hand (b) non-dominant hand (The asterisk denotes significant difference at a significance level of 5%).

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Day: Wednesday
Session: Neuroergonomics
Time slot: 11:35 – 11:59
Talk no.: 3

THE AUTOMATIC CLASSIFICATION OF HUMAN FACTORS ASSOCIATED WITH DECISIONS INVOLVING RISK DURING DRIVING SIMULATION

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ABSTRACT
We report work in progress that seeks to classify the human factors associated with decisions involving risk in an automotive vehicular context. Using a combination of psychophysiological and telemetric data we aim to create a multimodal classification model of "decisions involving risk" and then apply the model to automatically classify those types of decision using machine learning approaches. This research represents the first stage of an experimental program which seeks to confirm if the classification model is transferable fully, or in part, from an automotive to an aerospace context. In this new context, the classification model will be used to classify decisions involving risk during simulated helicopter flight. Transferable elements will then be applied to drive an adaptive real-time flight scenario creator, and classification outputs will be integrated into post-flight debriefing processes to highlight problematic manoeuvres, allowing instructors to better train pilots. In addition, it is envisaged that classification outputs will also be integrated into a system used to adapt automation strategies during real-time flight operations.

Figure 1. Driving Simulator, Eye Tracker, Camera Setup, overlaid upon Telemetry collected in parallel with driving Simulation.

The experimental task is split into 2 parts: a battery of psychological tests consisting of an n-back task to induce variations in cognitive load, the BART [1] and the IGT [2] to induce decisions involving risk. Each task lasts 10 minutes, for an overall duration of 40 minutes including return to baseline periods. Part two of the task involves simulated driving using a high-fidelity racing car simulation, for this Project Cars 2 (Slightly Mad Studios Ltd, London, UK) is used which allows for 3rd party applications to access simulation data. The driving task involves the completion of laps around a track, after an initial lap to become familiar with the control interface, a financial incentive tied to performance is introduced. To encourage decisions involving risk, task difficulty is manipulated each extra lap for 5 laps.

Data collection is currently underway utilising a participant pool drawn from HEC business school students. Participants are screened based on good health, normal or corrected to normal vision and a valid driving license. Participants sign consent in line with the University's ethics board, and are provided with a mouse, keyboard and a force feedback steering wheel and pedals. Participants sit approximately 92 cm in front of 3, 27" computer screens, positioned to provide a 120-degree field of view and 5760*1080 screen resolution. We use a 64 electrode EEG (Brainvision, Morrisville, NC) to measure variations in brainwave activity at 512Hz, and a cap track during setup to measure head size and aid in spatial localisation. In addition, we use a smart-eye (Smart Eye, Gothenburg, Se), eye tracker with a 2-camera setup to capture measures of gaze and pupillometry at 60Hz, and a software telemetry module that captures 173 measures of vehicular activity at 60Hz from within the simulation.

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Day: Wednesday
Session: Neuroergonomics
Time slot: 12:00 – 12:24
Talk no.: 4

TOWARDS NEUROADAPTIVE TECHNOLOGY USING TIME WARPED DISTANCES FOR SIMILARITY EXPLORATION OF BRAIN DATA

Jayesh Dubey, Mihin Sumaria, Erden Oktay, Yu Li, Ziheng Li, Rodica Neamtu, Erin T. Solovey*

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OVERVIEW

In this paper, we describe BrainEx, a tool for similarity exploration of brain data for neuroadaptive technology (Figure 1). We then demonstrate how we used it to explore brain data collected in two experiments to build a foundation for neuroadaptive technology. Experiment 1 examines fNIRS data to identify periods of elevated driver workload in a simulator. Experiment 2 explores the detection of mind wandering states during a cognitive control experiment. We show that our exploratory tool can use different similarity distances for robust identification of similar patterns in the brain data during complex tasks. This builds a foundation for interactive systems that are capable of identifying cognitive states and adapting system behaviour to better support users.

BACKGROUND

Classifying time domain data continues to be a central problem in neuroadaptive technology, for which there is a need to process large time series datasets to get insights into brain activity and patterns. Promising solutions use elastic or warped distances to compute the similarity between sequences with different lengths and temporal misalignments. The quadratic complexity and lack of triangle inequalities for warped distances make their use impractical for large datasets.

BRAINEX

We address some of these challenges through BrainEx, a versatile multi-warped distance driven similarity exploration tool which reduces the mining space by using a "process one-query many'' paradigm based on simple-to-compute pointwise distances, including Euclidean [1], Manhattan, and Chebyshev. The resulting reduced pre-processed dataset is later efficiently explored using specific warped counterpart distances [2].

EXPERIMENTAL TASK

Experiment 1 used an n-back experiment paradigm to induce elevated workload during simulated driving [3, 4]. Twenty-three subjects were asked to perform three blocks of 2-back tasks where the numbers 0-9 were presented every 2.5 seconds, and the participant had to recall the number that they had heard 2 back from the current number. The goal was to find patterns that differentiate the 2-back (elevated workload) periods from the periods of driving only. Experiment 2 used a

Sustained Attention to Response Task (SART) [5] task paradigm designed to induce mind wandering. Nine subjects participated and their responses were used to label the data into "correct" and "incorrect" responses to the stimulus, which may be associated with cognitive control and mind wandering. In both experiments, fNIRS sensors were applied to the prefrontal cortex.

Figure 1. Snapshot of the BrainEx interface showcasing exploration and retrieval of similar sequences of data. This can be valuable in the early stages of development of neuroadaptive technology. From left to right we display a scenario where the analyst chose a specific query sequence from a dataset and is retrieving the three most similar matches (displayed on center right panel). The similarity exploration uses Dynamic Time Warping, which enables the retrieval of similar sequences of different lengths and with temporal mis-alignments. The top right panel shows statistics about the natural distribution of time series in clusters for specific lengths, contributing to better understanding of the data. Left lower panel displays the ability to select subsequences of time series and use them as queries, while right lower panel gives information about the results including patient, chanel, start, end and length of the matching sequence. The analyst can display/hide the matching sequences as needed for better visualization and interpretation.

ANALYSIS AND RESULTS

We used BrainEx to query the most similar subsequences for a given sample of brain data collected during each experiment. Our goal was to gain insights into whether brain data during similar task periods have similar time series characteristics. For example, during elevated workload periods, do we find similar patterns of brain data? We were able to explore the effects of choosing different similarity thresholds, different pre-processing methods, as well as different similarity measures to inform our algorithms for preprocessing and automatically detecting similar sequences of brain data.

CONCLUSION

BrainEx has promise for supporting data exploration to identify similar sequences of brain data, which is an essential step in the early stages of neuroadaptive technology development.

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Day: Wednesday
Session: Neuroergonomics
Time slot: 12:25 – 12:49
Talk no.: 5

ATTENTIONAL CONTROL DURING THE FLOW EXPERIENCE IN VIRTUAL REALITY GAMES

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INTRODUCTION

Flow is traditionally defined as the subjective, optimal experience that ensues during video game playing and it is primarily characterized by intense concentration. Facilitating the onset of this experience is essential for designing effective and enjoyable video games, as it has been linked to a feeling of gratification. The two polar extremes of flow, boredom and anxiety, trigger in presence of a discrepancy between the game's challenge and the player's skills. When the player's skills exceed the game's demands, boredom may emerge as a failure to allocate attentional resources, even if the player is motivated to engage [1]. In contrast, anxiety may trigger when the game's demands surpass the player's skills [2].
Additionally, there appears to be an individual proclivity toward experiencing either of these states, with personality mediating their relationship [3]. Attentional control stabilizes during flow and eye-blinking rate may progressively decrease during increased mental load [4]. However, a study distinguishing mental from visual load showed that blinking rate increased during mental load but decreased during visual load [5], thus making the evidence on mental load inconclusive. Notably, eye movement patterns have also been linked to personality traits [6], which are consistent with the personality traits conducive to the flow experience. In this work, we used three separate classification algorithms to assess mental load in virtual reality as a proxy measure for concentration.

METHODS

A Tower Defense game was developed for virtual reality, comprising trials designed to elicit flow, anxiety and boredom. Flow scores collected retrospectively from self-reports were utilized to segregate the sample into low- and high-flow groups. Electrooculograms (EOG) were acquired from 28 participants across 30 trials segmented into three epochs each. Further, a C-Support Vector Machine (SVM) with radial basis function kernel, k-Nearest Neighbours (kNN) with three nearest neighbours and squared Euclidean distance and a CART Decision Tree (CART DT) were trained using six features extracted from the EOG data during the game session (a) and the resting baseline (b). Each observation in (a) was multiplied by the sum of agreeableness, extraversion, openness and conscientiousness and subtracted from the neuroticism scores, as well as subtracted from the features in (b).

RESULTS

After applying a 10-fold cross-validation, the classifiers were able to separate the low- and high-flow groups with a mean accuracy of 86.5% (SVM), 89.3% (kNN) and 90.5% (CART DT). In addition, the high-flow group was found to have longer inter-blink intervals ($p < .01$) and fewer blinks per minute ($p = .016$) than the low-flow group, indicating increased attentional control.

DISCUSSION

The results corroborate previous findings on blinking rate during the flow experience. However, they cannot be interpreted on the basis of visual load [5], since the discriminatory, binary categories were not derived from the trial types (flow, boredom and anxiety), but from the self-reported flow scores. Both low- and high-flow groups were exposed to the same levels of visual load. Instead, we propose that the differences in blinking rate reflect the differences in mental load during the game. However, research has also explicated the relationship between eye blinking rate and the dopaminergic system [7], the same system implicated in the flow experience [8]. Although blinks are primarily regarded as markers of arousal [9], their link to the dopaminergic system suggests that they may carry information of affective valence as well [10]. The described approach has a promising biofeedback potential to adapt different aspects of the game for the sustenance of the player's focus and enjoyment.

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Ambulatory

Day 2

Day: Wednesday
Session: Ambulatory
Time slot: 14:30 – 14:54
Talk no.: 1

EXAMINING ECONOMIC DECISIONS FOR HOUSEHOLD PRODUCTS USING MOBILE EEG

H. Roberts[1,*], J. Tyson-Carr, V. Soto[1], K. Kokmotou[1,3], A. Byrne[1,2], N. Fallon[1], T. Giesbrecht[3] and A. Stancak[1,2]

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BACKGROUND

Economic decision making involves the computation and assignment of subjective values along a common scale in order to appraise the value of a product [1]. Many researchers have attempted to isolate the neural correlates of economic decision making. However, little is known about the temporal dynamics of how economic decisions evolve in the brain. Using mobile electroencephalographic (EEG) methods, it is possible to decipher when and where in the brain economic decisions for products occur in freely moving participants during realistic scenarios [2, 3]. The current study aimed to extend the results presented in our recent paper (Roberts et al., 2018) by examining the spatio-temporal brain dynamics that accompany economic decisions for products in realistic environments using mobile EEG and eye tracking.

METHODS

Participants viewed and rated images of everyday household products (priced £0.50 - £12.00) in a product gallery setting whilst EEG and eye tracking was recorded. Afterwards a Becker-DeGroot-Marschak (BDM) auction task elicited willingness to pay ratings for products, which was used to split stimuli into subjective value conditions (low, low medium, high medium and high value). Eye movement related potentials (EMRPs) were examined and an independent component analysis (ICA) was used to decompose sources of activation from the grand averaged EEG for 20 individual data sets across all conditions between 200 before and 600 ms after image onset. A K-means clustering solution was employed for the decomposed grand averaged EMRP data for 20 subjects using the PCA EEGLAB routine. Each cluster's mean activation was statistically compared across subjective value conditions between -200 and 600 ms.

RESULTS

The analysis revealed four clusters that showed significant differences in amplitude for subjective value conditions between 50 and 230 ms. Cluster 3 showed enhanced amplitude for low value products compared to higher conditions (116-127ms) followed by enhanced amplitude for high value products compared to medium conditions (193-204ms). Cluster 5 showed enhanced amplitude for low value products compared to low medium (50-63ms), as well as high value (132-148) followed by enhanced low value amplitude compared to both medium conditions (170-183 ms). Cluster 6 showed enhanced amplitude for low value products versus the highest value products (56-58 ms), followed by all value conditions versus high medium value products (225-230 ms). Cluster 9 showed enhanced amplitude for high medium value products compared to all others (158-185).

DISCUSSION

Findings suggest that in real world scenarios low value products receive a prioritization of attention by the brain (50 ms). Lower value products are quickly isolated and are then compared against high and high medium products, followed by low medium value products. Finally, high medium value products receive enhanced attention at around 158 ms and again at 230 ms, as decisions regarding these products may require more deliberation. This prioritization of attention for low value products may represent an aversive mechanism that exists to maximize economic resources. This research demonstrates the brain does not allocate attention for differently valued products during economic decisions in a linear manner.

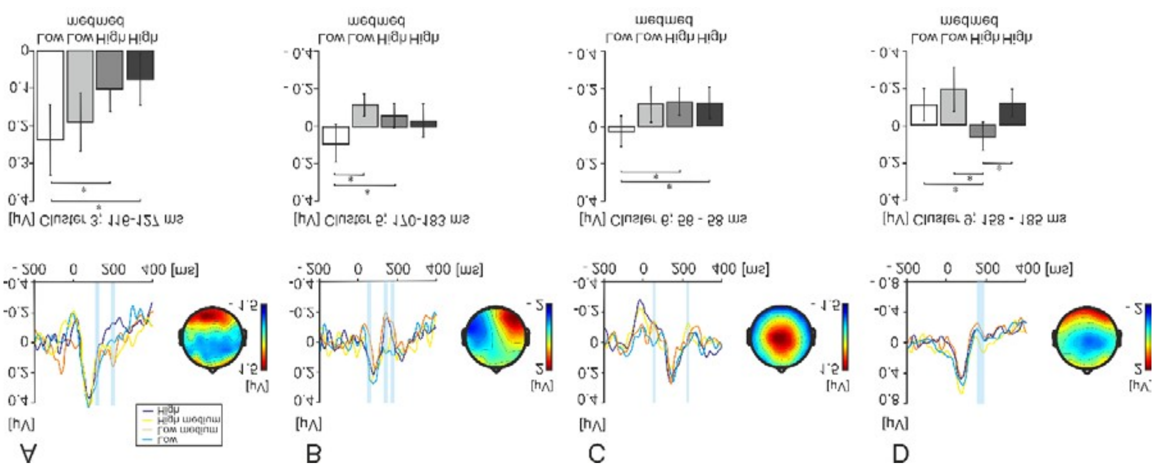

Figure 1. 1. Grand averaged IC cluster activity (μV) and statistical differences in product value. Intervals within significant differences between mean cluster amplitude across conditions ($p < .05$) are indicated using blue bars or a single asterisk. (A) Grand averaged waveform, topographic map and bar graph illustrating statistical differences in product value for cluster 3 between 116-127 ms. (B) Grand averaged waveform, topographic map and bar illustrating statistical differences in product value for cluster 5 between 170-183 ms. (C) Grand averaged waveform, topographic map and bar graph illustrating statistical differences for cluster 6 between 56-58 ms. (D) Grand averaged waveform, topographic map and bar graph illustrating statistical differences for cluster 9 between 158-185ms.

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Day: Wednesday
Session: Ambulatory
Time slot: 14:55 – 15:19
Talk no.: 2

WALKING IMPROVES THE PERFORMANCE OF A BRAIN-COMPUTER INTERFACE FOR GROUP DECISION MAKING

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ABSTRACT
We show that walking on a treadmill improves the performance of an EEG-based collaborative brain-computer interface (cBCI) for assisting group decision making.

INTRODUCTION

Collaborative brain-computer interfaces (cBCIs) have been used to improve group decision making thanks to their ability to estimate the decision confidence of individuals from their brain signals and response time (RT) [1-3]. However, previous studies used the cBCI in controlled lab conditions, where users performed limited muscular activity while making decisions. Here, we developed and tested a cBCI in situations where users perform decision-making tasks while walking on a treadmill.

METHODS

Ten participants were presented with video sequences (frame rate = 4 Hz) of a dynamic environment representing the viewpoint of a user walking at a constant pace along a corridor, where characters could appear from side doorways for one frame (Fig. 1 (left)). In each trial, the participants had to decide whether the character was wearing a helmet or a cap within 2.5 s. After reporting their decisions, participants had to indicate their degree of confidence using an 11-point scale (from 0=not confident, to 100=very confident) within 2 s. The experiment was composed of 12 blocks of 42 trials: six blocks where the participant was walking on a treadmill in a leisurely manner (2 km/h), and six blocks where he/she was sitting on a comfortable chair, in a counterbalanced order. A Biosemi ActiveTwo EEG system was used to record the neural signals from 64 electrode sites following the 10-20 international system. The EEG data were sampled at 2048 Hz, referenced to the mean of the electrodes placed on the earlobes, and band-pass filtered between 0.15 to 40 Hz to reduce electrical noise. Decision confidence was estimated by logistic regression using the RT and two neural features, extracted by applying Common Spatial Patterns filters to low-pass filtered (16 Hz) response-locked EEG epochs starting 1 s before the response and lasting 1.5 s. The data collected from the participants were then combined off-line to form all possible groups of increasing size.

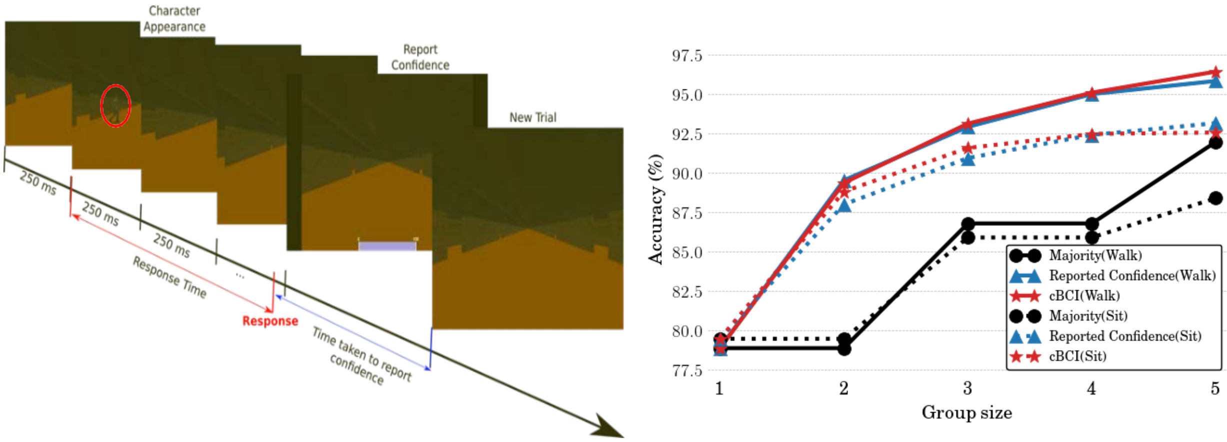

Figure 1. Example of sequence of stimuli used in one trial of the experiment. Average group accuracies for groups of size 1 to 5 using standard majority (in black), reported confidence (in blue), and cBCI (in red) while sitting (dashed lines) and walking (solid lines).

RESULTS

Fig. 1 (right) shows the mean accuracies for group sizes one to five using either standard majority (black) or a weighted majority using the confidence reported by the participant after each decision (blue) or the confidence estimated by the cBCI (red), for the walking (solid lines) and sitting (dashed lines) conditions. This shows that cBCI and reported confidence produce similar results, but walking improves the group performance statistically significantly ($p < 0.03$ for Wilcoxon signed-rank tests) for reported confidence and cBCI when compared to the corresponding sitting conditions.

CONCLUSIONS

While muscular artefacts caused by walking on a treadmill could be expected to produce negative effects on the ability of the cBCI to decode the decision confidence of users, the similarity between the cBCI and reported confidence performance in both the walking and sitting conditions indicates otherwise. Instead, we found that walking improves group performance in the task considered in this paper, which is likely due to increased level of alertness, leading to overall better performance, in the walking conditions. This suggests that the cBCI may work well on a wider range of operating environment than just a lab.

ACKNOWLEDGEMENTS

This research was supported by the Defence Science and Technology Laboratory (Dstl) on behalf of the UK Ministry of Defence (MOD).

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Day: Wednesday
Session: Ambulatory
Time slot: 15:20 – 15:44
Talk no.: 3

FEMG AND EMOTION IN VIRTUAL REALITY

Christopher Baker[1], Ralph Pawling[1], Chelsea Dobbins[2] & Stephen Fairclough[1]

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ABSTRACT

Many studies have attempted to use virtual reality as a method to induce emotional experiences. In this talk I will discuss an analysis of a study which sought to examine the effects of room-scale VR on perception of virtual height by combining VR with ambulatory psychophysiology and the broader attempt to build an emotional model with the results according to the Evaluative Space Model Cacioppo et al. (2012) . A custom environment was created using Unreal Engine to deliver a graded experience of threat wherein participants must physically cross a suspended grid of ice blocks at a series of elevations of 200 m and above. In addition, the probability of the ice blocks that crack and even disintegrate leading to a virtual 'fall' was increased across three levels. Thirty-four participants took part in this study and psychophysiological data were collected from: electrocardiogram, respiration band, skin conductance level and two channels of facial electromyography (corrugator and zygomaticus) two facial muscles which are known to provicde insight into the negative and latterly positive emotional state of human participants Schwartz et al. (1976) . During the talk I will briefly describe the development of the virtual environment conceptually and practically which may instruct those who wish to develop similar bespoke environments for use in psychological studies. I will discuss the challenges faced by the resultant large set of datas and what was revealed by the datas as participants experienced greater levels of threat, i.e. higher probability of virtual fall. The final part of the talk will discuss how the results demonstrated some evidence for habituation to the task and how this initial study has informed current ongoing studies, notably in response to published criticism with regard to the motion of participants during the task may be obscuring physiological results and how we have attempted to overcome this issue.

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Day: Wednesday
Session: Ambulatory
Time slot: 15:45 – 16:09
Talk no.: 4

PROMOTING DIGITAL WELLBEING THROUGH REAL-TIME STATE CLASSIFICATION OF PSYCHOPHYSIOLOGICAL SENSOR NETWORKS

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ABSTRACT
Boundaries between digital experiences and our daily activities have been blurred as technology has become more pervasive. Research is needed to understand how these digital experiences effect users' 'digital wellbeing' - the capacity to look after personal health, safety, relationships and work-life balance in digital settings [1]. We propose the application of psychophysiological sensor networks for predicting user state as they engage in daily activities, in real-time for positive intervention and digital wellbeing. To achieve this, in a constrained mobile operating environment, we propose the application of a novel pruning algorithm in Deep Learning (DL) to improve operational efficiencies and classification generality.

DL is a promising approach towards classifying human state using data derived from physical psychophysiological sensors. In this context, DL has been shown to provide high classification accuracy [2] and robustness to noise [3] in a wide variety of application domains. To obtain an optimum network architecture it is often necessary to apply time-consuming iterative improvement cycles. In real-time applications, with constrained hardware, the complexity of the trained neural network should be reduced as much as possible to improve operational efficiency, usually to a much less complex architecture than the initial design. It has been shown that pruning improves performance of simpler neural networks [4]. Correlated activity pruning (CAP) is an interactive pruning method that uses heuristics to identify units that failed to contribute to the solution and therefore can be removed with no net degradation in performance. This approach removes units with correlated activations over all the training patterns as these are not participating in the solution. This is a much faster process than retraining so can be carried out in 'real time', reducing the size of a complex, multi-layer ANN without significantly reducing its accuracy. We propose that the benefits will be even larger when pruning is applied to complex multi-layer networks used in deep learning.

User state classification may be performed by using psychophysiological data sources such as ECG, fNIRS, EEG and EDA. DL networks will allow digital systems to predict measures such as mental workload, task engagement, fatigue and emotional states. Neuroadaptive interfaces will promote digital wellbeing by mediating the attention of users as they interact with a digital system based on their current user state. An example of one such intervention would be the delivery of mobile device notifications. In an week long, in-situ observation of 15 mobile users, Pielot et al. reported that notifications disrupted the primary life task in 50% of cases [5]. An intelligent digital system, that is aware of current user state will be able to mediate the delivery of mobile notification according to the current state of the user. Such systems may also positively impact worker productivity and task engagement.

In this work, we propose the application of CAP in developing efficient multi-layer prediction networks for predicting user state. User state will then be used to inform neuroadaptive interfaces. The impact of CAP will be ascertained by comparison against a baseline of non-minimised DL networks in a constrained mobile-device based environment using psychophysiological sensors networks.

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Day: Wednesday
Session: Ambulatory
Time slot: 16:10 – 16:34
Talk no.: 5

GROUP EYE TRACKING RESEARCH AND APPLICATIONS

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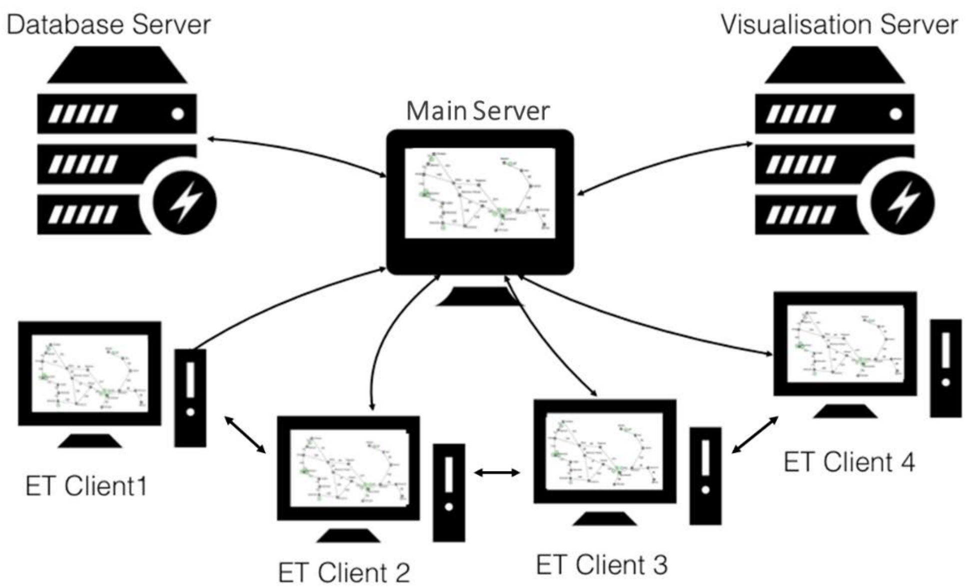
ABSTRACT
The last few years have been subject to major changes in eye tracking technologies. New sensor technologies have enabled the production of low-cost, affordable eye tracking devices. This development has led to the chance to adopt multi-user eye tracking paradigms to study social interaction. GET (Group Eye Tracking) is such a paradigm, that aims at making multi-user eye tracking available to community. We expect this paradigm to be the third generation interaction paradigm, after (i) the first generation single-user eyetracking paradigm that is in use since 1990s and (ii) the second-generation dual eyetracking paradigm that has been developing since the 2010s (Rayner, 1998).

The GET paradigm has been employed as an experimental paradigm in various domains, including the design and application of a multi-user, gaze-based game (cf. Human-Computer Interaction as the domain of research) and the investigation of the concept of gaze cue in game theory and economical decision making. The term gaze cue refers to the markers displayed on the screen that correspond to the gaze positions of other users on the screen. The main research goals of these applications include how the presence of other users in the environment and the information about the momentary gaze positions of other users affect the group decision-making processes, and how the dynamics of the interaction are formed.

The Group Eye Tracking (GET) paradigm has novel aspects for research in social interaction as well as having potential for multimodal and multiuser studies in neuroadaptive research. The multi-user paradigm that has been developed has the potential to have socio-economic impacts in addition to its impact in related practical domains of use. We believe that multi-user eye tracking has the potential, in future, to become a major human-interaction medium in a wide spectrum of problems and domains ranging from the improvement of social interaction skills of children with the usage of multi-user eyetracking games to social games that are played on the Internet.



GET (Group Eye Tracking Platform Infrastructure)

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Foundations

Day 3

Day: Thursday
Session: Foundations
Time slot: 10:15 – 10:39
Talk no.: 1

APPLICATION OF DEEP LEARNING IN LIP READING

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ABSTRACT
Automatic lip reading is one of the open problems in classification and pattern recognition. During the last decade, different methods have been applied in some languages in order to perform automatic conversion of speech to text by lip reading. This study aims to evaluate and survey lip reading studies and analyze applying deep learning to this problem. Deep learning as a last and most effective learning approach in pattern recognition has attracted researches from academic community to apply this method, in pattern recognition and classification. This study analyzes application of this method to improve lip reading accuracy.

Today, visual information obtained from cameras is being used in various studies. One of these studies is lip reading by computer aided systems instead of conventional experts. Lip-reading, is extracting speech information by visually interpreting the movements of the lips, face and tongue when sound information is not available. In the last decade, detailed studies in different languages, especially in English have been carried out on lip-reading. Results obtained from these studies are expected to be used in robot-human interaction, communication with hearing impaired people, exposing the content of speech for security reasons, other cases where sound is not available and related studies.

Flowchart of automatic lip reading is given in figure. Initially, according to the performance of the camera, image sequences must be acquired. The recommended frequency is 50Hz. Then at each frame face detection must be performed. In the later stage lip detection takes place for each detected face. Using convolutional clustering symbolic classes are obtained to be used as inputs for Deep Learning. Outputs of DNNs are morphologically matched with languages using Natural Language Processing (NLP) method.

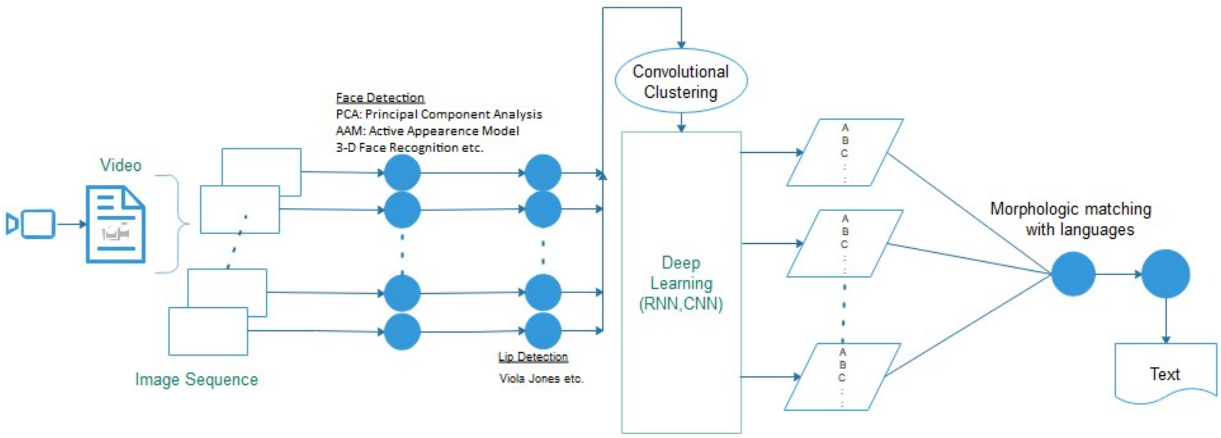

Fig. Flowchart for Automatic Lip Reading with Deep Learning

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Day: Thursday
Session: Foundations
Time slot: 10:40 – 11:04
Talk no.: 2

SPONTANEOUS RADIOFREQUENCY EMISSION FROM NONEQUILIBRIUM ELECTRON SPINS WITHIN DROSOPHILA

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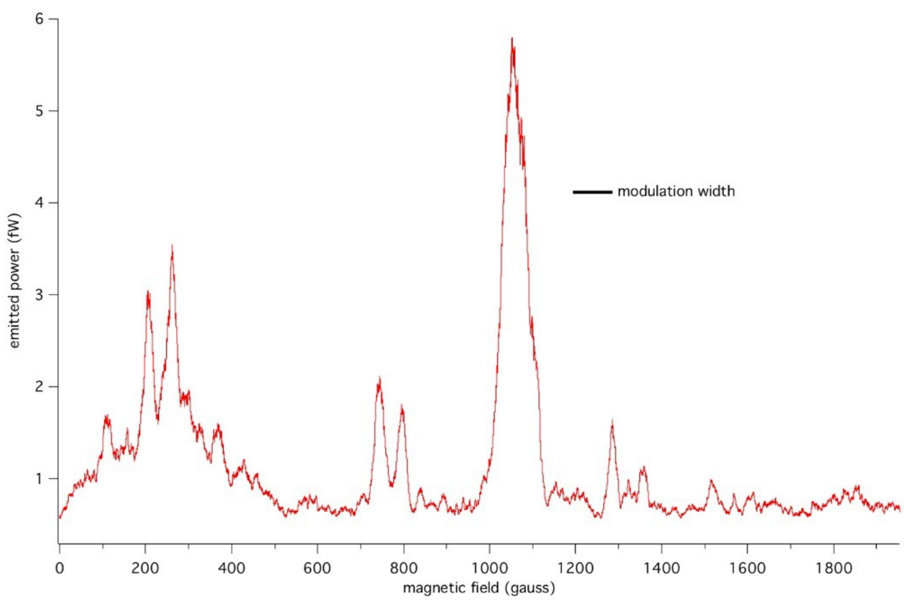
ABSTRACT
Using readily available radiofrequency instrumentation and lock-in detection, we report the measurement of spontaneous RF emission from a single Drosophila fruit fly immersed in a magnetic field. The emission exhibits resonant features similar to those seen in pulse electron paramagnetic resonance, but without RF energy input. We propose that these radiofrequency emissions are due to in vivo nonequilibrium spin-polarised populations caused by chirally induced spin selectivity (CISS) acting on cellular electron currents. The RF emissions respond to general anesthetics and may therefore be correlated with neuronal activity. The potential use of this novel and entirely passive method as a noninvasive measurement technique will be discussed.



Legend: Radiofrequency emission from ≈ 10 fruit flies contained in a Teflon tube at the magnetic maximum of a WR229 waveguide, detected at 4.5-4.8 GHz with a room temperature C-band satellite receiver. The value of the steady magnetic field is given in the abscissa, emitted RF power in the ordinate. The signal is detected using a logarithmic power meter and a lock-in amplifier, with a modulation frequency of 16 kHz, a width of ≈90 gauss and a response time constant of 1 second (6dB per octave). The steady magnetic field is ramped at approximately 10 gauss/second.

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Day: Thursday
Session: Foundations
Time slot: 11:05 – 11:29
Talk no.: 3

SINGLE SESSION TRANSCRANIAL DIRECT CURRENT STIMULATION (TDCS) CAN IMPROVE ROBOTIC SUTURING SKILLS IN SURGICAL TRAINEES

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INTRODUCTION
Complex surgical tasks, such as robotic suturing, typically require extensive training to facilitate development of surgical proficiency, opportunities for which have become limited with recent healthcare reforms. Non-invasive brain stimulation with transcranial Direct-Current Stimulation (tDCS) has recently demonstrated improvements in motor strength [1], hand dexterity [2] and skills learning [3]. Despite these advantages, studies investigating the impact of tDCS on surgical performance are limited; existing studies either involve medical students or stimulation of the motor cortex [4]. Our group has previously demonstrated acquisition of a new surgical skill to be dependent upon prefrontal cortex engagement [5] which therefore represents an appropriate area for neuro-augmentation with tDCS. The results attest to the impact of bifrontal tDCS to improve robotic surgical performance in a cohort of surgical trainees.

METHODS
In a double-blind crossover trial design, 15 right-handed surgical registrars (8 males, 7 females; age range 30-38 years) naïve to robotic surgery were randomised to either active or sham tDCS in two separate sessions in a counterbalanced order. The active group received 2mA to the prefrontal cortex bilaterally for 15 minutes whilst the sham group received 30s ramp up followed by immediate ramp down. During each session, subjects performed a robotic-suturing task three times defined as “pre-”, “intra-” and “post-intervention” episodes. Time (seconds) and multi-modal measures of technical skill were assessed as illustrated in Figure 1.

RESULTS
There were no significant baseline differences in performance between the two groups. Both groups demonstrated significantly faster completion times from “pre” to “post-intervention” [median (IQR); active: pre=143s (83) vs. post=113s (40), $p<0.001$; sham: pre=152s (81) vs. post=115s (64), $p<0.001$]. In the active tDCS group, significant improvement was observed in error scores from “pre- “to “post-” [median (IQR): pre=1mm (2) vs. post=1mm (1), $p<0.01$]. Knot tensile strength was significantly greater following active tDCS compared to sham stimulation [median (IQR); active=44.46N (32.48) vs. sham=29.66N (51.13) respectively, $p<0.01$]. There

were no significant differences in progression scores and all other between and across-group comparisons were not significant.

DISCUSSION

This study is the first to demonstrate the potential of a neural enhancement technique such as tDCS to not only reduce error but enhance knot tensile strengths during robotic suturing. Further studies are required to further define the parameters and timing of tDCS to maximise benefits for applications in surgical training. We acknowledge the clinical impact of performance enhancement with tDCS is currently unknown and requires further research to elucidate benefits to clinical outcomes and patient safety.

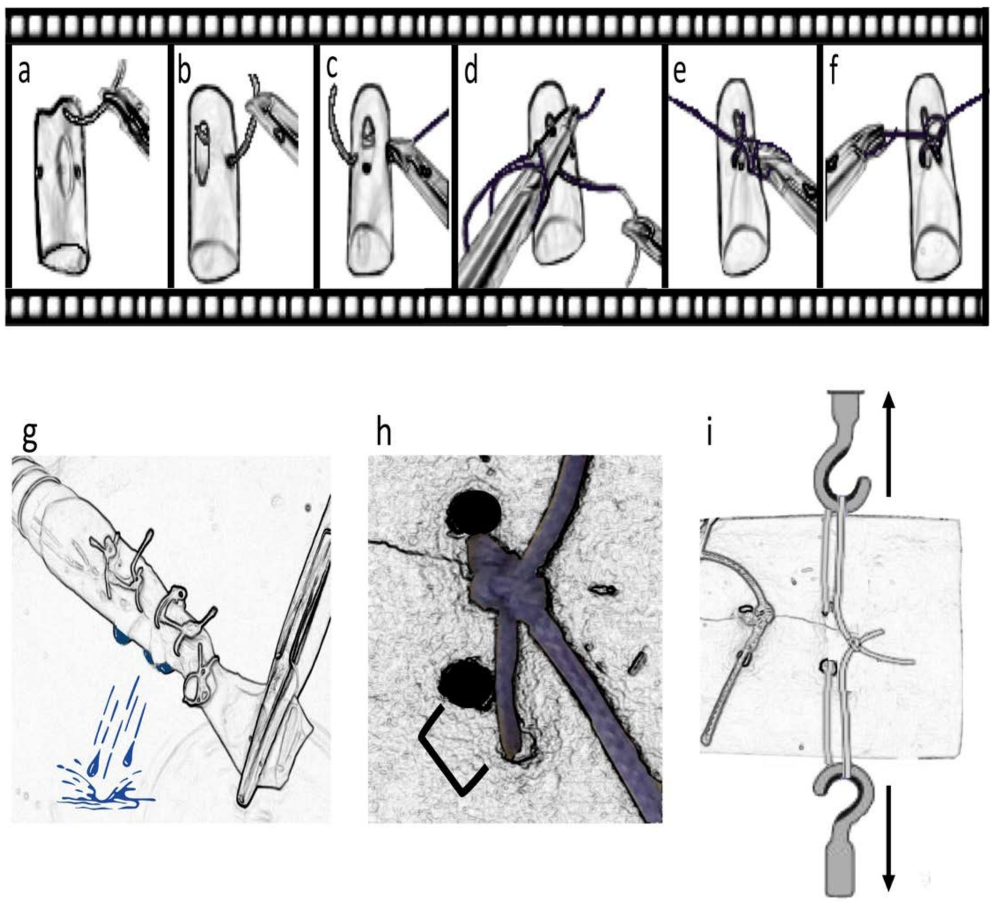

Figure 1. Technical skill assessment:
Progression score (au) with 1 point allocated for successful progression through 6 steps. (a) mounting needle (b) needle entry (c) needle exit (d) double throw (e) first single throw (f) second single throw;
(g) leak volume (mL) of saline through clamped drain in 1 minute;
(h) error in distance (mm) from pre-marked entry and exit dots;
(i) tensile strength (N) of knots measured using tensiometry.

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Day: Thursday
Session: Foundations
Time slot: 11:30 – 11:54
Talk no.: 4

APPREHENDING AUDITORY ACTIVITY IN ECOLOGICAL CONTEXTS WITH UNOBTRUSIVE EEG

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ABSTRACT
Accidents analyses disclosed that critical auditory stimuli such as alarms could fail to reach awareness, with devastating consequences. Previous research indicated that it is possible to perform single trial classification to detect this inattention phenomenon using a 32-wet-electrode Biosemi EEG [1]. Nevertheless, such systems are bulky and difficult to use in everyday life situations or applied contexts [2]. Fortunately, new unobtrusive EEG have been developed. This preliminary study aims to assess the possibilities of such systems (cEEGridR, TMSI [2]) for research applied later in simulated and real-flight aeronautical contexts.

METHODS
Five participants took part in a classical oddball paradigm with two levels of workload: a low workload condition — participants only had to detect the odd target sound (25% of sounds) — and a high workload condition — participants had to perform a backward counting task while responding to the target sounds. Data were recorded from 20 electrodes (10 around each ear) with a Bluetooth-streaming portable LiveAmp amplifier (Brain Products, GmbH) at 1000Hz, and referenced to the left ear's CMS/DRL (electrodes L4a and L4b [3]). Data were offline filtered between 0.5-40Hz, cleaned with artefact subspace rejection (ASR), and re-referenced to the R5 and L5 electrodes (closest to the mastoids). 2.5-second stimulus-locked epochs were drawn ([-1;1.5] s). ERPs and time-frequency data were then measured and analyzed according to the type of sound (odd vs. standard) and the workload (high vs. low). Statistical analyses were performed with a permutation test with FDR correction under EEGLAB (v14.1.2).

RESULTS
We observe early and late auditory processing components (respectively the N1 and P3) at several electrodes of the cEEGrid. When looking more carefully at the R1 electrode (as in [4]), the amplitude of the N1 (maximum around 180ms) and the P3 (maximum around 465ms) is increased for target detections (hit, red) compared to standard sounds (standard, blue; Fig.1a). Statistics reveal a significant difference between hits and standard at the N1 and P3 latencies (ps<.05). We observe an overall increased spectral activity for targets compared

to standard sounds (Fig.1b). This increase is significant in both the early (100-400ms post-stimulus) α frequency band (8-12Hz, p<0.01) and the later (300-600ms post-stimulus) θ frequency band (4-8Hz, p<.01). Regarding the effect of workload, early auditory-related ERPs seem to be increased (at least the P2 component) in the high workload condition compared to the low workload one. Statistics didn't reach significance. Concerning the effect on time-frequency data, no difference is observable between the two conditions.

CONCLUSION AND PERSPECTIVES

The cEEGridR shows promising results for the study of auditory EEG activity, with changes in components' latencies and localization though. We were able to observe, with 14 electrodes in the end, usual auditory oddball time-locked and time-frequency activity. The statistical power in this preliminary study is quite low due to the small number of participants, yet we observed significant differences on ERPs and ERSPs. Our next step is to compare the cEEGrid R recordings with a dry-electrodes system in simulator and real flight conditions, and try to classify these data for the study of inattentional deafness.

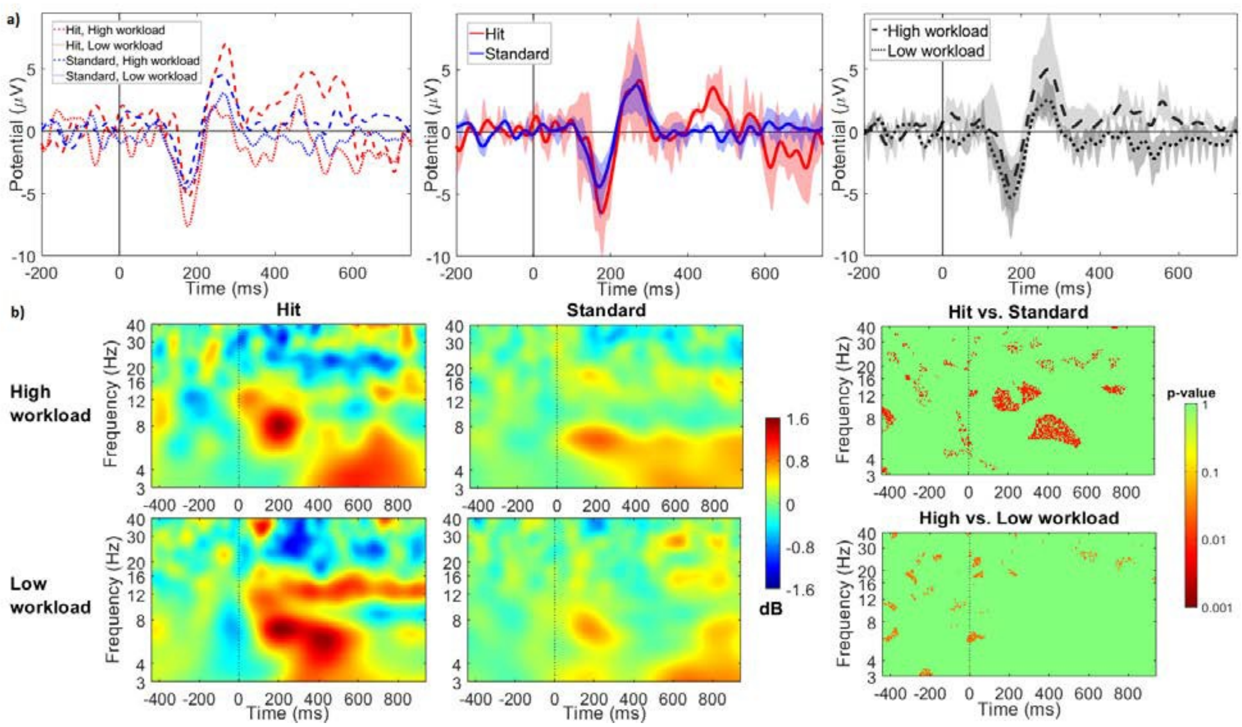

Figure 1. Cerebral activity recorded with the cEEGrid(R) (TMSI) system at the R1 electrode during a classical oddball paradigm with two levels of workload (high and low). (a) ERPs computed at the moment of the sound for the four conditions (let graph; type of sound x workload) and for each independent variable separately (type of sound – middle graph – and workload – right graph). Mean EEG response to target sounds detected (red) shows a higher amplitude than for standard sounds (blue) at the latencies of N1 and also P3 components. No effect of workload seems to be observed. (b) ERSPs computed at the moment of the sound for target sounds (hit – left panel) and standard sounds (middle panel) for both high workload (top) and low workload (bottom). Statistical analysis (right panel) revealed a main effect of the type of sound (top) in the theta and alpha frequency bands mainly, and sparse effects of the workload (bottom), but no interaction effect on the time-frequency data.

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Day: Thursday
Session: Foundations
Time slot: 12:10 – 12:34
Talk no.: 5

THE IMPACT OF ELECTRODE SHIFTS ON BCI CLASSIFIER ACCURACY

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ABSTRACT
We investigated electrode shifts of the recording EEG (electroencephalogram) on the scalp. We used simulated data to assess the influence of electrode shifting on the classification accuracy of a Brain-Computer Interface (BCI, [1]).

INTRODUCTION

Many BCI approaches use spatial filters to weight the EEG electrodes according to their importance for classification. For example: a common BCI approach is motor imagery, where the participant imagines left and right hand movements to control a cursor. For this approach, the right and left motor cortex are most relevant for classification. These areas are typically represented by electrodes C3 and C4. Thus, a spatial filter may assign high weights to these electrodes. If these important electrodes shift on the scalp, the recorded data changes. In general, we assume that a shift of relevant electrodes has an impact on the classification accuracy of any BCI. Our research questions are:

1. Does electrode shifting influence the classification accuracy?
2. Is the impact of shifting more important (in terms of the spatial filter) electrodes higher than shifting less important electrodes?
3. The recorded EEG activity for a single time point composes an activation pattern which displays projection intensities on the scalp [2]. Does an electrode which shifts within the same area of activation have a lower influence on classification accuracy than an electrode which changes areas of activation?

METHODS

With the toolbox SEREEGA [3], we simulated EEG data that would result from participants who completed an oddball paradigm [4]. We varied source locations and projections to simulate 20 artificial subjects and added random noise. The data was separated into a part used to train the classifier and a part to test it (see fig.1). Simulated data allowed us to have identical source activations in different copies of the test set. Electrode shifts were implemented in each copy and varied in terms of direction, magnitude and which electrode was shifted. For classification, a windowed means approach was trained on 8 consecutive 50ms windows of the training data and then applied to the test data with and without shift. The obtained accuracies were compared.

RESULTS

The classification accuracy after calibration varied between subjects between 84% and 99%. Electrode shifts lead to an accuracy change of -8% to 2%, mean -1.04%, standard deviation 0.7%. The research questions were answered as follows:

1. A t-test of mean accuracies (with and without shift) determined that there is a significant effect ($t=12.775$, $p<<0.01$) of electrode shift on the classification accuracy.
2. A regression analysis between filter weight and impact on the classification accuracy yielded a significant ($t=6.252$, $p<<0.01$) positive relation: shifting an electrode with a higher (positive or negative) weight has a stronger effect.
3. An ANOVA with factors weight and pattern deviation revealed that there is a strongly significant interaction effect of the factors ($F(1,39)=8.674$, $p<<0.05$), but no single effects.

OUTLOOK

The next step to further research the problem of electrode shifts in BCI is to shift multiple electrodes, as well as testing the findings in real, non-simulated data.

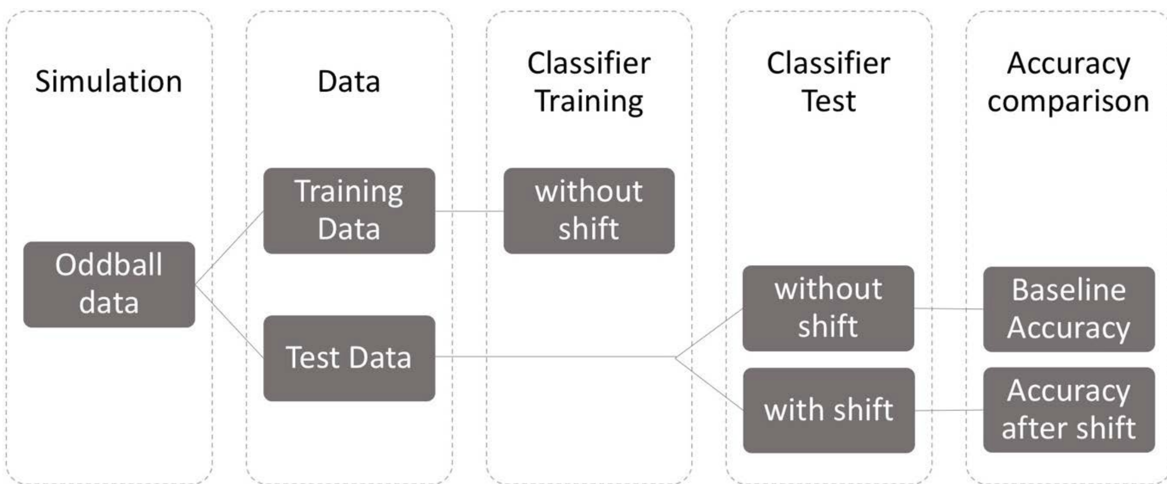

Fig. 1 Experiment structure.

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Day: Thursday
Session: Foundations
Time slot: 12:35 – 12:59
Talk no.: 6

N170 COMPONENTS OF REAL AND COMPUTER-GENERATED FACIAL IMAGES

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ABSTRACT
The exposure to computer-generated (CG) stimuli in the real world is vast, with the prominence of CG in movies, television and video games today. There is an increasing number of scientific researches which utilise the medium of CG to conduct experiments [2], therefore it is necessary to know whether our brains process these stimuli the same way in which we process real stimuli. The N170 component can be observed at the occipitotemporal brain areas between 140-200ms post-stimulus onset, typically characterised by a negative peak. With facial stimuli, the N170 component can also be further identified by having a stronger amplitude compared to that of non-facial stimuli [1]. Current studies which investigate whether there are any differences between the activities of the N170 component between presentation of CG images and real images is scarce and present conflicting results. Due to the lack of a validated measure of 'computer-generated-ness' or 'cartoon-ness', it is difficult to obtain or create the appropriate means of presentation for CG facial stimuli [3]. In this study, we attempt to detect and evaluate any modulation effects from the finer facial cues of static CG stimuli, by applying a simple cartoon filter, and compare that to the N170 component activity results of static real images. The hypothesis is that there will be little to no difference in the activity of the N170 component between the two conditions.

We obtained face images from the Stirling face database [4] and converted them into the CG counterparts. House images, real and CG, were included as a control to demonstrate the face-specific activity of the N170 component. Electroencephalogram (EEG) from 10 participants (1 male, 9 females; age 20.5 ± 2.59) was recorded at 32 scalp locations following the extended 10-20 system with BrainVision BrainAmp DC amplifiers. The images were presented with a Unity program consisting of 16 blocks. Real and CG images were presented across blocks in a random order, with face and house images randomly assorted and shown in each block. Each image was presented for 5000ms, with a jittered interval of 1000-2000ms between images. N170 activities were quantified as the mean amplitude between 134 and 154ms post-stimulus at channels P7/P8, PO7/PO8 and PO9/PO10. Statistical analysis was then conducted using a 2 (face vs house) x 2 (real vs CG) x 2 (left hemisphere vs right hemisphere) repeated measures analysis of variance (ANOVA). Faces generated stronger N170 than houses (F(face, house) = 6.047, p = 0.036). Furthermore, this observation was found to be generally stronger in the right hemisphere in

comparison to the left hemisphere (F(left, right) = 5.140, p = 0.049). On the other hand, the main effects and interactions of real images vs CG images did not approach significance (F(real, CG) = 0.472, p = 0.509). These results support the hypothesis that CG images, to the extent of the cartoon filter used in this study, does not modulate the effects of the N170 component differently to that of real images.

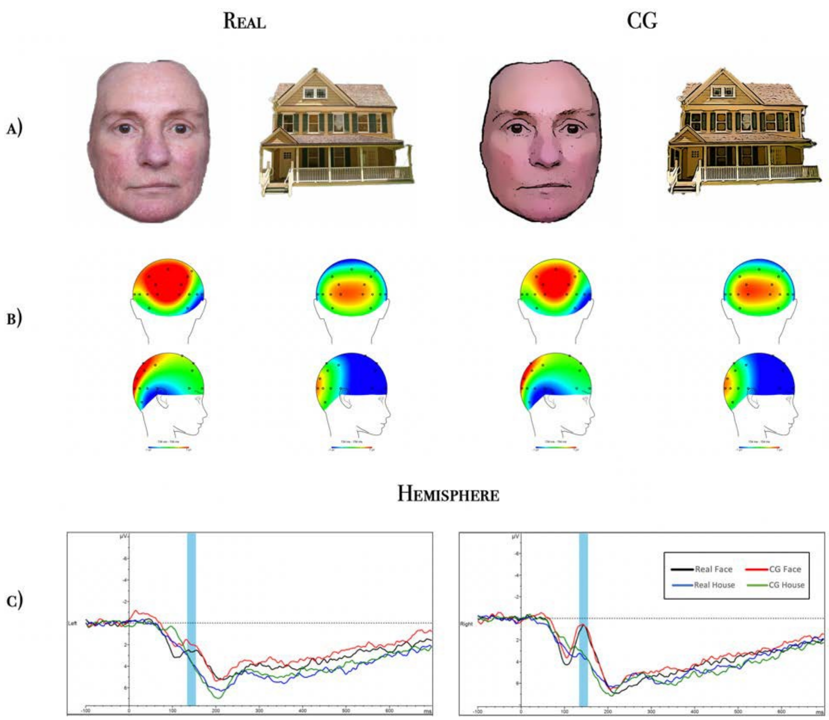

Figure 1. Images used in the study; (a) Real and CG faces and houses, (b) topographical maps demonstrating negative activity primarily in the right occipitotemporal lobe, (c) and ERP data for each hemisphere (PO9/PO10) highlighting a 134-154ms time window.

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Day: Thursday
Session: Foundations
Time slot: 13:00 – 13:24
Talk no.: 7

USING LINEAR DECONVOLUTION TO ACCOUNT FOR OVERLAPPING BRAIN POTENTIALS: AN EYE-FIXATION RELATED POTENTIALS STUDY

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ABSTRACT
The computation of economic value is an intrinsic part of everyday decision making [1], allowing us to track and maintain the most subjectively useful alternatives. Electroencephalographic eye-fixation related potentials (EFRPs) are a frequently used method, especially in the developing field of mobile brain/body imaging (MoBI), to investigate ongoing neural processing in free-viewing situations. However, there are limitations to this tool that need to be addressed appropriately, such as the inherent issue of multiple fixations occurring within a single data epoch. Using simultaneous electroencephalography (EEG) and eye-tracking recordings, the present study aimed to investigate the neural correlates of economic value for both individually presented products and product bundles. Linear deconvolution methods implemented in the Unfold toolbox [2] are used to account for overlapping brain potentials. Additionally, Unfold is used to account for non-linear effects of eye-movement characteristics on EFRPs using regression splines.

Participants completed a Becker-DeGroot-Marschak (BDM; [3]) auction task involving individual products and product bundles. Product bundles were comprised of a low value product priced between £0 and £4, and a high value product priced between £8 and £12. Product bundles were also comprised of either two complementary products, or two non-complementary products. Products and product bundles were then split into low and high value based on subjective willingness-to-pay (WTP).

Systematic differences in fixation durations between conditions resulted in saccade onsets occurring irregularly within EEG data epochs depending on the condition, possibly explaining observed differences between experimental conditions. Using Unfold, EEG data were analysed using linear deconvolution to extract brain potentials unique to fixation onset, accounting for activity due to saccade onset within data epochs. Modulatory effects of saccade amplitude on visual lambda and spike potential activity may also mean observed effects could be explained by differences in saccade amplitude between conditions. Using spline regression, the non-linear effect

of saccade amplitude on neural responses to fixations was modelled and parsed from the data.

Simultaneous EEG and eye-tracking recordings allow us to investigate the ongoing neural processing in free-viewing situations, a venture that is receiving vast interest in recent years, especially in MoBI research ([4]; [5]). However, due to modulatory effects of eye-movement characteristics on specific EFRP brain components, observed differences between conditions could easily be explained by characteristics of the fixation, such as the amplitude of the saccade prior to fixation onset, or the resulting duration of the fixation. Newly developed and powerful methods, such as the Unfold toolbox, allow us to not only account for the intrinsic issue of multiple saccades within a single data epoch, but also to account for linear and non-linear effects of eye- movement characteristics on brain potentials.

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Day: Thursday
Session: Foundations
Time slot: 13:25 – 13:49
Talk no.: 8

ISOLATING AFFECTIVE INFLUENCES ON IMPLICIT CURSOR CONTROL

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ABSTRACT
An implicit cursor control experiment has previously demonstrated the use of passive brain-computer interfaces for a primary control loop [1, 2]. Instead of explicitly controlling the cursor, participants were observing an autonomously moving cursor and evaluating each movement as "appropriate" or not, given their current goal. Using a passive brain-computer interface (pBCI), these evaluations were assessed and fed back to the cursor for reinforcement learning. In effect, the participants' evaluations controlled the cursor, but the participants were consciously unaware of having any influence. This highlighted a number of issues with respect to i.a. the nature of interaction, data privacy, and consent.

Data privacy and consent issues are particularly sensitive when the pBCI focuses on personal, subjective interpretations as opposed to more objective (e.g. merely visual) processing of the stimuli. It has been suggested that the response elicited by the implicit cursor control paradigm may contain an interaction between processes related both to salience (i.e. surprise or expectancy), and valence (i.e. the subjective value of an outcome) [3].

We now present an adapted experimental design to investigate these two processes separately. One, larger grid was used in two different conditions, with only its centre node highlighted. In one condition, participants were instructed that the cursor's goal was to reach the centre (the "positive" condition). In another, the goal was to stay away from the centre ("negative"). Thus, equally salient cursor movements are "appropriate" in one condition and "inappropriate" in the other. The conditions were counterbalanced within subjects.

In both conditions, a windowed-means classifier [4] could distinguish between movements away from the centre and towards the centre with significant accuracy. However, in the positive condition, classification accuracy was approximately 10 percentage points higher than in the negative condition, with 83 versus 71% on average ($p < 0.01$). This rules out that classification is done exclusively based on visual salience, as visual stimuli were identical.

Using independent component analysis, we identified components that significantly contributed to classification across conditions [5]. Most of these reflected processes in the visual cortex, while a separate subset of components bore close resemblance to the primary identified processes in the original experiment in the medial prefrontal cortex. After manual clustering, an analysis of these two clusters' event-related potentials revealed the occipital cluster to show consistent significant differences between movements going away from versus going towards the centre, but no such differences between valence conditions. The frontal cluster did show consistent significant differences between valence conditions, as well as between movement conditions, but at later latencies. See figure 1.

This is data based on 8 initial participants. A number of additional effects can be seen in figure 1 that are not readily explained. Although we wait for additional recordings for further analysis, current findings are in line with the suggestion that separate salience and valence processes play a role in the evaluation of events. To the extent that implicit control is based on valence, this again highlights both the possibilities of neuroadaptive technology for personalisation, and the need for clear consent and privacy guidelines.

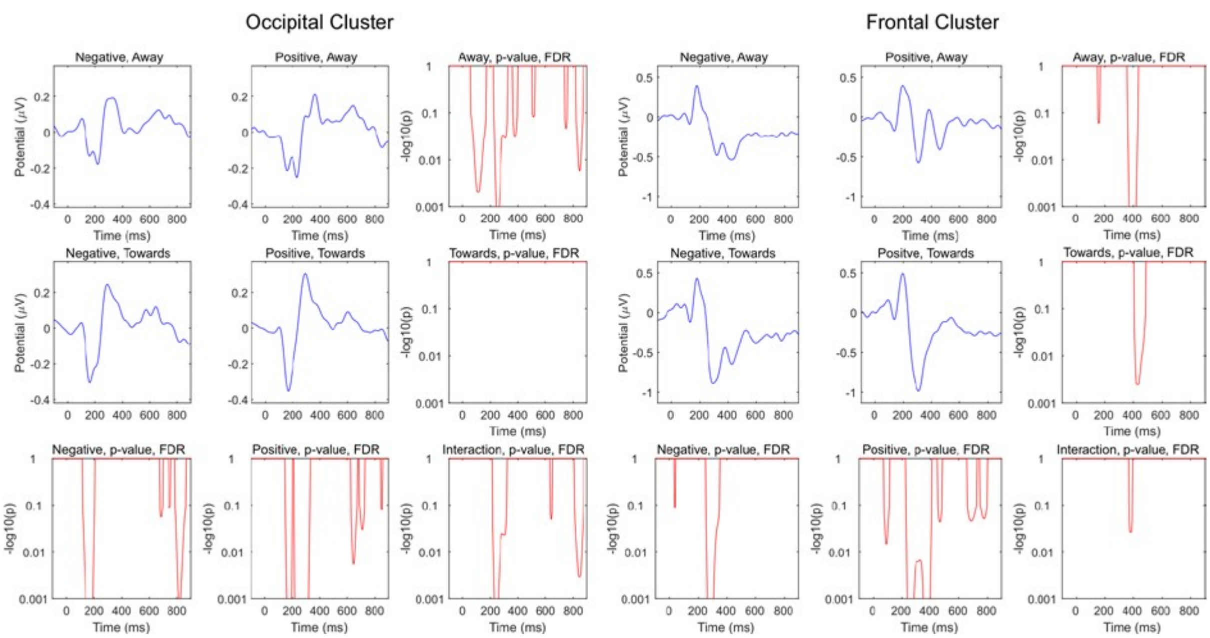

Figure 1. Negative: Cursor movements in the `negative' condition; movements towards the centre were undesirable and vice versa. Positive: Cursor movements in the `positive' condition; movements towards the centre were desirable and vice versa. Away: Cursor movements that went away from the target. Towards: Cursor movements that went towards the target. Blue graphs: Grand-average ERPs of the occipital (left) and frontal (right) clusters separated by condition and movement class. Red graphs: FDR-corrected p-values calculated on the differences between conditions and movementclass

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