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Extension of Performativity by a BCI

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Abstract: In the project *inter@FAŢA*, the creative team developed various algorithms for the generation of music, starting from real time monitored EEG. Among the music generating algorithms, together with other models, an EEG alpha spectrum analysis software was used, which was based on the difference of valence of sensors AF3-AF4. The post-performance analysis signals the correlation of these valence changes (change of potential difference between the left and right brain hemispheres) with the most intense moments of the performance and, respectively, with the most marked alternations of performance styles. The use of music and of the background sound produced, based on the EEG, emphasizes, thus, a deep, stable structure of the performance, measurable and reproducible in a number of performances. The spectator's emotional participation is thus removed from its shroud of invisibility, and it becomes an element of visible action, accessible to other spectators. This paper looks into the work stage of the project in 2014; at present, it is developed according to the conclusions described herein.

Keywords: BCI, EED-based prediction of emotions, performativity, interactive theatre, participatory art, computer generation of music

For the 2014 *inter@FAŢA* performance, apart from the established performing means, such as the actors' or the dancers' action, the use of video-projects, the creative team has also employed the EEG monitoring of an actor and of a spectator. The EEG monitoring had a two-coordinate role:

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one directly performative, sound generation starting from the monitored EEG signal, and one more subtle, linked with the symbolic-semantic level of the representation, given by the use of real time prediction software for the emotional state of the monitored subject, in a documentary theatre performance on the issue of discrimination.

EEG, electroencephalogram, concerns the monitoring of cerebral electrical activity, by means of sensors placed on the scalp. EEG measures the electrical potential difference between the sensor and the scalp area where it is placed. Neurons have spontaneous and directed electrical activity; its frequency, phase and amplitude changes according to various factors, such as wakefulness, sleep, focus etc.; its organization is coherent, in waves both at neuron, neuron group level and at units of cerebral regions. Electrical rhythms have a role in the encoding and transmission of cerebral information. The potential difference recorded with the EEG represents the synchronous activity of thousands up to millions of neurons with an evenly steered spatial organization.

EEG use for sonification purpose is a procedure that has been used starting with the '30s:

> During his postdoctoral studies with Alexander Forbes and Hallowell Davis at Harvard University (1933-35), Lindsley himself served as the subject for the premier public demonstration of EEG to the American medical community. Initially, Berger's work was largely ignored. It was not until five years after his first paper was published, when his results were verified by the pioneering physiologists E.D. Adrian and B.H.C. Mathews, that his discovery began to draw attention. In their 1934 article in the journal Brain, Adrian and Matthews also reported the successfully attempt to sonify the measured brainwave signals which they had recorded according to Berger's methods. While listening to his own alpha presented through a loud speaker, Adrian tried to correlate his subjective impression of hearing the alpha come and go with the activity of looking or not looking with his eyes. This was the first example of the sonification of human brainwaves for auditory display. (Zaccaria Giovanni Marco 2011)

The first artistic works that use EEG for music production appear starting with the development of experiments in the field of digital art or art produced with the new technical means of the '60, oscilloscope, copier, computer etc. One of them is composed by Alvin Lucier in 1965, *Music for Solo Performer.* In the composition, the alpha wavelength peaks were sampled and amplified by producing vibrations of percussion instruments arranged on the stage. In the subsequent years, a number of artists and scientists experimented various methods of producing sound from EEG, often by using the possibility to control the change of the dominant wavelength by biofeedback training. Experiments peaked with the extended project *Cortical Art* by Roger Lafosse and Pierre Henry in the '70s, which was also released on vinyl. They proposed a sophisticated live performance system called *Cortical Art*, presented in various versions. As we can see in a video record[1], a small number of electrodes would be connected to synths that were handled by Pierre Henry; there were also moment when the sound was generated without external human intervention. A very interesting aspect is the mention of color changes in a TV image during Pierre Henry's performance, when he was being filmed, depending on the EEG activity.

Very early in the history of the EEG use, we observe both the possibility of self-control by training of the EEG activity, as well as the link between the external stimuli and this activity. These observations were the basis of most of the projects in the last two decades, enabled by the availability of the EEG technology, respectively by the appearance of EEG machines for the consumer audience. In the '70s, the first academic centers and laboratories for musical BCIs appeared, as well as for the use of other types of bio-signal (GSR or EMG) for the generation of music: one of the most important ones is the Laboratory of Experimental Aesthetics at York University, Toronto, by David Rosenboom. (GSR-is the galvanic reaction at skin level, used especially in the polygraph technique and EMG is electrical charge monitoring at muscle level).

At present, there are major attempts of EEG sonification in the diagnosis of brain disorders such as Alzheimer (Mohamed Elgendi, Brice Rebsamen, Andrzej Cichocki, Francois Vialatte, and Justin Dauwels 2013), in music therapies for the disabled, as well as other important research in the field (Eduardo Reck Miranda, Ken Sharman, Kerry Kilborn, and Alexander Duncan 2003). The BCIs that make use of EEG vary from control devices for individuals with locomotor disabilities to (sound or visual) sign selection systems, becoming communication interfaces.

Our intent with the *inter@FAŢA* performance was to symbolically employ, based on EEG-monitoring and subsequent sound generation, the spectator's and actor's synchronous actions, assimilated as involuntary performative actions linked with the continuous interaction with the environment of stimuli prompted by the progress of the performance.

[1] https://www.youtube.com/watch?v=VzRvM64gv-4

Particular interest was vested in the relevance of the electrical activity in relation to emotions and the current BCIs developing this type of application of recognition of emotion-related parameters.

The topic of *inter@FAȚA* is discrimination in the Romanian society, researched mainly on three communities: the Jewish, the Roma and the homosexuals. Among methods specific to documentary theatre, the audience is told various tales of discrimination, placed at various historic times. The performance proposes a deeply participatory action, in an open convention that invites the audience to take part in various tasks and actions of the representation.

Before they enter the hall, the spectators receive a pink or a red card. They are greeted in the performance hall by the actors who dance and who invite them to do it, too, or to sit, according to the color of this card. Once they are seated, the meneur du jeu, Paul Dunca, explains the division in two categories: red-spectators, pink-volunteers. The spectators will watch and applaud and some of the volunteers will be selected to be EEG monitored. The performance then shows monologues or scenes where the subjective choices are the nodal point. This venture into the typologies of "choice" starts from the one carried out by some children for a football team and peaks with the selection for elimination of the Jewish or Roma individuals. The performance creates a parallel between these discriminating choice circumstances and the repeated choices of the EEG monitored subjects, enacted by the actors. The most transparent connection is made by a spectator's selection by height, by having the "pink" spectators go under a meter like in the story told by Octavian Fullop, Auschwitz survivor, who describes how Mengele had all the young men pass under a board fixed at the height of one of the tallest prisoners, and those who could not meet the standard height were killed by gassing.

The performance alternates moments of full relaxation with emotionally-tense ones, for the purpose of "refreshing" the spectator's emotional state. The theatrical modality applied is that of suggestive theatricality, with minimal setting elements, and with spaces designed by the actors' actions or by stage directions. In the fragment dramatized with Vasile Nussbaum, starting from his testimony of camp survivor, directions on the description of the setting are spoken and the space is configured from minimal modular setting, abstract elements (50/50 wooden cubes). The fictional nature entailed by the theatrical representation of some events is broken by the presentation of the legal situations – the reading of the laws that led to the discriminatory events depicted in the performance.

Fig. 1 and 2: Images from the representation: Picking one of the monitored subjects, *inter@FAȚA* 3 2015, Replika center

In this context, we thought that exposing the spectator's subjectivity gains a symbolic value, while we tried to outline the dialectic of subjectivity that creates identity in an approach/rejection process. We tried to offer elements that could ready the spectator's imagination toward self-analysis relating to this aspect of "approach-rejection", by circumventing the creation of a barometer interface and by choosing, instead, a symbolic one.

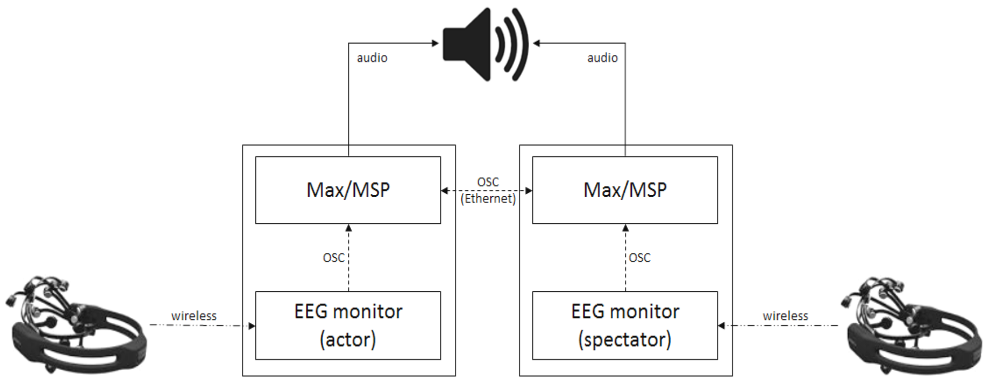
Methodology

The methodology employed for the EEG monitoring was similar with the ERP (event related potential) EEG investigation technique, whereby a subject is given a stimulus that triggers an electrical response at brain level. Neuro-marketing developed this type of research by using emotional and cognitive analysis software to investigate the brain electrical response to the design of specific products, ranging from cars to fiction films; thus, information was obtained on the consumer's emotional response (at present, neuro-marketing also uses fMRI techniques for the same purpose).

During the performance, a subject from the "volunteer zone" is selected, together with the actor who wears the EEG headset. The volunteer is replaced in the first two parts of the performance. In the last part, the headsets are worn by two volunteers. The spectators are warned from the beginning about the use of EEG and they are also given basic information on the use of the machine. During the representation, they receive additional information on how the EEG signal is used, including the fact that an emotion-prediction software is used. The creative team tried to have invisible or even volatile parts of the spectators' and, respectively, of the actors' reactions reach a perceptible and even measurable level. The team found this was especially relevant to the theme of the performance, since discrimination by the emphasis of the hidden layers of emotions, along the "approach-rejection" coordinates, can generate particular significations in the presentation of discrimination accounts.

Instruments

Instruments: Two Emotiv Systems 114-channel EEG headsets were used (AF3, AF4, F3, F4, FC5, FC6, F7, F8, T7, T8, P7, P8, O1, O2) with a 128Hz sampling rate, and 0.16-43Hz frequency response. For visualization, Emotiv TestBench EEG signal monitoring software and Affectiv Engine emotion predictive software were used; the latter produces five parameters: frustration, temporary interest, commitment and contemplation. The five values are given by proprietary algorithms and they are transmitted at a rate of 1Hz.



The EEG monitoring component is specific software developed in C++ in the project, which interfaces directly with the Emotive API, for the real time processing of the signal transmitted by the EPOC headset and for its further transmission to Max/MSP (or, potentially, any software that recognizes the OSC protocol). Furthermore, a secondary feature is the taking of EEG EDF (such as those produced by Emotiv TestBench) for tests and analyses without an EPOC headset.

The processing of the EEG signal occurs in a thread synchronized at the computer clock, which ensures the transmission of the OSC packs at the right time. A buffer is loaded with the relevant values (either straight from the EPOC headset or from the EDF file); a signal limitation process follows, for the removal of artificial peaks and of the continuous component of the signal, by translating it around the value zero.

The EEG signals in the AF3 and AF4 sensors are furtherly FFT transformed for the extraction of the delta, theta, alpha and beta values. The Hamming-weighted FFT buffer has 128 values, which leads to 64 spectral bins. Bin values are squared to obtain the spectrum of powers. The 4 fields (delta, theta, alpha, beta) are linked each with a bin range, and the value of the wave is given by the ratio between the power of the largest bin in the range and the total power of the spectrum. To the set of values we add the 5 mental states (values between 0 and 1) in Affectiv Engine, which come directly from API. The OSC pack thus obtained is sent to Max/MSP, at 1/s rate.

Apart from the four abovementioned mental states, the EEG data of the 14 channels are sent at the same rate.

Methodology of sound generation starting from the EEG

The performance's soundtrack generation strategy is based on the execution of interactive algorithms – with the Max/MSP software – that are influenced in real time by the variation of the parameters given by the EEG analysis and it follows two guidelines: the use of data obtained from the five curves given by the emotion prediction software (translated by s-valence) and the spectral-acoustic transformation of the gross values received by each of the 14 sensors attached to the subjects' scalp.

The correspondence of the five emotions and the musical parameters is done in the following manner: temporary interest is linked with the tempo (weak interest – slow tempo, increased interest – fast tempo); short-term commitment is linked with the change rate of sound peaks (weak commitment – imperceptible changes, strong commitment – quick changes), long-term commitment is linked with long sound, "acoustic traces" of temporary commitment; frustration is matched with a tune that accelerates and goes up in acute tones proportional to its increase, while contemplation is matched with long, variable, harmonic intervals. Tone qualities (timbres) were selected to sustain as close as possible the dramaturgic ideas. The 5 musical entities thus obtained generate – by overlapping – heterogeneous musical syntaxes, with different densities.

Parameters from the 14 electrodes are matched with numeric values that are later used in the generation of sinus sound overlapping (three at a time), activated and modified by the variations of other parameters or the involvement in noise resonance processes.

Other components used in the generation of sound, starting from the EEG, were:

1. the rhythmic component, which meant the running of an audio sample (gamelan notation, typewriter, vehicle noises etc.) in a two-dimension *wavetable*. We obtain the repeated play of the sample, at different rates and start/stop positions. Parameters: position & play rate (on axes X and Y), stereo delay time

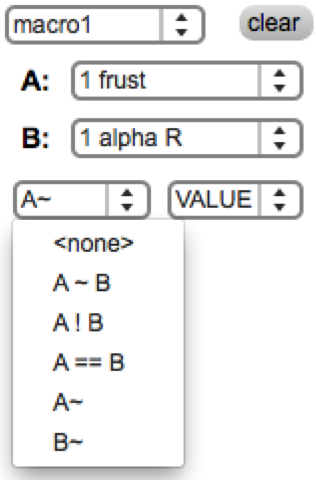
2. tonal components (see the aforementioned sine waves: parameters: frequencies & amplitudes of the sinusoids

3. Granular resonator component, which divides an audio sample in short grains that give a sound texture from which certain resonance frequencies are marked. Parameters: play rate, height, duration of grains, resonance frequencies.

The control of the aforementioned parameters is either prearranged or dynamically assigned, depending on the moment of the play. For the dynamic assignments, we created a system of macros that describe the control relationship between the input values and the musical parameters. The relationship versions are:

- similarity – extent to which two values evolve in the same direction;
- opposition – extent to which two values evolve in opposite directions;
- coincidence – activation when two values are equal;
- simple proportionality – direct matching of a selected value.

Finally, the macro output can be *VALUE* or *BANG*, respectively a quantification of the relationship or only one pulse when the relationship is activated (e.g., when the two value begin to evolve in the same direction).



Preparations

During rehearsals, the EEG signal was monitored in order to test the prediction capability of the software offered by the EEG headset manufacturers; major connections were noted at the monitoring of the actors' post-evaluative reports, the observation during the representation and post-representation, based on the recorded material. *Eight* sessions were conducted, and *seven* of them monitored both an active subject, actor, and a spectator-subject. During monitoring, we noted strong dynamics of the degree of frustration and some correlations with temporary interest, as well as relatively strong dynamics of commitment and a low contemplation one. In all cases, the moment that was self-reported as the most emotional one, both by the actor and by the spectator, coincided with moments of marked shift in the dynamic of the emotion-related software parameters. The parameters *frustration* and *interest* were found not to be influenced by the actor's speech; the parameter *commitment* was considerably more sensitive to movements, its monitoring being automatically interrupted by the software in the presence of movements. At a subsequent correlated analysis of the image of the subject/EEG and of the emotion prediction software, the existence of "noise" in the EEG was found around or just at the time when the parameter was changed in the prediction of the emotional state. We also noted an important change in the parameters visibly linked with focus, involvement and emotion: acceleration of breathing, change in the color of teguments, change in the blinking rate. In an analysis of the material, performed with Raul Mureșan and Vlad Moca, from RIST (Romanian Institute of Science and Technology), Cluj, we concluded that, particularly at the actor, it is impossible to establish with certainty the extent to which emotional dynamics is estimated by the software based on the electrical activity at scalp level or on other electrical activities, such as those generated by face muscles, although a marked connection between the emotional activity and the parameters of the manufacturer's software was found. The movements of facial muscles, of the eyes, of the cheeks or of the phonatory system generate electrical current, like the movements of the limbs that overlap the electrical charges detected by EEG at scalp level, which leads to the appearance of elements that are not driven by the brain electrical activity in EEG monitoring; these elements are called artefacts. We concluded that, without the use of a complex artefact removal software, the EEG monitored data from a subject who does not speak is not scientifically analyzable.

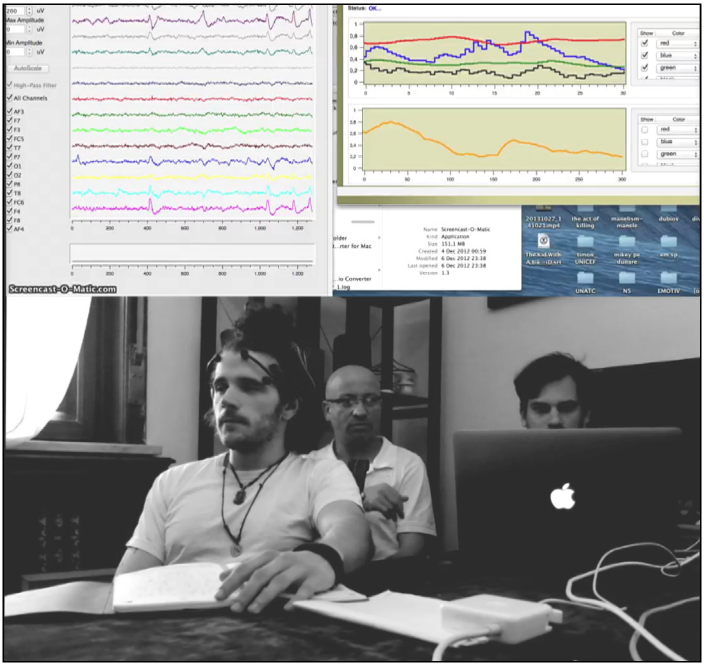


Fig. 3: EEG Screen and Emotion prediction software screen captures from the measurement synchronized with the recording of actor Liviu Popa during a test monitoring scene. At the upper left side, the screen of the EEG monitoring, at the upper right side, screen of the emotion prediction software Affective Suite, red curve – commitment, black – temporary interest, blue – frustration, green contemplation, orange-long-term interest.

After the analysis, we concluded that the software is relevant in the prediction of emotional state changes, especially in the attention range, *which was, otherwise, predictable, because the EEG band changes between the alpha length to gamma indicates an increased extent of cognitive activity and, thus, an increase of attention. This allows the execution of an emotion prediction model even if exclusively on the inclusion in a real time analysis software of the shift of the EEG spectrum from the alpha wavelength to gamma.* Since we could not estimate the importance of the other electrical parameters in the operation of the proprietary software, while also considering that the type of analysis could not be included in a scientific report without additional information from the manufacturer on the operation of the software, we established the necessity to develop our own model of analysis in real time of the EEG.

From the scientific literature, we selected an emotion prediction methodology based on the valence difference between the prefrontal sensors AF3-AF4, since the valence change was linked, in various studies (see Jones, N.A., Fox, N.A 1992), with the change from the state they "feel good/feel bad", respectively positive emotion/negative emotion:

The asymmetrical frontal EEG activity may reflect the valence level of emotion experienced. Generally, right hemisphere is more active during the experience of negative emotions while left hemisphere is more active during positive emotions. It was found that when one is watching a pleasant movie scene, a greater EEG activity is appeared in the left frontal lobe, and with unpleasant scene, right frontal lobe shows relatively higher EEG activity. (Jones, N.A., Fox, N.A 1992)

This connection was emphasized by numerous studies (see James A. Coan, John J.B. Allen 2004), on various types of stimuli, sound visual film, advertising or face recognition:

Over 70 published studies have now examined the relationship between emotion or emotion-related constructs and asymmetries in electro-encephalographic (EEG) activity over the frontal cortex. A review of these studies suggests asymmetries in frontal EEG activity – including resting levels of activity as well as state-related activation – are ubiquitous and involved in both trait predispositions to respond to emotional stimuli and changes in emotional state. (Coan J.A.; Allen J.J.B 2004)

The relationships of the alpha wavelength spectrum at the frontal lobes with the emotional state, as well as with the cognitive processes, are extremely complex and studied *in extenso*; the alpha rhythm is the first one that was discovered and perhaps the most investigated of the brain rhythms. The aim of our research was not to generate new clarifications, but to apply knowledge from neuroscience to performing arts. However, several explanations are required for the emphasis of the aspects to be described later: the frontal cortex is engaged in mainly cognitive brain activities, while emotional processes are linked with the deeper structures of the brain, respectively the limbic system. The role of the frontal cortex at the level of emotional processes is that of a moderator and a mediator, an aspect also shown at the level of the EEG activity, see James A. Coan, John J.B. Allen 2004. Moderator means:

Moderators are essentially third variables that represent conditions under which some independent variable becomes maximally potent or effective, while mediators:

Mediators, by contrast, are third variables that represent the mechanism through which (or partially through which) the effect of a given independent variable is made manifest. For example, if one of the components of an ordinary fear experience is a motivational tendency to withdraw, then eliciting that component of fear might require activity in the brain systems tapped by frontal EEG asymmetries. (*Ibid*.)

The frontal cortex of both lobes has a very important role in the conscious processes of the brain; this aspect turns it in the preferred object of research regarding emotions and of EEG, with the EEG observations allowing comparisons with self-reporting.

After we analyzed several models, we came to the real time emotion recognition methodology developed and described by Yisi Liu, Olga Sourina, and Minh Khoa in their paper "Real-time EEG-based Emotion Recognition and its Applications". It considered a dimensional (quantitative) model wherein emotions are distinguished by the positive or, respectively, negative valence and by intensity (extent of excitation), which varies from zero upward. The aforementioned team's objective was to recognize, with EEG, six different emotional states: fear, frustration, sadness, happiness, pleasant, satisfied, in real time, starting from standardized visual stimuli, and their research reported a success rate of over 80%, while other studies indicated 90% success rates (see Lin, Y.P., Wang, C.H., Wu, T.L., Jeng, S.K., Chen, J.H., 2009)

Given the artistic purpose of the *inter@FAȚA* experiment, some of the complex elements of analysis of the signal were removed from the described methodology and replaced by a simplified calculation version in MAX MSP, the EEG data being saved for a later analysis, at a small 1Hz resolution, which allowed the running of music generation software in real time.

During the performance, the use of this element was exclusively artistic, present only by sound, the change of potential from left to right and the reciprocal being a trigger of sound algorithms. The interpretation of the recorded data was carried out subsequently and their scientific validation requires more sessions, better resolutions and more stable work conditions.

Unlike a laboratory environment, where the assayer offers to the subject an extreme stimulus for control, which approaches only one cognitive and emotional/perceptive level, during the performance the subject/spectator finds himself in a complex environment, with numerous visual and auditory stimuli, following complex information and experiencing various emotions. Furthermore, the theatre spectator selects constantly, independently, the parts of the performance on which he focuses. For this reason an "instantaneous electrical reaction" analysis was deemed slightly relevant, the post-performance analysis being an analysis carried out for the entire representation (which lasts for almost three hours) on the subjects who were monitored. Since the actor was moving too much to allow a clean EEG signal, their EEG was not analyzed, although it was used in the generation of sound and it will be possible to involve it in a later analysis, with the mentioned reserve.

During the performance, the following records were made: four performances on audio-video record, EEG signal record both for the spectator and for the actor, at 1Hz sampling rate on all the 14 channels; as well as at the level of the parameters, of the Emotive Engine emotion recognition software.

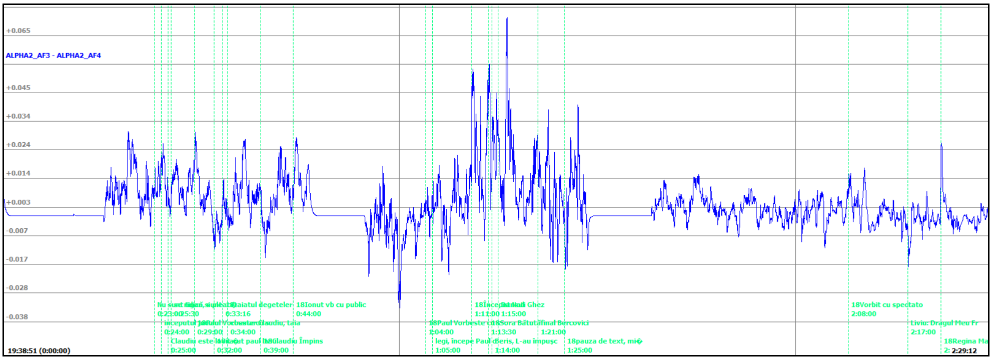
Post-performance analysis

After the post-performance analysis, we focused on the signal recorded with the C++ patch. The analysis was carried out with the software described in the paragraph on the instruments and with the EDF browser software, which generated the visual reports of the difference of potential between the AF3 and AF4 sensors (the odd number indicates position on the left hemisphere, while the letter indicator signals position on the cranial region, respectively frontal AF). Later, the qualitative analysis was performed for the ratio between the obtained diagram and the narrative flow of the performance.

For this purpose, a synchronization of the recorded EEG signal with the video record of two of the representations was operated, which allowed an accuracy of approx. 30 seconds. An analysis was performed in the alpha spectrum of the difference of potential between the AF3-AF4 sensors. Once the difference between the two values was obtained, a filter (LP butterworth) was applied for the removal of differences below 0.01Hz, in order to obtain an overall image of the chart. For the analyses, the EDF browser was used[2]. The curve is given by the difference of the instantaneous value, monitored each second, of the value recorded by the AF3 sensor and of the value recorded by the AF4 sensor. Therefore, a peak indicates a larger value of power in the left

[2] http://www.teuniz.net/edfbrowser/

hemisphere, while a minimum is either a value close to zero or one below zero, it indicates a higher monitored power in the right frontal. The presence of a higher power in the alpha spectrum at the AF3 sensor signals a less intense activity of this region and, reciprocally, in the left hemisphere; thus, positive peaks, where AF3 is greater, will indicate a negative emotion, while a position in the negative range of the difference of potential will indicate a mainly positive activity, meaning a more marked activation of the frontal cortex of the right hemisphere. (see Irene Winkler, Mark Jager, Vojkan Mihajlovi´c, and Tsvetomira Tsoneva, 2010) The qualitative analysis meant the listing of the performance moments in accordance with this position, positive emotion-negative emotion.



Although the data analysis is not very precise, neither as temporal resolution, nor in relation to the quality of the EEG signal, it does have the advantage of an extended record, which means "major" events become visible. Because of the aforementioned inaccuracies, we approached exclusively their qualitative analysis.

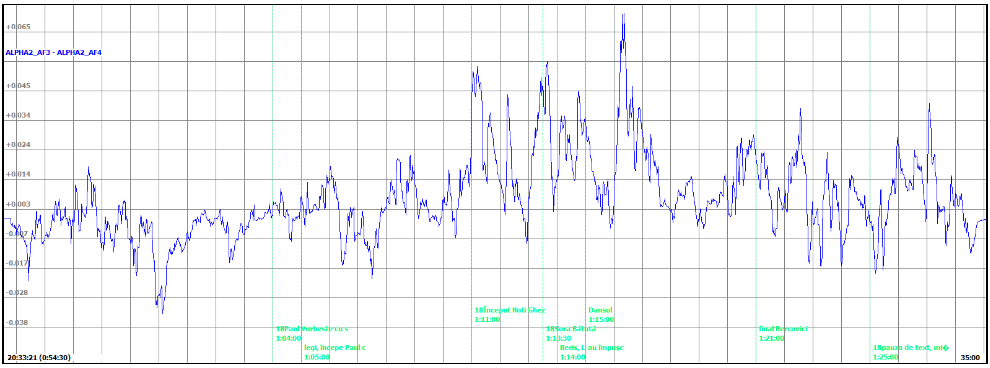


Fig. 4 and 5: Analysis of the AF3-AF4 valence for the 18 November performance

The analysis of the diagrams shows, at first sight, that they are very different for each oft eh 6 subjects (three per representation); furthermore, we note a relatively linear structure (with maximum and minimum values equal in time) for an overall duration, as well as considerably, above average, high peaks and values considerably lower than the average minimum. We also note zones at a subject where a several minute layout is seen in the inverse of the anterior average. Given the conclusions in the literature, we decided to approach only these moments, the shift of the monitored power from the left frontal hemisphere to the right and reciprocally being the sign of a change of state at the monitored subject. Approx. 30 such events were identified in the diagram, of which we describe the most important ones. We note that each spectator was monitored during a segment of time of the performance; therefore, the decision to analyze a maximum value, respectively a minimum value of the diagram, concerned first of all the structure of a unit (i.e. a subject) and not comparatively, since the observable peaks had very different values at different subjects.

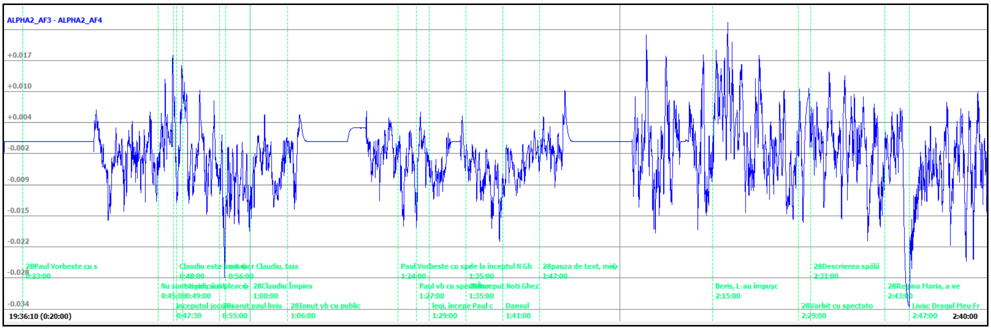


Fig. 6: Analysis of AF3-AF4 valence on 28 October

Since the beginning, in the analysis of the 18 November representation, we note a moment with a peak considerably above average, at 1h:19 of the performance. This is a maximum both at the subject A2.2, and compared with the other subjects. The moment is the testimony of witness Notti Gezan, who recounts how Jews were tortured to confess where they hid their treasures, how they were beaten and controlled to the bone, children included. The episode evokes the most marked cruelty recounted in the performance. While listening to the sound generated during the performance in the complete video record, we note the acceleration of the tune and the ascension to the acute tone, an algorithm in direct proportion with the parameter of frustration. This aspect was found in the sound of all the representations.

28-Oct	**18-Nov**			
Video IN	**Video IN**	**Description of moment**	**Type AF3-AF4 28/10/14**	**Type AF3-AF4/18/11/14**
00:15	00:27	I am not a gipsy, I am Greek, followed by sirtaki	minimum according to the notation on diagram 28.1	maximum
00:16	00:28	beginning of the football match with Claudiu	maximum	maximum
00:17	00:29:30	Claudiu stands up and leaves after a foul/or foul moment	maximum	maximum
00:17	00:29	Claudiu is hit and falls down during the match	minimum	minimum
00:29	00:43	Claudiu is pushed by neighbor	minimum	minimum
00:24:17	00:36.40	Paul Liviu kiss	minimum	minimum
00:24:56	00:37.16	Claudiu's fingers are cut	minimum	minimum
00:28:18	00:40:30	Close to the neighbor's cry "You gipsy"	low maximum	low maximum
00:35:10	00:48	Ionut talks with the audience about discrimination in RO	maximum	maximum
00:52	01:05	Paul talks with the spectator, describing the parameters	minimum	minimum
00:52	01:05	Paul talks with the spectator	minimum	minimum
00:56	01:09	laws, beings Paul in front of the spectator	*negative*	*negative*
00:57	01:10	Paul talks with spectator, then when Cătălina speaks, increases, music increase heard in the sound		
1:04.38	01:15	Begin Notti Gezan	series of markedly descending moments	series of markedly ascending moments
	01:15	from the beginning N Gezan to the end	positive interval	negative interval

28-Oct	18-Nov			
Video IN	**Video IN**	**Description of moment**	**Type AF3-AF4 28/10/14**	**Type AF3-AF4/18/11/14**
		Bercovici		
	01:18:19	Beaten sister	Maximum	minimum
01:10	01:19	Dance	brief negative interval in the aforementioned positive interval	brief positive interval in the aforementioned negative interval
01:16	01:29	text break, vey ample choreographic coat movement	minimum, below zero	minimum, below zero
02:23	02:07	Talk with spectator, Liviu: Description of Auschwitz, great changes of light and sound		
02:25	02:10	Description of washing and disinfection at Auschwitz		
02:31	02:16	Liviu: My dear brother	minimum	minimum
02:37	02:20	Queen Mary came/Judith Tata		

The analysis of the subsequent sequences found that all the peak positive and negative moments were linked with intensely emotional situations or with strong shifts of focus. An important series of moments that showed a positive peak (a negative emotion) was given when the actor talked directly to the monitored subject, which is often intimidating. Another important category of negative range moments, respectively from the range of positive emotional activation, is given by intense embodiment moments. If intense embodiment was followed by violent narrativity, both positive and negative peaks were registered, even for the same moment linked with another monitored subject, during another performance. The episodes of suggested fictional violence, for instance the cutting of Claudiu’s fingers in a nightmare, with a slightly surrealistic touch, were linked with a positive peak, corresponding to negative emotions. We note that this moment, easily seen in the chart of both performances, was followed by a marked shift in light design and background sound, which prompts automatically increased focus; the sinusoidal sound linked with this episode is generating distress.

Discussion

The study performed by Nancy Aaron Jones and Nathan A. Fox, "*Electroencephalogram Asymmetry during Emotionally Evocative Films and Its Relation to Positive and Negative Affectivity*", on 23 subjects picked according to scores obtained by their self-characterization on the amount of positive versus negative emotions they felt, noted:

> The data show that the happy video clip produced greater relative left hemisphere activation than the sad and disgust emotions. The sad and disgust emotions showed greater relative right hemisphere activation than the happy emotion (see Fig. 1). No other main effects or interactions were found.

Their prominent study meant to clarify the issue of brain functional lateralization, including perspectives on the assertion that the right hemisphere is specialized for rational judgment, while the left one for emotional processes. At that point the existence of emotional processes in the right hemisphere had already been emphasized, and the dismantling of the mentioned assertion had begun. The thorough analysis shows that most of the reported negative emotions were correlated with an increase of activation in various brain areas (frontal, temporal, parietal) in the right hemisphere, while positive ones were correlated with the activation of the left hemisphere, Moreover, correlations were found between the activation strength and the type of personality, positive versus negative.

An interesting element results from the AF3-AF analysis of the 28 October performance, by the spectator report in the second segment of the play. This report is obviously favorable to a considerably stronger and more extended activation linked with the right hemisphere, unlike all the other spectators. One possible interpretation might be that the subject experienced instead positive emotions during the representation. Albeit possible, this is unlikely, because a careful analysis finds that we have negative peak exactly during the testimony of Notti Gezan – as said, the most brutal event recounted during the performance:

> Fischer Margareta, interrogated by Boldizar Paul, who, to intimidate her, punched her so hard in the mouth that two teeth fell, while he kept throwing dirty words at her. Then he made her lie on a bench and hit her everywhere, genitals included, until she passed out. While she was being beaten, my sister was screaming with pain; he made her remove her socks, which he used to gag her, while continuing to hit her feet with a baton. When she recovered, at Boldiszar's order, the torturers there, namely from Huedin - Szentkuti Andrei, detective – put pencils between her fingers and then pressed her hand until she passed out again and this is how we took her out in the barrack. My sister Margareta never returned from deportation.

Fig. 7: Image from the representation, actress Cătălina Bălălău at the testimony of witness Notti Gezan, EEG monitored

Given the gender of the monitored subject, i.e. female, a positive emotional reference to this moment is unlikely, the observed phenomenon being explained rather by a different lateralization of left right valence asymmetry, associated especially to the left-handed, but not exclusively (see Hamann, Canli, 2004 and Lin, Y.P., Wang, C.H., Wu, T.L., Jeng, S.K., Chen, J.H 2009). For this reason, recognition BCIs required the scaling of each subject, to enable precision.

Going back to this point in the testimony of witness Notti Gezan, starting from the premise that the subject had an opposed lateralization of the valence, we find a strong link between the peak characters of the two moments. According to the creative team's expectations, it was estimated as the most intense moment of the performance, added to the one when the surviving Auschwitz witness, Vasile Nussbaum, recounts how he read the last letter from his 13-year old brother Alex, before the latter was gassed. This moment, too, was marked as followed by positive peaks, for one of the monitored subjects, in relation to the overall monitoring process.

Fig. 8: Image from the representation, actors Cătălina Bălălău and Ionuț Niculae

Conclusions

The role of the EEG alpha waves continues to be debated; currently, there are two directions: one that links them with sensory processing, and the other one with the allocation of attention. The majority of the data, including the correlation of EEG data with functional MRI data, pushes towards the latter hypothesis, respectively towards a role in the downward modulation of attention allocation (the one oriented externally and the one oriented internally), the neural sublayer being found in the right frontal cortex. How could such data come to terms with the data that involves frontal areas in emotions, as shown previously? In their neuro-computational model, Gray and Braver (2002) describe numerous proofs that suggest there is an integration of emotional states and of cognitive control at the level of the lateral pre-frontal cortex. This conclusion relies on the selective effects of emotion induced on behavioral performance and on brain activity. An integration of emotion and cognition could have an important computational role in self-adjustment, state the authors. An integration mechanism would enable selective self-adjustment, dependent on the emotional state, which also depends on the assessments of the situation. Approach/avoidance states may modulate in a differentiated way the subsystems of attention/working memory, for the priority of specific purposes in a manner sensitive to the events in progress. According to Gray and Braver's model, constant attention is considerably more important in states of avoidance, when emotions such as fear appear, to enable an extended processing of a potential threat. Failure to sustain attention or vigilance in such a situation would be disastrous. Constant attention and attention orientation are mainly localized in the right hemisphere, and experimental evidence indicates a facilitation of constant attention in states of avoidance.

The creative and analytical use of a brain-computer interface is within range for performers and performance creators, and it offers sufficiently rigorous and reliable instruments for the integration in the performance. The development of certain forms of plays that enable the inclusion of the actors' EEG assessment, as well as the improvement in the reliability of tools to obtain consistent results at this level could allow new perspectives on the relationship between the actor's experience and the spectator's.

The inclusion of the performer's analysis in a study requires, however, a considerably stricter experimental chart, which should limit to the maximum extent the actor's movement, or the experiment with systems of analysis able to remove speech- or movement-related artefacts.

Given the general conclusions of the studies on the different activation of the left frontal hemisphere versus the right one, in relation to positive versus negative emotions, we have concluded that the appearance, at the EEG test, of such a difference, signals a major change of state (even if it cannot explain specifically the type of emotion experienced by the subject), as expected if we consider the literature and the post-performance analysis – an indicator we find extremely pertinent for the subject of the performance and which will be integrated in an upcoming version.

Development possibilities for the 2nd version of the performance, prospective development

The development of the *inter@FAȚA* experiment is considering three coordinates: artistic, technical conditions, and research conditions. To improve the technical conditions of the project, the possibility to synchronize EEG signal sources with the video witness of the performance and with a potential video record of the monitored subject is vital; it will allow the accurate assessment of the effect of the subject's movements and of the relationship with the contents of the performance. Furthermore, the use of more reliable equipment, which should allow better and longer contact for a definite signal, will enable the improvement of the scientific value of the data. Moreover, the use of a solution less influenced by the subject's movements, e.g. EEG equipment used in the monitoring of sportsmen, could give good results for the investigation of the actor subject; we note here that the level of speech generated artefacts should be measured and eliminated, which is hardly achievable, if not even impossible. For the purpose of accuracy, an auto-report is also required at the end of the EEG monitoring of each subject.

For the accuracy of the emotional states, we may consider an analysis of the EEG spectrum, which will provide data on the subject's degree of attention and commitment, based on the examination of the dominant EEG bands (alpha, beta, and gamma).

At an artistic level, the event of change in the propensity of the left-right and reciprocal EEG activity will be associated with the generation of an unequivocal sound, which could emphasize for all the spectators the presence of such a moment. By associating a moment of the performance with this type of sound, the audience will be signaled that a special intense moment is in progress and they will be able to compare it with their own response to the said moment. Since it is assumed that such moments are strong ones, it is most likely that reactions will coincide at most of the spectators. We are considering the association of this type of signal with the control of lighting by DMX protocol, starting from the association of some color with a positive, respectively negative state of mind. Additional to these development, we may consider the inclusion of an analysis in the mu spectrum, linked with the activation of mirror neurons, which could provide a connection with the actors' movement on stage; this element could be developed in a wide range that could associate movement and sound.

The project team:

Alexandru Berceanu – stage director and dramaturge
Andreea Chindriș – dramaturge
Actors: Cătălina Bălălău, Paul Dunca, Ionuț Niculae, Liviu Popa
Ana Costea – choreographer
Cătălin Crețu – music coordinator
Grigore Burloiu – programmer

Maria Draghici – video artist
Adina Babeș – document researcher.

The project *Inter@FAȚA* was carried out, with non-refundable AFCN financing, by the dramAcum association; at present, a new version of the performance is in progress *inter@FAŢA3* with non-refundable financing from AFCN and ARCUB, Center of Cultural Projects of the Mayor's Office, Bucharest Mayor's Office, with equipment from UNATC, the CINETic center.

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