Monitoring emotional states *in the loop* and its potential applications

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Abstract

Emotions play a critical role in human cognition, perception, decision making, and interaction [1]. We present a novel non-invasive Brain-Computer Interface (BCI) system to monitor human emotion *in the loop*. In particular, we developed a continuous music-based emotion display embedded in an online BCI architecture. Our system measures emotional states from electroencephalography (EEG) signals and feeds back the affective state in real-time via the emotion display, establishing affective closed-loop brain interaction. We provide a thorough discussion on potential applications emerging from our concept, in particular its implications on affective human-machine interaction (HMI) and Ambient Assisted Living (AAL) [7] environments. Furthermore, we discuss the potential use of our system in diagnosis and treatment of affective dysfunctions, such as in depression or anxiety disorder.

Concept, Technical Realization, and Evaluation

Affective BCI architecture:
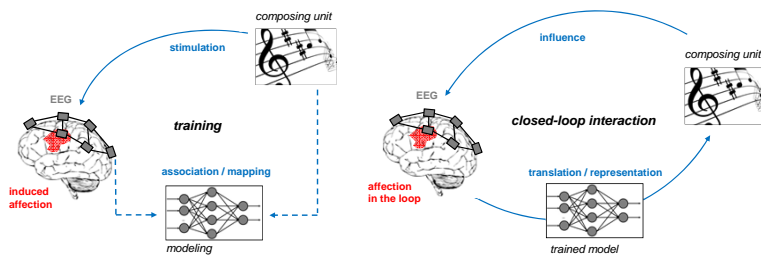

Modeling
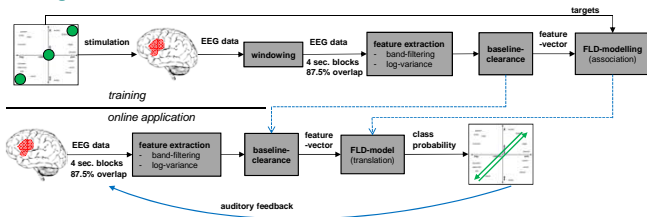
Signal processing and information flow in the affective BCI architecture:

Top row (training phase): Selected patterns of synthesized affective music are presented to a human subject; brain activity is measured simultaneously via EEG and further processed to built a Fisher-Linear Discriminant (FLD) model.

Bottom row (application phase): Brain activity is measured and processed according to the training phase; the model output is used to set control parameters for the composing unit, resulting in a real-time musical representation of the subjects affective state.
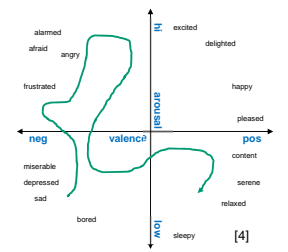
Composing Unit
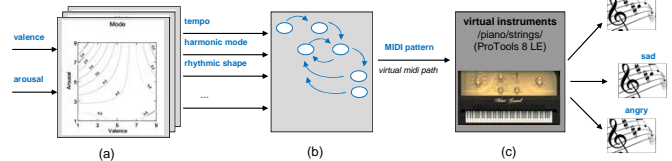
Music is a strong and reliable emotion stimulus [2] and can algorithmically be synthesized to form a continuous *affective display*.

Algorithm to generate continuous patterns of syn-thesized affective music:
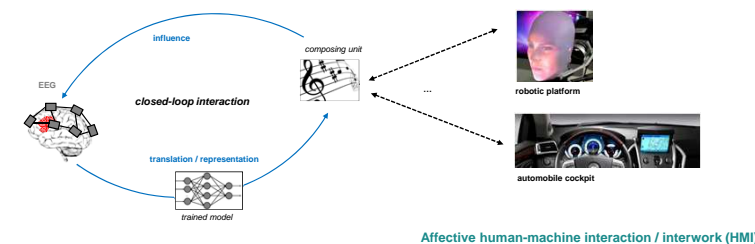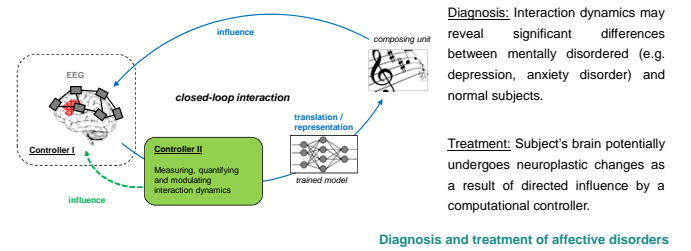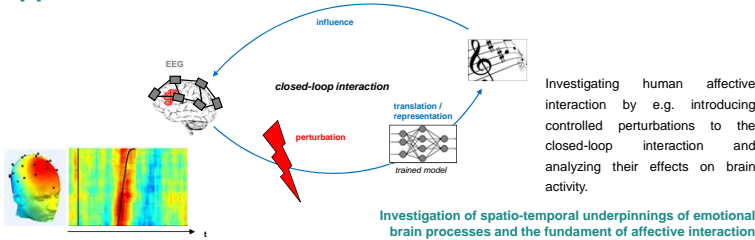
a) Mapping of emotion-specific parameters onto music structural control parameters according to psycho-physiological studies [3].
b) State-machine: generating streams of MIDI-events, modulated by music structural control parameters.
c) Translation of MIDI-patterns into sound.

Evaluation

Study I	Self-assessment **ratings of emotional affect** (11 subjects) for 13 patterns of *synthesized affective music*.	Self-assessment ratings correspond to expected emotions to be elicited.
Study II	Comparison of **EEG brain activity** patterns (9 subjects) evoked by emotionally congruent stimuli: *(a) synthesized affective music* *(b) affective pictures (IAPS)*	Similar alpha- (central-parietal area) and gamma-power (temporal sites) modulations; consistency with prior findings in emotion research, e.g. [5,6].
Study III	Subjects are asked to **intentionally modulate** the affective music feedback in the closed-loop application according to specific tasks (5 subjects).	3 of 5 subjects achieved statistically significant modulations according to the given tasks.

Application Relevance

Investigating human affective interaction by e.g. introducing controlled perturbations to the closed-loop interaction and analyzing their effects on brain activity.

Investigation of spatio-temporal underpinnings of emotional brain processes and the fundament of affective interaction

Diagnosis: Interaction dynamics may reveal significant differences between mentally disordered (e.g. depression, anxiety disorder) and normal subjects.

Treatment: Subject's brain potentially undergoes neuroplastic changes as a result of directed influence by a computational controller.

Diagnosis and treatment of affective disorders

Affective human-machine interaction / interwork (HMI)

Ambient Assisted Living (AAL) [7]

References

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