Closed-loop Interaction with Affective Brain-Music Interface

Stefan Ehrlich[1], Cuntai Guan[2], Gordon Cheng[1]

(1) Institute for Cognitive Systems
Technische Universität München, Germany
[stefan.ehrlich@tum.de, gordon@tum.de]

(2) Institute for Infocomm Research (I²R)
Agency for Science, Technology and Research (A*STAR), Singapore
[ctguan@i2r.a-star.edu.sg]

Emotion, Reason, and the Human Brain

Emotions play a critical role in rational and intelligent behavior; a better fundamental knowledge is indispensable for understanding higher-level brain processes [1].

Moreover, several challenging and hardly manageable mental diseases, such as depression and schizophrenia have their origin in emotional or emphatic dysfunctions [2].

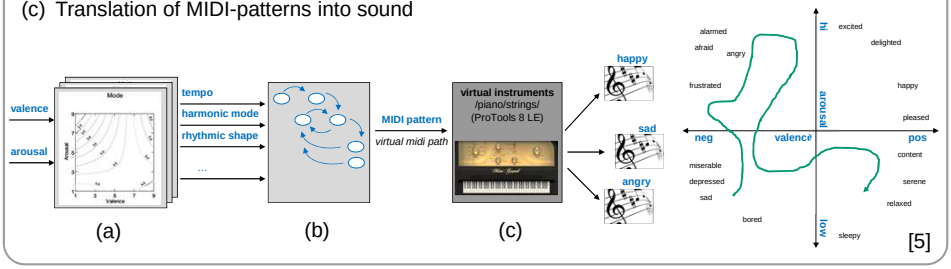
Our approach:

Online Brain-Computer Interface (BCI) architecture to *feedback* a subject's emotional state in a way such, that *closed-loop* affective brain interaction is established.

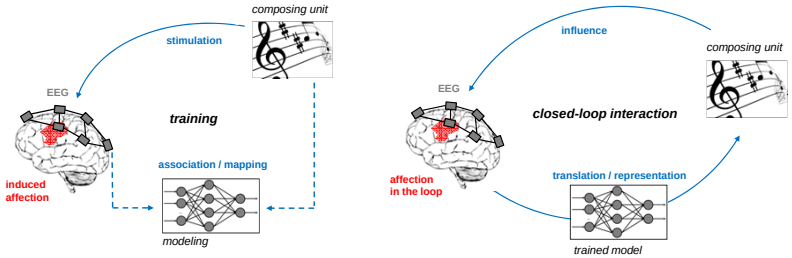
Music-based Continuous and Controllable Emotion Stimulus

Music can evoke strong emotions [3] and is commonly used in emotion research as reliable stimulus. Moreover, music is freely synthesizable and can thus serve as a continuous *affective display*.

Algorithm to generate continuous patterns of synthesized affective music:
(a) Mapping of emotion-specific parameters onto music structural control parameters according to results of psycho-physiological studies [4]
(b) State-machine: generating streams of MIDI-events, modulated by music structural control parameters
(c) Translation of MIDI-patterns into sound



Affective online-BCI Architecture



Training:

- Presentation of synthesized affective music (composing unit) to a subject
- Measurement of brain activity via *electroencephalography* (EEG)
- Data-processing and modeling

Closed-loop interaction (online-application):

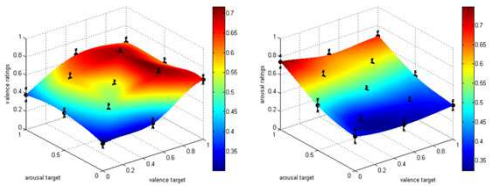
- Translation of subject's brain activity in real-time into a continuous musical representation
- Playback of musical representation establishes closed-loop affective brain interaction

Evaluation and Results

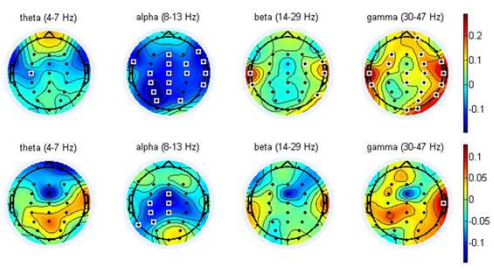
Studies:

1. Self-assessment ratings of emotional affect (11 subjects) for 13 patterns of *synthesized affective music*.
2. Comparison of EEG brain activity patterns (9 subjects) evoked by emotionally congruent stimuli:
   (a) synthesized affective music
   (b) affective pictures (IAPS)

- ➢ Self-assessment ratings correspond to expected emotions to be elicited
- ➢ Similar alpha- (central-parietal area) and gamma-power (temporal sites) modulations
- ➢ Consistency with prior findings in the field of emotion research, e.g. [6]



Interpolated self-assessment valence- (left) and arousal-ratings. Error bars represent the standard error of the mean.



Conditional differences of EEG brain activity patterns for synthesized music stimuli (top row, white markers show significant, p<0.05, deviations) and emotionally congruent affective IAPS pictures (bottom row, white markers show marginally significant, p<0.1, deviations).

Field test:
Exhibition showcase and test by 54 visitors

- ➢ Test-persons report meaningful system response and ability to modulate music feedback (e.g. by recalling positive versus negative memories).

Key Features

- Novel paradigm to *affectively* stimulate the brain in a *closed-loop* fashion.
- Platform to study emotions and related brain processes (e.g. *spatio-temporal dynamics*).
- Potential *medical applications* (e.g. *diagnosis* and *treatment* of mental dysfunctions related to emotions).

References
[1] Antonio Damasio. Descartes' Error: Emotion, reason and the human brain. Vintage Digital, 2008
[2] K. Adalarasu, M. Jagennath, S. Ramesh, B. Geethaniali, and S. Shukla, „A review on influence of music on brain activity using signal processing and imaging system," International Journal of Engineering Science, vol. 3, 2011
[3] Carol L Krumhansl. An exploratory study of musical emotions and psychophysiology. Canadian journal of experimental psychology, 51(4):336–353, 1997
[4] P. Gomez and B. Danuser. Relationships between musical structure and psychophysiological measures of emotion. Emotion, 7(2):377, 2007
[5] J. Russel, "A circumplex model of affect." Journal of personality and social psychology, vol. 39, no. 6, p. 1161, 1980.
[6] R. Dolan, R. Lane, P. Chua, and P. Fletcher, "Dissociable temporal lobe activations during emotional episodic memory retrieval," Neuroimage, vol. 11, no. 3, pp. 203–209, 2000.