2013 Humaine Association Conference on Affective Computing and Intelligent Interaction

Affective Brain-Computer Interfaces for Arts

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***Abstract*—We experience positive emotions when our hedonic needs, such as virtuosity or relatedness, are satisfied. Creating art is one way of satisfying these needs, so artistic computer applications can be considered as 'affective'. Artistic brain-computer interfaces (BCIs), which allow people to create art using brain signals, are such computer applications. Therefore, they can be considered as affective BCIs. In this paper, we provide an overview of artistic BCIs and discuss how affective BCIs can be used to create art and have hedonic experiences. Then we provide some guidelines for developing affective artistic BCIs.**

I. Introduction

A brain-computer interface (BCI) is a physiological computing system, specialised to operate based on brain activity. When Vidal used the term for the first time, he was wondering whether BCIs could be used "as carriers of information in man-computer communication or for the purpose of controlling such external apparatus as prosthetic devices or spaceships" [1](157). Today, his question has been partly answered with the prevalent use of assistive BCIs by disabled people for communication and control [2]. Controlling spaceships has not been possible yet although researchers did investigate the feasibility of BCIs for space applications [3], [4].

BCIs developed for communication and control aim at replacing the functionality of conventional human-computer interfaces (e.g. mouse, keyboard, joystick). They let their users make 2D movements [5], select items [6] and type words [7]. However, the state-of-the-art BCIs cannot replace conventional interfaces with equal reliability; they are not fully accurate. For this reason, so far, BCIs have been used mainly by severely disabled individuals who cannot generate any input other than brain activity to communicate with a computer.

For people who are not disabled, conventional interfaces provide a much more efficient and effective human-computer interaction (HCI) than current BCIs do. Researchers have been trying to invent better sensor technologies [8], signal processing methods [9] and applications [10] for BCIs, which have certainly improved and will keep improving the capabilities of BCIs. Maybe in the future we will think of a song and our computer will play it; or we will think of our password and immediately log in a system[1]. However, for the time being, BCIs are still not the suitable means to satisfy our pragmatic needs (i.e. to get things done).

We do not interact with computers only to satisfy our pragmatic needs. For example, we play computer games or use them to create digital art. Such interactions produce hedonic[2] experiences by satisfying our psychological needs. For example, while we are playing a computer game, we tackle several challenges; we keep on trying until we overcome the challenge. The effort we put in and the successful end result unfold a hedonic experience called virtuosity (or competence) [13], which is one of our psychological needs [14].

While BCIs are not the suitable means to get things done, they are suitable to fulfill our psychological needs and to have hedonic experiences. Affective BCIs (aBCIs) [15], [16], [17], which 'recognise' as well as 'influence' one's affective state, are particularly promising due to the clear link between positive affect and psychological need fulfillment. When we say hedonic experiences, we surely refer to the positive emotions we experience. Indeed, research has shown that we experience positive affect when our psychological needs are fulfilled [18]. Therefore, aBCIs can 'influence' our affective state by satisfying our psychological needs. Moreover, they can make use of our affective states that they 'recognise' to satisfy our psychological needs. One of the ways that aBCIs can do these is through artistic applications. As we will discuss further in this paper, art has a lot to do with our emotions and psychological needs and therefore aBCIs are promising technologies for artistic applications.

In the next section, we will present some background information about existing artistic BCIs. Following that, we will describe how affective BCIs can be used in artistic applications to provide hedonic experiences. We will conclude by remarks and recommendations for using aBCIs for arts.

II. Artistic BCIs

Artistic BCI applications date older than assistive BCIs. Years before Vidal described the first BCI, in 1965, Lucier was performing[3] the "Music for Solo Performer" that he was composing in real time using his electrical brain waves (EEG, short for electroencephalography) [19]. Following Lucier, many others tried composing audio and visual arts using BCIs.

Inspired by Miranda's classification [20], we can organize artistic BCIs in three categories with respect to the composition methods. Next, we will describe those categories and provide examples from previous work. All the work we will discuss rely on EEG.

[1]Though, potential implications of such BCIs on the society are matter of ongoing ethical debates [11], [12].

[2]Hedonic: Of, relating to, or characterized by pleasure.

[3]Lucier's performance can be watched at http://www.youtube.com/watch?v=bIPU2ynqy2Y

978-0-7695-5048-0/13 $26.00 © 2013 IEEE
DOI 10.1109/ACII.2013.155

Fig. 1. Staalhemel: person walks under the steel plates hung from the ceiling.

A. *Audification/Visualisation*

Audification (visualisation) is perceptualising the brain signals in auditory (visual) media. With basic (e.g. frequency filtering) or no processing, the brain signals are mapped onto audio signals (e.g. tones) or visual signals (e.g. lines, patterns). The resulting sounds and visualisations provide a direct representation of the brain activity.

With “Music for Solo Performer” [19] Lucier demonstrated the earliest example of audification. By frequency filtering, he extracted the brain signals in the alpha band (8-12 Hz) and then amplified them so that they produced audible distortion in the loudspeaker. Alpha rhythm is associated with physical relaxation and relative mental inactivity [21]. In “Staalhemel” [22], De Boeck hung steel plates from a ceiling (see Fig. 1). He extracted the brain signals in the alpha and beta (12-30 Hz) bands. Then, small hammers tapped the steel plates according to the amplitudes of these signals. Beta rhythm is associated with wakefulness [21].

Sobell’s “Interactive Brain Wave Drawing” project started in 1973 was a pioneering work in visualisation [23]. She plotted brain signals of two co-located people, superimposed on their faces. Her aim was to create a situation where using technology as a medium enabled people to express themselves more easily than without it[4].

B. *Musification/Animation*

In musification/animation, brain signals are processed but not mapped directly onto audio/visual signals. Rather, they are used to synthesize new or modify existing (complex) artwork in auditory and visual media.

Miranda developed a BCI that held core musical elements in a database and combined these elements to compose Beethoven-like or Schumann-like music according to the alpha/beta rhythm and signal complexity [24]. In May 2012, the Red Note Ensemble performed “Clasp Together” during the first Inventor Composer Coaction (ICC) concert. The spontaneous brain activity of band members were analysed in real-time and used to play back specific fragments of a piece[5]. Similarly, Makeig developed a system that people could compose music by imaginatively re-experiencing a feeling that they had previously associated with certain sounds [25]. He used advanced signal processing and analysis techniques (e.g. common spatial patterns filtering, independent component analysis) and data training in the system.

In the “Global Mind Project” [26], Casey and Sokol used brain signals to animate colorful patterns on a public display. The animations were complemented by sounds played according to brain signals. They did not report how the brain signals were processed to create the visuals and sounds. The aim of the project was to open up new methods of collaboration between artists and the public. Similarly, De Smedt and Menschaert [27] developed a system called “VALENCE”, which interpreted affective brain signals and animated colorful particles on a public display accordingly (see Fig. 2). When the user was relaxed, as indicated by the alpha rhythm, the particles that floated around on the screen converged, to form one sticky ball at the center of the screen. High valence, as indicated by frontal asymmetry, produced more colorful and more eccentric particles.

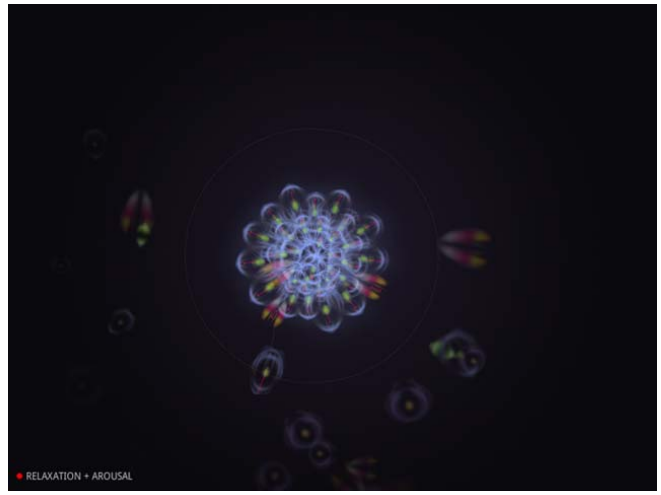

Fig. 2. VALENCE: particles are animated according to relaxation and emotional valence.

C. *Instrument Control*

Another way of creating art using BCIs is to convert brain signals to control commands for real or virtual artistic instruments.

In the “Xmotion” project [28], members of the Multimodal Brain Orchestra used BCI to selected from some pre-set string articulations (legatostaccato) and accentuations (pianoforte). The BCI relied on the P300 response and the steady-state visually evoked potential (SSVEP) of the brain. In the “MusEEGk” system [29], people used a BCI to select notes and play them in sequence. The BCI was based on the P300 speller paradigm.

The “Brain Painting” application [30] allowed disabled people to create digital pictures using BCI. People could select objects and colours, zoom in and out, move the cursor and place objects on a virtual canvas (see Fig. 3). The application relied on the P300 speller paradigm. Going one step further,

[4] Sobell’s performance can be watched at http://ninasobell.com/video/1973_large.html

[5] Red Note Ensemble’s performance can be watched at https://vimeo.com/50880180

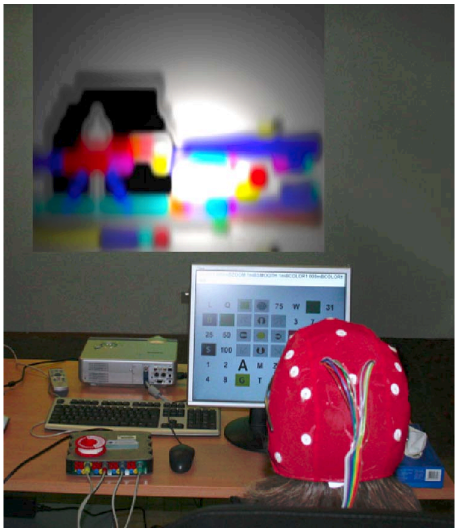

Fig. 3. Brain Painting: person selects a tool from the matrix on the screen. The virtual canvas can be seen on top.

the “BrainBrush” application [31] provided people with multimodal control. Users could not only select things using BCI but also convey extra commands using head movements and blinking.

III. Affective BCIs for Arts

BCIs are not capable of transforming a scene that we imagine in our head into shapes and colours; or a melody into notes. They cannot create art on our behalf. However, aBCIs can ‘contribute’ to creation of art with the inner state information they can provide. In this section we will discuss how creating arts using aBCIs can unfold hedonic experiences.

A. *Expressing Emotions*

Collingwood illustrates through the following example that expressing emotions is a need: “As unexpressed, he [a man] feels it [the emotion] in what we have called a helpless and oppressed way; as expressed, he feels it in a way from which this sense of oppression has vanished.” [32](110).

Expressing emotions resides at the centre of creating art. Art is a means for expression; someone can write music to express a deeply felt emotion for example [33]. However, not everyone can do this. We all have emotions but arguably only a few of us know how to convert them into an artistic piece such that others can recognise our emotions. At this point, collaboration with computers may prove useful.

Though limited, computers have some intelligence, and BCIs can recognise our emotional states. So, perhaps the computer can create the basics of an art piece and then enrich or manipulate it with the emotional or, in general, inner state information coming from the BCI. We do not expect one to create a sophisticated artwork such as Da Vinci’s Mona Lisa but perhaps one can create an abstract work, such as one representing ‘De Stijl’[6]. For example, a system called “MONICA” (short for MONdriaan-Imitating Computer Artist) was shown to create digital artwork that resembled the works of the Dutch painter Piet Mondrian [35]. Alternatively, the computer can start with an existing artwork, which is not necessarily abstract or simple, and then manipulate it according to the inner state information provided by the BCI. The feasibility of this approach has already been shown in affective applications, which did not rely on BCIs but facial expressions detected by computer vision. Such applications manipulated existing images by rendering strokes, curves and colours based on affective state information [36], [37].

We do not claim that by using a BCI for a couple of minutes, one can imitate even a seemingly simple artwork. Creating art can take days, months, and even years. It is a repertoire of experiences. Rather, we envision that one who does not claim to be an artist can experience the pleasure of expressing their inner state through art. The user and the computer can form a composing team.

B. *Exploring Emotions*

From time to time, we are not able to recognise even our own emotions: “At first, he [a man who is said to express emotion] is conscious of having an emotion, but not conscious of what this emotion is” [32](109).

If art is a means to express emotion, then through art we might understand what emotion we are experiencing. If this is the purpose, then it might be desirable that the produced art piece is a simple one and an interactive one so that the artist can understand the relation between their inner state and its influence on the product. Then, we would expect the BCI to simply sonify or visualise some low-level features extracted from the brain signals (e.g. the alpha rhythm) continuously, without aiming for a sophisticated artistic product. An example is the interactive artistic installation called “VALENCE” [27]. This system interprets the alpha rhythm and the valence state of the brain. With high alpha (i.e. relaxation) the particles that float around on the screen converge, to form one sticky ball at the center of the screen. High valence produces more colorful and more eccentric particles. As the relation between their brain signals and the visualisations becomes clear to the users (either with an explanation or with interacting), they realize the emotional state they are in. People can use such installations not only to explore their inner states but also to train themselves, so that they can have prolonged positive hedonic experiences (e.g. relaxation, positive valence). Several examples of such interactive affective systems exist in the literature, using other physiological measures than brain activity (e.g. heartbeat, respiration [38], [39])

IV. Recommendations

In this section, we will provide some recommendations for developing artistic applications using affective BCIs to provide hedonic experiences.

[6] ‘De Stijl’ (Dutch for ‘The Style’) was an artistic movement effective from 1917 to 1931, promoting simplicity and abstraction. It confined itself to the elementary means of expression: vertical and horizontal lines, primary colours and no-colours. Member artists included Theo van Doesburg, Gerrit Rietveld and Piet Mondrian [34].

A. Multidisciplinary Collaboration

BCIs rely on neuroscience, since they operate based on brain activity. They rely on electrical and electronics engineering, since they pick up and process electrical brain signals. They rely on computer science, since they recognise the features in the brain signals and actuate computers. We can extend this list further if we consider the domain specific BCI applications. For example, BCI games rely also on designers, artists, ergonomists and so on.

Currently, especially the hedonic BCIs suffer from the lack of multidisciplinary collaboration. For example, we see a big discrepancy between the artistic BCIs developed by different communities. On the one hand, there is the technical BCI community. Their applications serve as tools for testing some psychological hypotheses or evaluating the performance of signal analysis and classification techniques. Thus, less attention is paid to artistic characteristics than to technical aspects. On the other hand, there is the artistic BCI community. Their applications are developed with respect to principles of arts. However, they rely on consumer grade sensor headsets so that the technical procedure (e.g. signal acquisition, processing, classification, interpretation) can be by passed. The technical community often criticises the reliability of such headsets. To remove discrepancies and for fruitful BCI research and development, people with different disciplinary backgrounds should collaborate.

B. User Experience Evaluation

Arguably, there are three aspects of concern with technology and each of them should equally be evaluated: functionality, usability and user experience (UX) [40]. However, with hedonic BCIs, usability and UX evaluations are practised much less frequently than functionality evaluations [41]. Even with a pragmatic product, such as a word processing software, positive UX can improve the quality of the interaction and let us ignore some usability flaws [42]. For a hedonic product, such as an artistic BCI, UX is even more crucial because providing a hedonic experience is what an artistic BCI is aimed for and, therefore, what should be evaluated. Obviously it is not possible to interact with a system that does not work but neither functionality nor developing usable products with respect to logic, conventions or common sense can guarantee a positive UX. It is essential to investigate the data that the users themselves yield (e.g. their actions, opinions, feelings) rather than the potential capabilities of the game (e.g. accuracy, speed, ease of use).

C. Hedonic BCIs for Abled Users

Influenced by assistive BCIs, many artistic BCIs aim at replacing the functionality of conventional modalities, which narrows their user domain down to disabled individuals. For example, the "Brain Painting" application allows its users to select objects and colours, zoom in and out, move the cursor and place objects on a virtual canvas. As the studies with ALS patients also confirm, this is a precious opportunity for disabled people who are longing to satisfy their need for self-actualisation [30]. For those who are not disabled, the situation is not the same. These people can already use a mouse to do the things that Brain Painting offers. So, Brain Painting cannot improve upon their current capabilities to create art. Another example is the "Xmotion" project [28] where the orchestra members use BCIs to select from fixed tape piece compositions and discrete sound events. Again, disabled individuals could benefit a lot from such a setup but healthy individuals can either use a mouse to select things or can play the instruments themselves. So, other than creating a halo effect due to their novelty, such replacement BCIs cannot motivate healthy people to interact in the long run.

In short, artistic BCIs should furnish their users with new abilities. This means that researchers and developers should carefully identify the capabilities and expectations of their target user group. A BCI that is aimed for disabled people cannot be assumed to satisfy the hedonic needs of healthy people, and vice-versa.

References

[1] J. Vidal, "Toward direct brain-computer communication," *Annual Review of Biophysics and Bioengineering*, vol. 2, no. 1, pp. 157–180, 1973.

[2] J. Wolpaw, N. Birbaumer, D. McFarland, G. Pfurtscheller, and T. Vaughan, "Brain-computer interfaces for communication and control," *Clinical Neurophysiology*, vol. 113, no. 6, pp. 767–791, 2002.

[3] C. de Negueruela, M. Broschart, C. Menon, and J. del R. Millán, "Brain-computer interfaces for space applications," *Personal and Ubiquitous Computing*, vol. 15, no. 5, pp. 527–537, 2011.

[4] R. Poli, C. Cinel, A. Matran-Fernandez, F. Sepulveda, and A. Stoica, "Towards cooperative brain-computer interfaces for space navigation," in *Proceedings of the 2013 International Conference on Intelligent User Interfaces (IUI '13)*. New York, NY, USA: ACM, 2013, pp. 149–160.

[5] D. McFarland, D. Krusienski, W. Sarnacki, and J. Wolpaw, "Emulation of computer mouse control with a noninvasive brain-computer interface," *Journal of Neural Engineering*, vol. 5, no. 2, pp. 101–110, 2008.

[6] G. Edlinger, C. Holzner, C. Groenegress, C. Guger, and M. Slater, "Goal-oriented control with brain-computer interface," in *Foundations of Augmented Cognition. Neuroergonomics and Operational Neuroscience*. Berlin/Heidelberg, Germany: Springer, 2009, pp. 732–740.

[7] R. Scherer, G. Muller, C. Neuper, B. Graimann, and G. Pfurtscheller, "An asynchronously controlled EEG-based virtual keyboard: improvement of the spelling rate," *IEEE Transactions on Biomedical Engineering*, vol. 51, no. 6, pp. 979–984, 2004.

[8] L.-D. Liao, C.-T. Lin, K. McDowell, A. E. Wickenden, K. Gramann, T.-P. Jung, L.-W. Ko, and J.-Y. Chang, "Biosensor technologies for augmented brain-computer interfaces in the next decades," *Proceedings of the IEEE*, vol. 100, no. Special Centennial Issue, pp. 1553–1566, 2012.

[9] S. Makeig, C. Kothe, T. Mullen, N. Bigdely-Shamlo, Z. Zhilin, and K. Kreutz-Delgado, "Evolving signal processing for brain-computer interfaces," *Proceedings of the IEEE*, vol. 100, no. Special Centennial Issue, pp. 1567–1584, 2012.

[10] B. J. Lance, S. E. Kerick, A. J. Ries, K. S. Oie, and K. McDowell, "Brain-computer interface technologies in the coming decades," *Proceedings of the IEEE*, vol. 100, no. Special Centennial Issue, pp. 1585–1599, 2012.

[11] F. Nijboer, J. Clausen, B. Allison, and P. Haselager, "The Asilomar survey: Stakeholders' opinions on ethical issues related to brain-computer interfacing," *Neuroethics*, pp. 1–38, 2011.

[12] G. Tamburrini, "Brain to computer communication: ethical perspectives on interaction models," *Neuroethics*, vol. 2, no. 3, pp. 137–149, 2009.

[13] M. Kubovy, *On the Pleasures of the Mind*. New York, NY, USA: Russell Sage Foundation, 1999, pp. 134–154.

[14] K. Sheldon, A. Elliot, Y. Kim, and T. Kasser, "What is satisfying about satisfying events? Testing 10 candidate psychological needs," *Journal of Personality and Social Psychology*, vol. 80, no. 2, pp. 325–339, 2001.

[15] C. Mühl, "Toward affective brain-computer interfaces: Exploring the neurophysiology of affect during human media interaction," Ph.D. dissertation, University of Twente, Enschede, The Netherlands, 2012.

[16] G. Chanel, "Emotion assessment for affective computing based on brain and peripheral signals," Ph.D. dissertation, University of Geneva, Geneva, Switzerland, 2009.

[17] G. Garcia-Molina, T. Tsoneva, and A. Nijholt, "Emotional brain-computer interfaces," *International Journal of Autonomous and Adaptive Communications Systems*, vol. 6, no. 1, pp. 9–25, 2013.

[18] M. Hassenzahl, S. Diefenbach, and A. Göritz, "Needs, affect, and interactive products – facets of user experience," *Interacting with Computers*, vol. 22, no. 5, pp. 353–362, 2010.

[19] R. Teitelbaum, "In tune: some early experiments in biofeedback music (1966-1974)," in *Biofeedback and the Arts: Results of Early Experiments*. Vancouver, BC, Canada: Aesthetic Research Center of Canada Publications, 1976.

[20] E. R. Miranda, W. L. Magee, J. J. Wilson, J. Eaton, and R. Palaniappan, "Brain-computer music interfacing (BCMI): From basic research to the real world of special needs," *Music and Medicine*, vol. 3, no. 3, pp. 134–140, 2011.

[21] G. Deuschl and A. Eisen, Eds., *Recommendations for the Practice of Clinical Neurophysiology*, 2nd ed. Amsterdam, The Netherlands: Elsevier, 1999.

[22] C. De Boeck, "Staalhemel: responsive environment for brainwaves." [Online]. Available: http://www.staalhemel.com/

[23] N. Sobell, "Streaming the brain," *IEEE MultiMedia*, vol. 9, no. 3, pp. 4–8, 2002.

[24] E. Miranda, "Brain-computer music interface for composition and performance," *International Journal on Disability and Human Development*, vol. 5, no. 2, pp. 119–126, 2006.

[25] S. Makeig, G. Leslie, T. Mullen, D. Sarma, N. Bigdely-Shamlo, and C. Kothe, "First demonstration of a musical emotion BCI," in *Affective Computing and Intelligent Interaction*. Berlin/Heidelberg, Germany: Springer, 2011, pp. 487–496.

[26] K. Casey and H. Sokol, "Global mind project." [Online]. Available: http://www.globalmindproject.com

[27] T. De Smedt and L. Menschaert, "VALENCE: affective visualisation using EEG," *Digital Creativity*, vol. 23, no. 3-4, pp. 272–277, 2012.

[28] S. Le Groux, J. Manzolli, and P. Verschure, "Disembodied and collaborative musical interaction in the multimodal brain orchestra," in *Proceedings of the International Conference on New Interfaces for Musical Expression*, 2010, pp. 309–314.

[29] Y. C. D. Chew and E. Caspary, "MusEEGk: a brain computer musical interface," in *CHI '11 Extended Abstracts on Human Factors in Computing Systems*. New York, NY, USA: ACM, 2011, pp. 1417–1422.

[30] J. I. Münßinger, S. Halder, S. C. Kleih, A. Furdea, V. Raco, A. Hösle, and A. Kübler, "Brain Painting: first evaluation of a new brain-computer interface application with ALS patients and healthy volunteers." *Frontiers in Neuroscience*, vol. 4, no. 182, 2010.

[31] B. van de Laar, I. Brugman, F. Nijboer, M. Poel, and A. Nijholt, "BrainBrush, a multimodal application for creative expressivity," in *Sixth International Conference on Advances in Computer-Human Interactions (ACHI 2013)*. Redhook, NY, USA: IARIA XPS Press, 2013, pp. 62–67.

[32] R. Collingwood, *The Principles of Art*. New York, NY, USA: Oxford University Press, 1958.

[33] R. Harré, "Emotion in music," in *Emotion and the Arts*. New York, NY, USA: Oxford University Press, 1997, pp. 110–118.

[34] H. Jaffé, *De Stijl, 1917-1931: The Dutch Contribution to Modern Art*. Amsterdam, The Netherlands: J.M. Meulenhoff, 1956.

[35] A. Gómez de Silva Garza and A. Zamora Lores, "Case-based art," in *Proceedings of the 6th International Conference on Case-Based Reasoning Research and Development*. Berlin/Heidelberg, Germany: Springer, 2005, pp. 237–251.

[36] S. Colton, M. F. Valstar, and M. Pantic, "Emotionally aware automated portrait painting," in *Proceedings of the 3rd International Conference on Digital Interactive Media in Entertainment and Arts (DIMEA '08)*. New York, NY, USA: ACM, 2008, pp. 304–311.

[37] M. Shugrina, M. Betke, and J. Collomosse, "Empathic Painting: interactive stylization through observed emotional state," in *Proceedings of the 4th International Symposium on Non-Photorealistic Animation and Rendering (NPAR '06)*. New York, NY, USA: ACM, 2006, pp. 87–96.

[38] E. Edmonds, D. Everitt, M. Macaulay, and G. Turner, "On physiological computing with an application in interactive art," *Interacting with Computers*, vol. 16, no. 5, pp. 897–915, 2004.

[39] M. Omata, K. Moriwaki, X. Mao, D. Kanuka, and A. Imamiya, "Affective rendering: Visual effect animations for affecting user arousal," in *2012 International Conference on Multimedia Computing and Systems (ICMCS '12)*. Piscataway, NJ, USA: IEEE, 2012, pp. 737–742.

[40] N. McNamara and J. Kirakowski, "Functionality, usability, and user experience: three areas of concern," *interactions*, vol. 13, pp. 26–28, 2006.

[41] H. Gürkök, "Mind the Sheep! User experience evaluation & brain-computer interface games," Ph.D. dissertation, University of Twente, Enschede, The Netherlands, 2012.

[42] M. Hassenzahl, A. Beu, and M. Burmester, "Engineering joy," *IEEE Software*, vol. 18, no. 1, pp. 70–76, 2001.